UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA

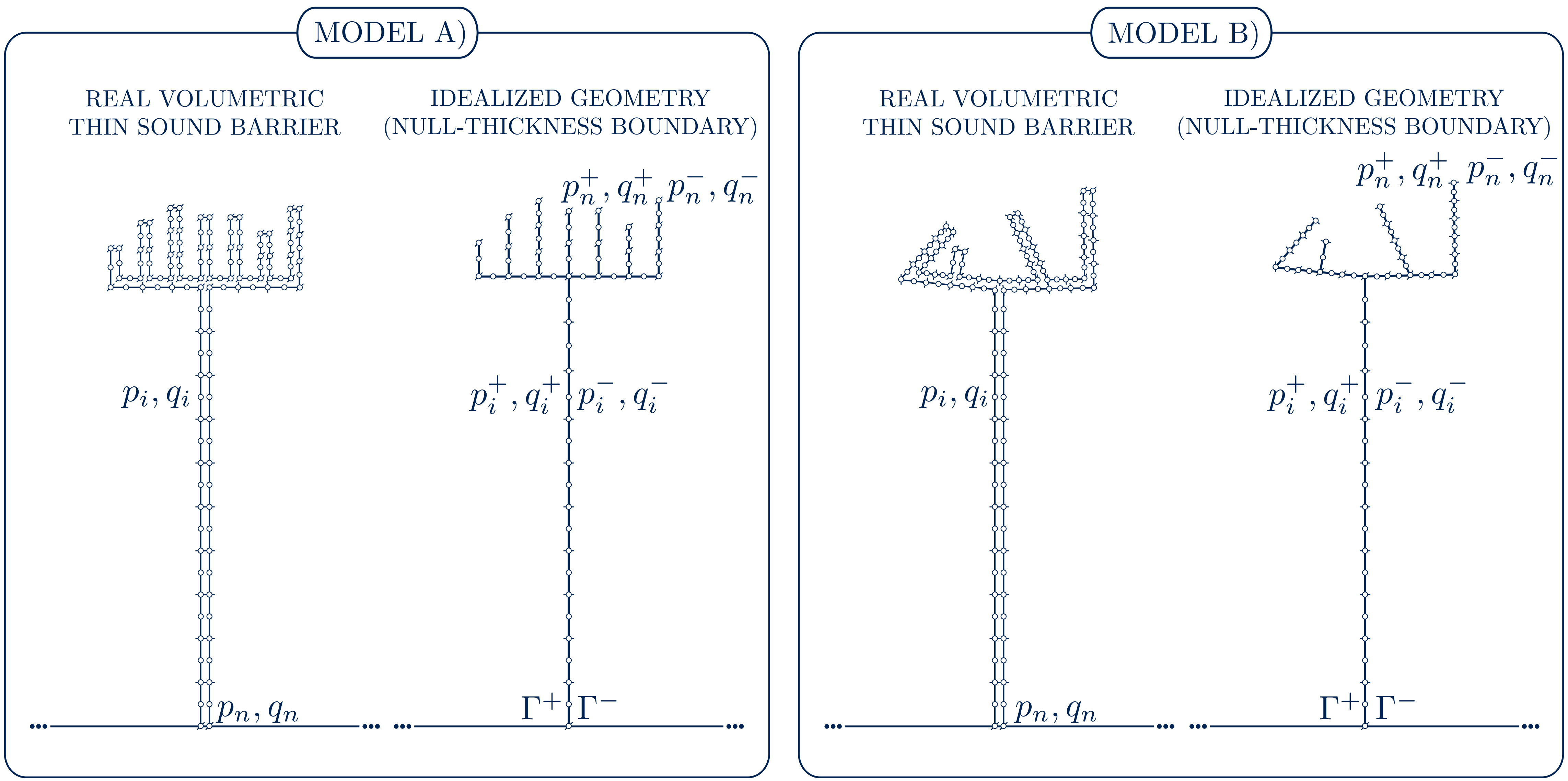
INSTITUTO UNIVERSITARIO EN SISTEMAS INTELIGENTES Y APLICACIONES NUMÉRICAS EN INGENIERÍA (SIANI)

11th WORLD CONGRESS ON COMPUTATIONAL MECHANICS (WCCM)

Barcelona, 23th July 2014

A procedure for the top geometry optimization of thin acoustic barriers

R. Toledo, Juan J. Aznárez, O. Maeso and D. Greiner



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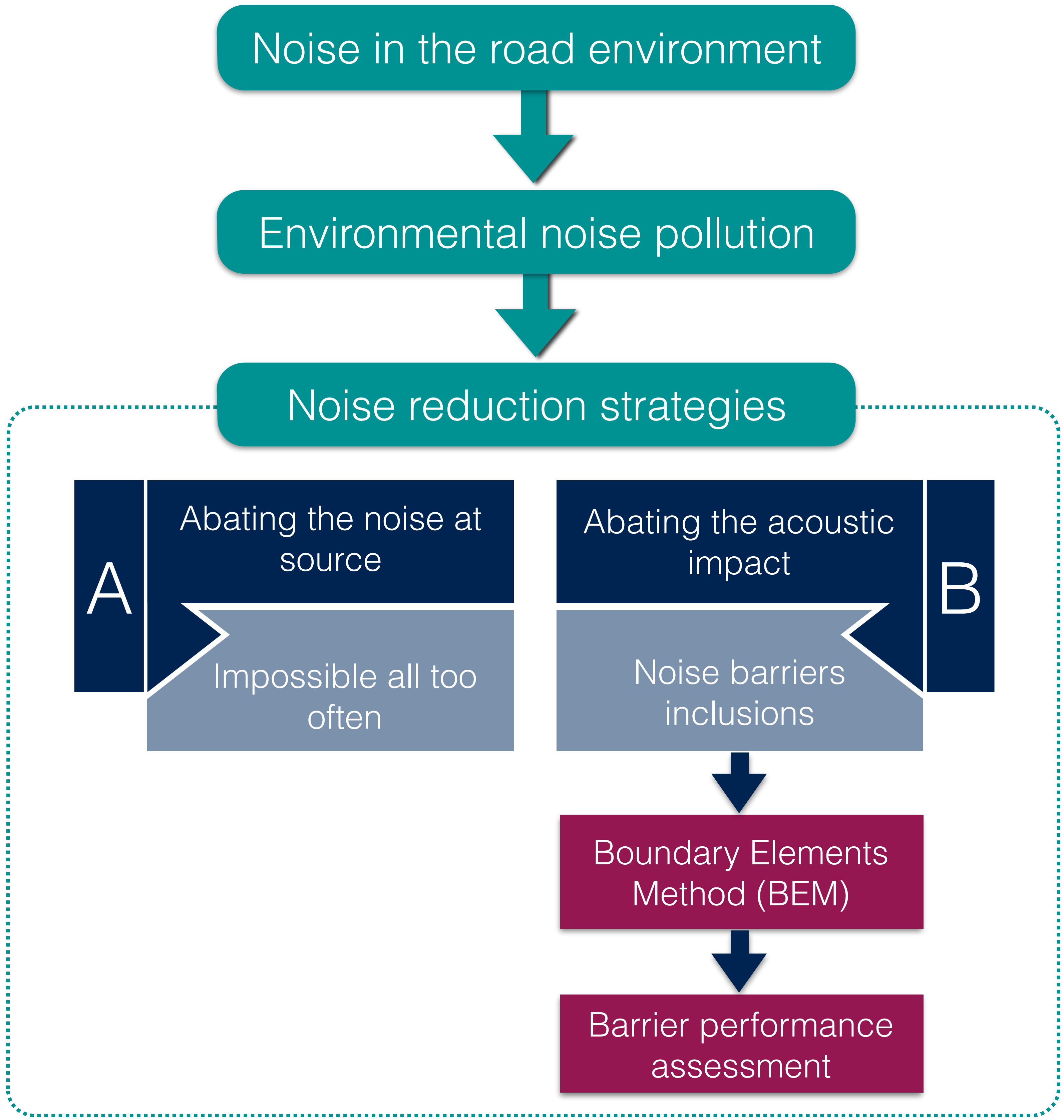
Introduction



Introduction

EXAMPLES OF SOME NOISE BARRIERS

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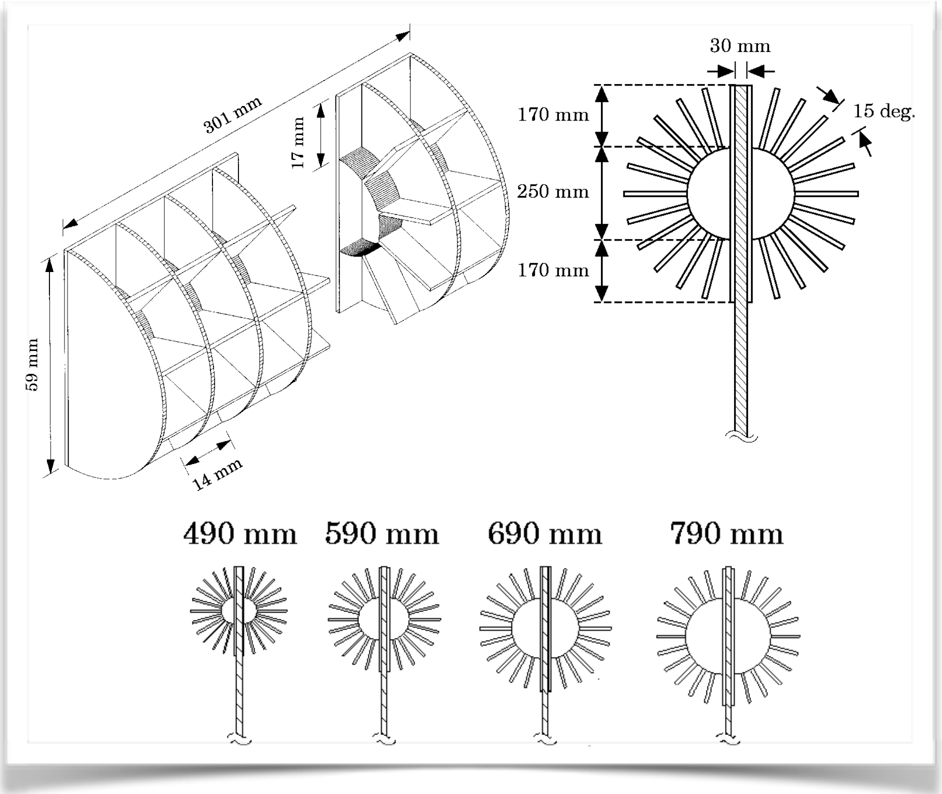
State of the Art

