

Modeling 1D-diffusers - the missing link

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Introduction

2D-scattering models

1D-scattering

Predictions

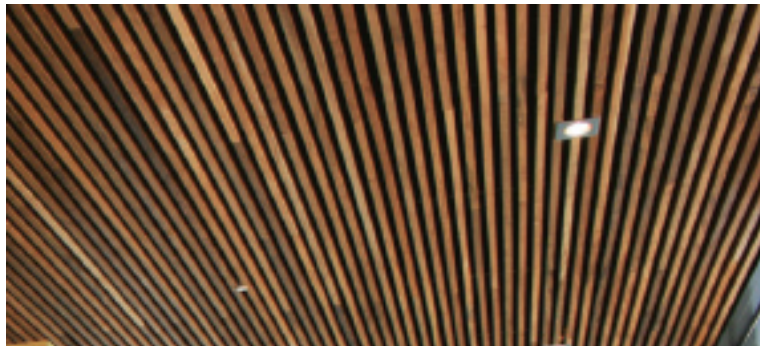
Measurements

Summary

Introduction 1:2

1D-diffusers in rooms

- Many surfaces in rooms can be seen as 1D-diffusers: ceilings with beams, walls with battens, stage walls or reflectors with battens, dedicated 1D-diffusers such as QRD, and in general 1D corrugated surfaces
- Such surfaces have in modeling generally been treated as if they were 2D diffusers and it appears to have been essentially satisfactory
- However, naturally, it must depend on how many 1D-diffusing surfaces that are present, where they are located, and how sensitive the room shape is to the properties of scattering distributions



Introduction 2:2

1D-diffusers in rooms

- 1D-diffusers have clearly been a missing link in room acoustics modeling and the ISO scattering coefficient measurement standard does not distinguish between 1D- and 2D-diffusing surfaces
- This paper presents a way to model 1D-diffusers based on the Lambert distribution using the same scattering coefficients as if the surface were a 2D-diffuser with a similar depth-variation
- the current experience from estimating frequency dependent 2D scattering coefficients can thus be directly applied

2D-scattering 1:2

Four different 2D-scattering distributions can be found in commonly used prediction software:

- **Specular or Lambert**
- Three distributions based on **specular and diffuse vector mixing**

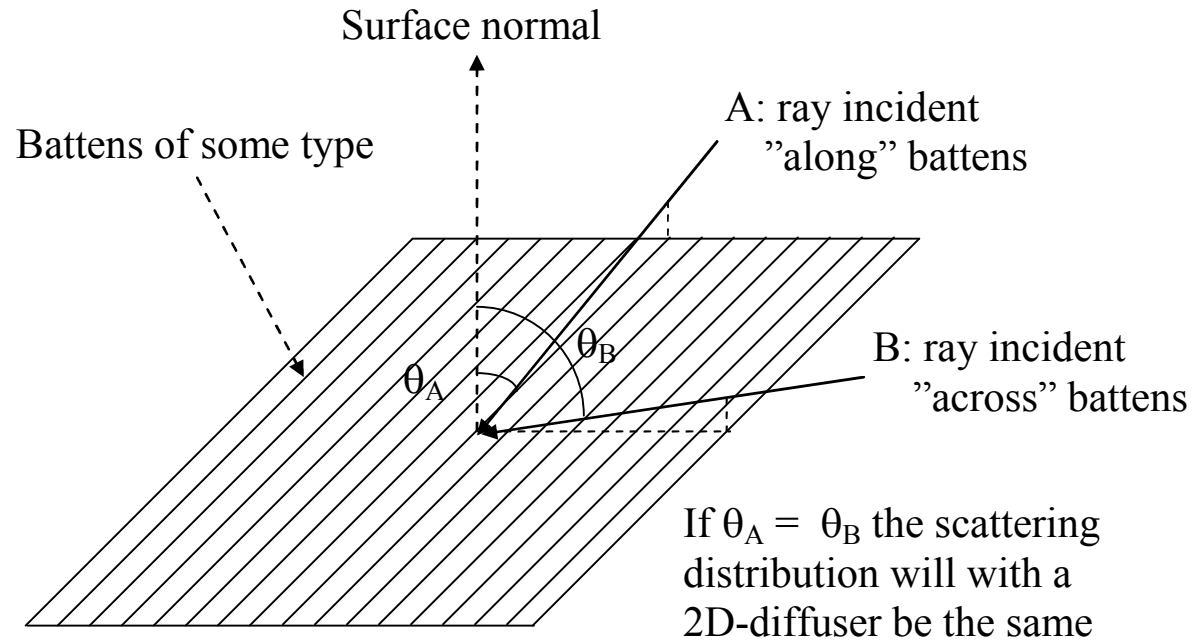
These four distributions were discussed, and their properties shown, in:

“Scattering distributions in geometrical acoustics”

B-I Dalenbäck, Forum Acusticum, Aalborg 2011

None of these distributions can directly simulate a 1D-diffuser, since the distributions are only dependent on the incidence angle to the surface normal

2D-scattering 2:2



1D-scattering 1:8

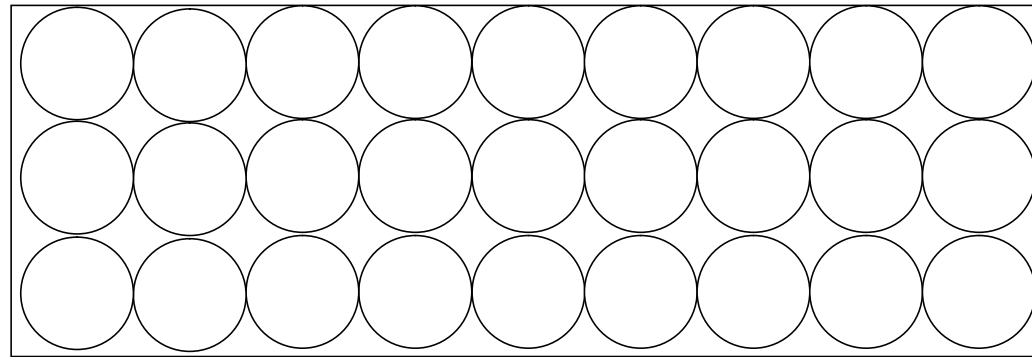
The 1D-diffuser model

- I started to work on a 1D-diffuser 6-7 years ago but put it on the shelf since I could then not find a solution that would fit actual diffuse ray-splitup without a considerable increase in calculation times
- The idea then was to modify the shape of the Lambert distribution depending on the horizontal incidence angle (horizontal, assuming a 1D-diffuser on the floor)
- The new implementation, that will be discussed here, does not change the shape of the Lambert distribution but instead changes the scattering coefficient used at each ray impact depending on the incidence angle
- With this technique the prediction algorithm core does almost not have to change
- To estimate the frequency dependent scattering coefficient the same experience as for 2D Lambert can be applied, but only the depth-variation in the diffusing direction needs to be considered and the only additional information required is the direction of the battens, beams, wells etc.

