Perceptual evaluation of numerical dispersion in finite-difference time-domain simulations

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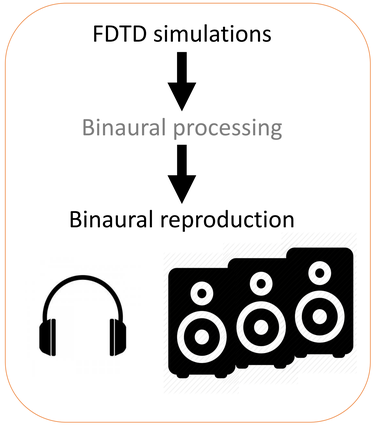
INTRODUCTION

Finite-difference time-domain (FDTD) simulations are a powerful tool for room acoustics applications (e.g., [2,3]). However, FDTD simulations are computationally costly and contain **numerical dispersion** which can lead to **audible artefacts.**

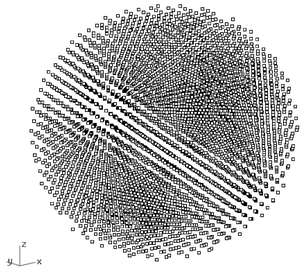
Since the error depends on the simulated conditions, there exists no general rule to determine whether the artefacts will be audible or not. So, there is a need to measure perceptual thresholds for audibility of the error for various scenarios. It has been done in previous studies for ideal cases and can be extended to more realistic cases as well as for **dynamic binaural reproduction**.



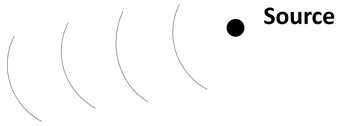
General framework for perceptual evaluations

PERCEPTUAL EVALUATION

Free-field propagation, 27 volumetric receiver arrays tested [1]

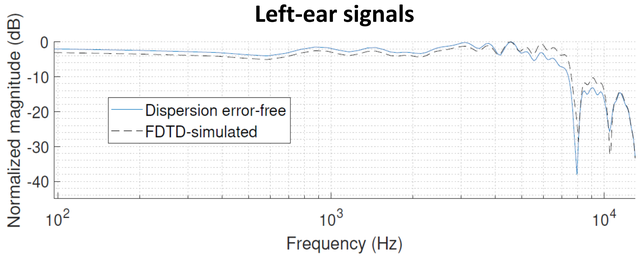


Volumetric receiver array



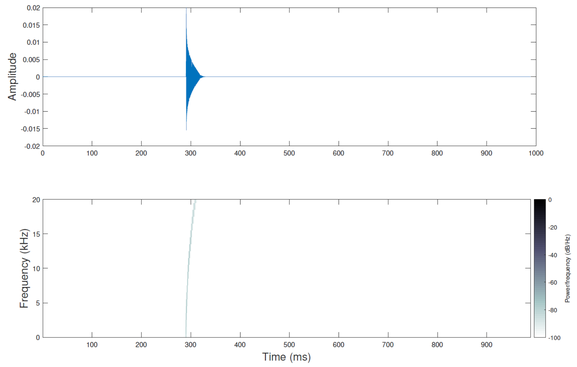
Spherical harmonics processing
(*spatial decomposition* & inclusion of free-field HRTFs)

Left-ear signals



Overall reconstruction error =
Averaged magnitude spectrum difference

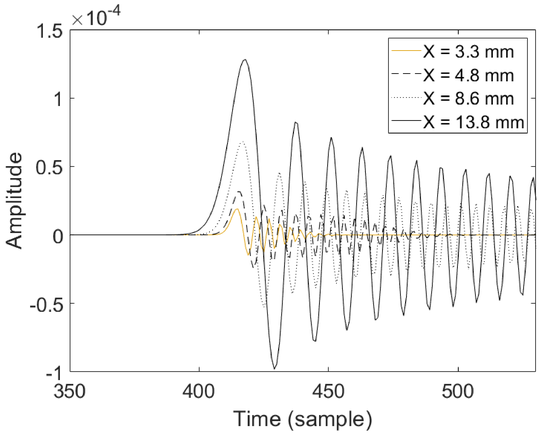
How does it sound? Example:



Known dispersion error-free solution?

yes → = Reference
=> Absolute threshold

no → No reference
=> Difference threshold



Some conclusions

- For 5 out of 27 receiver arrays, the FDTD-simulated binaural auralizations were indistinguishable from the dispersion-error free binaural auralizations.
- Perceptual attributes used to detect differences: coloration, loudness, source width, localization, reverberation.
- Overall reconstruction error does not suffice to describe the perceptual differences.
- Increasing the receiver density does not guaranty inaudibility of numerical dispersion.

What's next?

Perceptual threshold measurement for numerical dispersion in full room responses (e.g., with varying diffuseness).

[1] Meyer, J., Lokki, T. and Ahrens, J., 2020. Identification of virtual receiver array geometries that minimize audibility of numerical dispersion in binaural auralizations of FDTD simulations. *149*th *AES Convention*

[2] Meyer, J., Savioja, L. and Lokki, T., 2019. A case study on the perceptual differences in FDTD-simulated diffuser designs. *146th AES Convention*

[3] Meyer, J. and Lokki, T., 2018. Optimization of a diffuser geometry using parametric modeling tools and FDTD simulations. *Auditorium Acoustics*

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