Edge diffraction in room acoustics computer modelling

U. Peter Svensson[1], Paul T. Calamia[2]

[1]Acoustics Research Centre, Dept. Of Electronics and Telecommunications, Norwegian University of Science and Technology (NTNU), Trondheim, Norway

[2]Program in Architectural Acoustics, School of Architecture,

Rensselaer Polytechnic Institute, Troy, NY, USA

This presentation

Motivation for edge diffraction in room acoustics computer modelling

Three challenges to diffraction modelling

Focus of this paper: how to prune the less important diffraction contributions

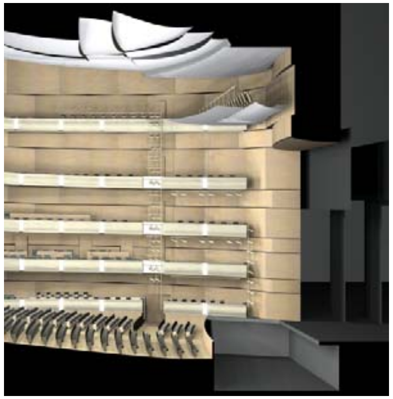
Conclusions

Motivation for edge diffraction modeling in room acoustics

Edge diffraction corrects the discontinuity of specular reflections and gives continuous sound fields.

Examples where diffraction is significant:

1. Reflectors
2. Around corners (orchestra pits, balcony edges,…)
3. Reflections from arches, domes
4. Propagation around pillars



.... but also in any interior space, at low frequencies.

Motivation for edge diffraction modeling in room acoustics

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H.264 decompressor
are needed to see this picture.

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Challenges to edge diffraction modelling

1. Rapid growth of number of components

   Main topic of this presentation. How can we find which components could be skipped/pruned?

2. Non-rigid surfaces

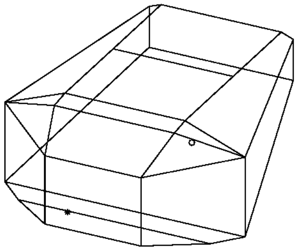
   Exact edge diffraction solution exists only for diffraction from rigid wedge.

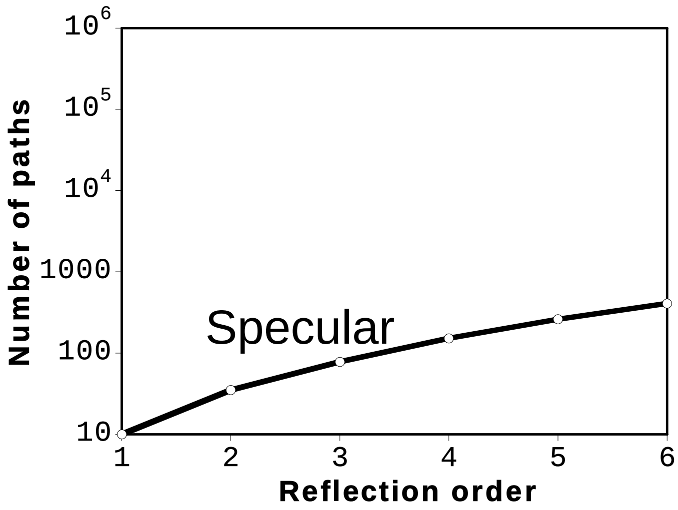
3. Zone-transitions (discontinuities)

   Numerically robust techniques exist [Svensson and Calamia 2006]

Challenge 1 - Rapid growth of number of components

Example from simple room: 19 planes, 36 edges
[Mechel, JSV 2002]