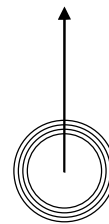
1D-scattering 2:8

Schematic explanation of the 1D-diffuser model

First for reference: normal 2D Lambert



Scattering coefficient
independent of
horizontal incidence
angle

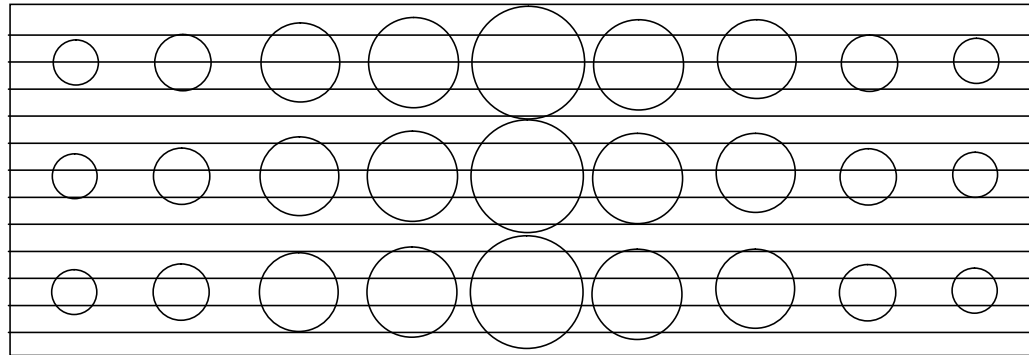


Circle radius indicates
scattering coefficient
magnitude

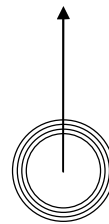
1D-scattering 3:8

Schematic explanation of the 1D-diffuser model

Incidence across battens



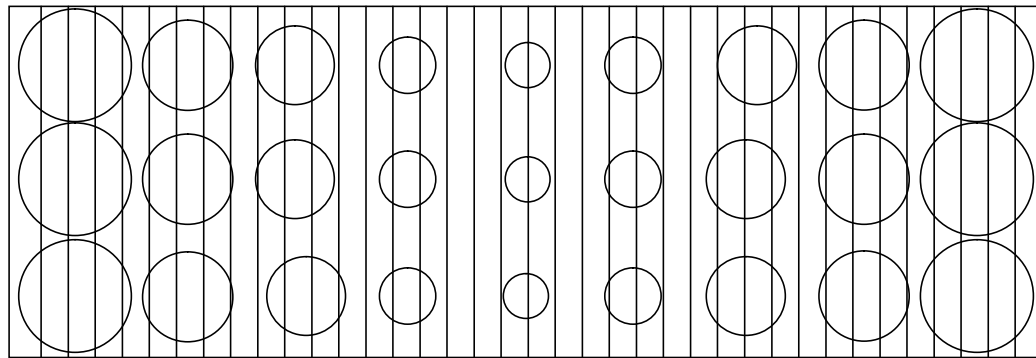
Scattering coefficient
depends on horizontal
incidence angle



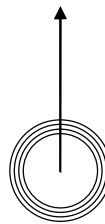
1D-scattering 4:8

Schematic explanation of the 1D-diffuser model

Incidence along battens



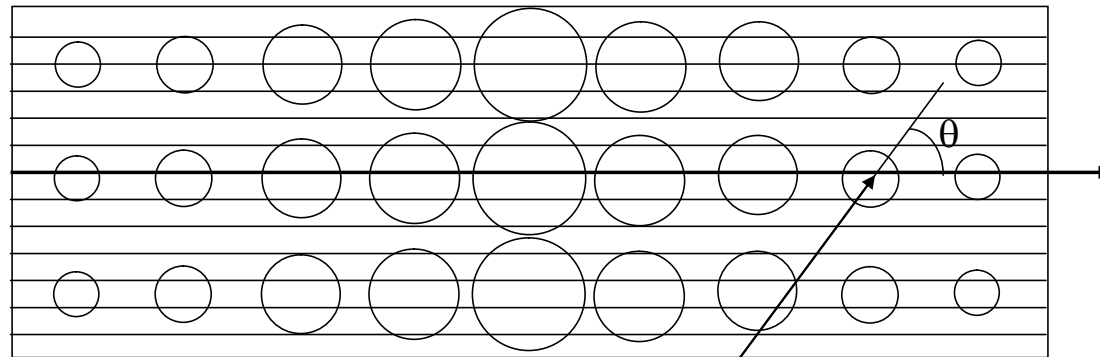
Scattering coefficient
depends on horizontal
incidence angle



