CSTB
le futur en construction

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Journées techniques “Acoustique et Vibrations” 2011

Avancement des travaux au sein du WP5 du projet européen QUIESST

Aix-en-Provence
8 juin 2011

Content

1. QUIESST project and WP5 overviews

2. Progress status of tasks 5.1, 5.2, 5.3, 5.4

3. Perspectives and future work

Appel à Proposition de Recherche

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- SEVENTH FRAMEWORK PROGRAMME
- Theme: Transport (including Aeronautics)
- FP7-SST-2008-RTD-1

  Activity: 7.2.1 - The greening of Surface Transport

  Area: 7.2.1.1 - The Greening of Products and Operations

  Topic: SST.2008.1.1.3 – **Holistic Noise and Vibration Abatement**

Montage du projet

- Au sein du WG6/TG1 du CEN/TC226 « Noise protection barriers »
- Suite du projet européen ADRIENNE (1995-1997)
- Première version : juin 06 / Finalisation : mai 08 / Sélection sept. 08 / Accepté fin 08
- Démarrage novembre 2009

Objectifs

The concept of QUIESST is to merge […] the consideration of the “true” intrinsic acoustic characteristics of **Noise Reducing Device**, together with their extrinsic acoustic characteristics, and their sustainability in a holistic way […].

Thèmes abordés

- the near field / far field relationship (WP2)
- the in-situ measurement of “true” sound absorption and airborne sound insulation (WP3)
- the comparison of the existing laboratory tests results of European NRD with the corresponding in-situ measurement test results (WP4)
- **the holistic approach of NRD optimization (WP5)**
- the sustainability of NRD (WP6)

QUIESST overview

Beneficiary name	Beneficiary short name	Member State
Acoustic Technologies / A-Tech SA/NV	A-Tech	BE
Netherlands Organisation for Applied Scientific Research	TNO	NL
University of Bologna - Dipartimento Ingegneria Energetica Nucleare e del Controllo Ambientale	UNIBO	IT
Österreichisches Forschungs- und Prüfzentrum Arsenal Ges.m.b.H. – arsenal research	Arsenal	AT
Centre Scientifique et Technique du Bâtiment	CSTB	FR
University of Bradford School of Engineering, Design and Technology	UNIBRAD	UK
European Union Road Federation	ERF	EU
Fundación Cidaut	CIDAUT	ES
Associazione Costruttori di Acciaio Italiani	ACAI	IT
Laboratoire de Recherche des Ponts et Chaussées	LRPC	FR
Rheinisch-Westfälische Technische Hochschule Aachen	RWTH	DE
Federal Highway Research Institute	BASt	DE
Katholieke Universiteit Leuven	KULeuven	BE

2 types of NRD characteristics/performances:

Acoustical

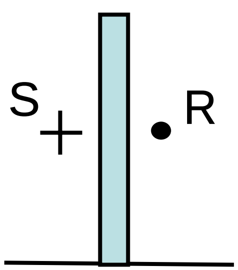
- Reflection
- Transmission
- Diffraction

Non-acoustical

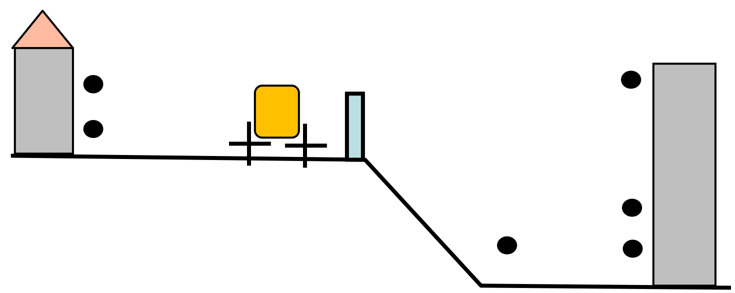
- Construction cost
- Global Warming Potential
- Waste
- … (LCA)

3 scales of study:

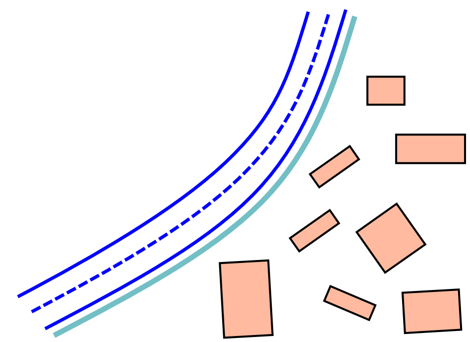
Intrinsic



Extrinsic / Holistic

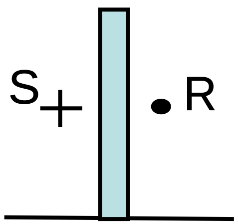


Global



WP5: Holistic optimization and global noise impact

Intrinsic



Acou

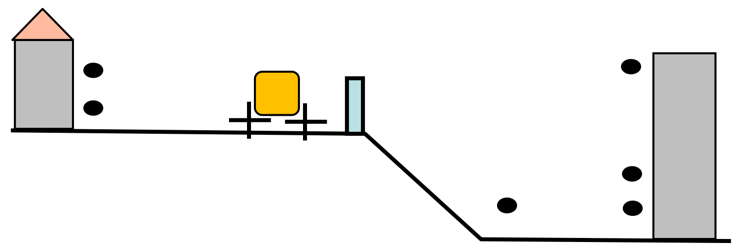
models1

Optimisations

(Refl°,Tr°,Diff°)
separ.+ simultan.

T 5.3

Extrinsic / Holistic



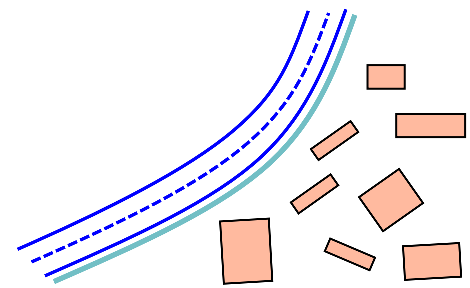
Acou models2

Acou+Non-Ac models2

Optimisations

T 5.4

Global



Acou+Non-Ac

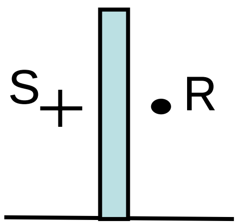
models3

Impact

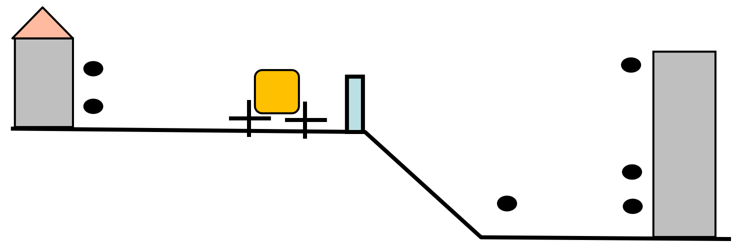
T5.5

WP5: Holistic optimization and global noise impact

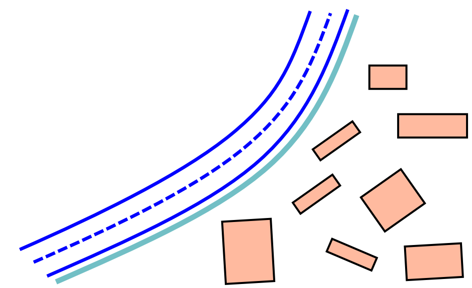
Intrinsic



Extrinsic / Holistic



Global



The goal of WP5 IS NOT to design new optimized NRDs

The goal of WP5 IS to assess the potential acoustical and/or non-acoustical “gains” that can be expected for different sets of environmental configurations from multiple-criteria NRD optimisations

WP5: Holistic optimization and global noise impact

Leader : CSTB (Jérôme Defrance)

Task 5.1: State of the Art of existing optimization methods and noise prediction approaches (finished)

Task 5.2: Setting a methodology for a holistic optimization of noise reducing devices (finalization)

Task 5.3: Application to intrinsic acoustic optimizations (ongoing)

Task 5.4: Application to extrinsic acoustic optimizations and holistic optimizations (ongoing)

