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# A Heuristic Approach Of Designing Parallel Filter Using An Enriched Pole Placement Technique

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**Abstract-In digital signal processing systems parallel filters are highly efficient to reduce noise in the signal and also power consumption. Based on the earlier study of parallel filter design for equalization and transfer function modeling a new method is proposed. The contribution of this work is to present an advanced design of a parallel filter using a united pole set obtained from two techniques spectral smoothing to smoothened the target frequency response to the required resolution and the multiple warped IIR filter design with different warping parameter to smoothened the target divided into frequency band. This method increases accuracy and reduces noise compared to the earlier techniques.**

**In this paper loud speaker – room response modeling and equalization are efficiently presented.**

**Index terms ----Parallel filter,** Kautz filters**IIR digital filter, Logarithmic frequency resolution, and frequency warping, Audio signal processing, loud speaker room response equalization**.

## 1. INTRODUCTION:

Digital filters plays an important role in audio signal processing for modeling and equalization of an audio system.Audio applications usually requires a logarithmic frequency resolution that better fits the properties of human hearing.Equalization is one of the most common methods used in filter design applications.

In filter design Loud speaker room equalization provides an additional reason for using logarithmic frequency resolution.The equalization improves the sound in a finite region of space.It should be more precise at low frequencies where the transfer function is less dependent on the listening position,while at high frequencies it should be only correct the overall trend of the response.

In this paper various design approaches have been presented for obtaining filters with a logarithmic frequency resolution.

An advanced parallel filter is designed using fixed pole design of second order parallel filters has been presented.By using this parallel structure noise can be efficiently reduced.

The frequency resolution of the parallel filter can be controlled by choosing the suitable poles.Two different ways have been proposed for choosing the pole positions of the parallel filter depending on the modeled or equalized.To get bestaccuracy filter order is in the same range as the system order can be achieved by designing a warped IIR filter to the target response and using the polesof this warped IIR filter as the poles of the parallel filter. On the other hand, if the filter order is significantly smaller than the order of the system, then only the averagetrend of the system response can be modeled. In this case better results are achieved if the pole set is predetermined based on how much resolution we wish to achieve in thedifferent frequency regions.

For example, placing the poles according to a logarithmic frequency-scale results in a parallel filter response that is basically the logarithmically-smoothed version of the target response. It has been demonstratedthat already using this predetermined pole set resultsin better performance compared to IIR, warped FIR, and warped IIR filters estimated by the Stieglitz–McBride method.

The present letter proposes a new pole positioning method that provides a significant improvement over using the predetermined pole set to design an advanced parallel filter.

This paper is organized as follows:

Section II outlines the structure of the parallel filter and the least squares estimation of filter weights. Section III proposes thesmoothed multi-band pole positioning method, and Section IV provides a comparison to previous pole positioning techniques.SectionV presents a loudspeaker–room equalization example and gives comparison to various equalizer design methods Finally, Section VI concludes the letter.

## II.STRUCTURE OF THE FILTER

The general form of the parallel filter consists of a parallel set of second-order sections and an optional FIR filter path.

$$H(z^{-1}) = \sum_{k=1}^{K} \frac{d_{k,0} + d_{k,1}z^{-1}}{1 + a_{k,1}z^{-1} + a_{k,2}z^{-2}} + \sum_{m=0}^{M} b_m z^{-m}$$

where K is the number of second order sections, an d M is the

order of the FIR part.
Using frequency domain algorithm by the equation

H=MP

The FIR path is derives and minimum error in the mean squares is obtained. It is advantageous in using minimum phase filter design where it results in lower computational complexity compared to second order sections. This letter presents only minimum phase modeling and equalization but FIR part is not used.

## III. SMOOTHED MULTI-BAND POLE POSITIONING METHOD

In enriched pole positioning technique based on smoothed response using warping parameters involves three steps.

1. Smoothing the target response
2. Design of the warped IIR Filter
3. Finding the poles and de-warping

### 1.Smoothing the target response:

Initiallythe target response is smoothened to the required resolution by applying the octave smoothing technique.It involves the transfer function by variable width smoothing function.The smoothed response is cut to separate frequency bands.6$^{th}$ octave smoothed version is displayed in Figure 1(c).

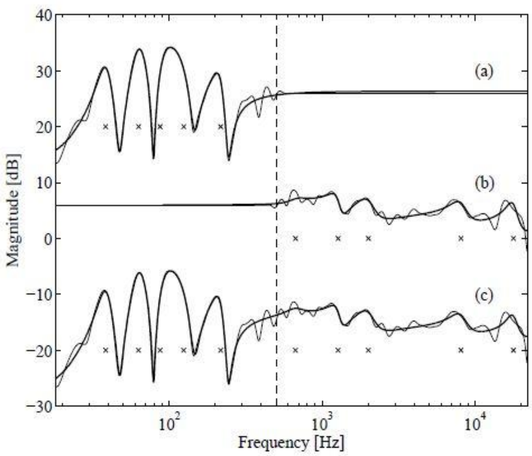


**Figure 1:**Parallel filter design with dual pole position technique.

This assumes that the warped IIR designs will only produce poles in their respective frequency bands.

### 2. Design of the Warped IIR filter:

In the design of warped IIR filter λ=0.986 and λ=0.65 are used for low and high frequencies respectively.Warped filters have the maximal logarithmic resolution in the middle of their respective bands by finding such values where the minimum of

$$\frac{\Delta f}{f} = \frac{1+\lambda^2 - 2\lambda\cos(2\pi f/f_s)}{(1-\lambda^2)f}$$

These are designed by the StieglitzMcBride algorithm.Frequency response of low frequency warped IIR filter is displayed by thick solid line.