1D-scattering 5:8

Schematic explanation of the 1D-diffuser model

Principle angle dependence

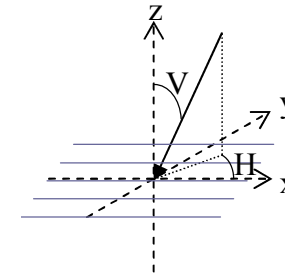
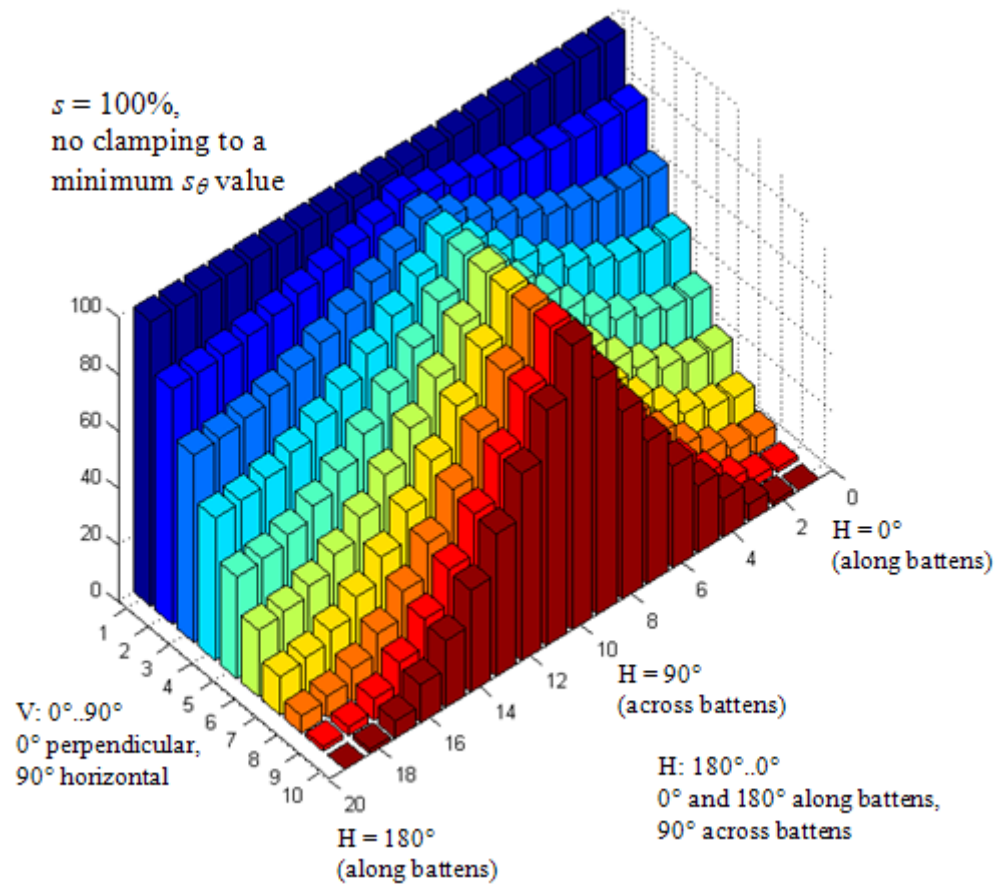