Challenge 1 - Rapid growth of number of components

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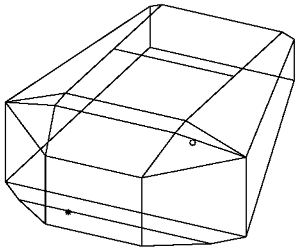
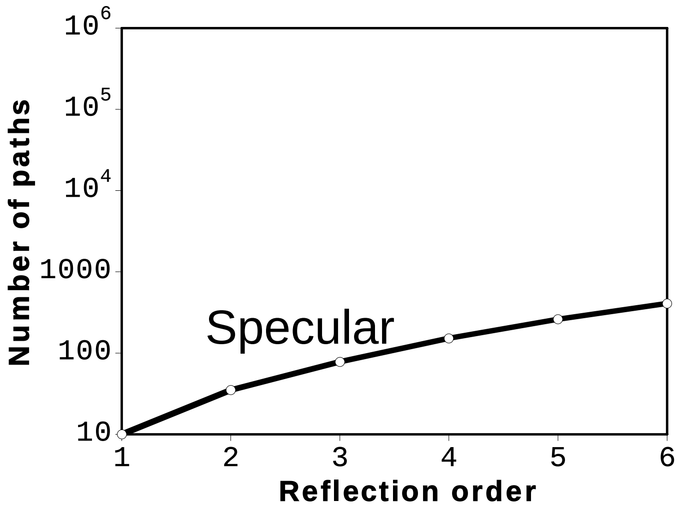
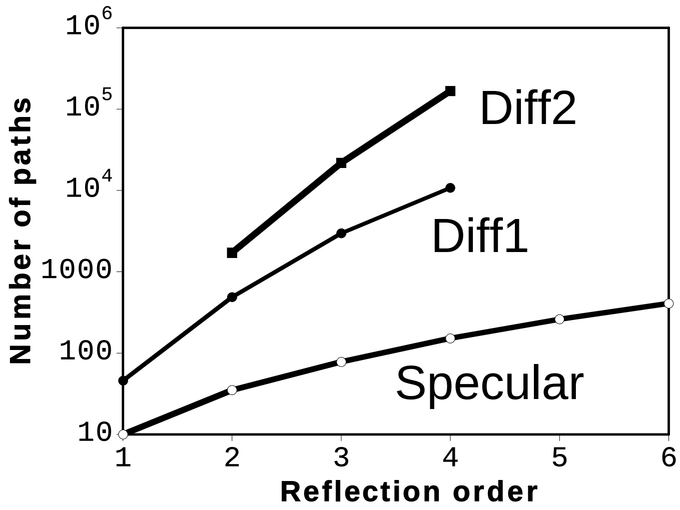


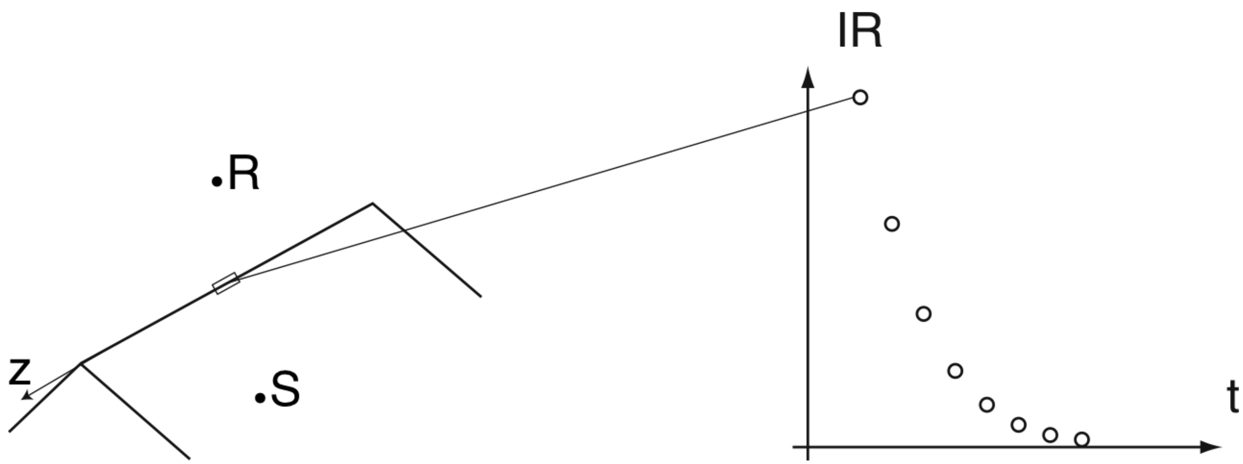




Diff 1, refl order 3 = DSS,SDS,SSD

Computations involved in diffraction, 1

Each edge diffraction component IR requires a numerical integration <u>for each sample value</u>: a summing of contributions from points along the edge



