Odeon
ROOM ACOUSTICS SOFTWARE

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Diffraction around corners and over wide barriers in room acoustic simulations

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Outline

- Introduction
- Theory
- Diffraction paths
- Verification against traffic noise barriers
- Verification in frequency bands
- Conclusion

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Introduction

- Background
  - Diffraction is usually of minor importance in rooms, because reflections from room boundaries are much stronger
- Diffraction has been included in Odeon ver. 10
- Applications include
  - Office screens
  - Industrial halls
  - Orchestra pit in opera houses
  - Outdoor scenarios, PA calculations

Theory

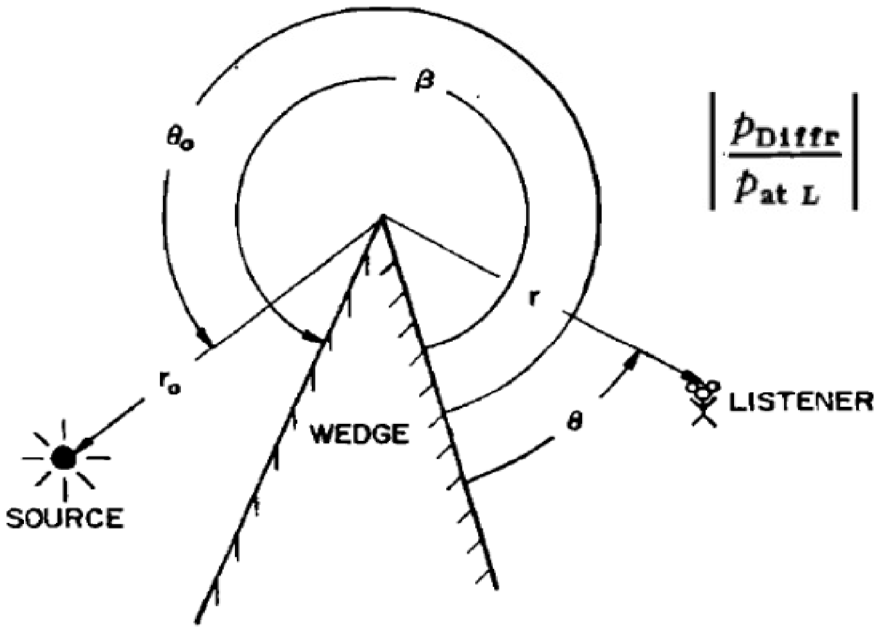


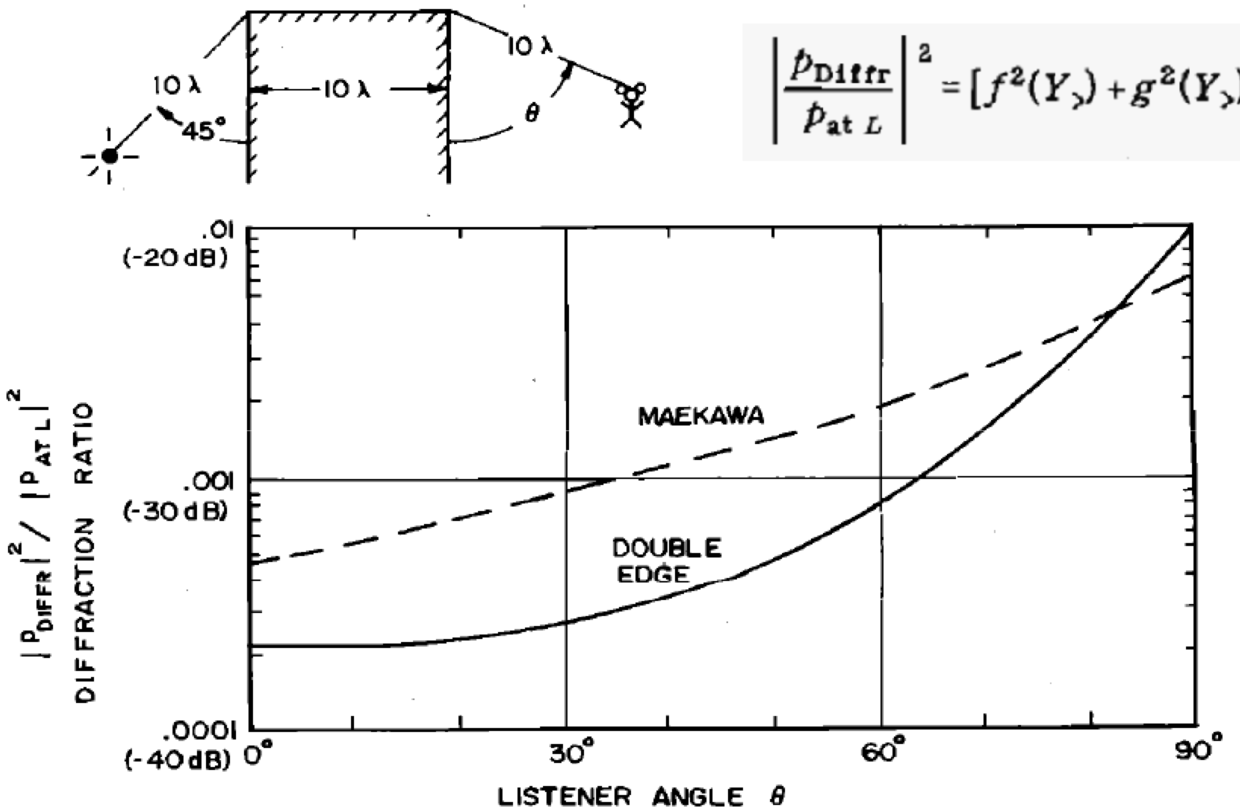
FIG. 1. Definition of symbols used in the discussion of sound diffraction by a rigid wedge of exterior angle β. Here (r_0, θ_0, z_0) and (r, θ, z) give coordinates of source and listener, respectively. The z axis coincides with the edge of the wedge.

$$\left|\frac{p_{\mathrm{Diffr}}}{p_{\mathrm{at}\ L}}\right|^2 = \frac{1}{2}\left\{[f(X_+)+f(X_-)]^2+[g(X_+)+g(X_-)]^2\right\}.$$

Here f and g are auxiliary Fresnel functions (diffraction functions)

Ref.: A.D. Pierce, Diffraction of sound around corners and over wide barriers, *J. Acoust. Soc. Am.*, **55**, 1974, 941-955.