BEM IN PERFORMANCE OF NOISE BARRIERS

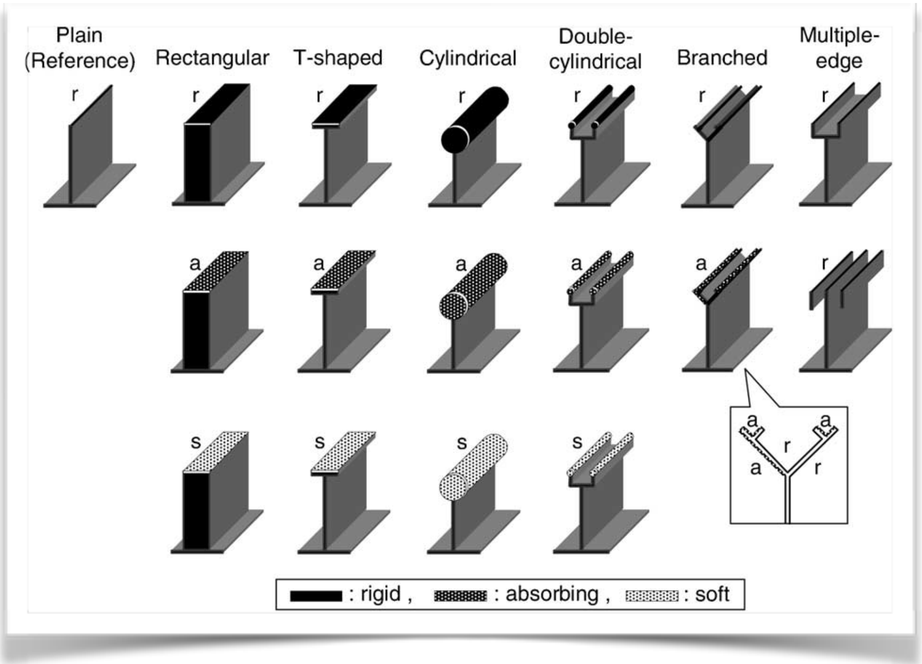
OKUBO & FUJIWARA (1998)

- Efficiency of a noise barrier on the ground with an acoustically soft cylindrical edge. *Journal of Sound and Vibrations*, **216**(5), 771-790.



ISHIZUKA & FUJIWARA (2004)

- Performance of noise barriers with various edge shapes and acoustical conditions. *Applied Acoustics*, **65**, 125-141.



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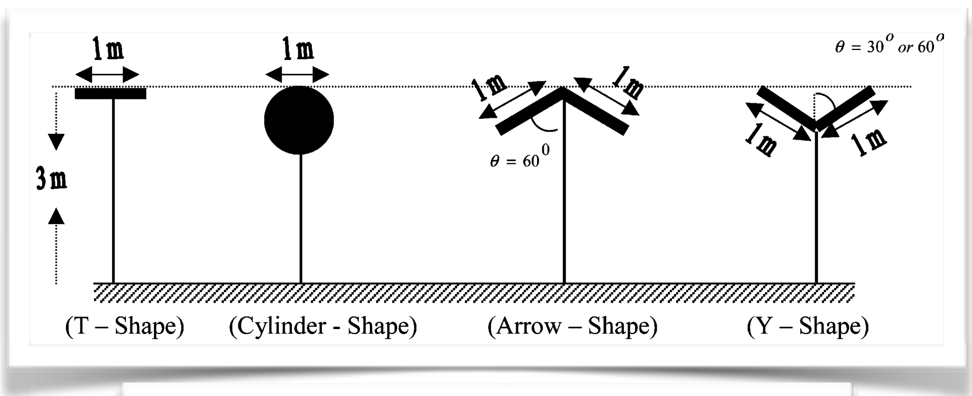
State of the Art

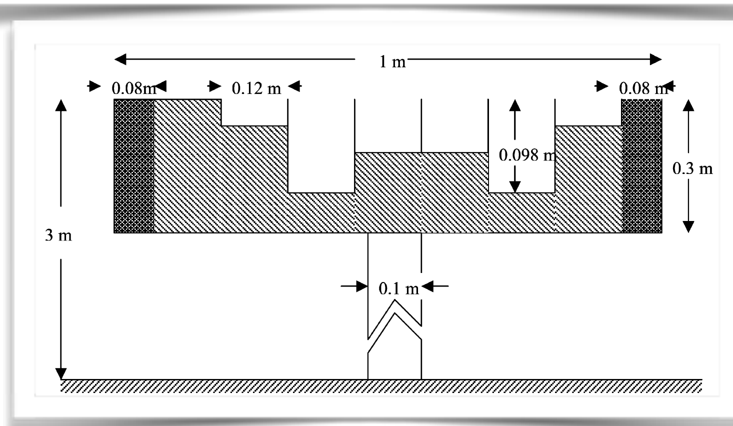
- Introduction
- State of the Art
- Optimization Protocol
- Boundary Element Method
- Problem Presentation
- Results
- Conclusions
- Future Developments

BEM IN PERFORMANCE OF NOISE BARRIERS

MONAZZAM & LAM (2005)

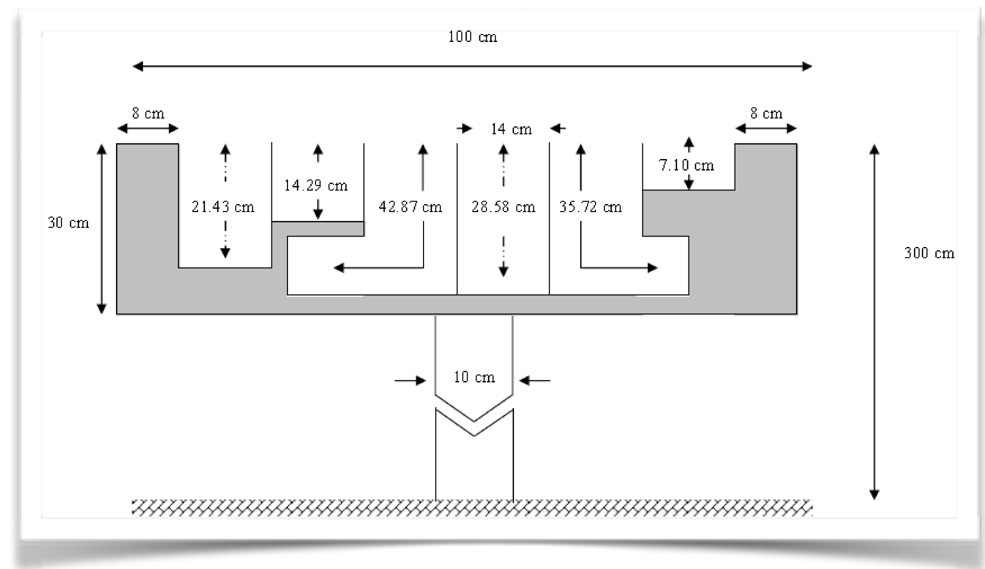
- Performance of profiled single noise barriers covered with quadratic residue diffusers. *Applied Acoustics*, **66**, 709-730, 2005.





MONAZZAM ET AL. (2010)

- Performance of environmental T-shape noise barriers covered with primitive root diffusers. *Archives of Acoustics*, **35** (4), 565-578.

