FNRS

Intelsig

Numerical simulations of the sound propagation in non rectilinear streets

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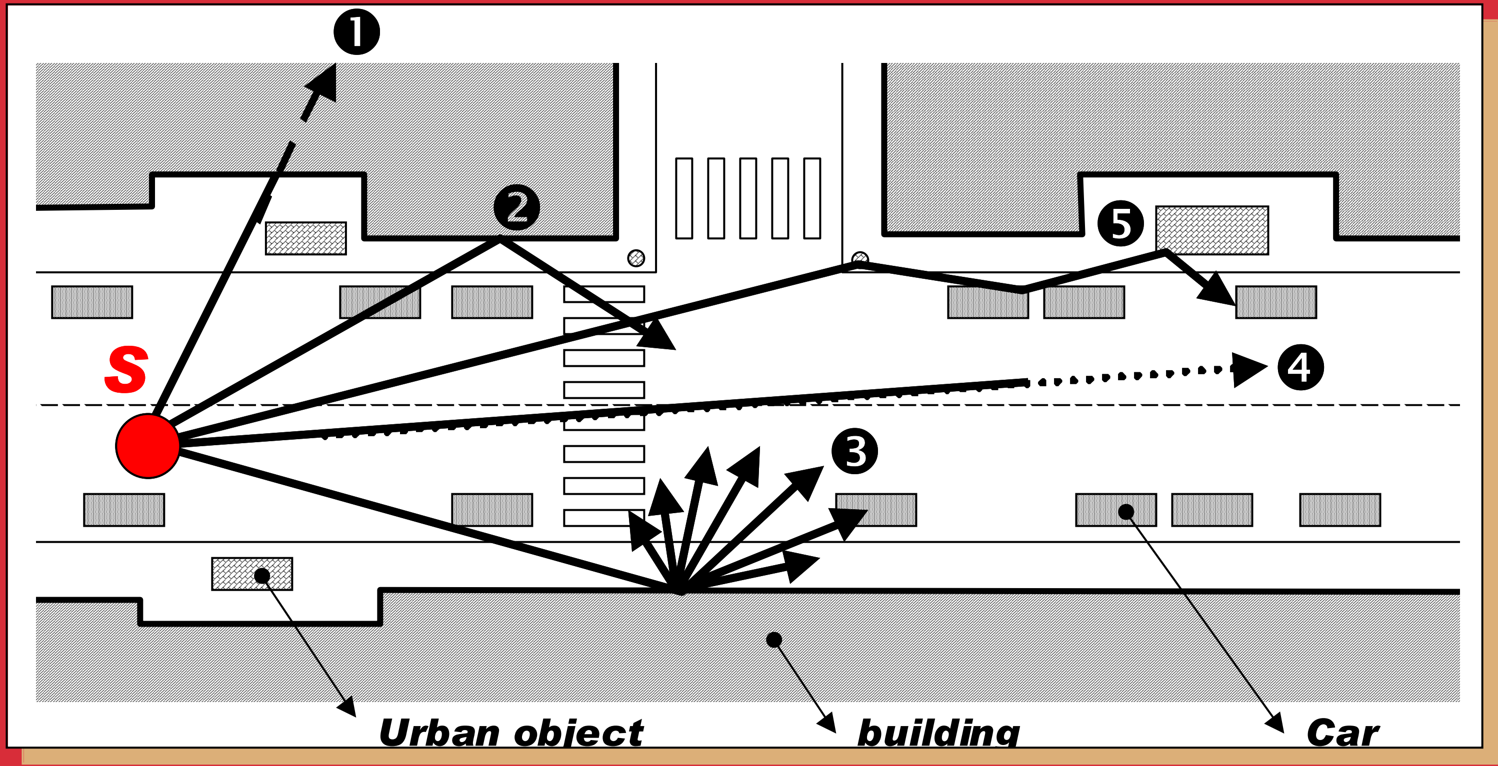
1. Introduction



- Integrating all these physical phenomena;
- Minimizing the computation time;
- Dealing with complex geometries.