Double edge diffraction

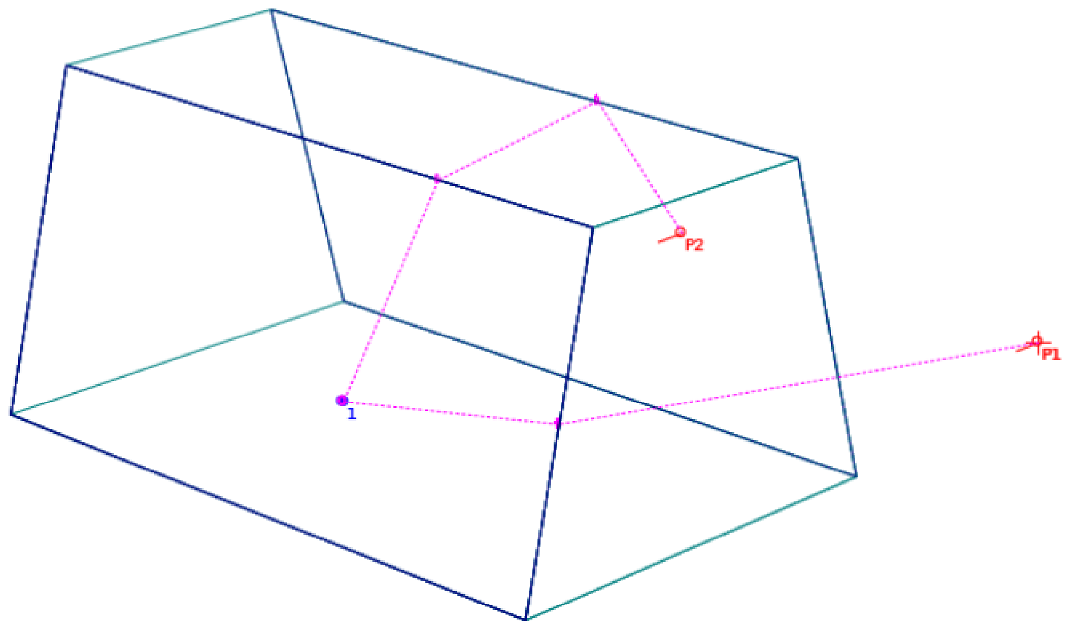


$$\left|\frac{p_{\mathrm{Diffr}}}{p_{\mathrm{at}\ L}}\right|^2 = [f^2(Y_>) + g^2(Y_>)][f^2(BY_<) + g^2(BY_<)].$$

Ref.: A.D. Pierce, Diffraction of sound around corners and over wide barriers, *J. Acoust. Soc. Am.*, **55**, 1974, 941-955.