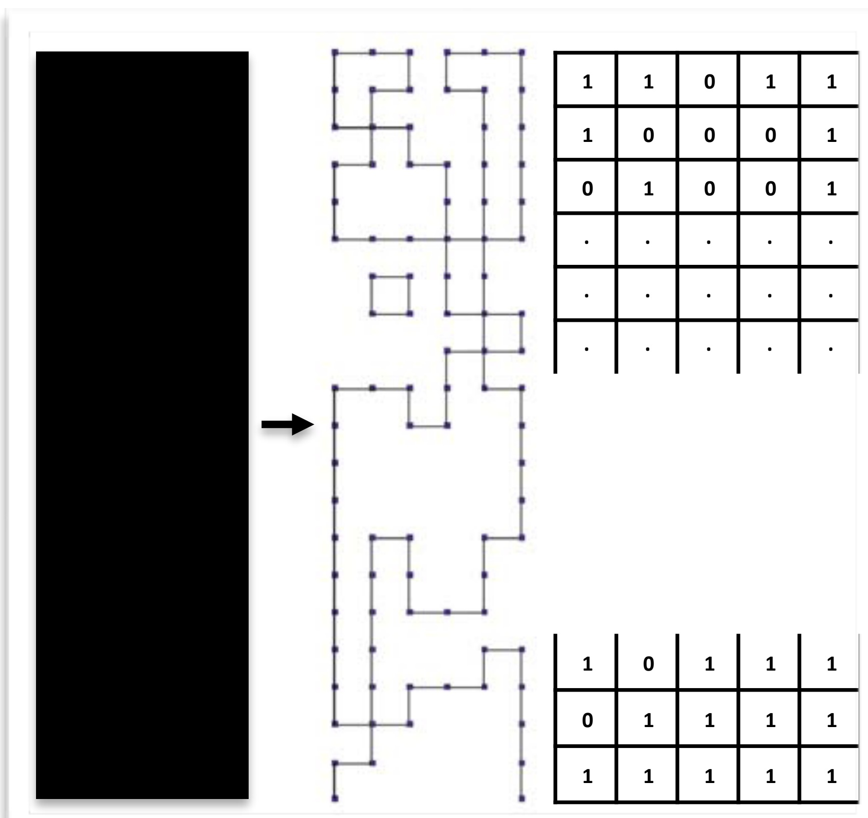


State of the Art

GA AND BEM IN SHAPE OPTIMIZATION

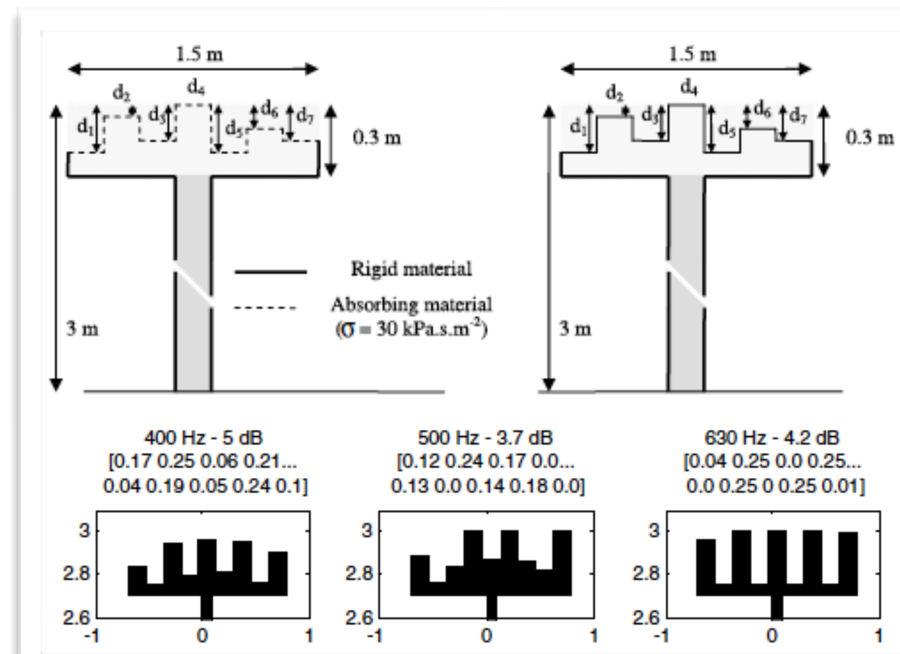
DUHAMEL (2006)

- Shape optimization of noise barriers using genetic algorithms. *Journal of Sound and Vibrations*, **207**, 432-443.



BAULAC ET AL. (2008)

- Optimisation with genetic algorithm of the acoustic performance of T-shaped noise barriers with a reactive top-surface, Applied Acoustics, 69, 332-342.



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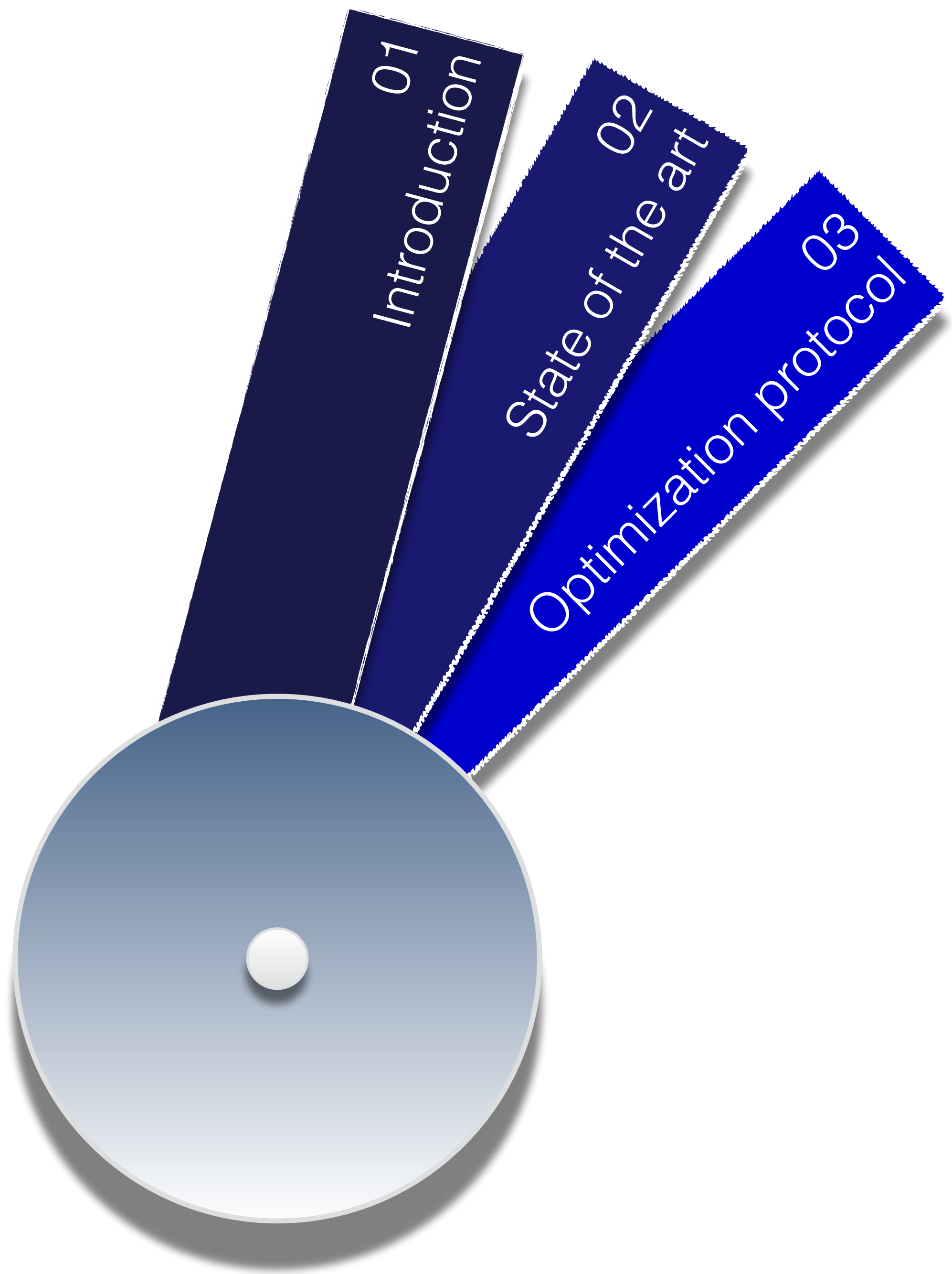

Optimization Protocol

ACOUSTIC EFFICIENCY OF THE BARRIER

INSERTION LOSS COEF. (IL)

- Broadly used in the evaluation of noise control measures.
- Difference in acoustic pressure levels before and after the inclusion of the barrier.
- Measured in decibels [dB].
- Expression:

$$IL = -20 \cdot \log_{10}\left(\frac{P_B}{P_{Hs}}\right) \; [dB]$$

EFFICIENCY ASSESSMENT

- IL values collected for certain values of the domain (receivers):