$$s_{\theta} = s \cdot (1 - |\cos(\theta)|)$$

$$\text{if } s_{\theta} < s/4 \rightarrow s_{\theta} = s/4$$

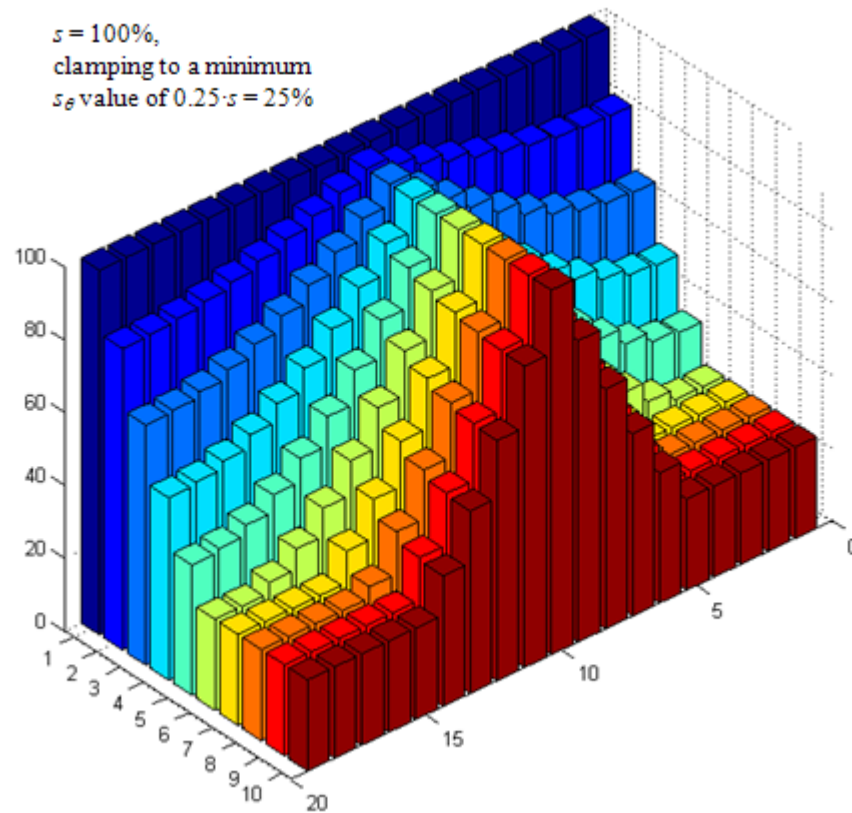
1D-scattering 6:8

Schematic explanation of the 1D-diffuser model



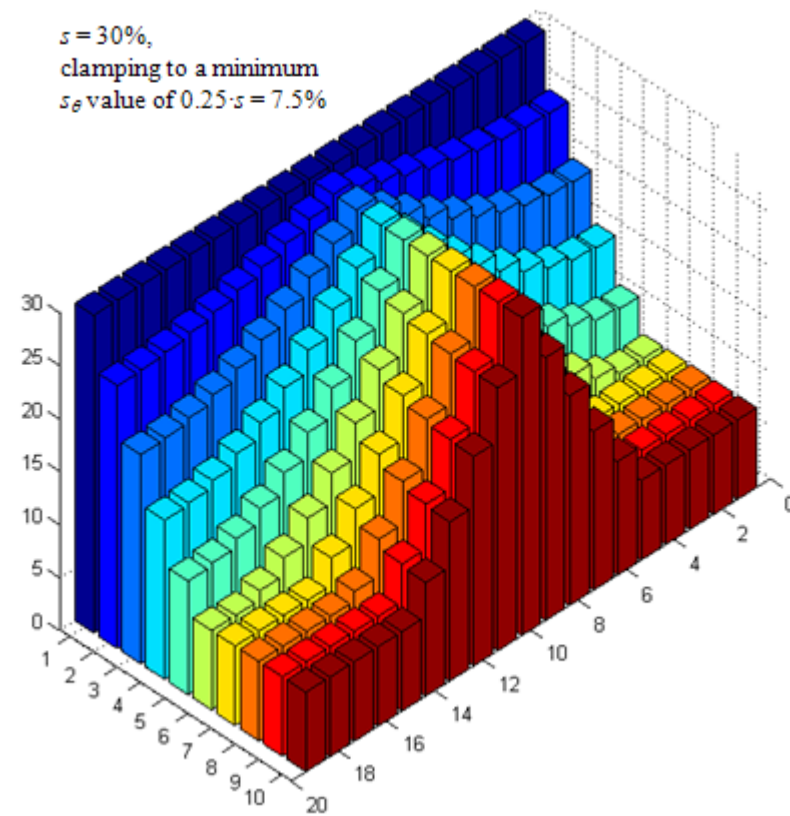
1D-scattering 7:8

Schematic explanation of the 1D-diffuser model



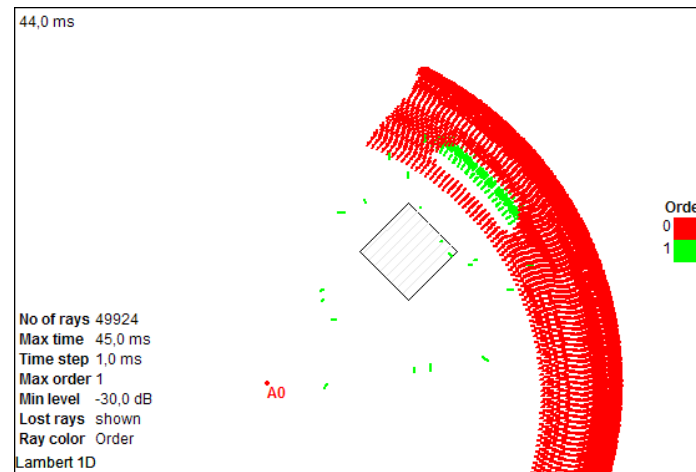
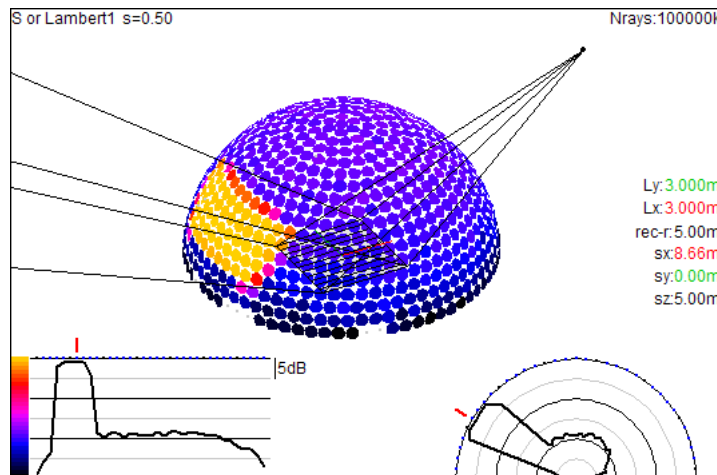
1D-scattering 8:8

Schematic explanation of the 1D-diffuser model



Predictions 1:7

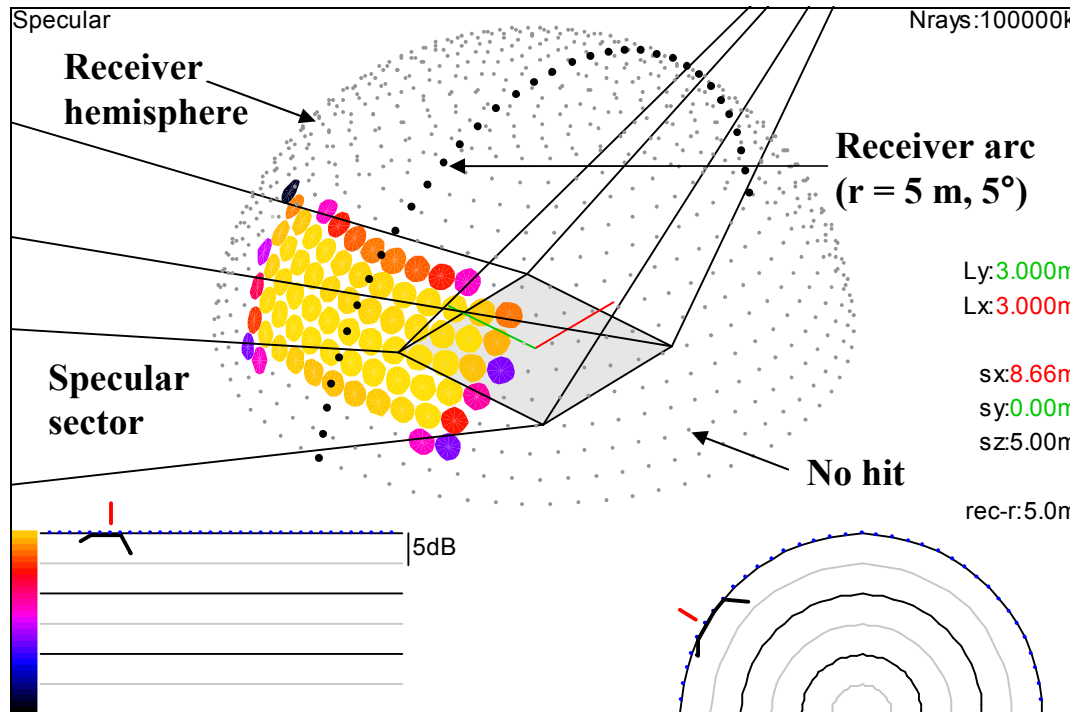
The properties of the 1D-diffusor model will be illustrated in two ways: predicted directivity and “Time trace” animated ray front displays:



Predictions 2:7

Predicted directivity

Rays are sent out uniformly from a source, specular case illustrates

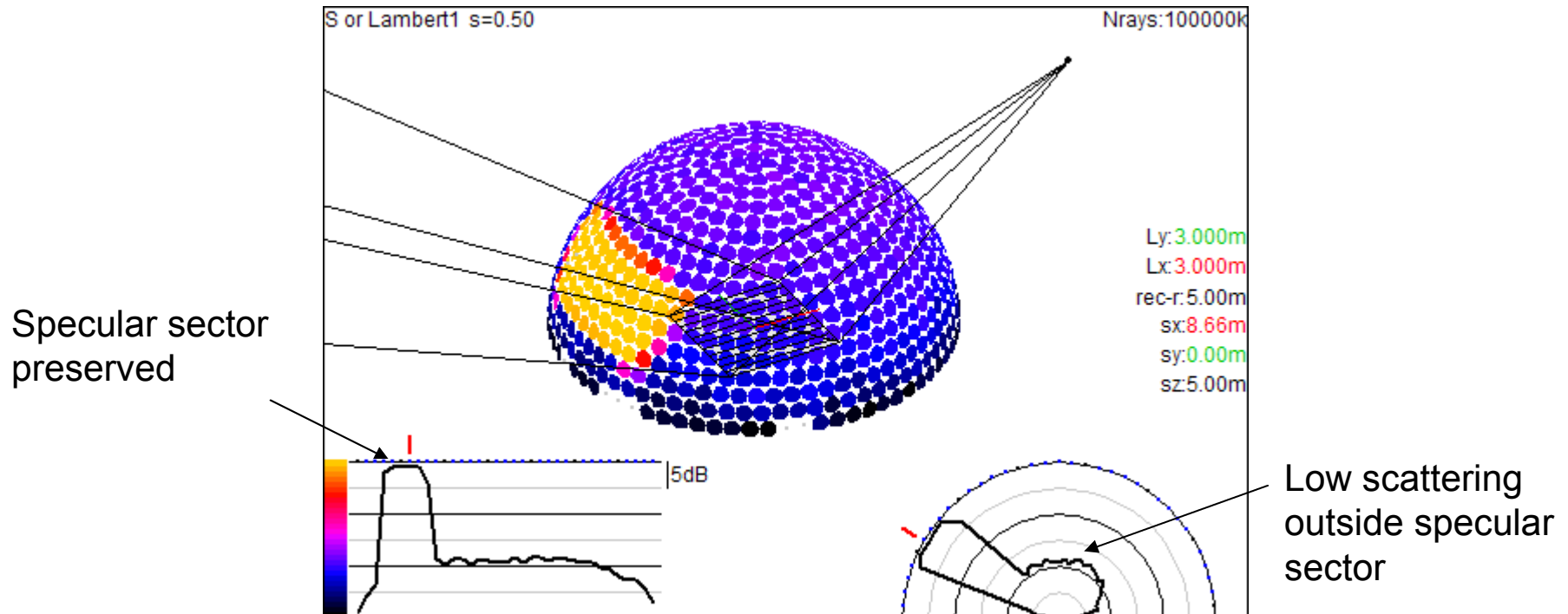


Incidence angle is 60°
(measured from the surface normal)

Source distance to surface center is 10 m.