- Comparison of ray-tracing's and diffusion model's results and experiments on scale models for non-rectilinear streets

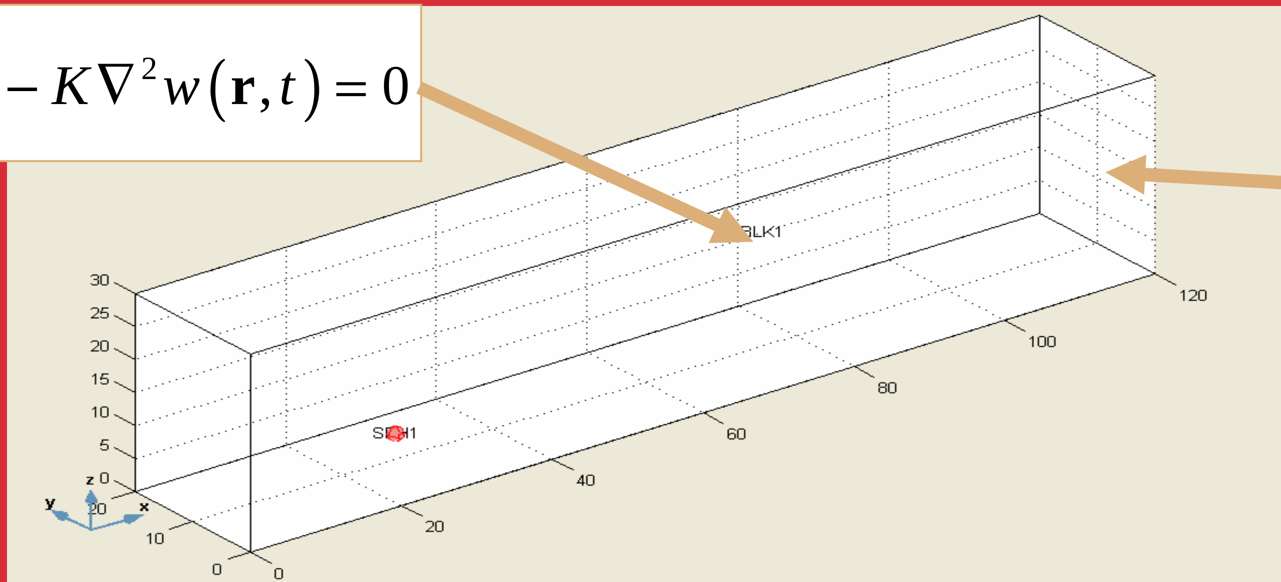
2. Models presentation

- Diffusion model
  - Starting with the motion of sound particles
  - Using an asymptotic development (Le Pollès, 2003)

    Transport equation → Diffusion equation

  - Solving using finite elements (Colle, 2006)