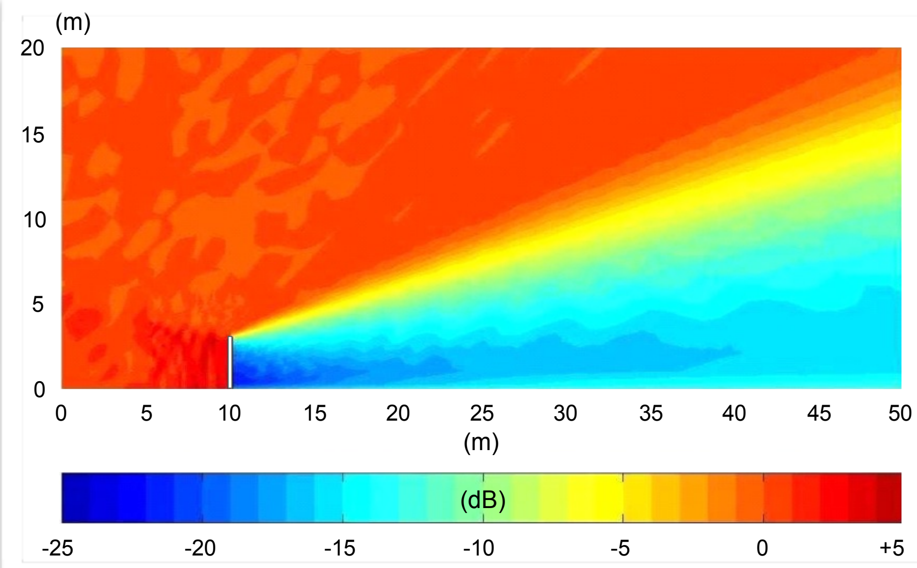

Figure 1: *IL colormap for a 3 m height vertical screen. Noise source at (0,0).*

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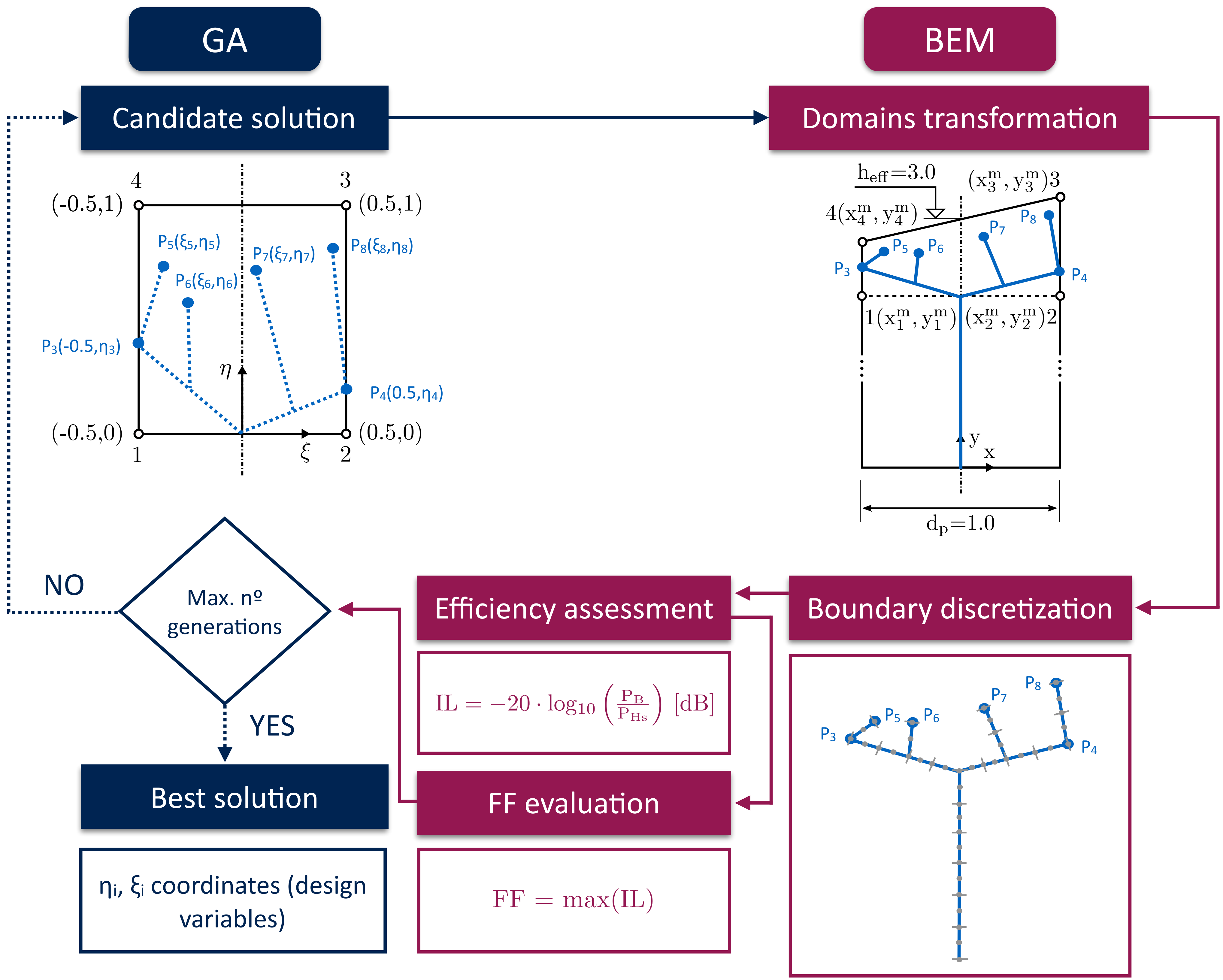
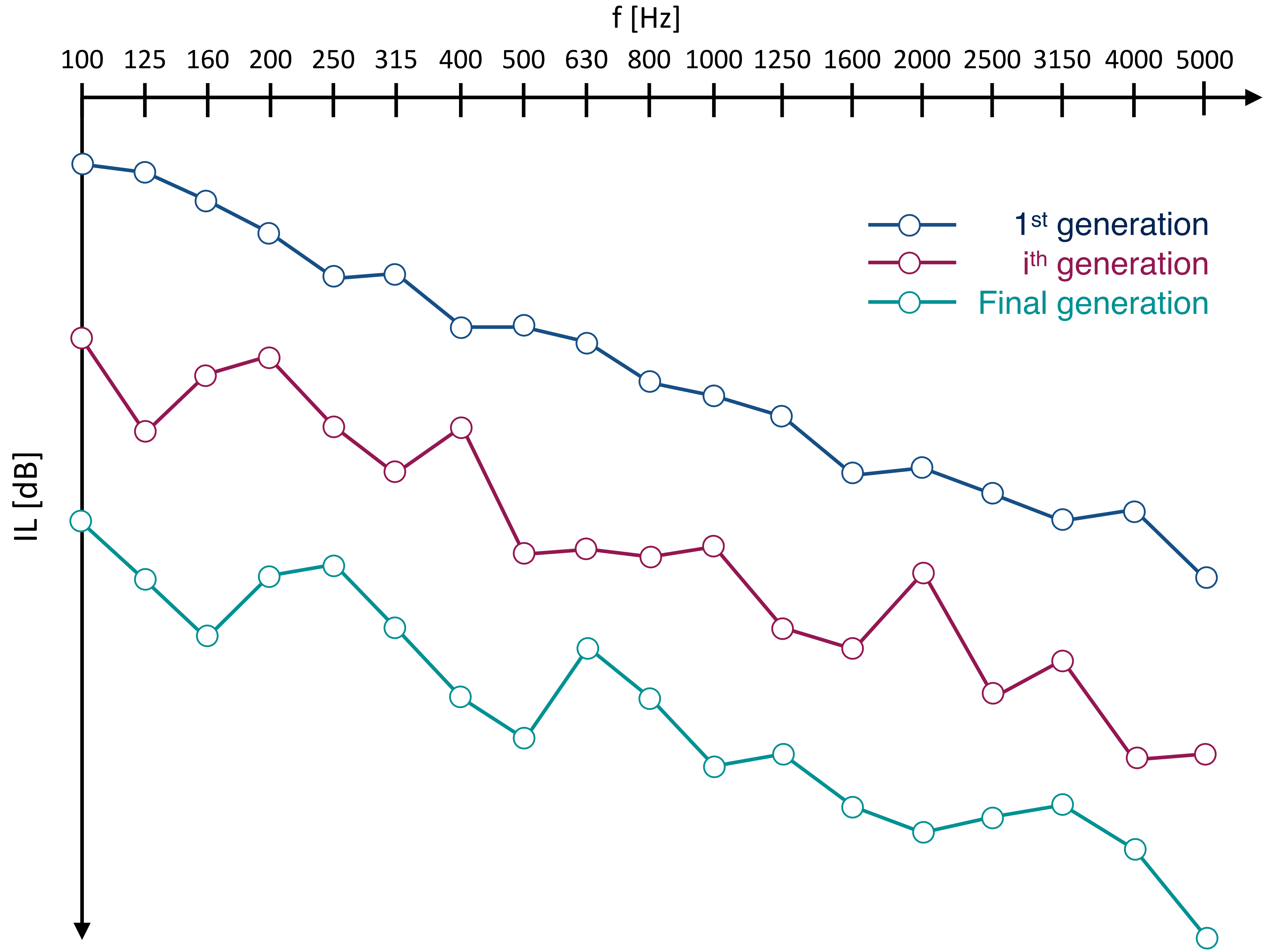
Optimization Protocol



Optimization Protocol

IL EVOLUTION THROUGH OPTIMIZATION



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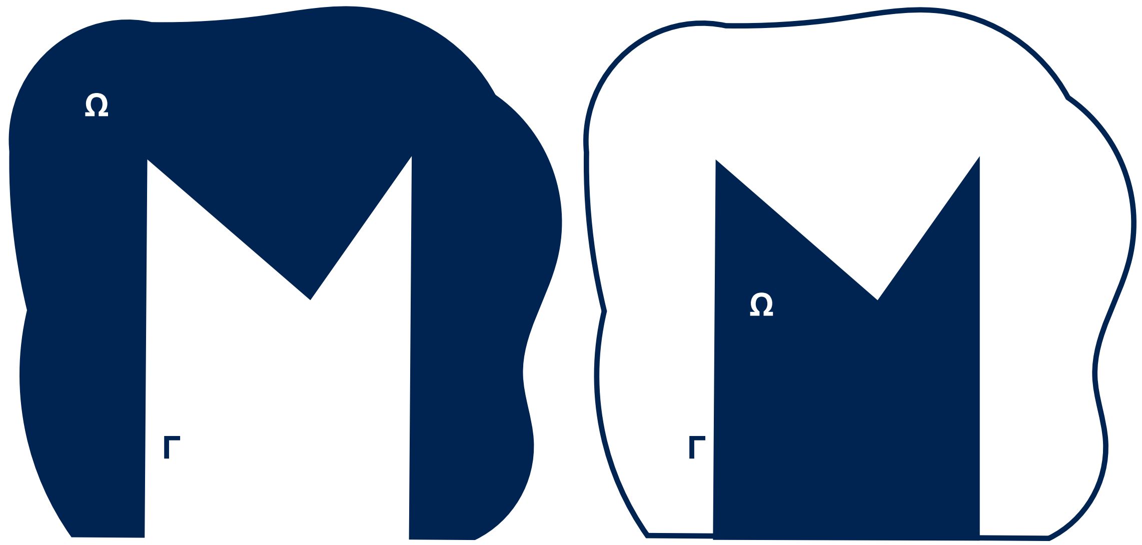
Classical BEM Formulation

DEALING WITH LARGE GEOMETRIES

OUTDOOR ACOUSTIC PROBLEM | INDOOR ACOUSTIC PROBLEM

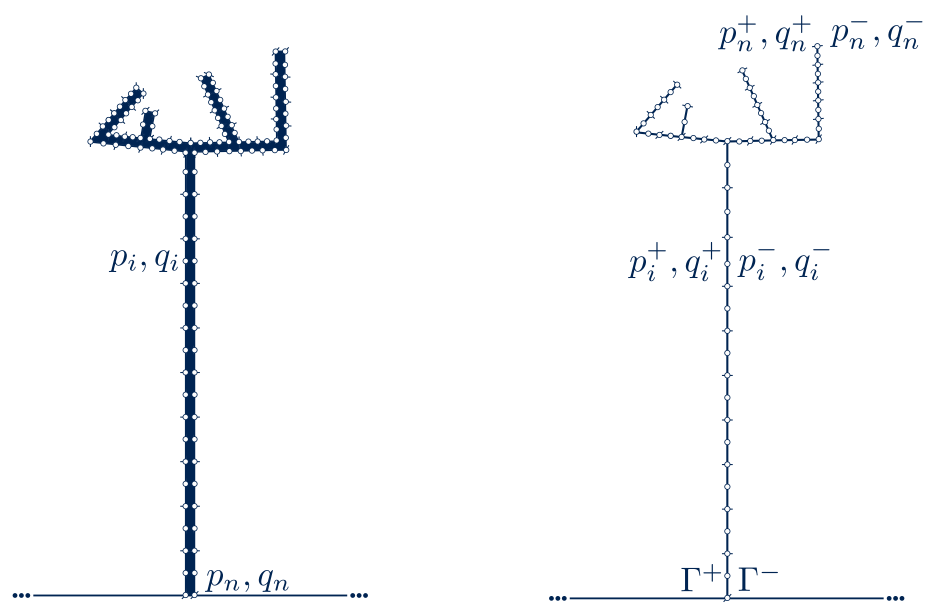


PROBLEMS RELATED

- Spurious frequencies (eigenfrequencies) related to the indoor acoustic problem arise.
- The acoustic efficiency of the barrier is seriously affected.

