Just Noticeable Differences of deviation in Biquad IIR filter Parameters

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Abstract

In this paper, Just Noticeable Differences (JND) of deviation in Biquad IIR filter parameters is investigated. Biquad filter is a core element of digital signal processing units that determines the quality of the product. The filter parameters, such as center frequency, quality etc. configure the filter specifications. In order to achieve a high accuracy of the deigned filter, acceptable deviation of the parameters is crucial to be determined. In the first part of the research, four commonly used filters are selected and the parameters are deviated. Secondly, an adaptive listening test is developed to determine the just noticeable differences of deviation in the filter parameters. Finally, the results are presented as a guideline for the purpose of DSP unit design.

Introduction

In design and evaluation of Biquad filters, just noticeable differences of the frequencies are very critical to determine the accuracy of the designed filter. There has been plenty of research paper based on the Just Noticeable Differences (JND) of tonal signals, however, in case of filter design the JND should be studied for the broad band signal. This paper is assigned to investigate the JND of the deviation in cut-off frequency of biquad filter while the excitation signal has broadband characteristics. In this regard, first the acoustic stimuli are prepared accordingly and a listening test is conducted. The results of the listening test are statistically analyzed and the results are presented.

Case Study

A broadband pink noise signal is used as input excitation and four types of Biquad filters are determined as test filters: Low-pass, high-pass, peaking band filter gain +10 and -10 dB. All filters are swept across the whole frequency range with subdivisions of Bark scale. The lower cut-off frequencies of Bark-scale are selected as reference and are swept to the higher cut-off frequencies.

Measurement Chain

The sound stimuli are generated using the measurement chain in figure below.

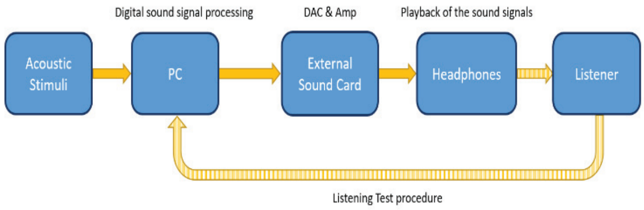

Figure 1: Measurement chain of the listening test

Listening test

A listening test is conducted to specify the perceptual sensitivities of the human auditory system to the deviation of the Biquad filter cut-off frequencies. The listening test was conducted in a hearing room at the IAV GmbH Company, Munich. The listening test setup is shown as a block diagram in Figure 2. The acoustic stimuli, which were obtained in the measurement procedure were played back to the participants via audio Interface to the headphone inside the listening test room. A Graphical User Interface (GUI) was developed to play the stimuli of the listening test.

A total of 92 acoustic stimuli were utilized in this listening test, these samples were chosen from four groups of acoustic conditions: broad band signal filtered with four types of biquad filters.

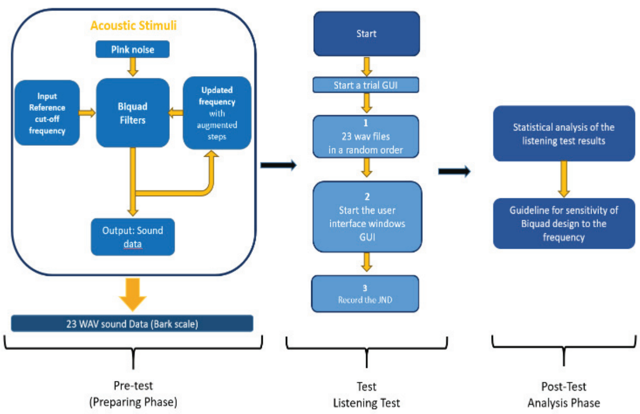

Figure 2: Block diagram of the listening test implementation

Results

The data is visualized in terms of their quartile by arranging a set of data from the lowest to the highest rate. The first quartile is assigned as 25 percentile of data Q1, the second quartile (median) is 50 percentile Q2, and consequently Q3 is 75 percentile of the data observation. In Figure 3 to 6, just noticeable difference sin frequency of four filters are plotted. The JND of each filter type are compare in Figure 7.