Diffraction paths

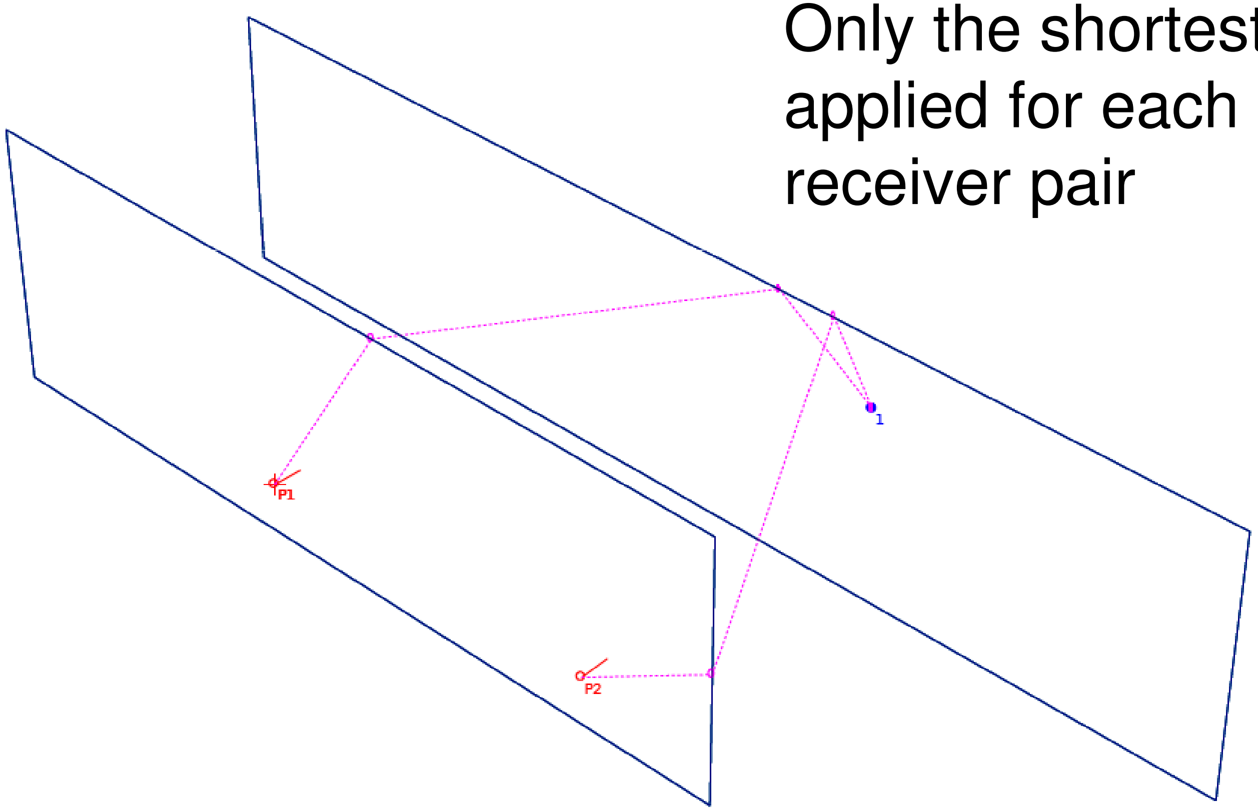
One or two edges



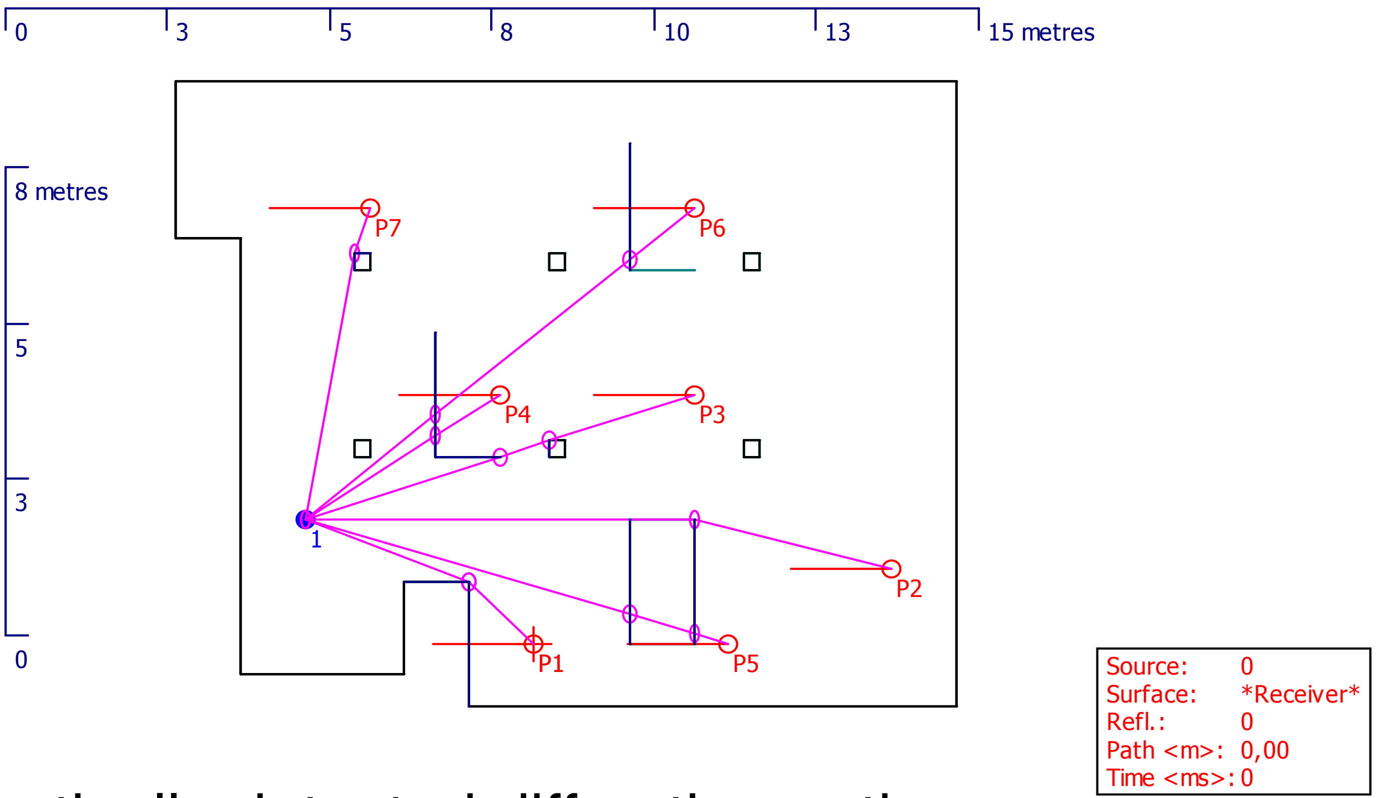
Diffraction paths

Across or around two thin screens

Only the shortest path is applied for each source-receiver pair



Diffraction paths

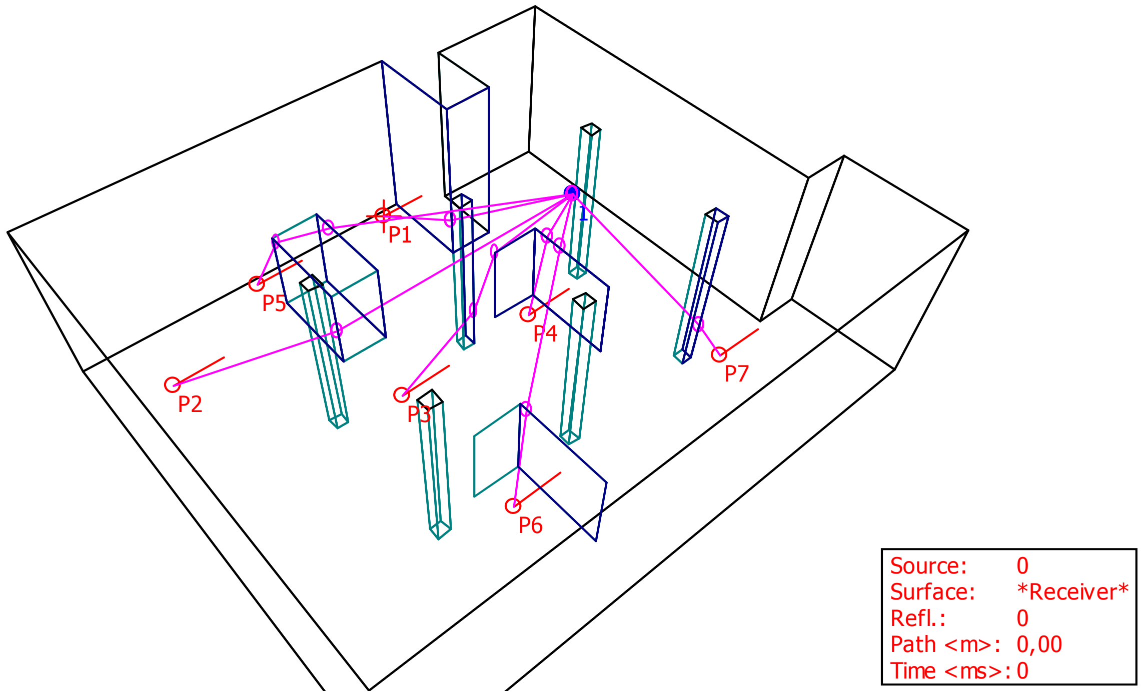


Automatically detected diffraction paths

Diffraction paths

Examples
Single diffraction:
P1, P4, P7

Double diffraction:
P2, P3, P5, P6



Diffraction paths

Examples
Single diffraction:
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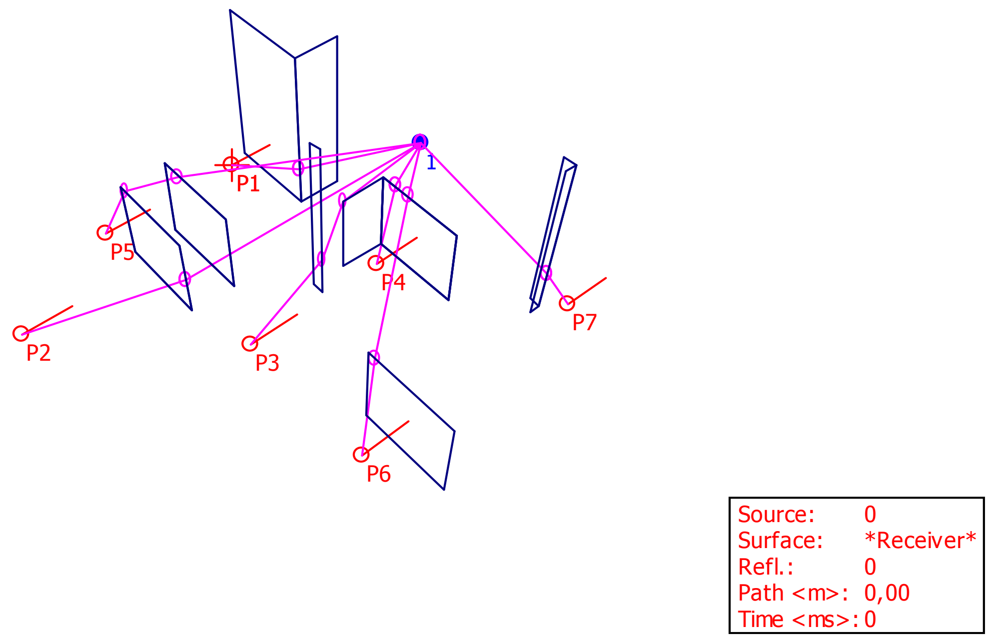
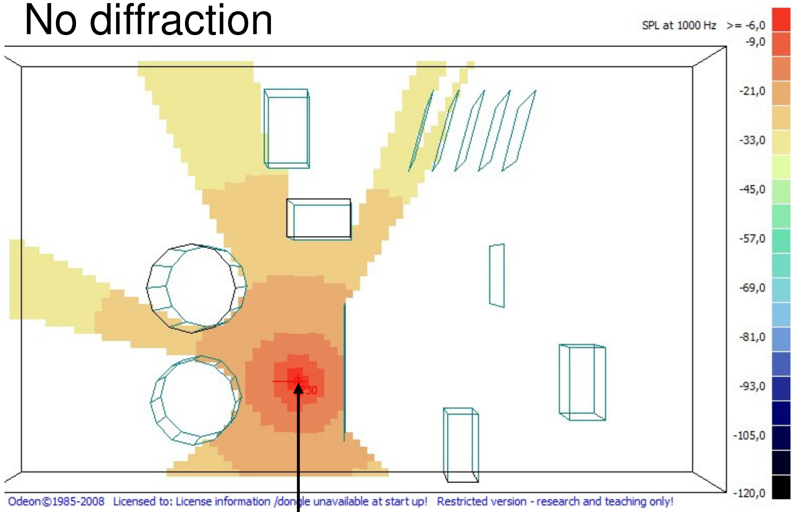