DEALING WITH THIN CROSS SECTION CONF.

REAL THIN BARRIER | IDEALIZED BARRIER



PROBLEMS RELATED

- Numerical integration problems may aries for volumetric thin barriers.
- The acoustic efficiency of the barrier is seriously affected.

Dual BEM Formulation

NULL-THICKNESS BOUNDARIES

SINGULAR FORMULATION

$$\frac{1}{2}\cdot\Sigma\mathbf{p}_i+\sum_{j=1}^{NE}\mathbf{H}_j^+\cdot\Delta\mathbf{p}_j=\sum_{j=1}^{NE}\mathbf{G}_j^+\cdot\Sigma\mathbf{q}_j+\mathbf{p}_0^*$$

\+

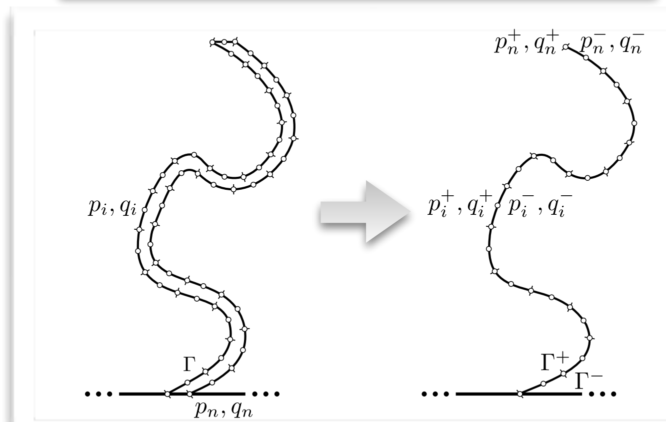
HYPER-SINGULAR FORMULATION

$$\frac{1}{2}\cdot\Delta\mathbf{q}_i+\sum_{j=1}^{NE}\mathbf{M}_j^+\cdot\Delta\mathbf{p}_j=\sum_{j=1}^{NE}\mathbf{L}_j^+\cdot\Sigma\mathbf{q}_j+\frac{\partial\mathbf{p}_0^*}{\partial\mathbf{n}_i}$$

RESULTING SYSTEM OF EQUATIONS

$$\begin{bmatrix}\frac{\mathbf{I}}{2}-\mathbf{G}^+\mathrm{A}^+ & \mathbf{H}^+-\mathbf{G}^+\mathrm{A}^- \\ \frac{\mathrm{A}^-}{2}\mathbf{I}-\mathbf{L}^+\mathrm{A}^+ & \frac{\mathrm{A}^+}{2}\mathbf{I}+\mathbf{M}^+-\mathbf{L}^+\text{-}\mathrm{A}^-\end{bmatrix}\begin{bmatrix}\Sigma\mathbf{p}\\ \Delta\mathbf{p}\end{bmatrix}=\begin{bmatrix}\mathbf{p}_o^*\\ \frac{\partial\mathbf{p}_o^*}{\partial\mathbf{n}_i^+}\end{bmatrix}$$

PRESSURE AND FLUX AT BOTH SIDES



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Problem Outline

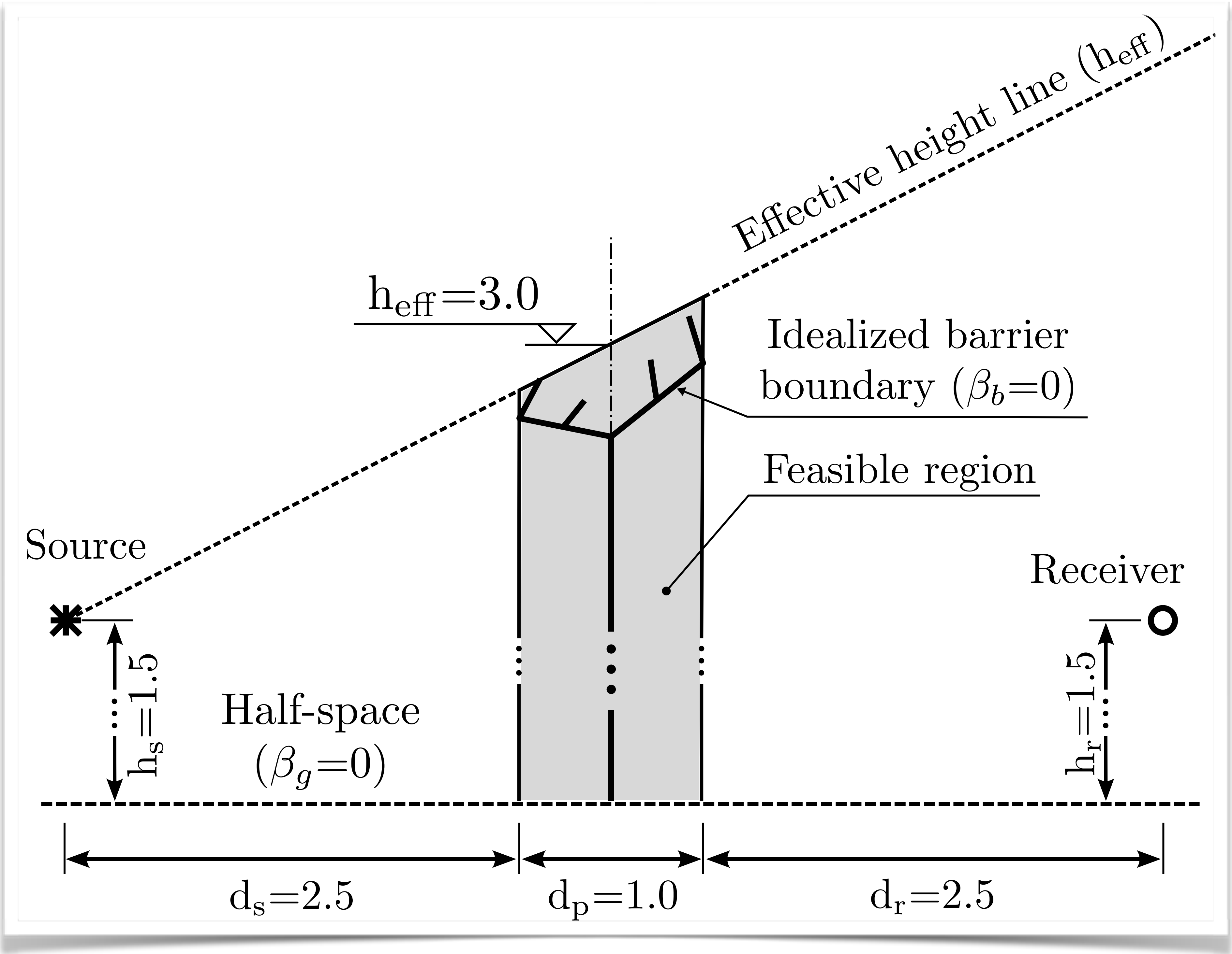

Figure 2: *Bi-dimensional configuration to be used in the optimization process of thin noise barriers. Distances and dimensions expressed in [m].*

Problem Presentation

PROBLEM OUTLINE

PROBLEM DEFINITION

- Perfectly reflective both barrier and ground surface ($\beta_b = \beta_g = 0$).
- Feasible region defined by effective height (h_{eff} = 3.0 m) and horizontal projection on the ground (d_p = 1.0 m).
- Noise source and the receiver are 1.5 m over the ground and 3.0 m away from the barrier.

CONFIGURATION

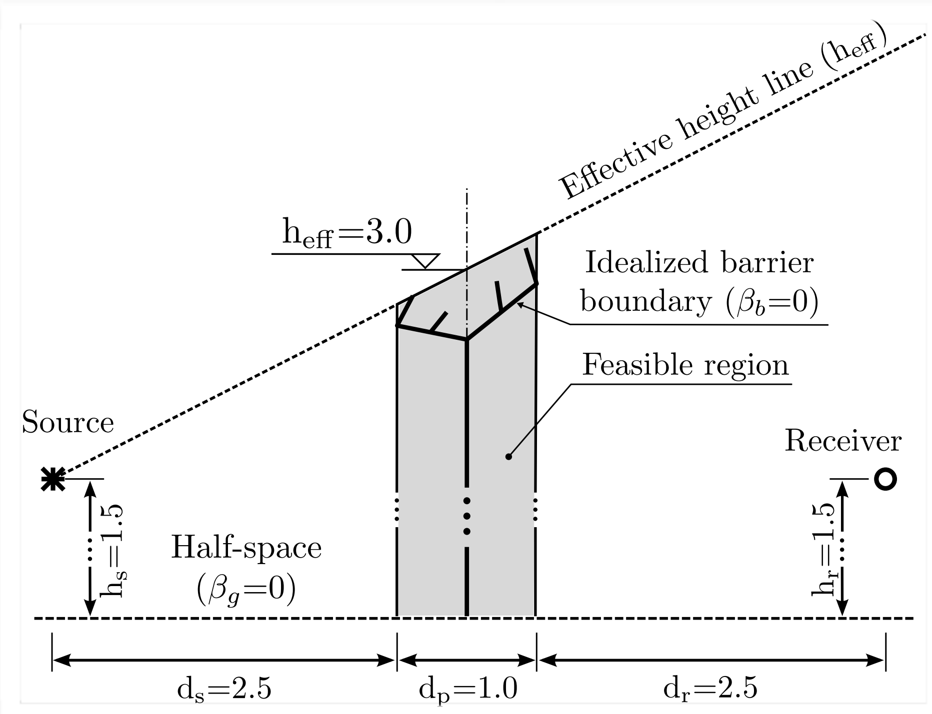

Figure 2: *Bi-dimensional configuration to be used in the optimization process of thin noise barriers. Distances and dimensions expressed in [m].*