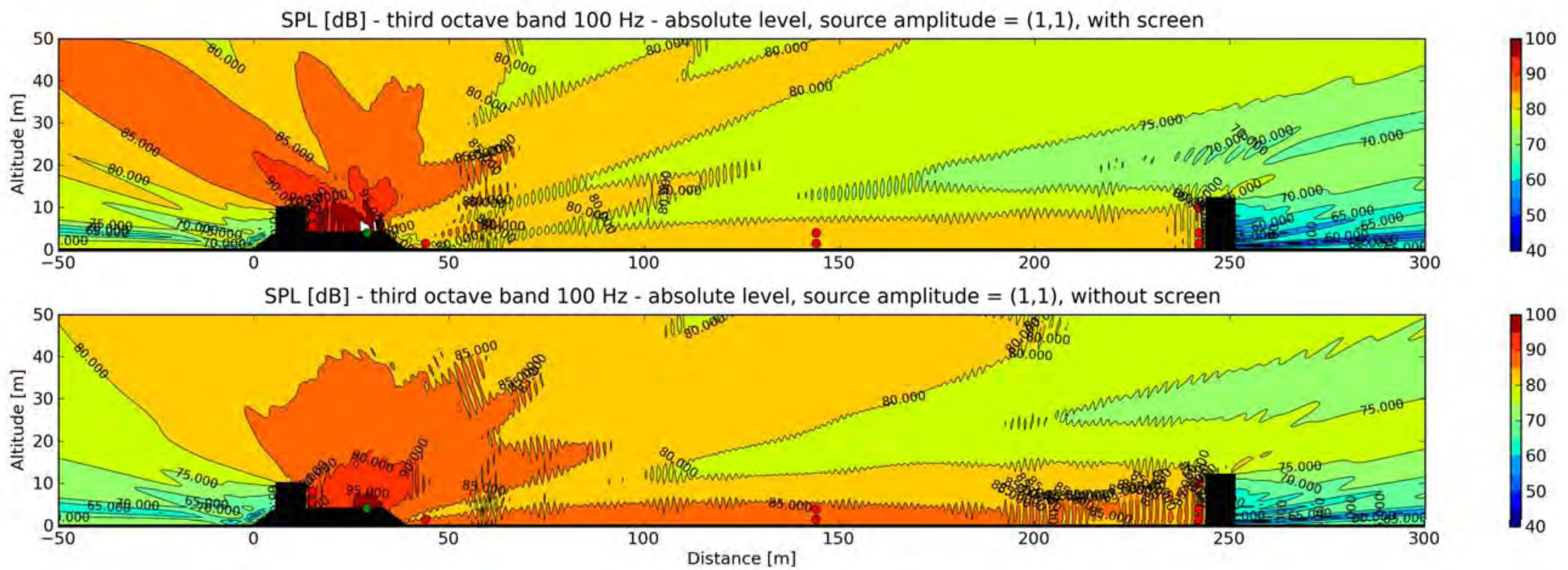
Task 5.5: Global impact on noise abatement (not started)

Task 5.6: Final report (not started)

T5.1: State of the art of existing optimization methods and noise prediction approaches

Selected noise prediction models:

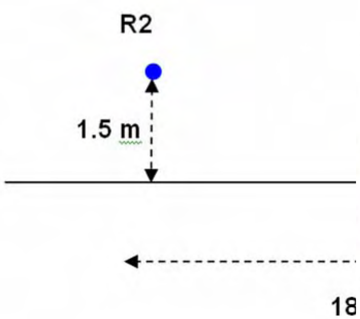
> Boundary Element Method (T5.3, T5.4)
> Finite Difference Time Domain method (T5.4 : meteorological effects)
> Transfer Matrix Method (T5.4 : meteorological effects)
> Asymptotic models (ray-based approaches) (T5.5 : global impact)