Computations involved in diffraction, 2

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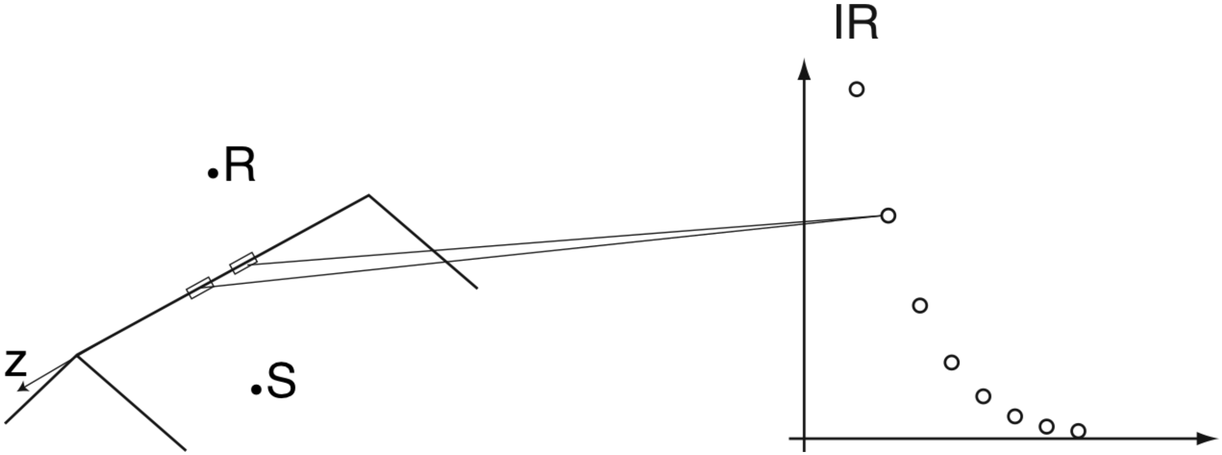

Computations involved in diffraction, 3

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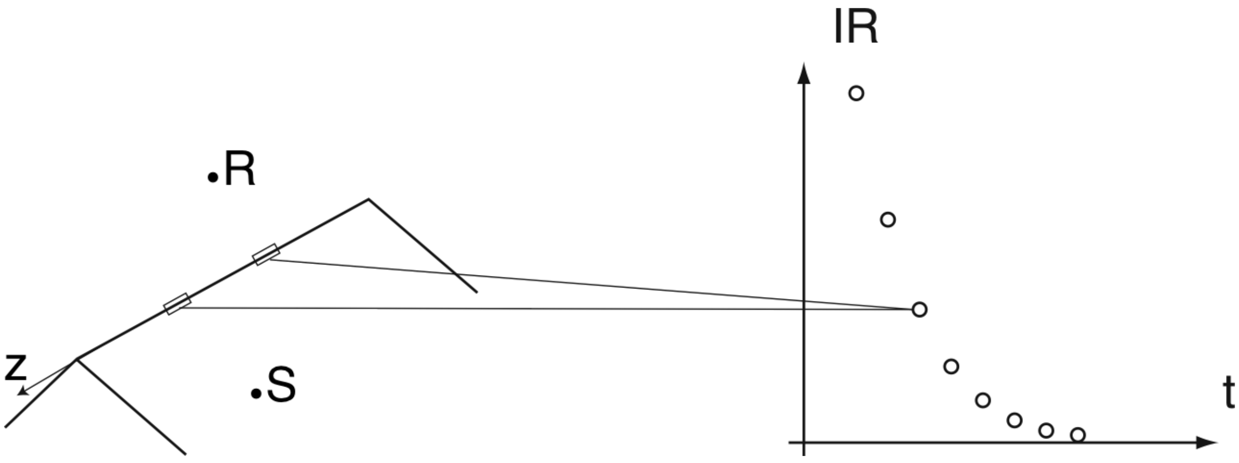
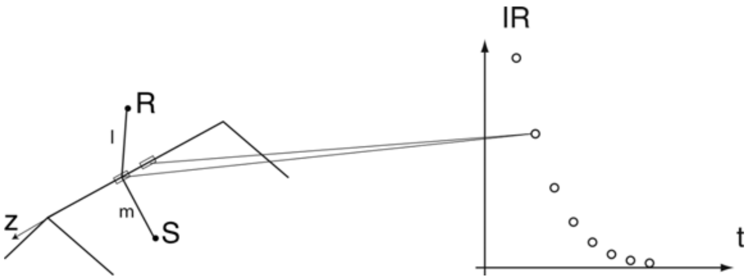