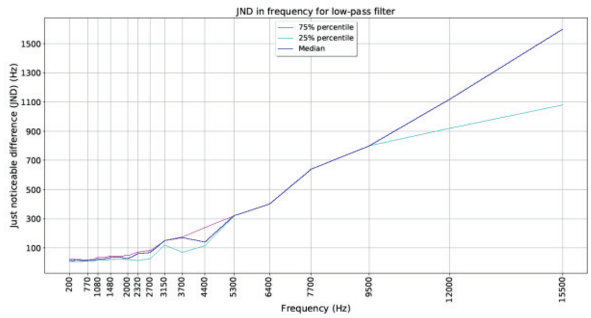

Figure 3: JND for low-pass filter

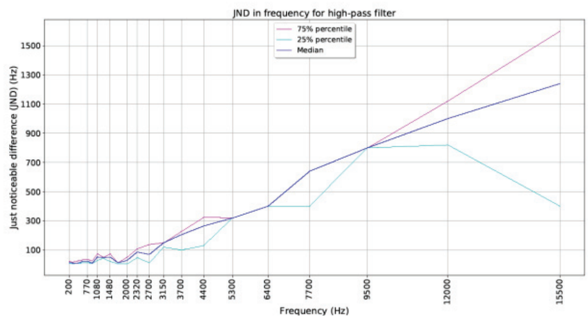

Figure 4: JND for high-pass filter

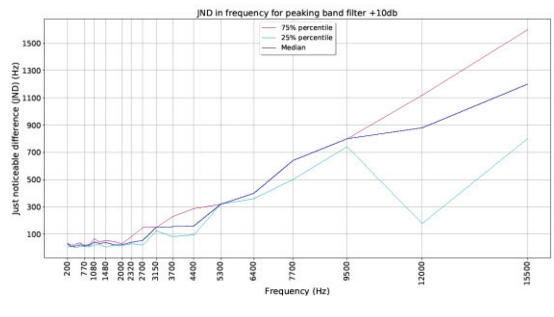

Figure 5: JND for peaking filter gain band +10 dB

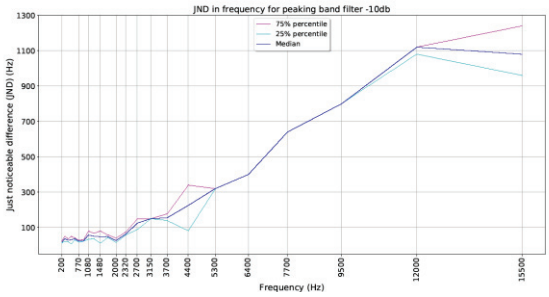

Figure 6: JND for peaking filter gain band -10 dB

Discussion

The collected data in the listening test are analyzed according to the research questions, which was concern about comparison of the just noticeable differences of the signal with pure tone and broadband characteristics. As it can be seen in Figure 3 to 6, all the JNDs of signals with broadband excitation are less than delta Bark, which reveals the higher sensitivity of the human hearing system to the group shifting of a broad band signal in specified filtering frequencies. In all cases a trend of increase of JND in frequencies can be recognized, however, the JND is very small around 3 kHz. It can be explained under resonance frequencies of the external auditory canal.

In Figure 7, all JNDs are plotted, it can be seen that the lower frequencies are more sensitive to the deviation of the filters cut-off frequencies, however in the higher frequencies, the trend are similar and have less sensitivity to the frequency deviation.

The results determines the required accuracy of the designed filter in each Bark band and can be used as a guideline for designing digital signal processing units.

Acknowledgement

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References

[1] FASTL, H. and ZWICKER, E. (2007). Psychoacoustics: facts and models. Vol. 22. Springer Science & Business Media (cit. on pp. 80, 83–85).