$$\frac{\partial w(\mathbf{r},t)}{\partial t} - K\nabla^2 w(\mathbf{r},t) = 0$$



$$h = \frac{c}{2}\alpha$$

$$K = \frac{2-s}{s}\frac{\ell c}{2}$$

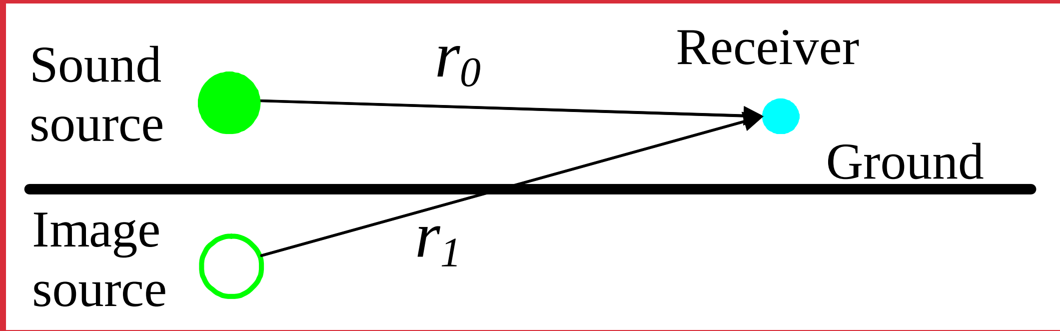
ℓ street half-width

s scattering coefficient

c sound speed

2. Models presentation

- Sound pressure level

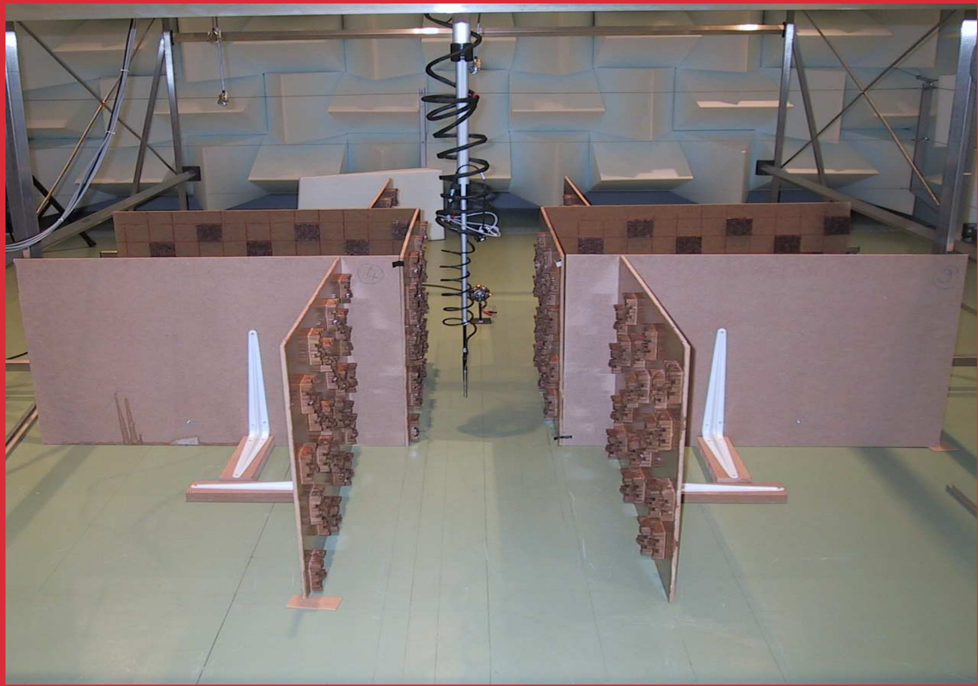


$$SPL(\mathbf{r}) = 10\log_{10}\left[\frac{\rho c}{p_{ref}^2}\left(\frac{W_s}{4\pi \mathbf{r}_0^2} + (1-\alpha_s)\frac{W_s}{4\pi \mathbf{r}_1^2} + cw(\mathbf{r})\right)\right]$$

- Good agreement in terms of SPL with numerical and experimental results for rectilinear streets
- Inability to predict sound decay (Billon & Picaut, 2008)

- Broadband ray-tracing Salrev (Embrechts, 2000)

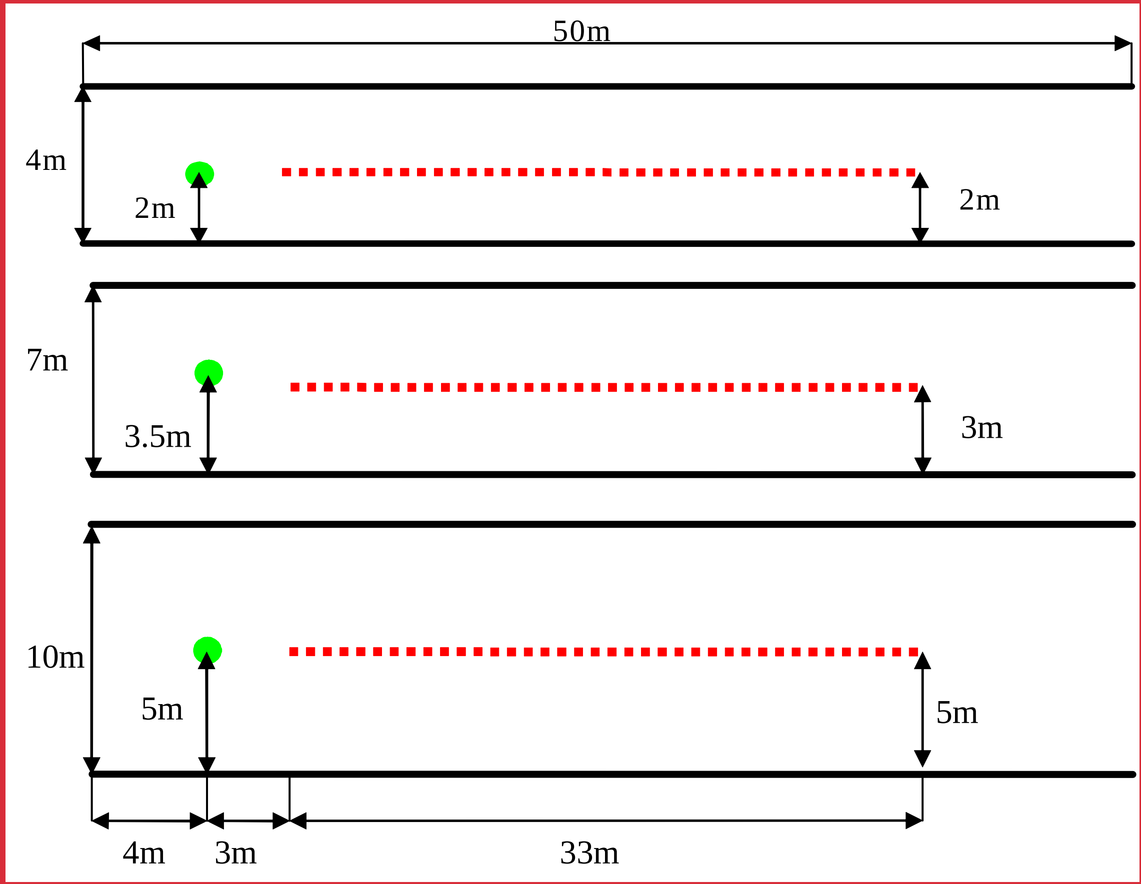
3. Experimental apparatus



- Scale 1/10th
- Ø 65 mm dodecahedric sound source
- ¼" free field microphone
- Varnished plywood fitted with sound diffusors
- Measurements between 100 Hz and 8 kHz (full scale)
- Atmospheric attenuation compensed with a time-varying filter
- Evaluation of SPL and reverberation times (RT10)