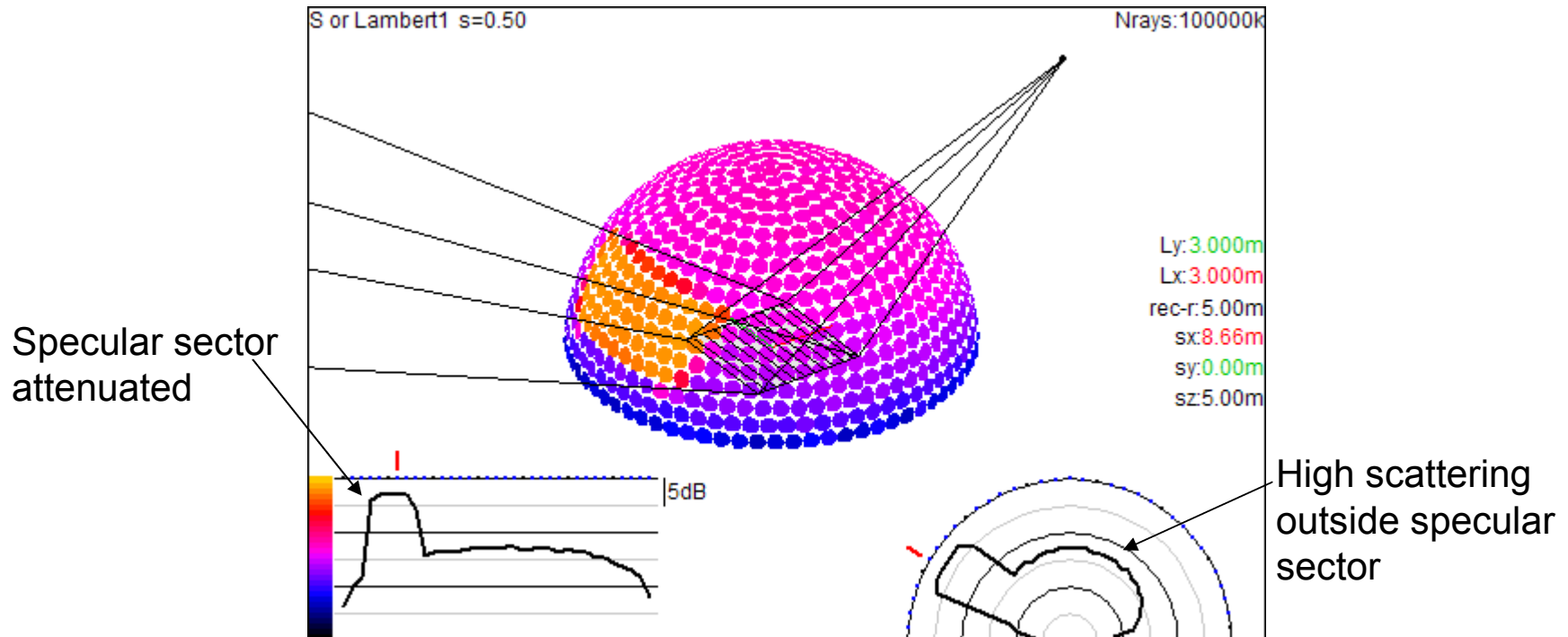
Predictions 3:7

Predicted directivity
New 1D-model: $s = 0.50$, along battens



Predictions 4:7

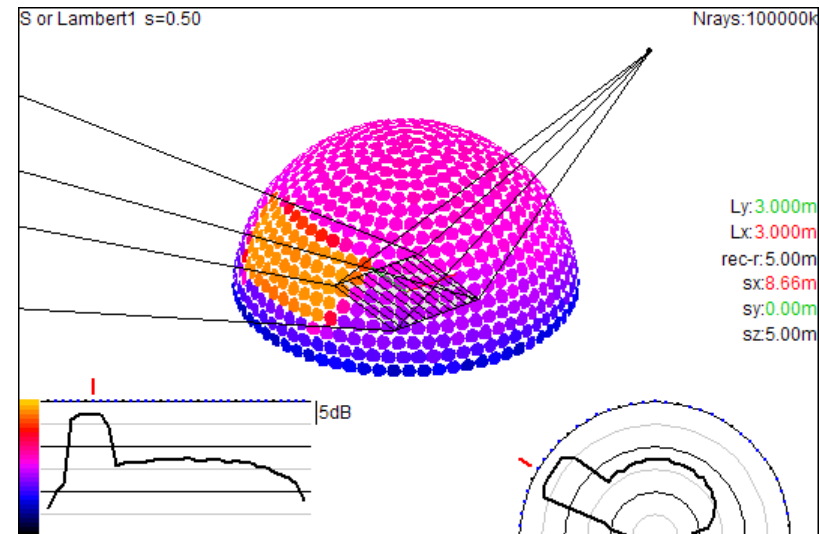
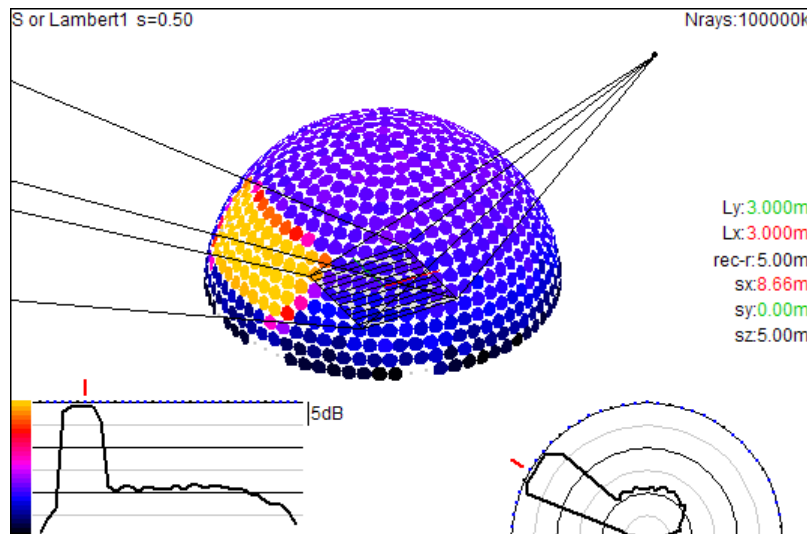
Predicted directivity
New 1D-model: $s = 0.50$, across battens



Predictions 5:7

Predicted directivity

New 1D-model: $s = 0.50$, along vs across battens

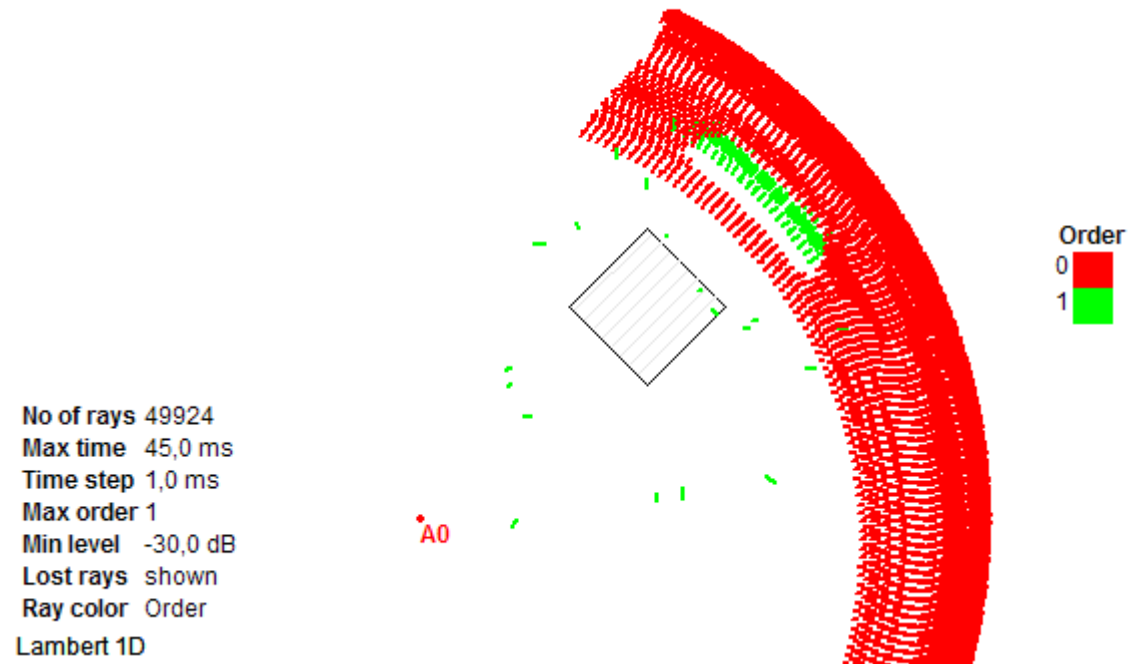


Predictions 6:7

Animated ray-fronts, along battens

(no animation in PDF)

44,0 ms



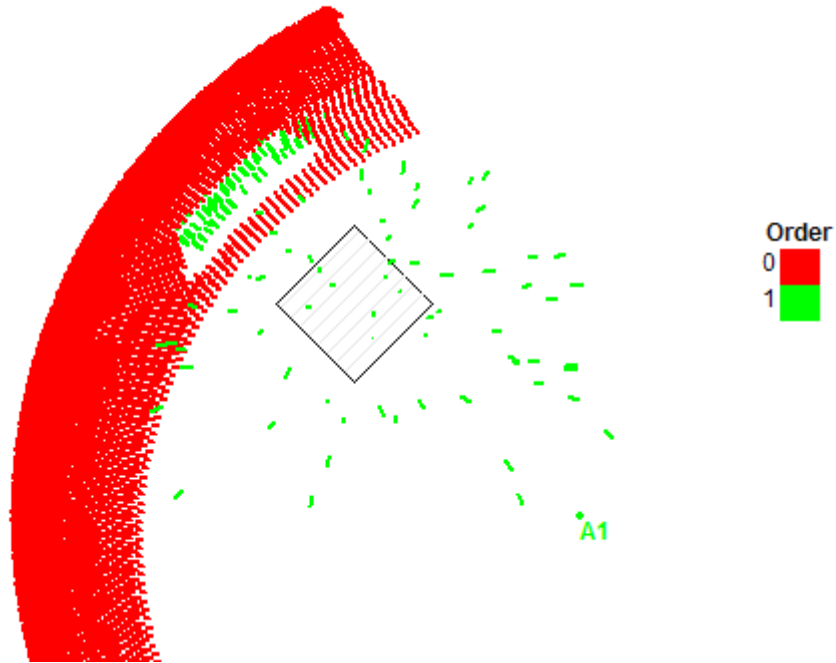
Predictions 7:7

Animated ray-fronts, across battens

(no animation in PDF)

44,0 ms

No of rays 49924
Max time 45,0 ms
Time step 1,0 ms
Max order 1
Min level -30,0 dB
Lost rays shown
Ray color Order
Lambert 1D