Computations involved in diffraction, 4

The numerical integration for each sample value:



$$h_{diffr}(n) = -\frac{\nu}{4\pi}\sum_{i=1}^{4}\int_{z_{n,1}}^{z_{n,2}} \frac{\beta_i}{ml}\,dz$$

$$\beta_i(z) = \frac{\sin(\nu\varphi_i)}{\cosh[\nu\eta(z)] - \cos(\nu\varphi_i)}$$

$$\eta(z) = \cosh^{-1}\left\{\frac{ml + (z - z_S)(z - z_R)}{r_S r_R}\right\}$$

$$\varphi_1 = \pi + \theta_S + \theta_R$$

$$\varphi_2 = \pi + \theta_S - \theta_R$$

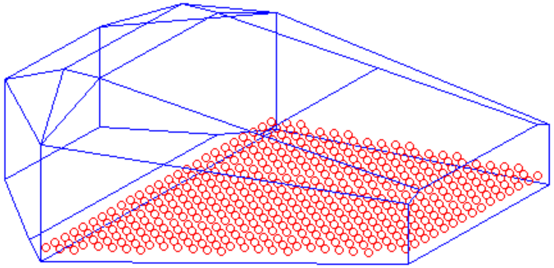
$$\varphi_3 = \pi - \theta_S + \theta_R$$

$$\varphi_4 = \pi - \theta_S - \theta_R$$

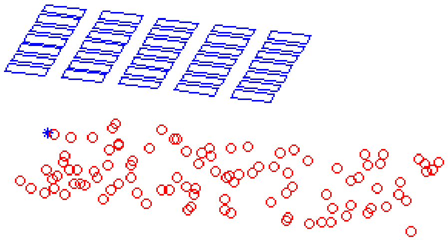
r_S, θ_S, z_S
r_R, θ_R, z_R
= cyl. coord. of S and R