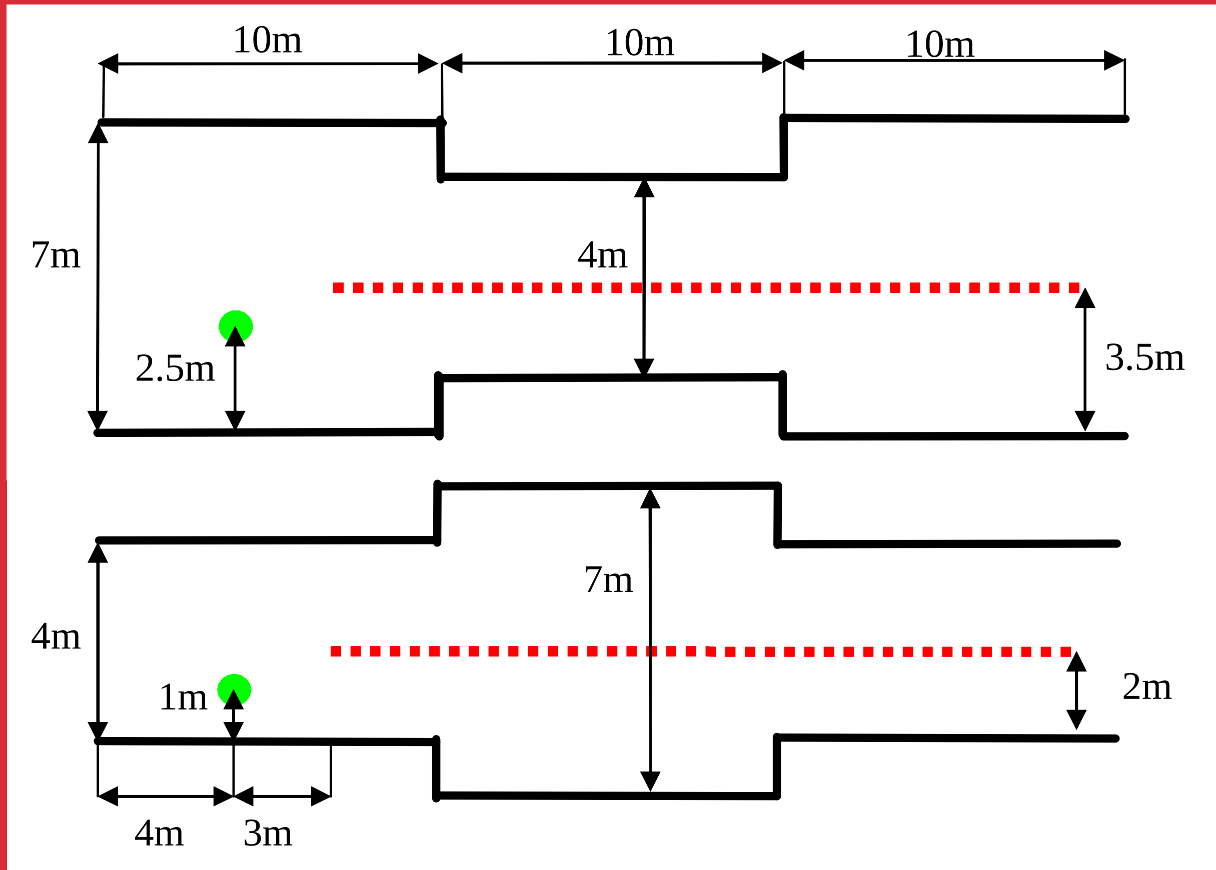
3. Experimental apparatus

- Tree straight configurations



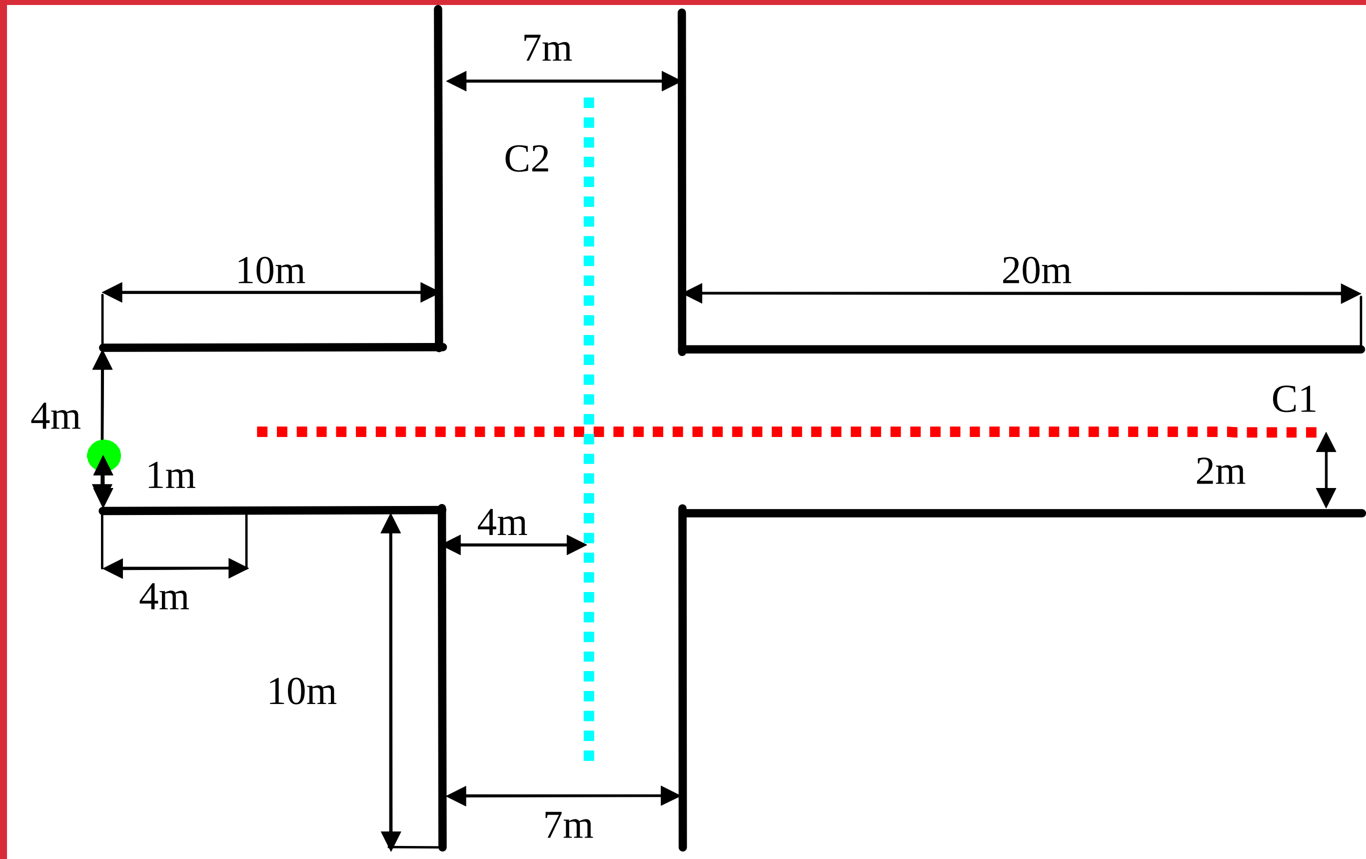
3. Experimental apparatus

- Two configurations with varying cross-section



3. Experimental apparatus

- Intersection



4. Numerical parameters

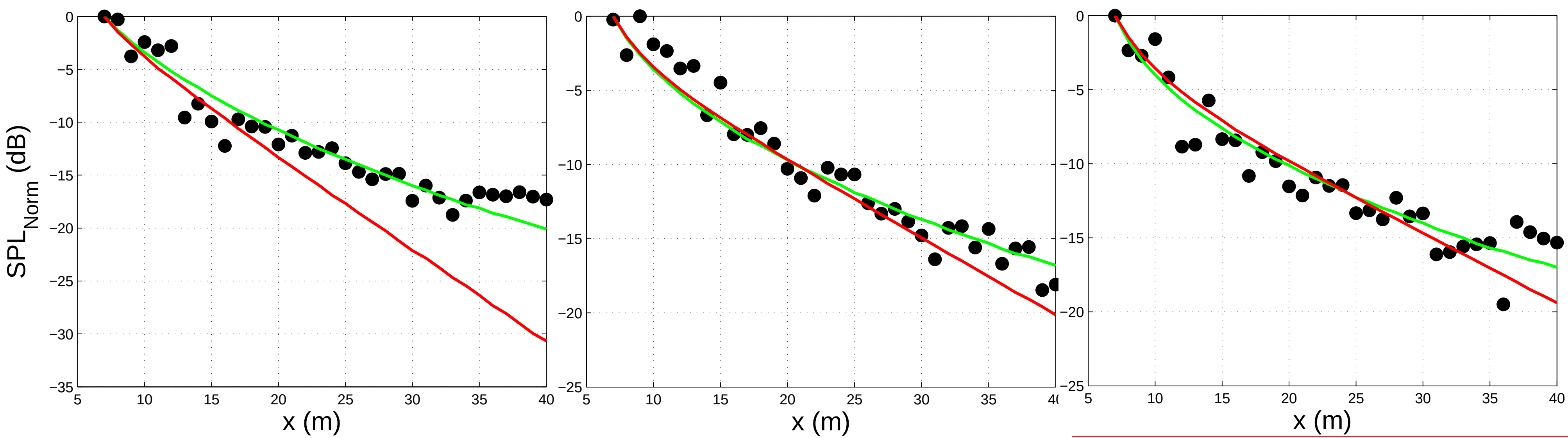
- Ray-tracing