Problem Presentation

PROBLEM OUTLINE

APPLIED SPECTRUM

- A-weighted normalized traffic noise spectrum used by CTE (UNE-EN 1793-3:1998).
- Study conducted for third band-frequencies ranging from 100 to 5000 [Hz]:

$$\overline{\mathrm{IL}} = -10 \cdot \log_{10}\left(\frac{\sum_{i=1}^{NF} 10^{(A_i - IL_i)/10}}{\sum_{i=1}^{NF} 10^{A_i/10}}\right) \text{[dBA]}$$

- The aim is to maximize the FF value:

$$\mathrm{FF} = \max\left(\overline{\mathrm{IL}}\right)$$

CONFIGURATION

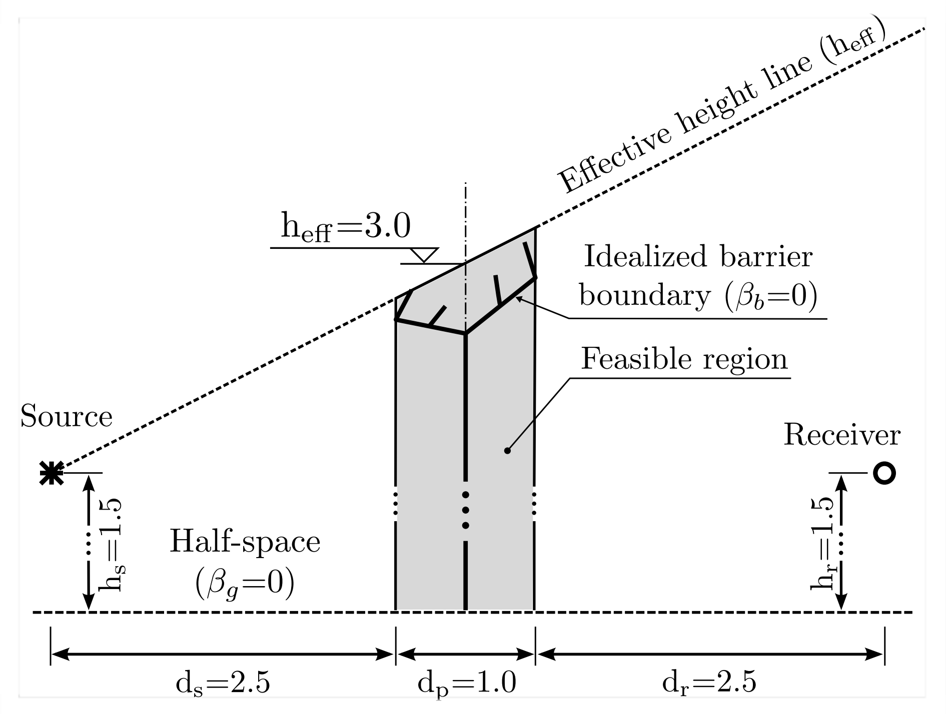

Figure 2: *Bi-dimensional configuration to be used in the optimization process of thin noise barriers. Distances and dimensions expressed in [m].*

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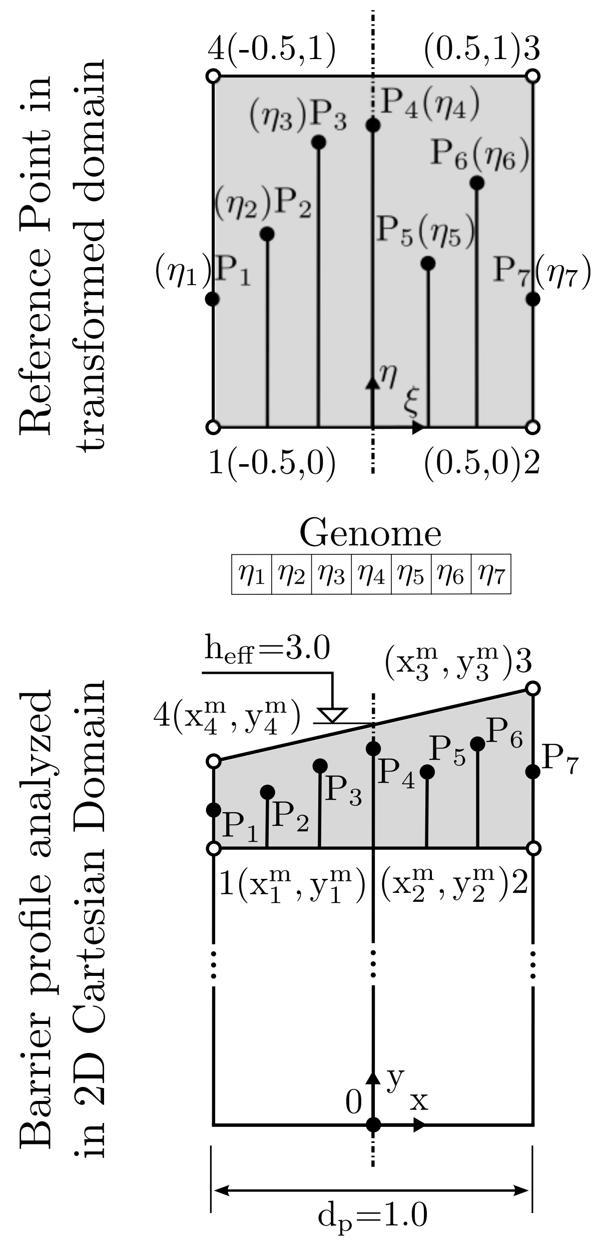
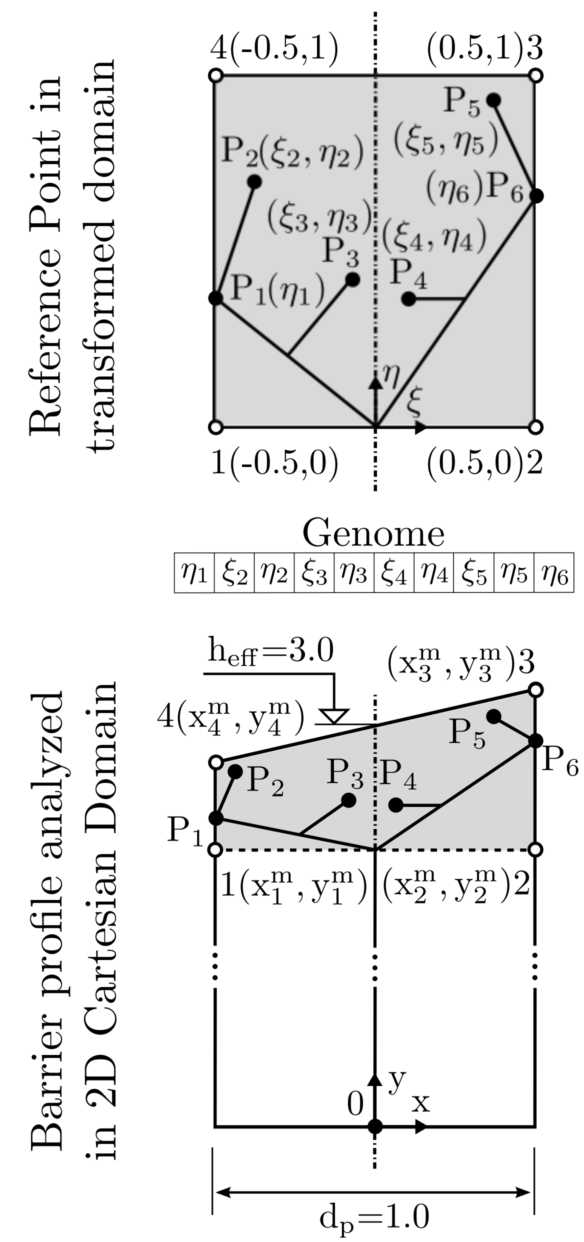
Problem Presentation

DESIGNS UNDER STUDY

MODEL A)



MODEL B)