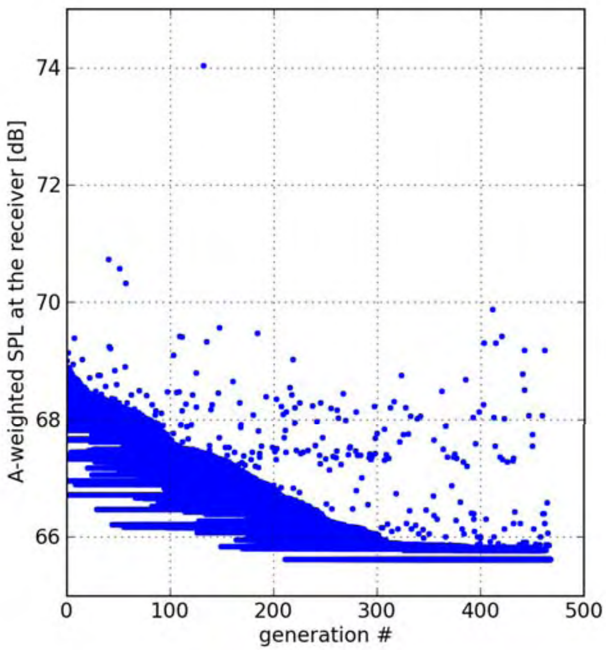


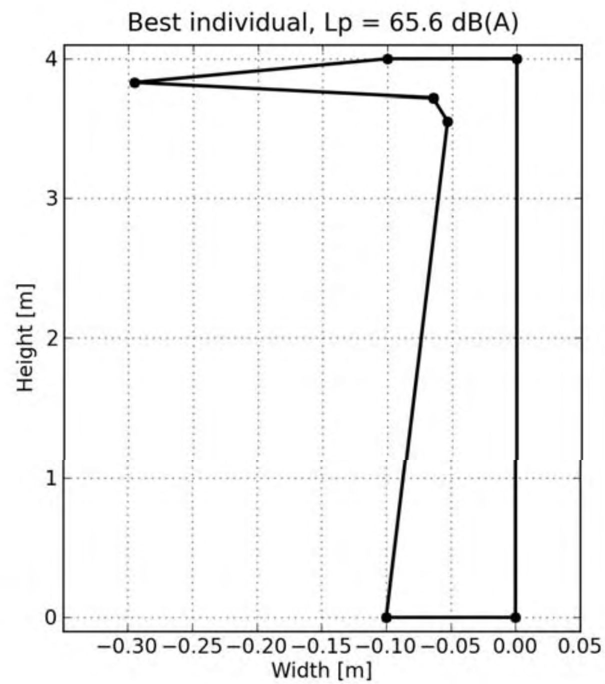
T5.1: State of the art of existing optimization methods and noise prediction approaches

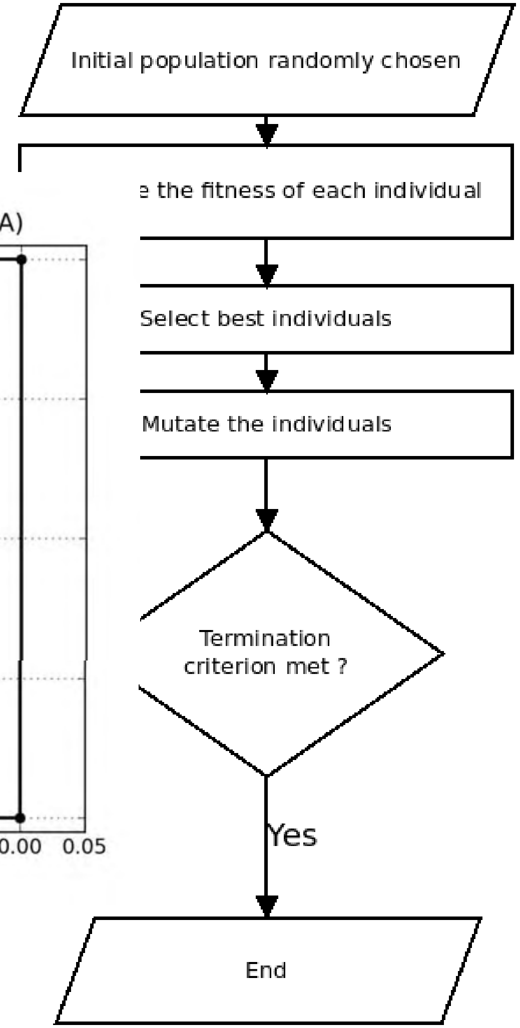
Selected optimization models:

> Genetic algorithms and Evolution Strategies









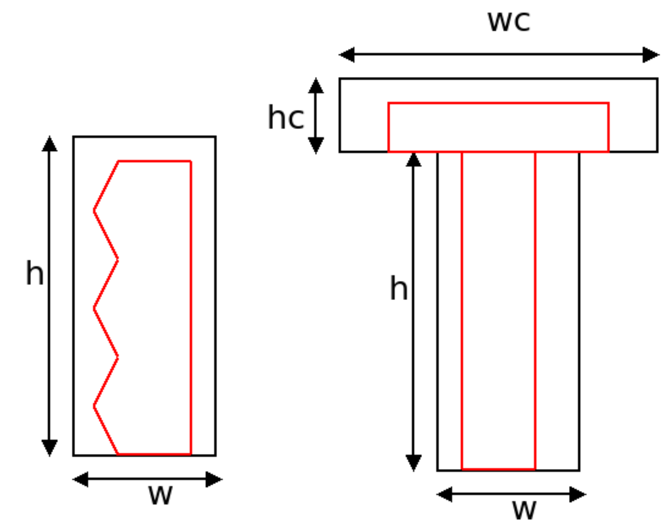
T5.2: Setting a methodology for a holistic optimization of NRD

- Limits of the holistic optimization
  - > NRD geometry
  - > NRDs materials
  - > Meteorology
  - > Non-acoustical parameters

- Classification of NRDs into coherent families
  - > Reference NRD
  - > NRDs families

Limits on NRDs geometry:

- Bounding box approach
- w < 50 cm
- h < 4 m or 6 m (road traffic noise)
- h < 2.5 m or 4 m (railway noise)
- Capped NRDs:
  - wc < 1 m
  - hc + h < limits given above



Panel length:

- Limited by aerodynamic load resistance criteria: wind load (effects of vehicles passing by is neglected).
- Peak velocity pressure from wind calculated with the EN 1991-1-4 standard
  - Terrain of category II (“*Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights*”)
  - Orography neglected
  - Category III region (mean wind speed = 26 m/s)

$$w = c_1.q_b.\frac{Min(H,L)^4}{Eh^3}$$

$$q_b(z) = \frac{1}{2}\rho.c_e(z).v_b^2 \qquad v_b = 26m/s$$

$$w_{\max} = \frac{L_s}{300}$$

NRDs materials considered:

- Are excluded:
  - Tunnel barriers
  - Green barriers
  - Gabions
  - Earth barriers
  - Photovoltaic barriers

Green barriers, Gabions, Earth barriers → HOSANNA EU Project

NRDs materials considered:

- Materials determined to account most of classical « NRDs »:
  - Concrete
  - Wood concrete
  - Pozzolanic concrete
  - Brick
  - Timber
  - Metal sheets
  - PMMA
  - Rock wool

Table 3: List of NRDs in the federal state of Brandenburg in Germany and their main building material

Main building material of NRD	Amount	Length [m]
Concrete	70	43 436,61
Glass	1	284,00
Timber	28	11 709,47
Metal sheets	9	5 192,54
Transparent thermoplastics	3	1 277,12
Sum	**111**	**61 899,74**

Limits of the holistic optimisation

Limits of the holistic optimisation

Limits of the holistic optimisation

Meteorological conditions:

> Accounted for only in extrinsic optimizations
> Homogeneous atmosphere used as reference for optimizations
> Upwind and downwind conditions assessed for optimized cases
> No turbulences

Environmental parameters:

Various environmental assessment methods :

Life-Cycle Assessment (LCA), → The most comprehensive
Environmental Risk Assessment (ERA),
Ecological footprint,
Carbone Footprint, etc.

Standards

International : ISO 14044 and SO 14040 (2006)
European : prEN 15804 (standard under development in the CEN/ TC 350)
French : NF P 01 010 (2004)

Limits of the holistic optimisation

Limits on environmental parameters :

set of a relatively important number of environmental indicators

No.	Environmental impact	Unit
1	Consumption of energy resources	MJ/FU
2	Resource depletion / Abiotic resources Depletion (ADP)	kg antimony equivalent /FU
3	Water consumption	litre/FU
4	Solid waste	kg/FU
5	Climate change / Global Warming Potential (GWP)	kg CO_2 equivalent /FU
6	Atmospheric acidification / Acidification potential of land and water sources (AP)	kg SO_2 equivalent /FU
7	Air pollution	m^3/FU
8	Water pollution	m^3/FU
9	Stratospheric Ozone Depletion Potential (ODP)	kg CFC-R11 equivalent /FU
10	Formation of photochemical ozone / Formation Potential of tropospheric Ozone Photochemical oxidants (POCP)	kg ethylene equivalent/FU
11	Eutrophication potential (EP)	Kg $(PO4)^{3-}$ equivalent/FU