Diffraction paths

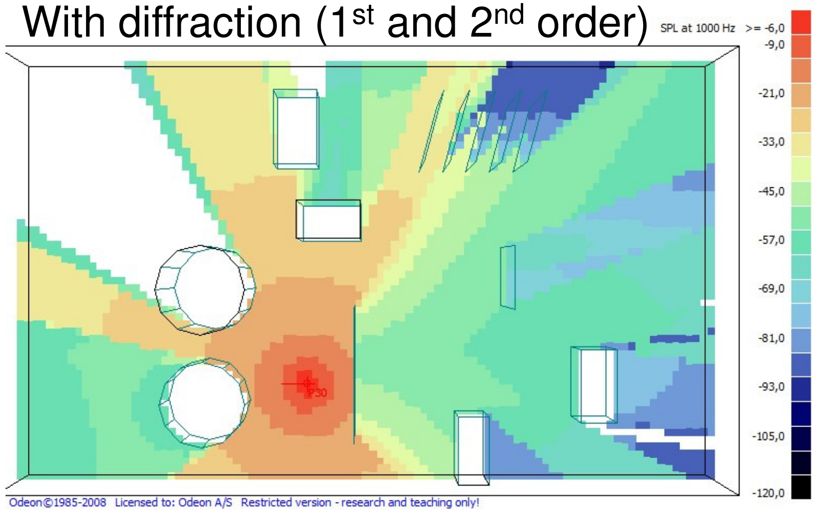
No diffraction



Sound source

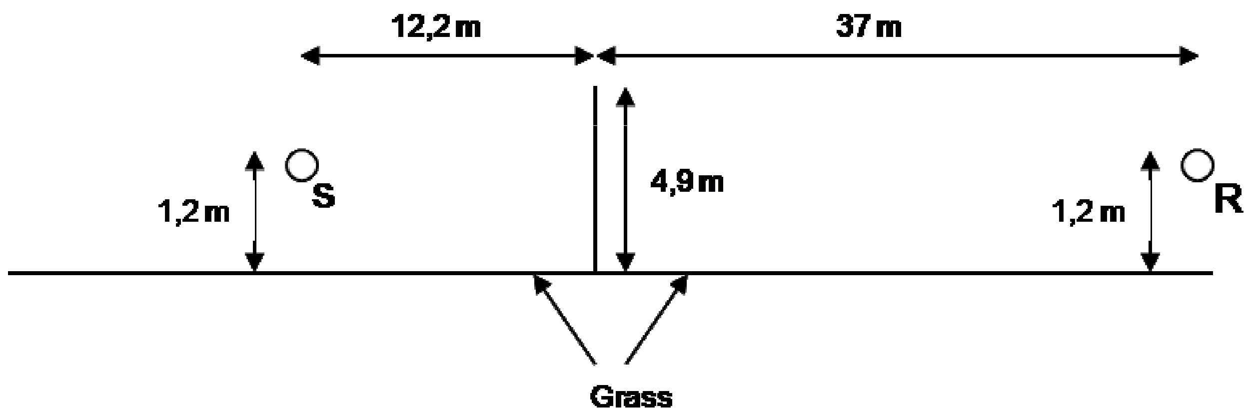
SPL at 1000 Hz in an arbitrary scenario with screening objects

With diffraction (1st and 2nd order)



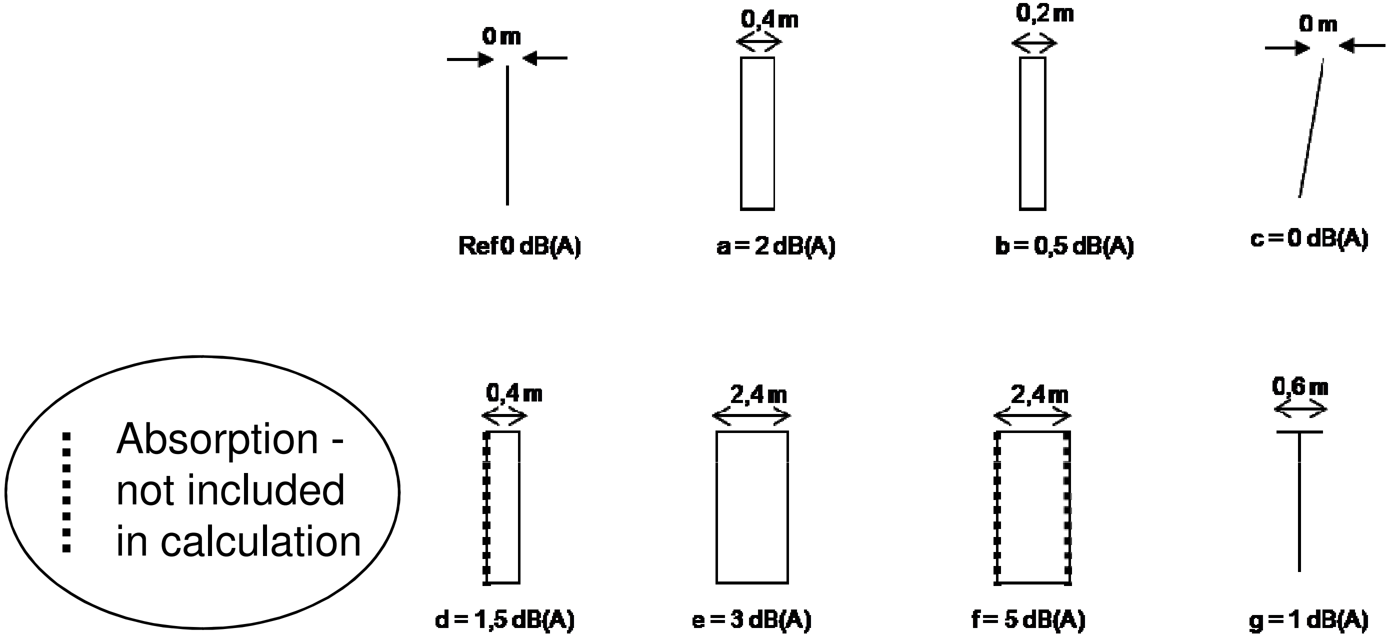
Verification – Traffic noise barriers

May & Osman (1980) J. Sound Vib. 712:
Measurements in 1:6 scale model.
Road traffic noise spectrum applied



Ref.: G. Watts, Acoustic Performance of Traffic Noise Barriers – A State of the Art Review. Part 2. *Acoustics Bulletin*, November/December, 1993, 29-39.