  - Ø 1 m sound receivers
  - 10^8 rays
  - Computation time 1h~1h30
- Diffusion model
  - 10^4 Lagrange linear elements
  - Computation time < 20 s
- 630 Hz third octave band (full scale)
- Boundary conditions evaluated from the rectilinear configurations

	Configuration 1 (width 4m)	Configuration 2 (width 7m)	Configuration 3 (width 10m)
α	0.16	0.07	0.02
s	0.55	0.5	0.65
Mean error on SPL	1.1 dB	1.0 dB	1.1 dB
Mean error on RT	6.0%	6.9%	8.8%

5. Results

- Straight streets

Width 4 m | Width 7 m | Width 10 m



(●) Experimental data, (—) diffusion model, (—) Salrev

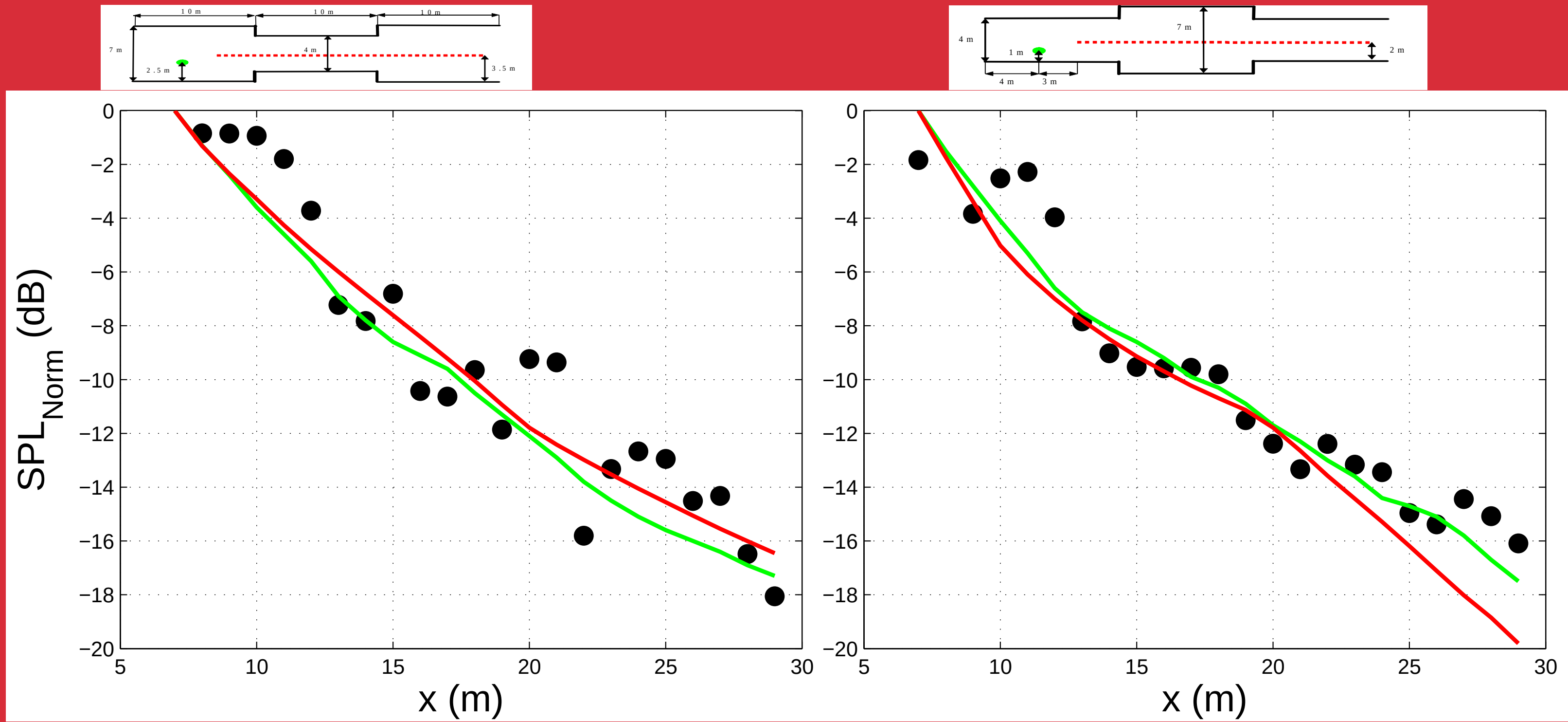
- Good agreement for the 7 and 10 m streets
- The diffusion model is inaccurate for the 4 m wide street