Proposal for the holistic optimization :

Based on :
- indicators interdependence
- environmental relevance

4 environmental parameters selected :

- Energy,
  MJ / FU
- Global Warming Potential (GWP),
  kg CO2 equivalent / FU
- Waste (non hazardous and inert),
  kg / FU
- Water consumption,
  Litre / FU

Economical parameters:

> construction costs

> maintenance costs

> demolition costs (transportation, no material reuse considered)

Only maintenance cost depends on material (man power >> material costs)

Table 5: Construction and demolition costs for different NRDs heights

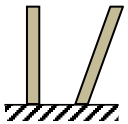
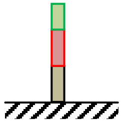
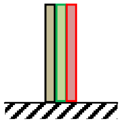
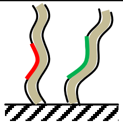
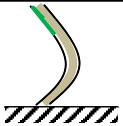
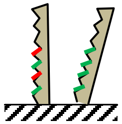
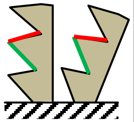
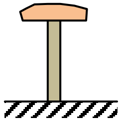
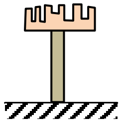
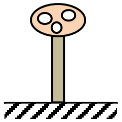
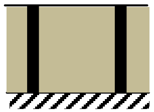
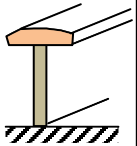
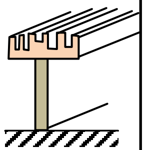
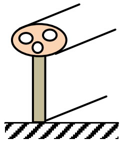
NRD height[m]	Construction cost [€/m]	Demolition cost [€/m]
1	825	278
2	1449	312
3	2066	345
4	2678	379
5	3284	412
6	3884	446

Table 6: NRD maintenance costs depending on the main NRD material, per m² and per year

Main building material of NRD	Cost [€ / m² / year]
Concretes and brick	2,93 €
Timber	2,44 €
Metal sheets	1,46 €
Transparent thermoplastics	1,48 €

Reference NRD:

> Performances are expressed as a gain (or loss) compared to a reference NRD (10 cm thick concrete)

	Flat barriers			Non-Flat barriers				Barrier caps		
	Single layer		Multiple layered	Smooth		Rough				
	Homo-geneous	Inhomo-geneous	Infinite	Small curvat.	Large curvat.	Small roughn.	Large roughn.	Smooth	Rough	With voids
2D schematic										
3D schematic										

Genetic algorithm optimisation parameters:

- Initial population:
  - Goals : maximize diversity, minimize redundancy
  - Initial population generated by stochastic methods (individuals parameters randomly chosen)
- Fitness evaluation:
  - Reflection index: $\Delta DL_{RI} = DL_{RI} - \Delta DL_{RI,\,ref}$
  - Transmission index: $\Delta DL_{SI} = DL_{SI} - \Delta DL_{SI,\,ref}$
  - Diffraction index: $\Delta DL_{\Delta DI} = DL_{\Delta DI} - \Delta DL_{\Delta DI,\,ref}$

Genetic algorithm optimisation parameters:

> Individuals mutation

> Use of Gaussian mutation with a 1/5 rule

1. If $m > m_r$, in which m_r is the mutation rate and m is a random number from a uniform distribution with bounds [0, 1), do not mutate the parameter.

2. If the parameter is to be mutated ($m < m_r$), calculate the new parameter with:

$$p_{new} = p_{old} + \nu.(upper\_bound - lower\_bound) \quad \text{Eq. 10}$$

in which p_{new} is the mutated parameter, p_{old} is the initial parameter value and ν is a random number obtained from a Gaussian distribution of mean 0 and standard deviation σ_p, σ_p being the mutation range associated with parameter p.

Furthermore, if for the entire population less that one-fifth of the individuals have been mutated, the mutation range σ_p is increased by 5%, such that for the next generation the number of mutated individuals is closer to one-fifth of the number of individuals.