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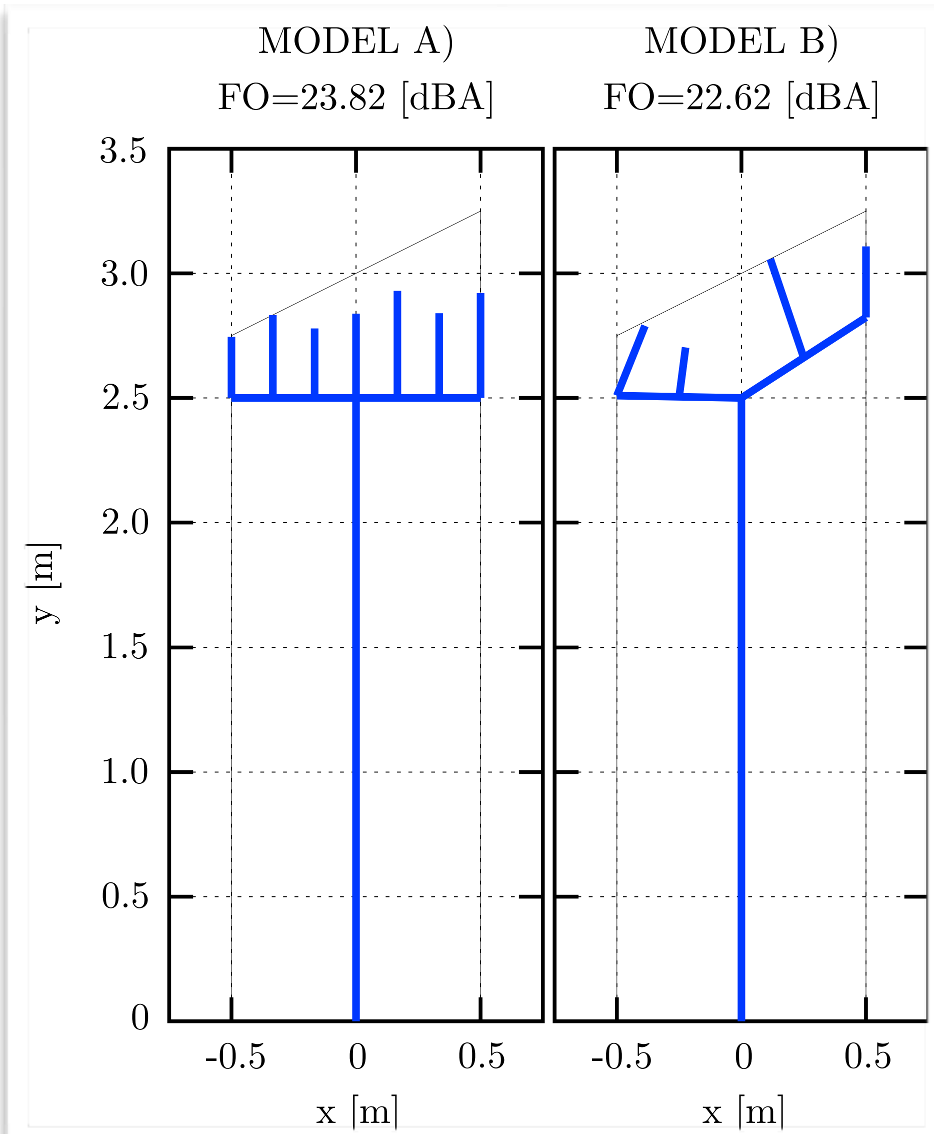
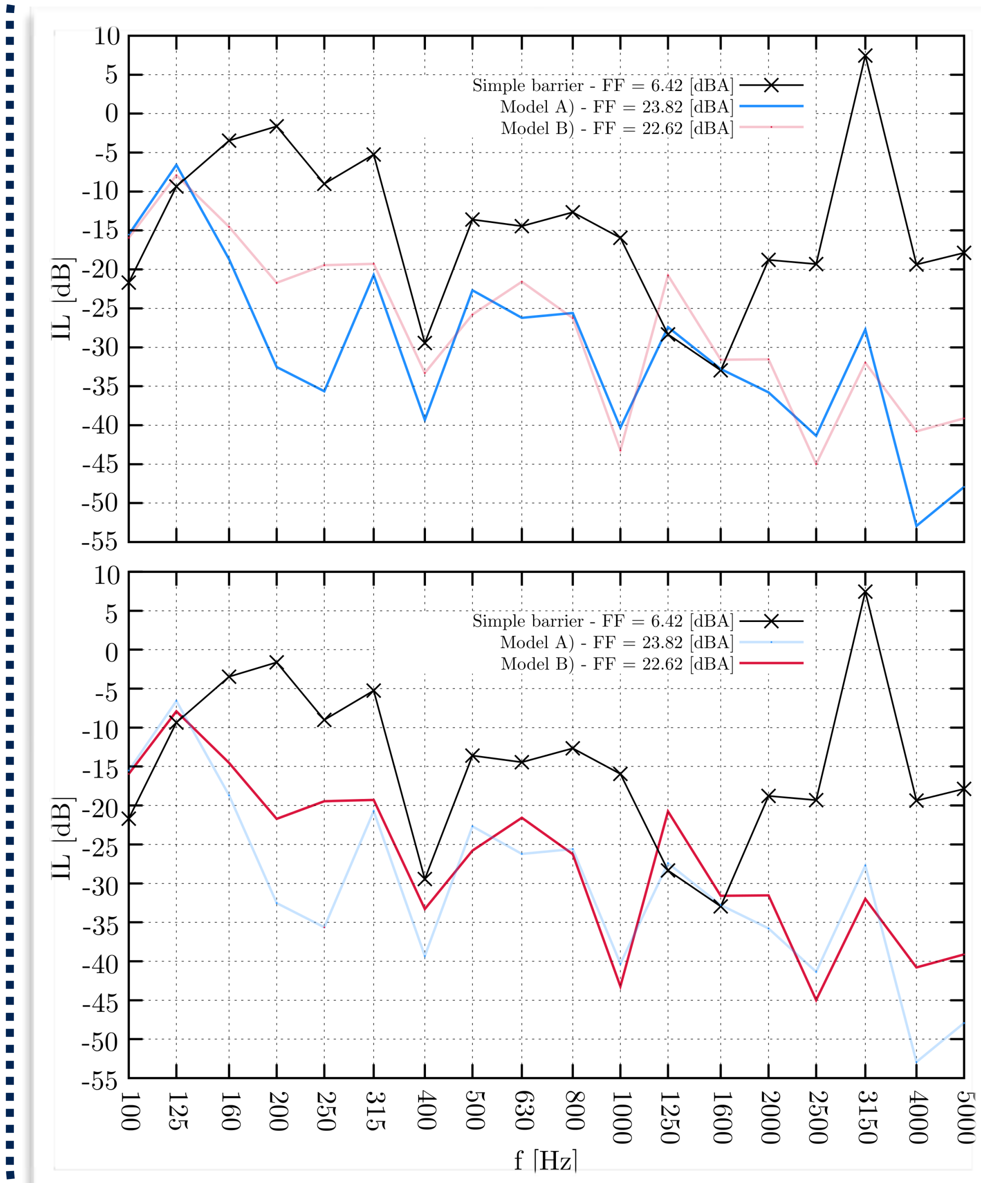
Results