Numerical examples

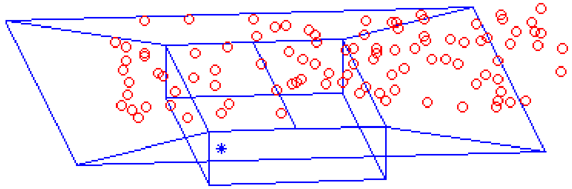
Hall



Reflector cloud



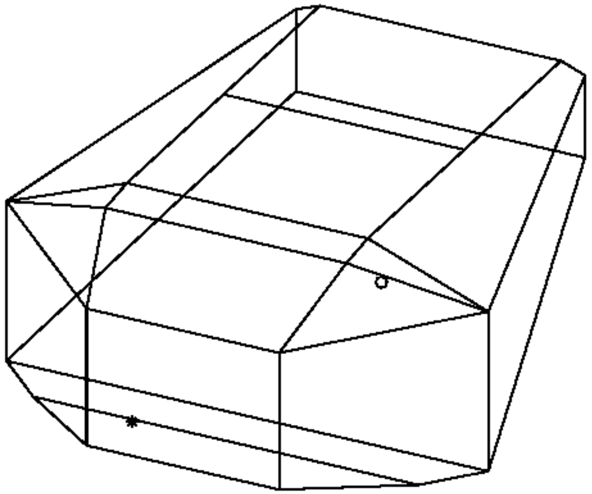
Orchestra pit

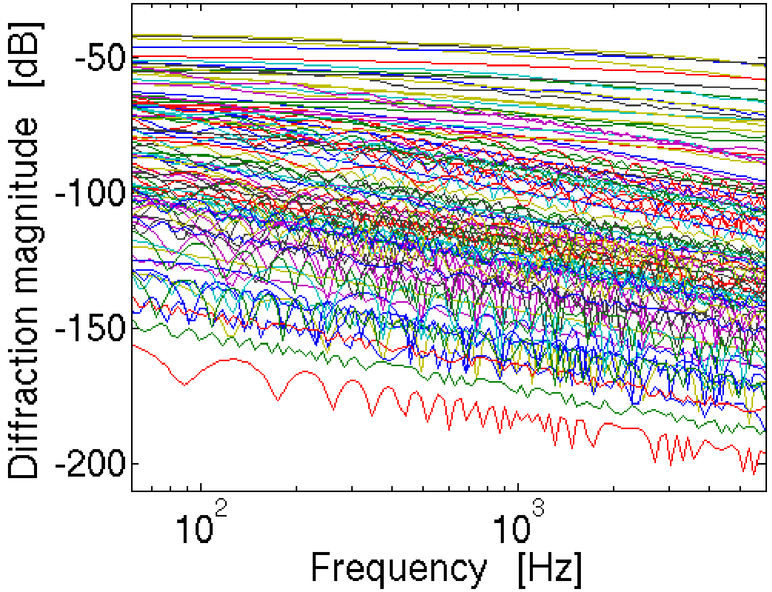


Chosen to represent a wide range. One source, many receiver positions. Hall from [Mechel 2002], Refl. cloud from [Calamia & Svensson 2006]. Orch. pit from [Løvstad & Svensson 2004].

Finding efficient pruning method

100 randomly selected diffraction IRs of type SDSS etc.