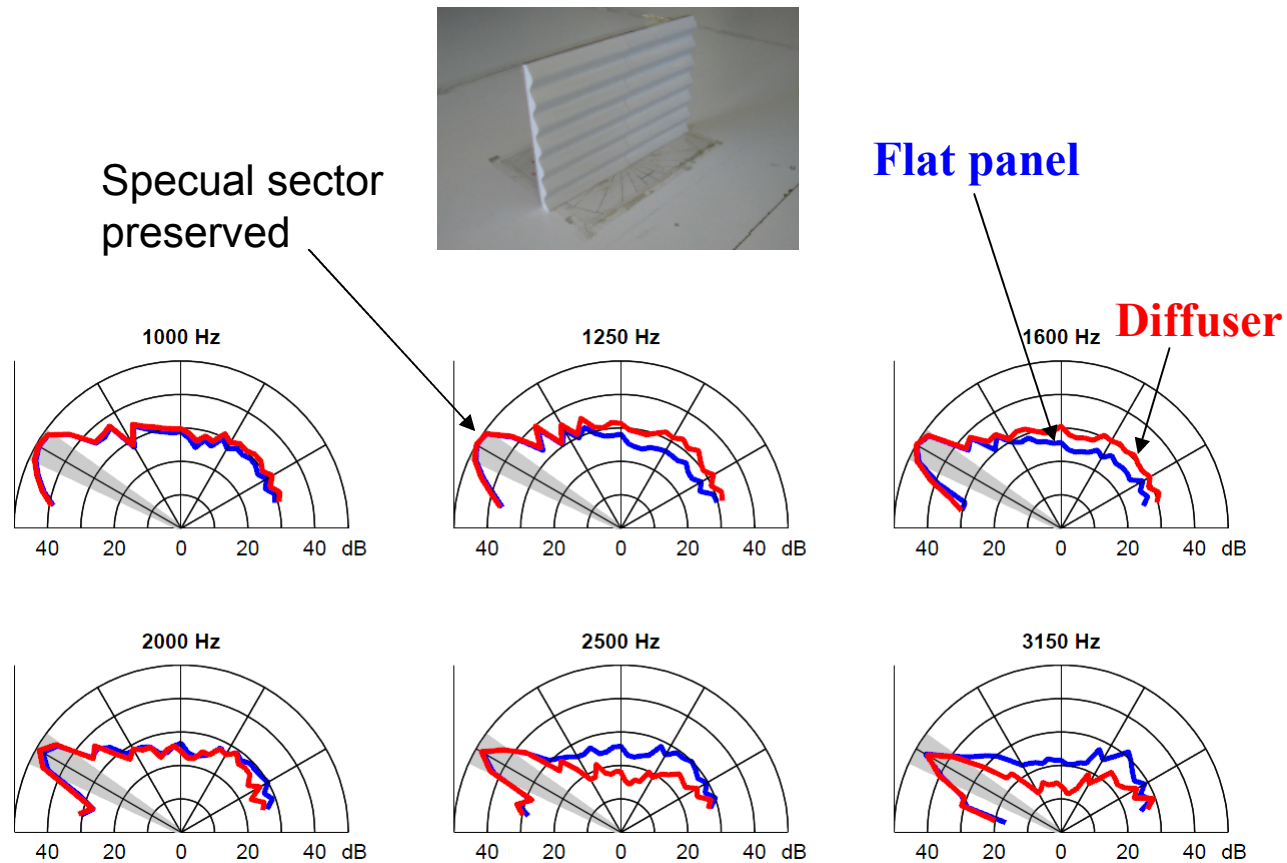
Measurements 1:6

Measurements along

– good news!