### 3.Finding the poles and de-warping effect:

Finally the poles of the warped IIR filter are found as the roots of the filter denominators. The warped poles are converted back to linear frequency scale by

$$p_k = \frac{\tilde{p}_k + \lambda}{1 + \lambda \tilde{p}_k}.$$

United pole set is shown in figure (c).20$^{th}$ order parallel filter designed using this pole set is displayed by thick line.It is sufficient to divide the full audio frequency range into two parts and use dual band design.since warped IIR design handle half of the audio band properly.

## IV. COMPARISON BETWEEN PREVIOUS POLE POSITIONING TECHNIQUES:

Figure 2 presents the new method of pole positioning technique for a minimum phase loud speaker room response modeling.The filter order is smaller than the order of the system the warping IIR design does not model overall system but pick few responses.The frequency resolution is concentrated to a limited region of the full frequency scale due to warping effect.The main objective of this method is to reduce the mean absolute db error computed target and filter response and evaluated on a logarithmic frequency scale.

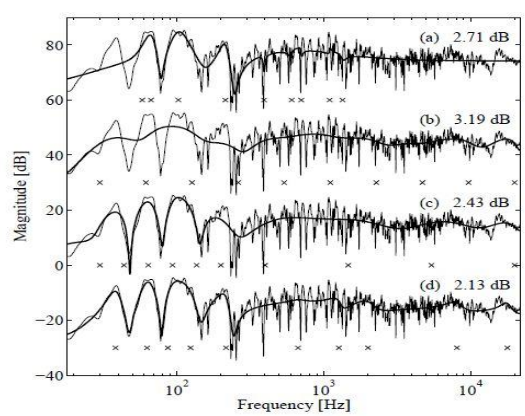

**Figure 2:** Parallel filter design with various pole position techniques.

**V. EQUALIZER DESIGN EXAMPLE:**

Fig(3) shows an equalizer design example using loud speaker room response. All filters designed by the various methods have a filter order of 32.Figure 3(a) thin lines displays the un-equalized response while the thick line shows its sixth-octave smoothed version. The loud speaker room response is equalized by 3(b) warped FIR and 3(c) warped IIR.A dashed line displays desired loud speaker room response. Equalization is excellent in the middle frequency range due to the limited frequency range of the effective resolution of the warping filters.3(d) shows combined warped FIR and IIR filters.3(e) shows similar result obtained by using iteratively optimized parabolic equalizers.3(f) shows the system equalized by a parallel filter where the pole positioning is based on the new pole positioning technique with a pole pairs.

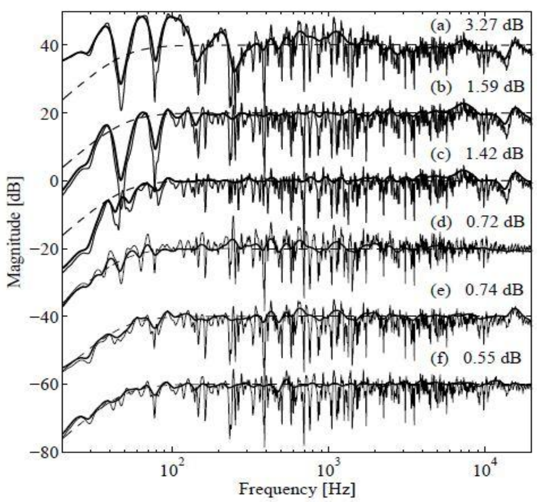


**Figure 3:**Minimum phase loud speaker room equalization comparison.

The performance of the new method(f) is superior compared to the earlier methods. Itis more advantageous in the view of quantization noise performance.

## VI. CONCLUSION

This paper presents an improved pole positioning technique for parallel filter design.It is designed based on warped IIR filters using warping parameters to maximize the warping effect in their respective bands.Then pole sets of the warped IIR filters are united and this united pole set is used for parallel filter design.This method outperforms previous pole positioning techniques.It provides superior equalization compared to warped FIR,Warped IIR and combined linear warped equalizers and reduces noise effectively.

## REFERENCES

[1] M. Water and M.B. Sandler, " Least squares IIR filter design on a logarithmic frequency scale ", in proc. IEEE, nt-symp. On circuits and syst., may 1993,pp.635-638.

[2]A.Harma,M,karjalainan,L.Saviojia,V.Valmiki,V.K.Laine, and J.Huopaniemi, "Frequency- warped signal processing for audio applications" J.Audio Eng. Soc., Vol.48, no.11, pp. 1011-1031,nov.2000.

[3] G.Ramos,J.J.Lopez, and B.Pueo, "combination of warped and linear filter structures for Loudspeaker equalization", in proc.124 AES conv. ,preprint no.7401, Amsterdam, The Netherlands, 2008.

[4] T.Paatero and M.Karjalainen, "Hautz filters and generalized frequency resolution theory and audio applications", J.Audio Eng. Soc., vol.51, no 1-2, pp.27-44,Jan/Feb 2003.

[5] "Audio equalization with fixed-pole parallel filters:An efficient alternative to complex smoothing", in proc.128th AES conv, preprint no.7965, London, UK may 2010.

[6] B.Bank, "Logarithmic frequency scale parallel filter design with complex and
magnitude only specification", IEEE signal processing let., vol.18, no.2, pp 138-144, Feb 2011.