SHAPE DESIGN OPTIMIZATION

OPTIMUM PROFILES

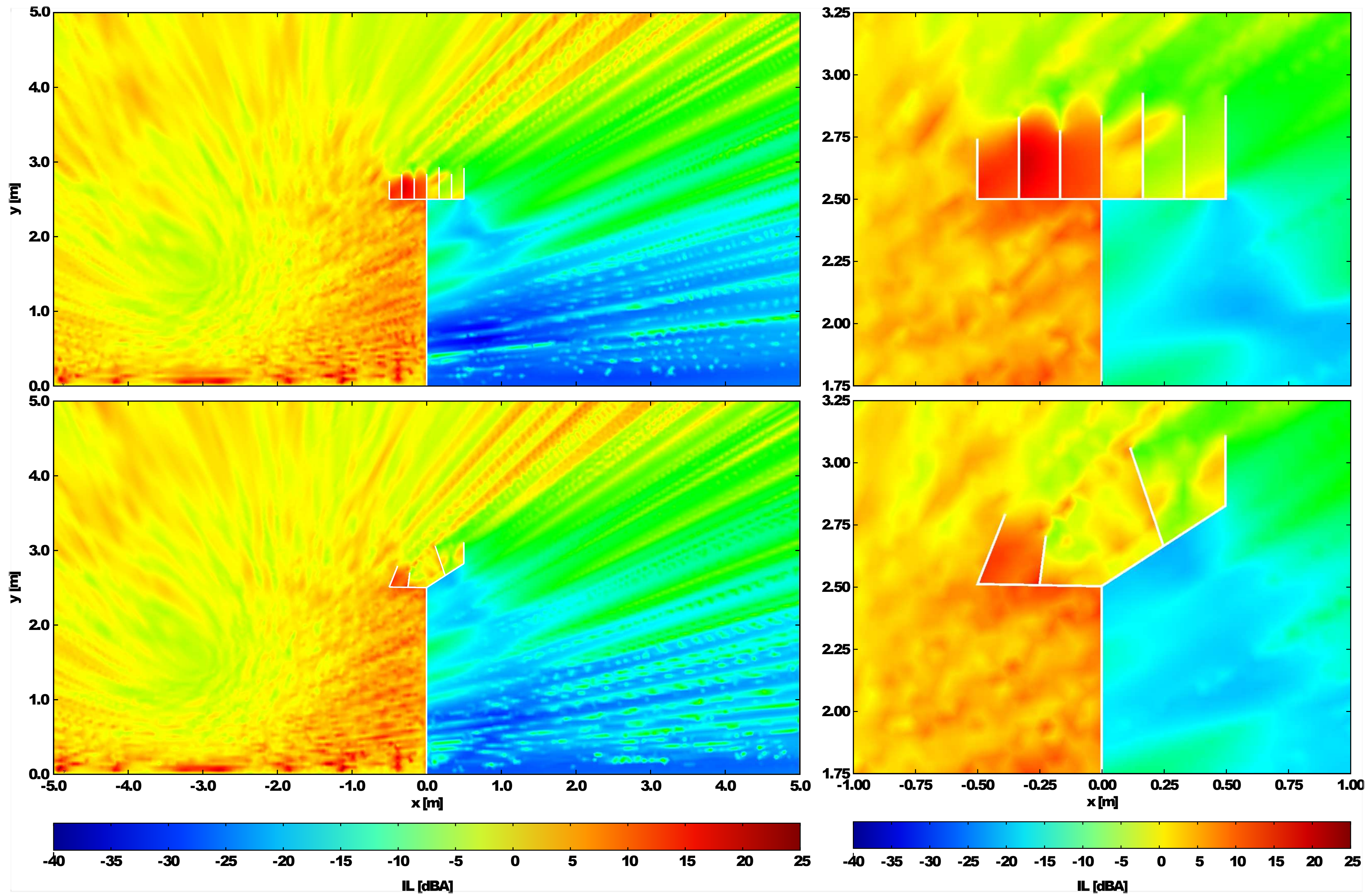


IL EVOLUTION



Results

IL COLORMAP

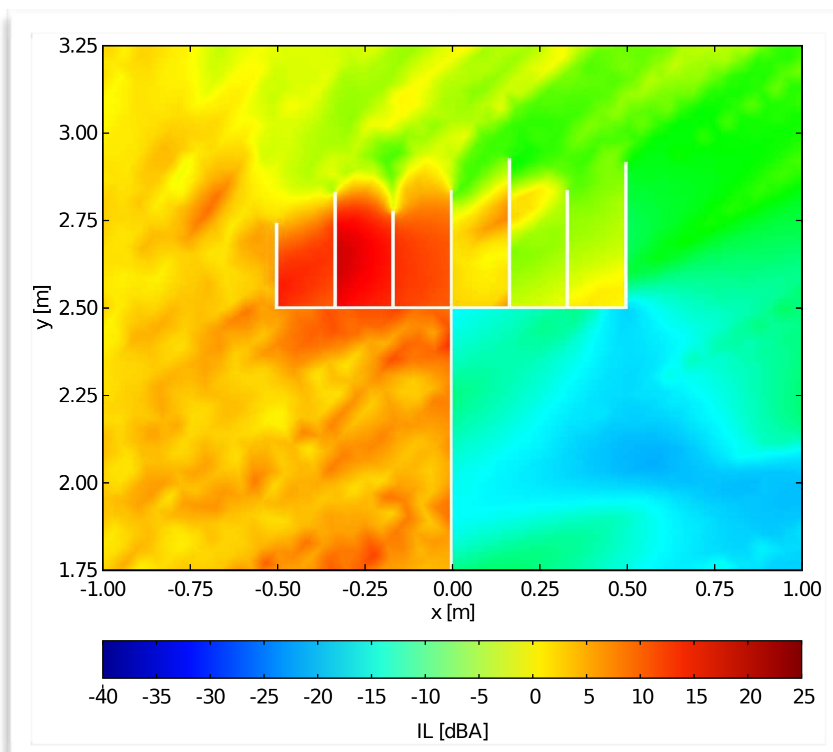


Results

DISCUSSION OF THE RESULTS

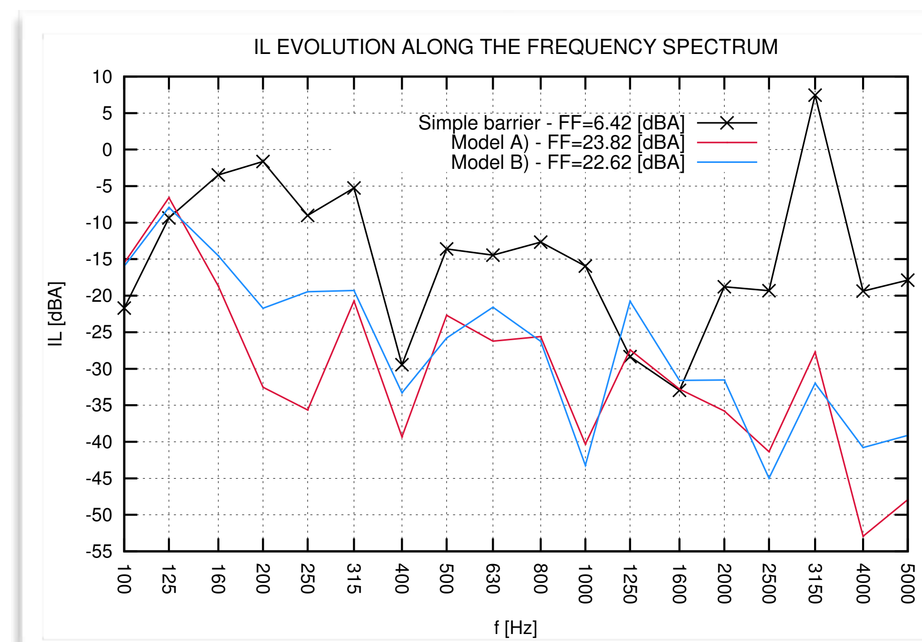
MODELS COMPARISON

- Acting on the top of the barrier is an appropriate strategy to minimize the acoustic impact: the highest levels energy get trapped among the boundaries.



MODELS VS. STRAIGHT

- The proposed barrier designs appear to be a valuable, successful alternative to the simple screen by clearly outperforming its acoustic efficiency (over 15 dBA).



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Conclusions

- A methodology for the optimization of the performance assessment of complex thin noise barriers designs by idealizing them as null thickness boundaries has been presented.
- Two noise barrier models have been studied to validate the method.
- The range of application of this procedure is broad and enables the study of diverse topological solutions, including those involving curve geometries.
- The presented procedure is a useful method to assess the acoustic behavior of thin complex noise barriers configurations and yields conclusions that might have been hardly drawn without its implementation.

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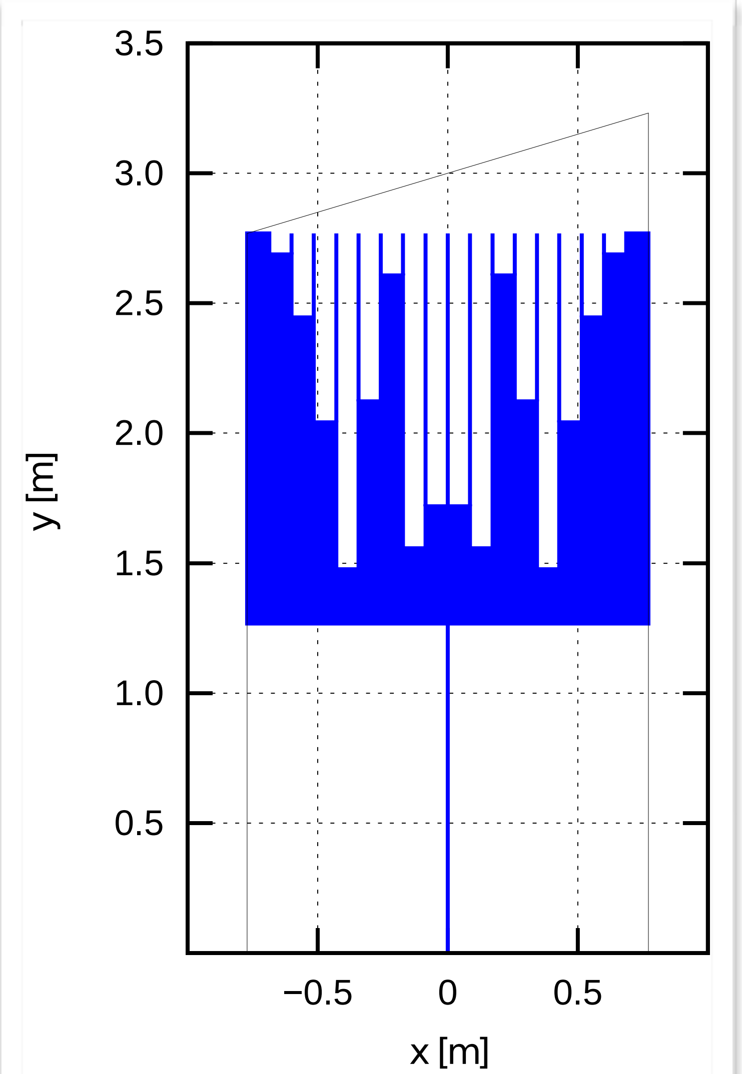
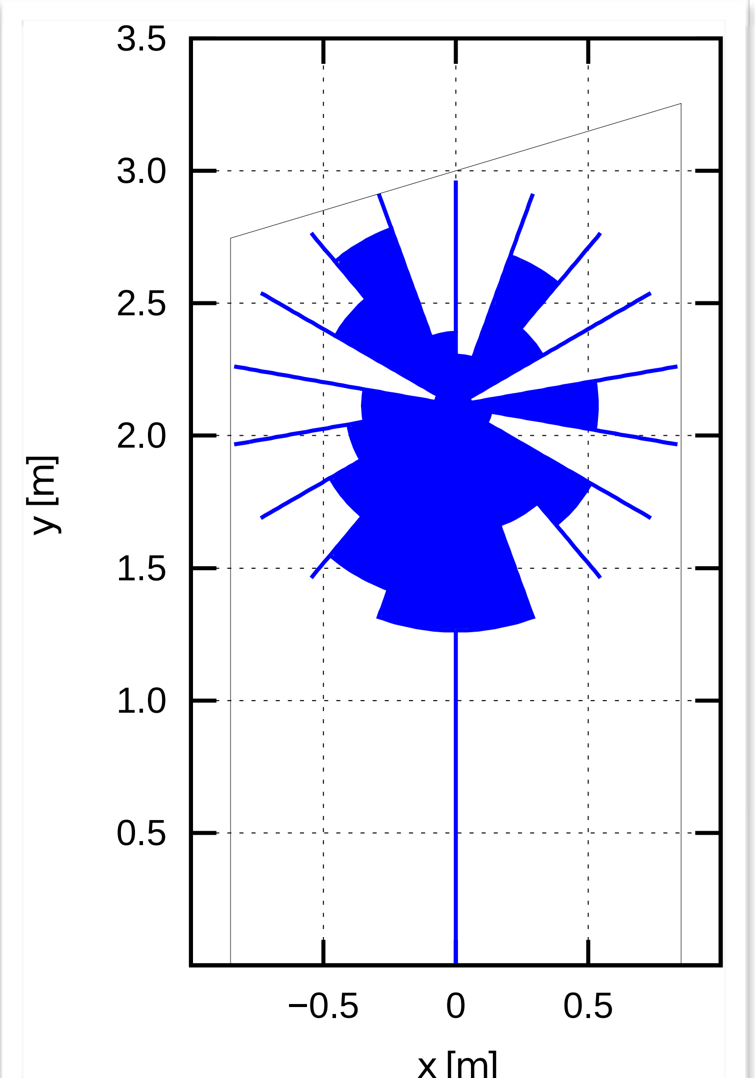
Future Developments

HYBRID-BOUNDARIED BARRIERS

QUADRATIC RESIDUE DIFFUSERS (QRD)



WATERWHEEL TOP CYLINDERS



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