Measurements 2:6

Along a 1D-sinusoidal depth variation



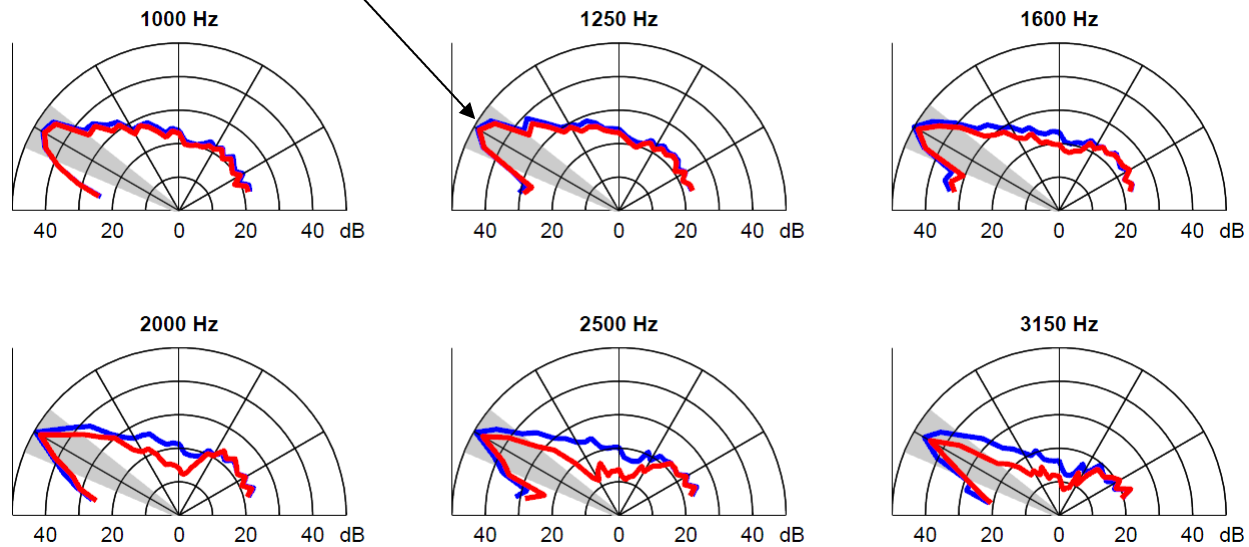
Courtesy: *RPG Diffusor Systems, Inc.*

Measurements 3:6

Along battens



Special sector preserved

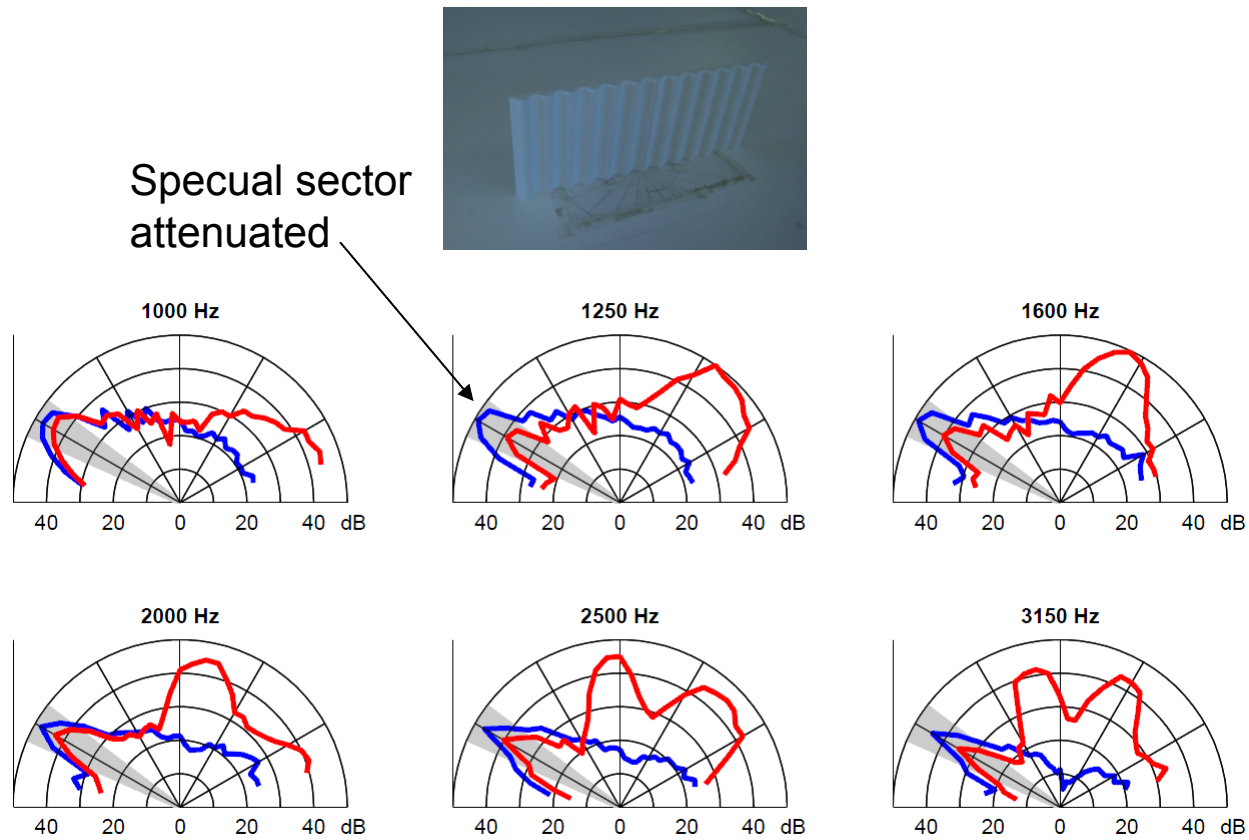


Measurements 4:6

**Measurements across –
not as good news
(complex behavior)**

Measurements 5:6

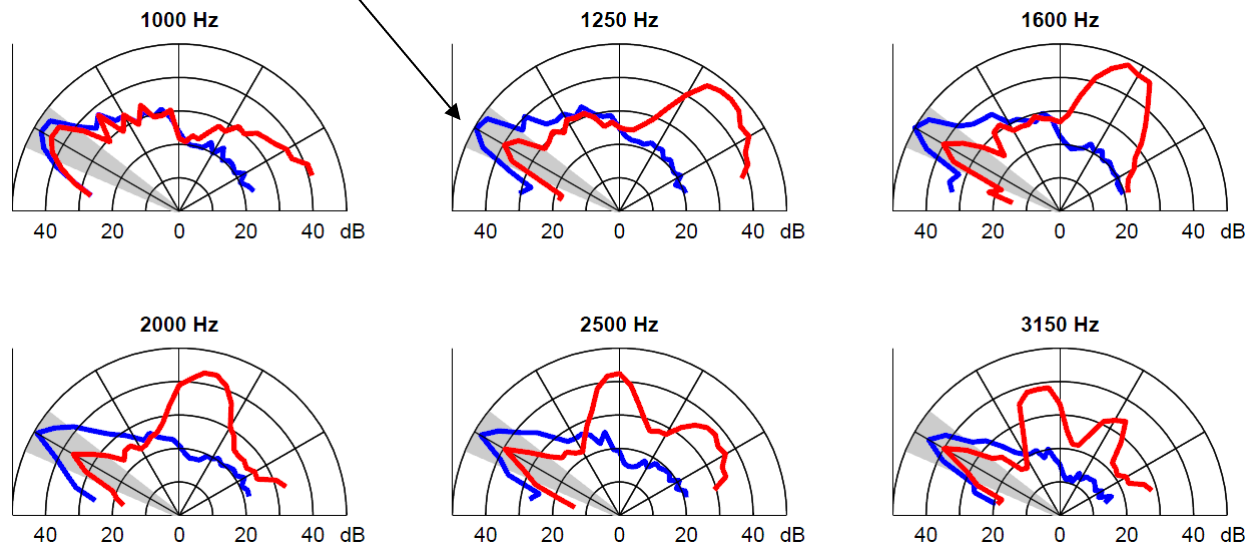
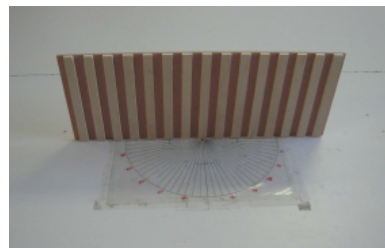
Across a 1D-sinusoidal depth variation



Measurements 6:6

Across battens

Specual sector
attenuated



Summary

- A model for 1D-diffusers within geometrical acoustics has been presented
- For ray incidence across battens the model gives high diffusion while incidence along battens gives near specular reflection
- The model is based on an incidence angle dependent scattering coefficient
- Previous experience from estimating scattering coefficients for 2D-diffusing surfaces can be used
- Measurements on two types of 1D-diffusers indicate that the assumption of specular reflection in the along direction is well fulfilled but that reflection in the across direction is complicated and very frequency dependent
- With the 1D-diffuser model presented the along direction can be well modeled and that is likely to be more important than to model the scattering details of the across direction, it is a clear improvement over modeling all diffusers as if they were 2D