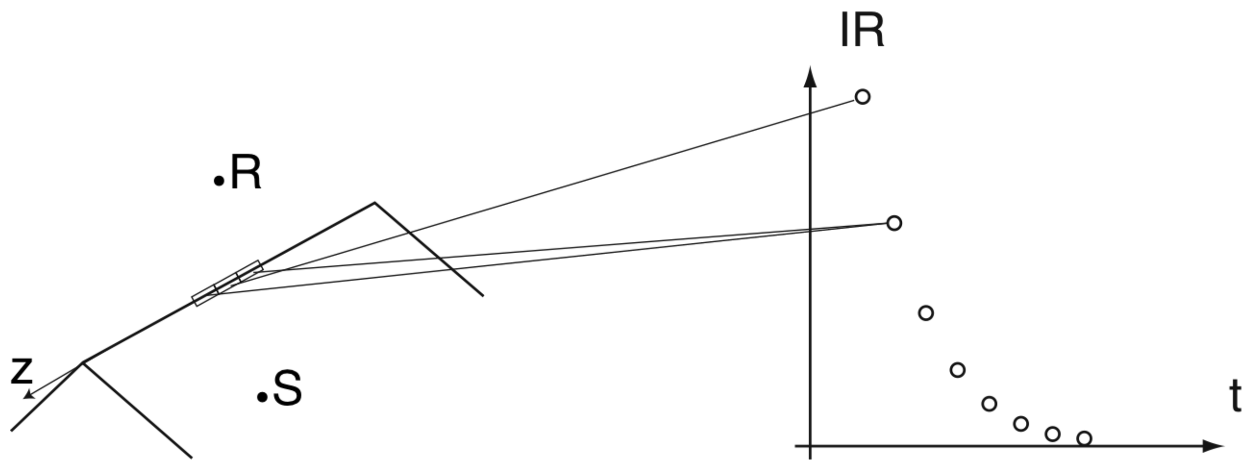




- Huge range of magnitude - possible to skip/prune some.
- Quite similar spectral shape - so we can look at <u>average level</u> as measure of importance.

Finding efficient pruning method

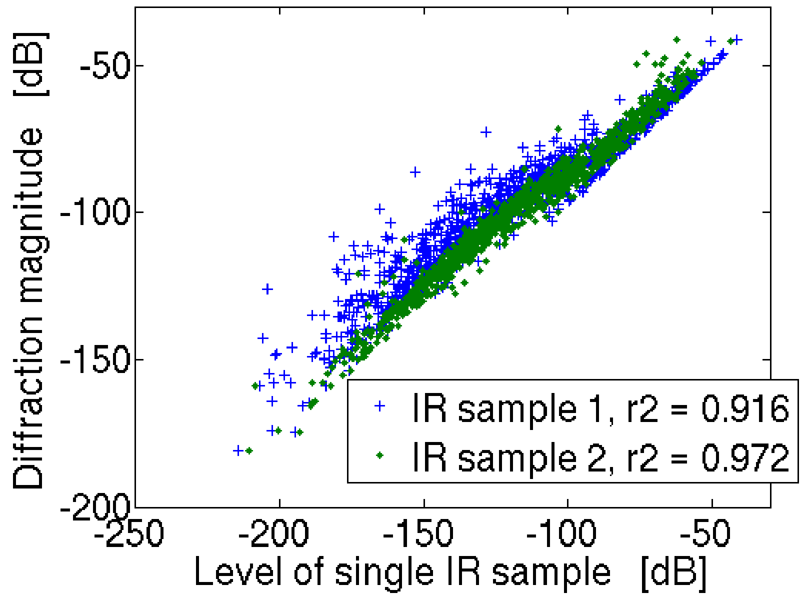
Candidate method - Compute first one or two sample values of diffraction IR (quick to compute)



Idea: since the IR almost always decreases monotonically, the start indicates how strong the rest would be.

Finding efficient pruning method

Candidate method - Compute first one or two sample values of diffraction IR (quick to compute)



High correlation between value of IR sample 1 or 2 and total diffraction IR energy
$\Rightarrow$ useful pruning criterion.

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Innovation and Creativity

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Suggested pruning method

For each of *N* diffraction components (*N* is large):

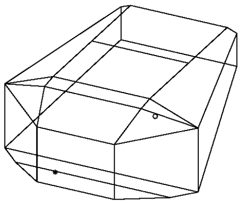
Compute IR sample values 1 and 2 (quite fast)