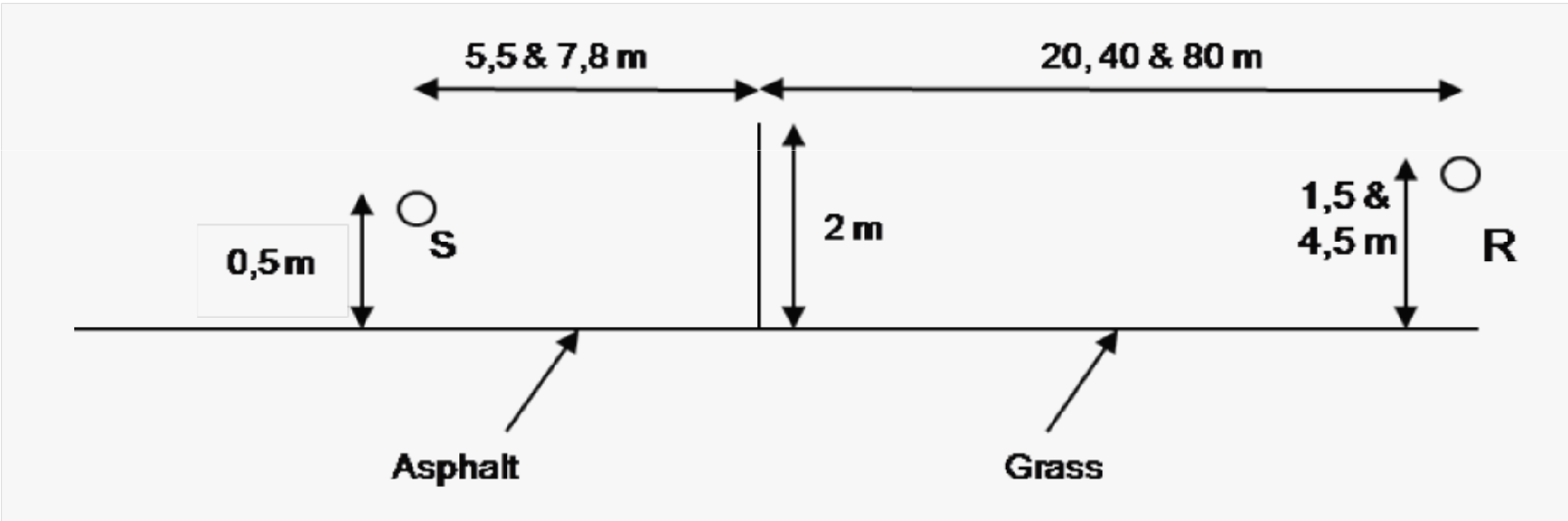
Verification – Traffic noise barriers



dB(A)	a	b	c	d	e	f	g
Calculated. Ref: Single surface	2,9	2,1	0,4	2,9	4,0	4,0	-
Calculated. Ref: 0,01 m thick box	2,9	2,1	0,4	2,9	4,0	4,0	-
Measured	2	0,5	0	1,5	3	5	1
Deviation	0,9	1,6	0,4	1,4	1	-1	-

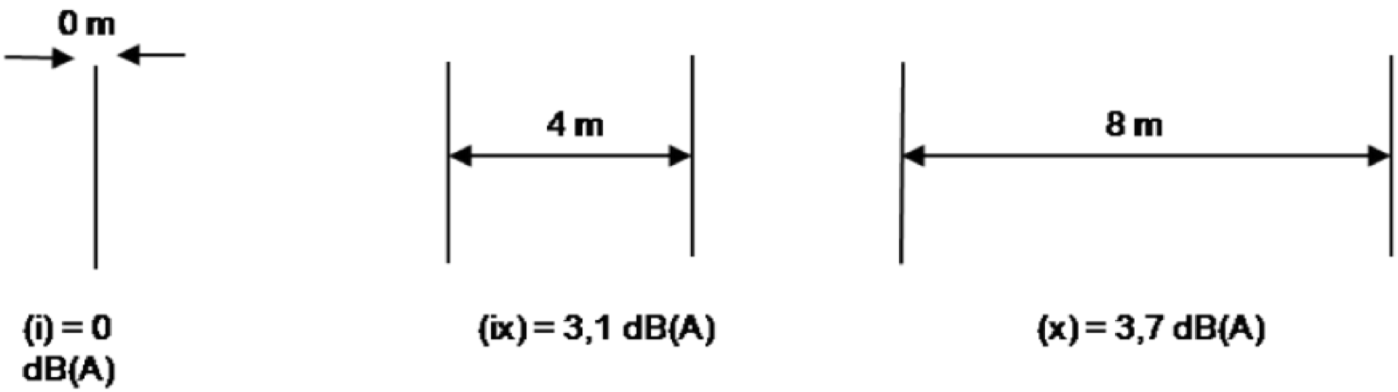
Verification – Traffic noise barriers

Hothersall, Crombie & Chandler-Wilde (1991) Appl. Ac. 32:
Measurements with road traffic noise in situ.
Average of two source positions and six receiver positions



Ref.: G. Watts, Acoustic Performance of Traffic Noise Barriers – A State of the Art Review. Part 2. *Acoustics Bulletin*, November/December, 1993, 29-39.

Verification – Traffic noise barriers



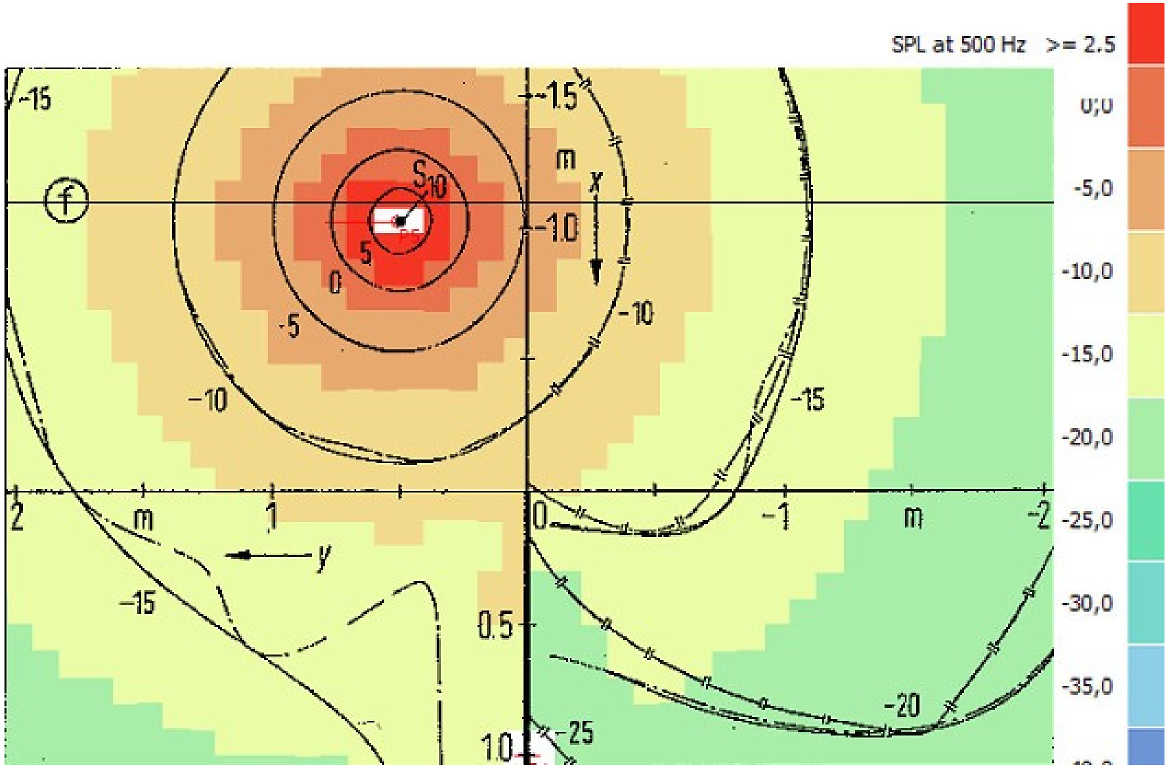
dB(A)	i	ix	x
Simulated	0	2,9	3,8
Measured	0	3,1	3,7
Deviation	0	-0,2	0,1

Verification in frequency bands

- A thin half plane
- Comparison with results from scale model measurements in anechoic room
  - Kawai et al. (1977)

Ref.: T. Kawai, K. Fujimoto, and T. Itow, Noise Propagation around a Thin Half-Plane, *Acustica* **38**, 1977, 313-323.