	MD	Sr
4 m	4.1	1.1
7 m	1.3	1.0
10 m	1.4	1.1

Mean error (dB)

5. Results

- Streets with varying cross-section



(●) Experimental data, (—) diffusion model, (—) Salrev

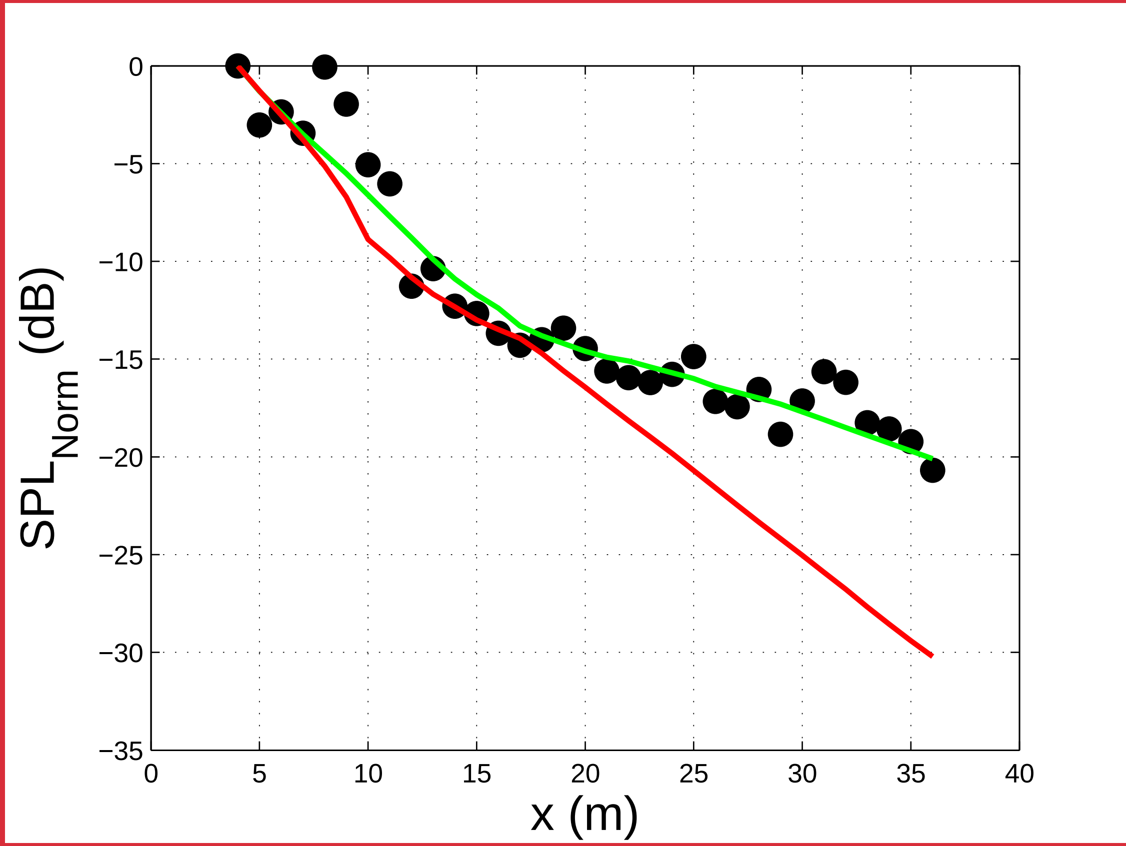
- Good agreement for both models

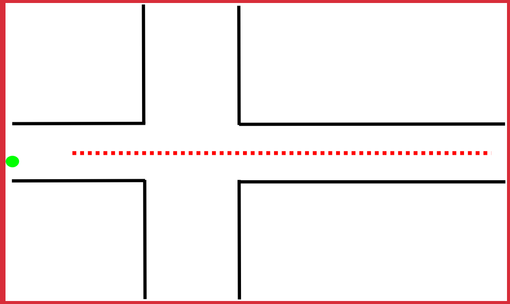
	MD	Sr
1	1.4	1.5
2	1.6	1.1

Mean error (dB)