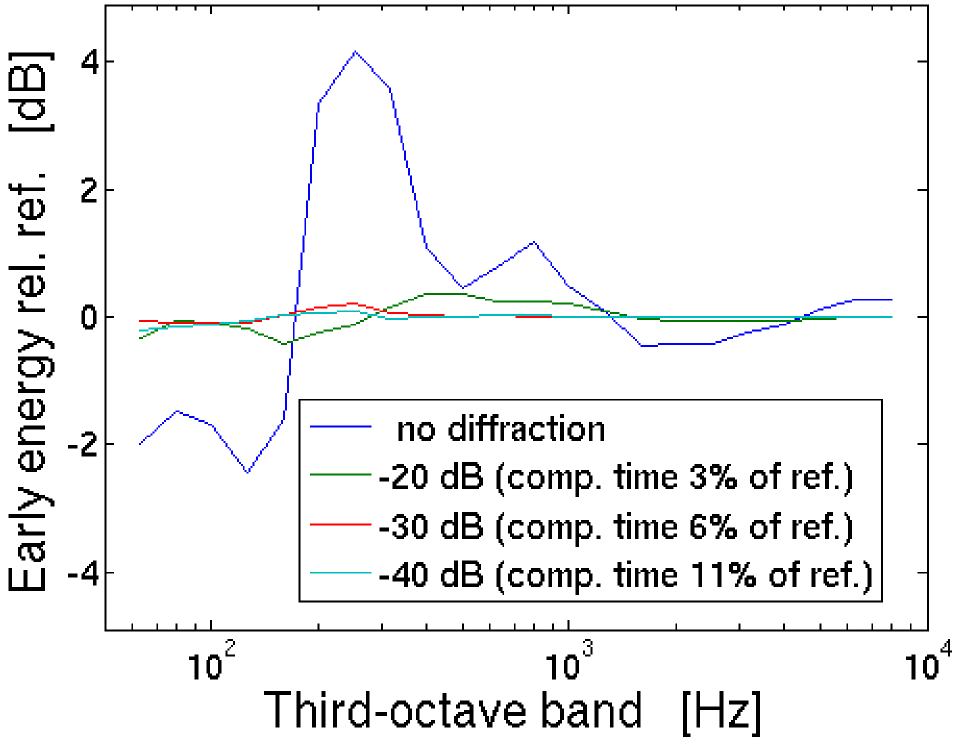
If IR sample value 2 > limit value, then

Compute full IR (time-consuming)

Limit value can be based on global maximum, or the maximum found so-far.

Evaluation of pruning method - Hall





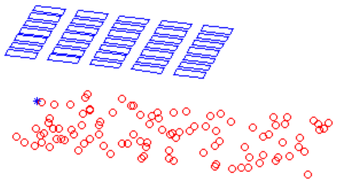
Single rec. pos.
Single diff. + up to 3rd order spec. ⇒ 10634 diffraction components.

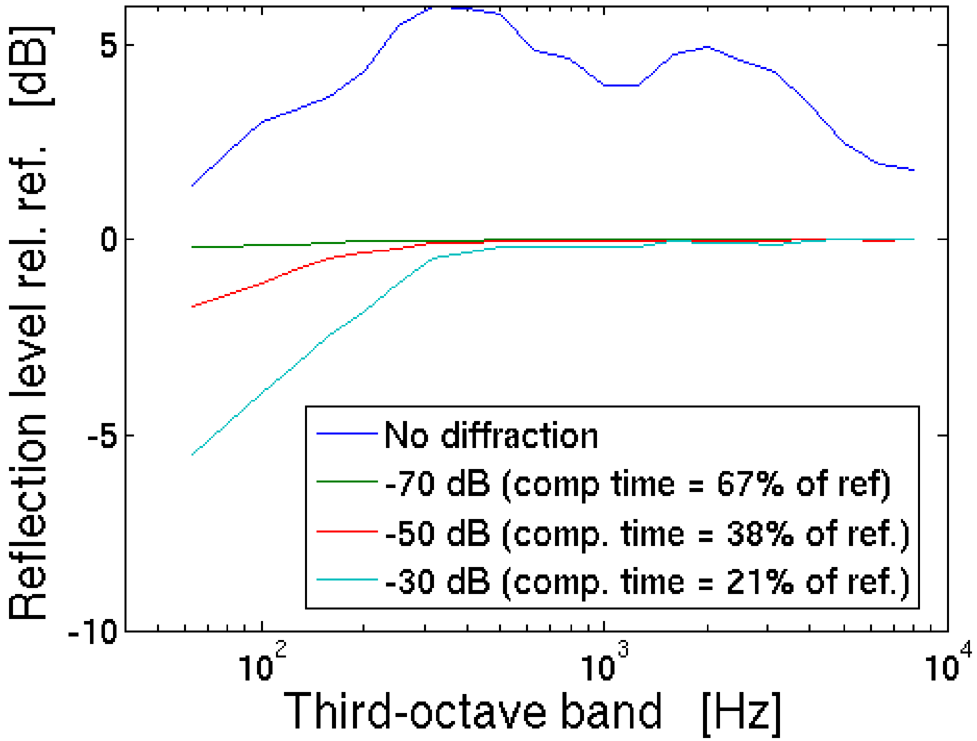
Many components can be pruned in interior geometry.