A thin half plane

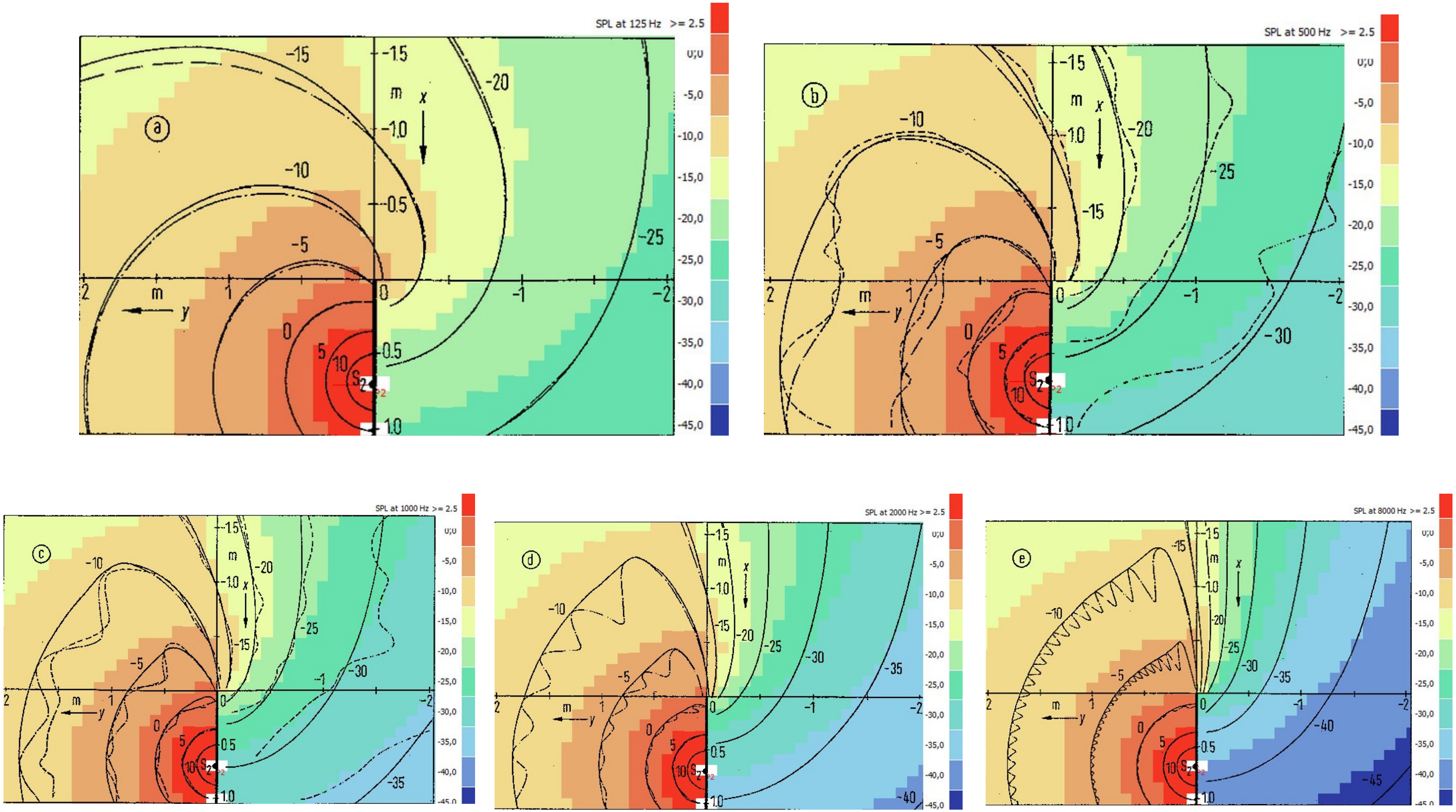


Odeon simulations:

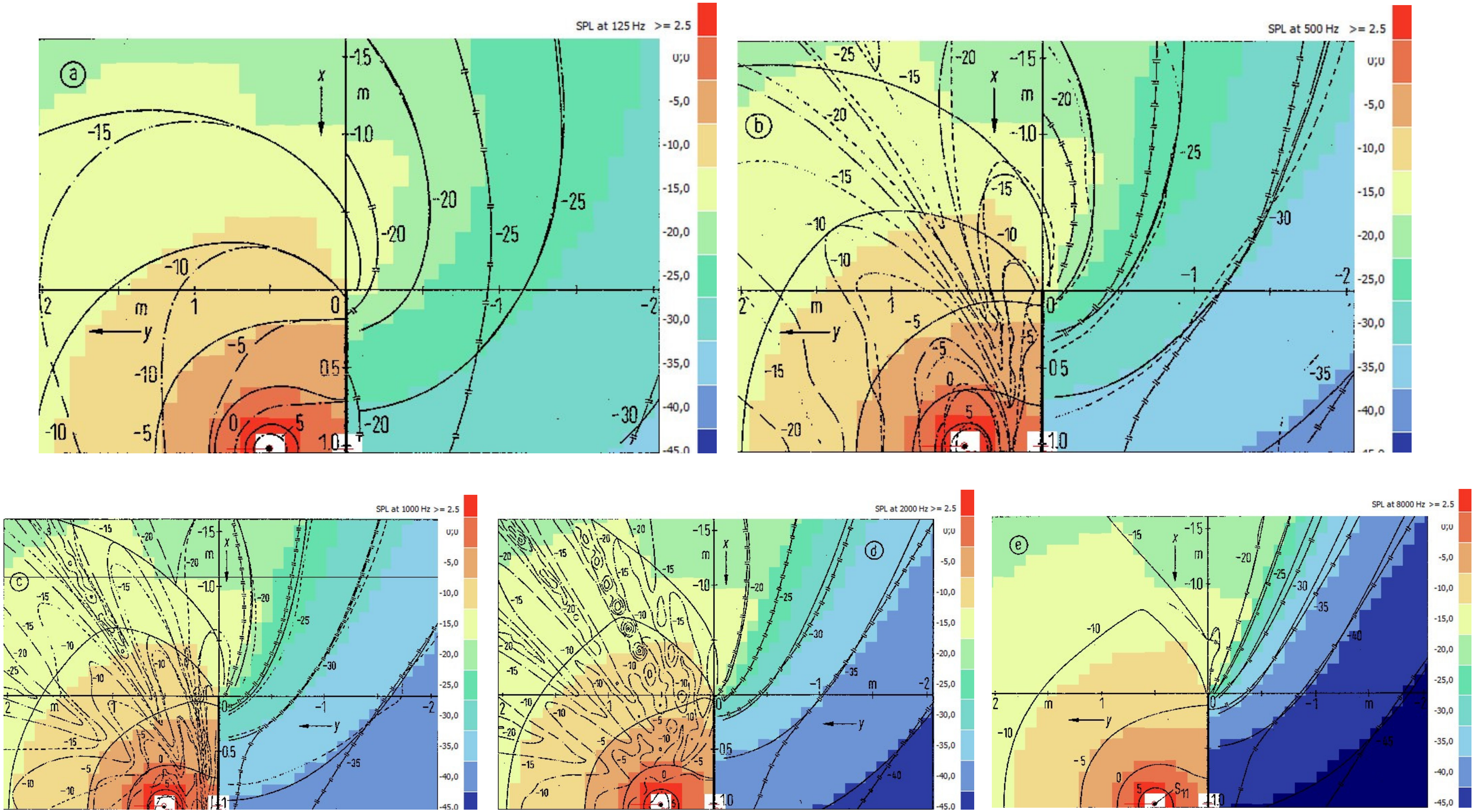
Numbers indicate the centre of the coloured 5 dB zones