5. Results

- Intersection

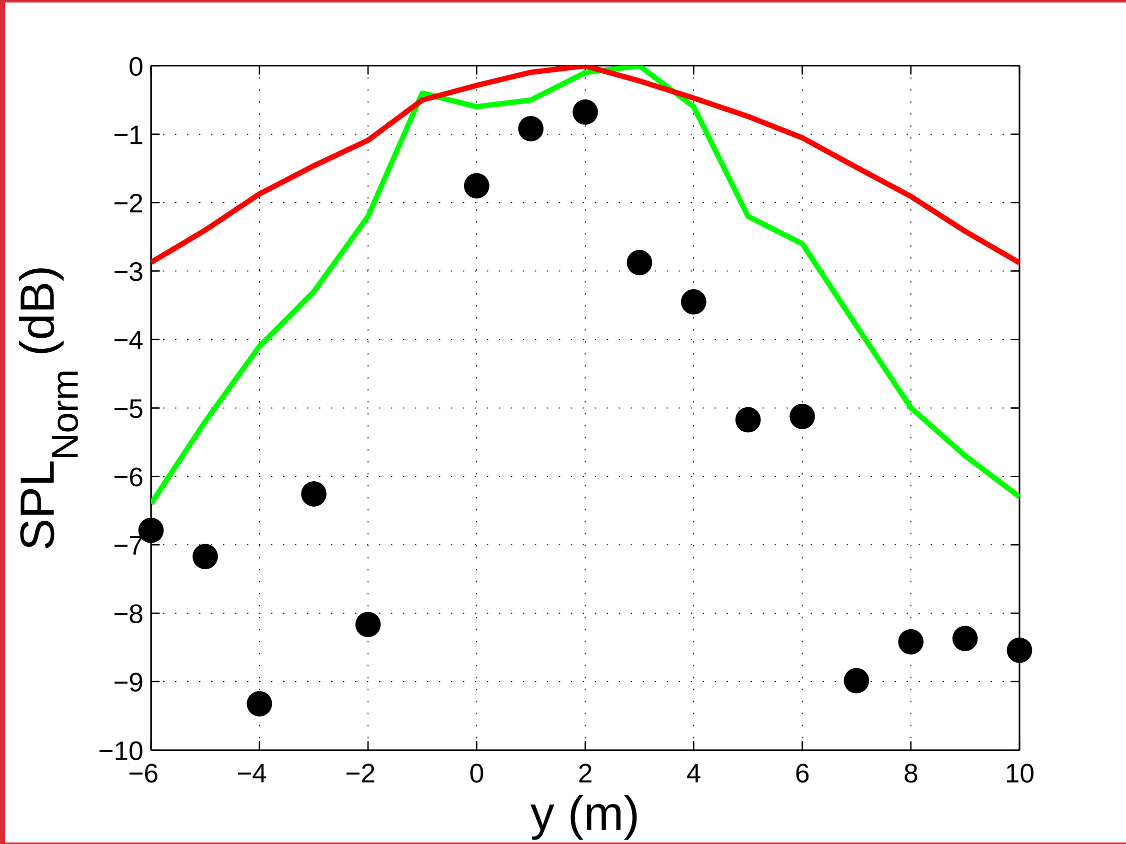


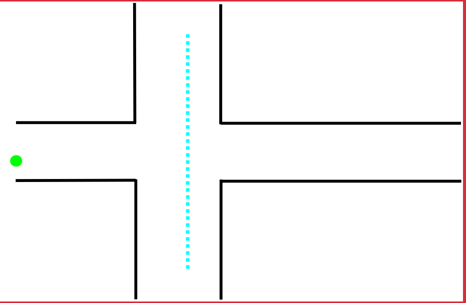


- Good agreement for Salrev (1.1 dB)
- The diffusion model overestimates the sound attenuation in the last section

5. Results

- Intersection





- Fair agreement for Salrev (2.6 dB)
- The diffusion model overestimates the energy flowing through the side streets

6. Conclusions

- Experiments on scale models have been carried out on various geometries
- Scattering and absorption coefficients have been deduced from the rectilinear streets' results
- Simulations have been made using the diffusion model and Salrev
- Salrev gives good results with a mean discrepancy around 1 dB
- The diffusion model's results are unrealistic around street corner, neglecting the directionality of the reverberant sound field

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