Diffraction important mainly at LF.

Ref = include all diffraction components

Evaluation of pruning method - Reflector cloud



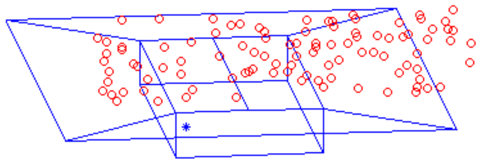


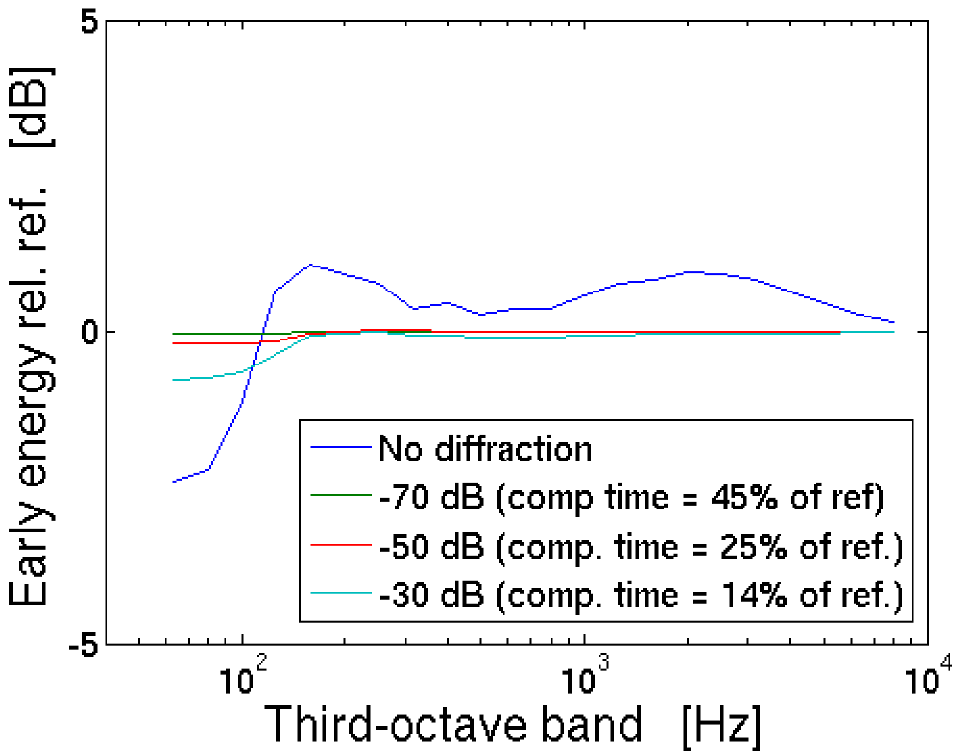
Average results for 100 rec. positions.

Diffraction much more critical than in hall, also at higher frequencies.

NB! Without diffraction, 48 out of 100 rec. pos. get zero reflection!

Evaluation of pruning method - Orchestra pit





Average results for 100 rec. positions. Up to 6th-order combinations.

Diffraction not so critical for the early energy.

Pruning quite efficient.

Conclusions

The huge number of diffraction components can be alleviated by first computing the first one or two samples of each diffraction IR. Based on their values, a decision is made on whether the rest of the IR is worth computing or not.

Some edges need more stringent criteria, typically reflector edges. They contribute at low and high frequencies.

Interior edges contribute significantly only at lower frequencies - but should not be ignored.

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