Dashed lines: Measured results
Full lines: Theoretical results

Thin screen – five octave bands



Thin screen – five octave bands



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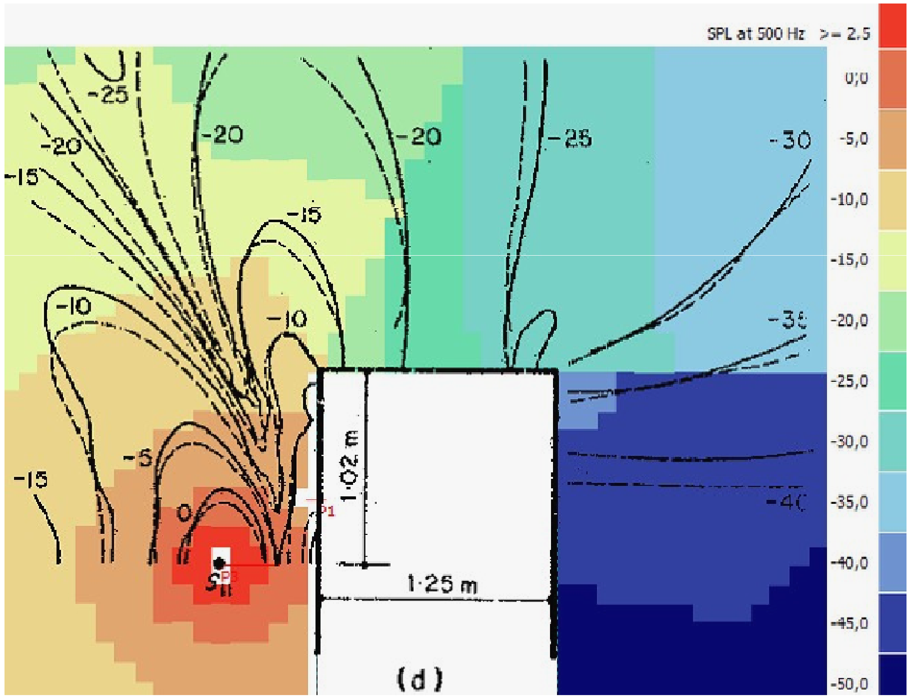
Verification in frequency bands

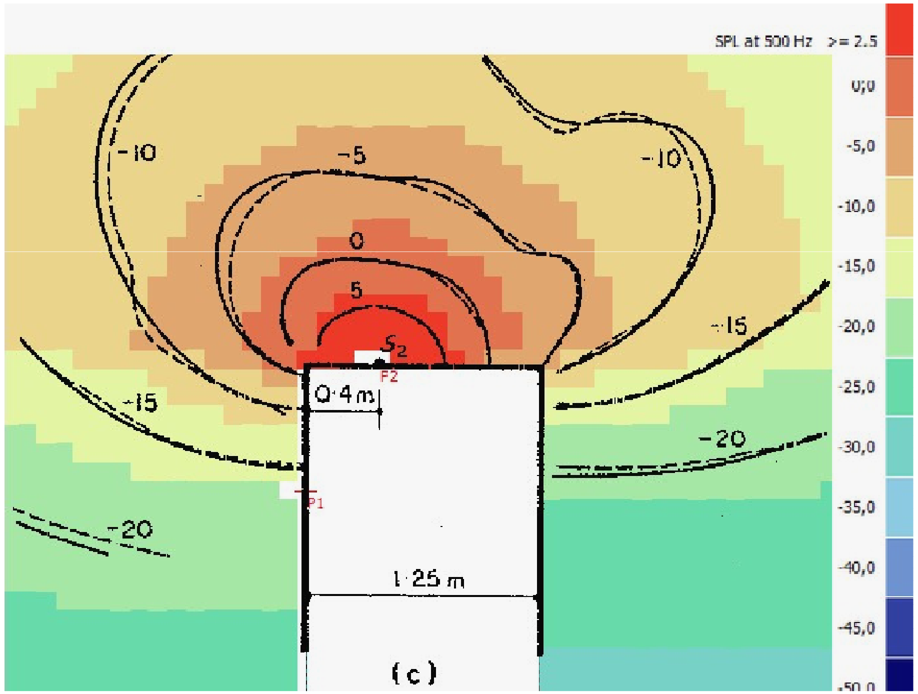
- Objects and many-sided barriers
- Comparison with results from scale model measurements in anechoic room
  - Kawai (1981)

Ref.: T. Kawai, Sound Diffraction by a Many-Sided Barrier or Pillar, *Journal of Sound and Vibration*, **79**, 1981, 229-242.

Thick barrier

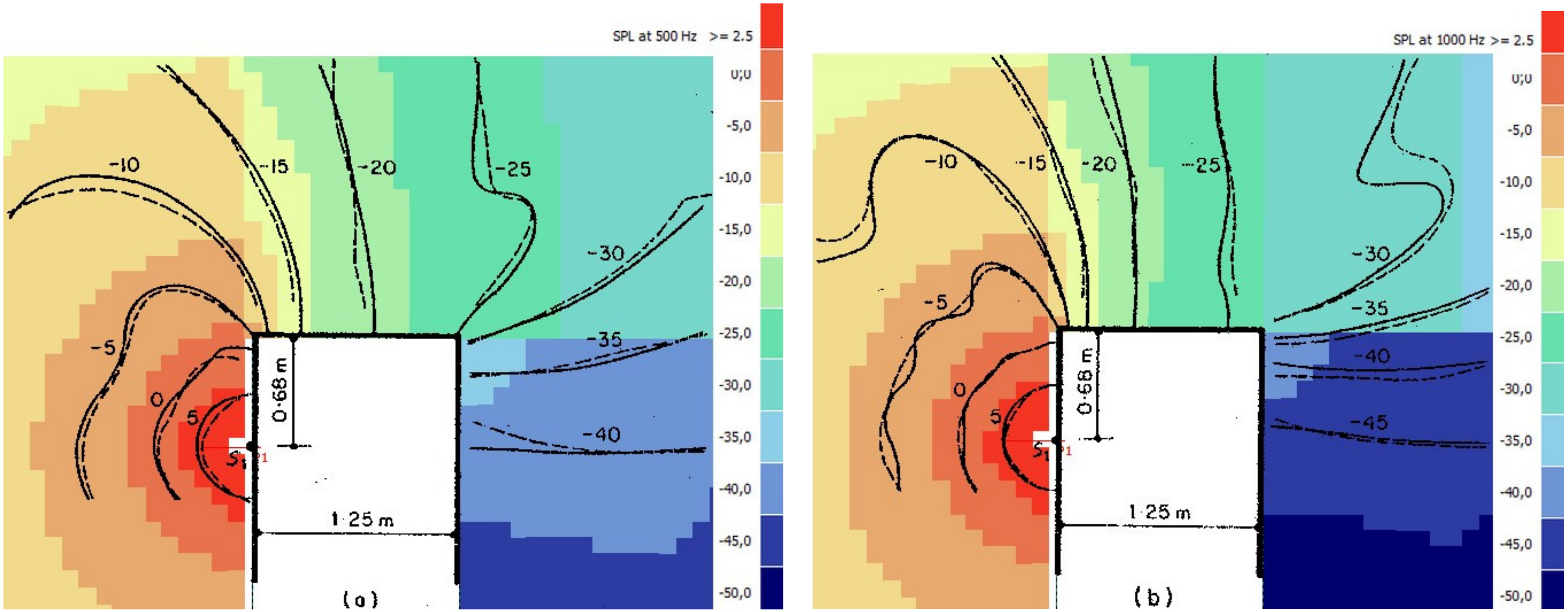
Different source positions – 500 Hz octave band





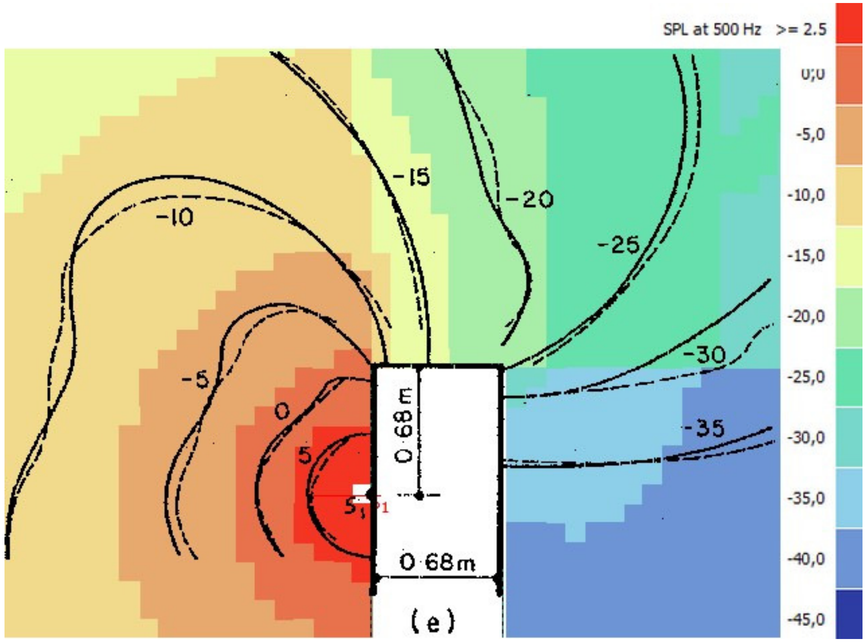
Thick barrier

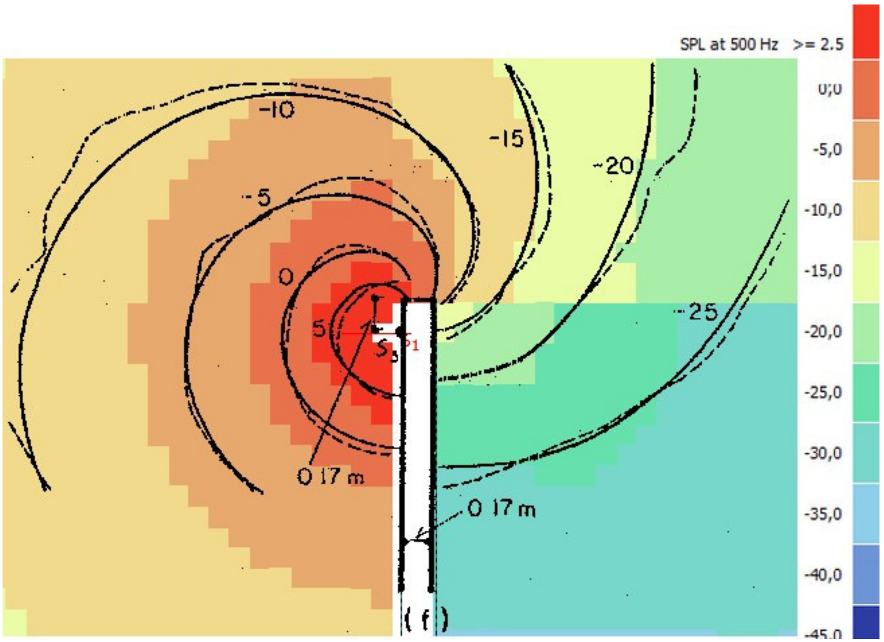
Source on the surface of barrier – different frequencies



Thick barrier

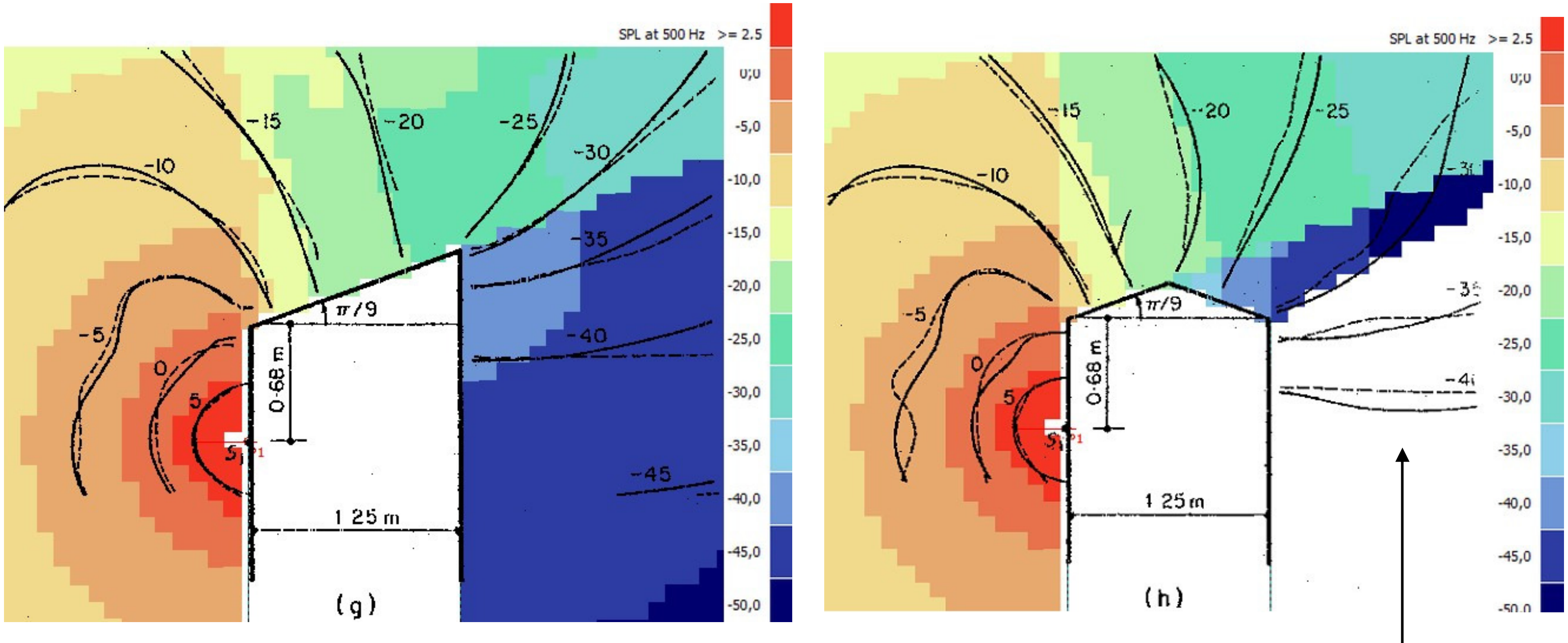
Different thickness of barrier





Thick barrier

Different shapes of barrier



No diffraction path is found for receivers in this region

Conclusion

- An automatic detection method for the relevant diffraction paths has been developed
  - This is thought to be essential for practical use in room acoustic simulations; a manual indication of diffraction paths is not realistic because room models are often very complicated
- Theoretical models for single and double diffraction have been implemented
- The results have been verified by comparison to measured results for various cases of single and double diffraction