Genetic algorithm optimisation parameters:

- Termination parameters:
  - The number of function evaluation has reached its maximum value
  - The number of generation has reached its maximum value
  - The fitness value cannot be increased anymore
  - The fitness value has reached its objective values

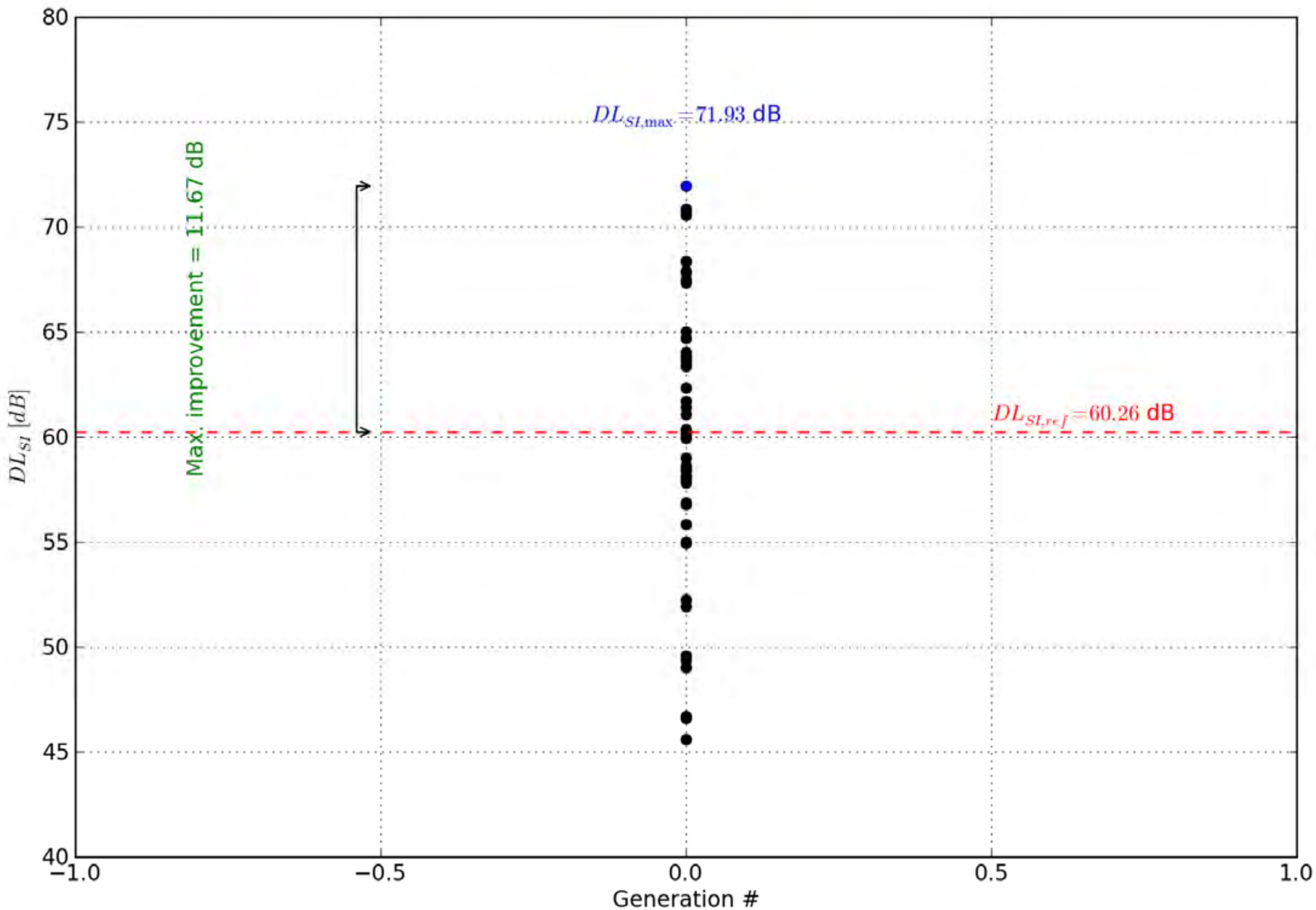
Initial parameters:

- Nb. of individuals in a population: 50
- Mutation rate : 0.2
- Mutation range: 0.15
- Max. nb. of generation : 20
- Max. nb. of function evaluation : 500

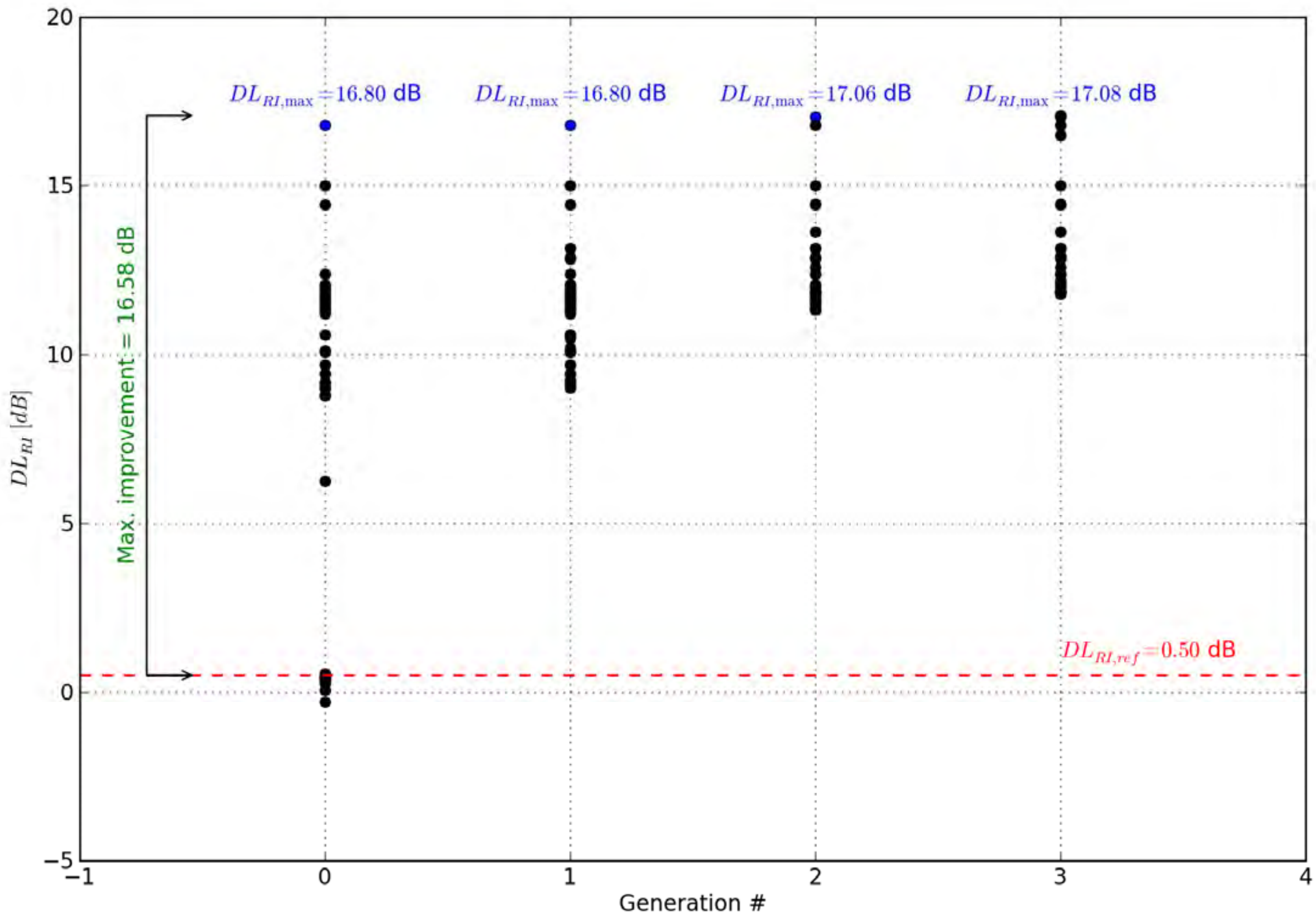
Optimization of a flat homogeneous NRD:

- Single-objective optimisation of DL_{SI}
- Single-objective optimisation of DL_{RI}
- Multi-objective optimisation of DL_{RI} and DL_{SI}

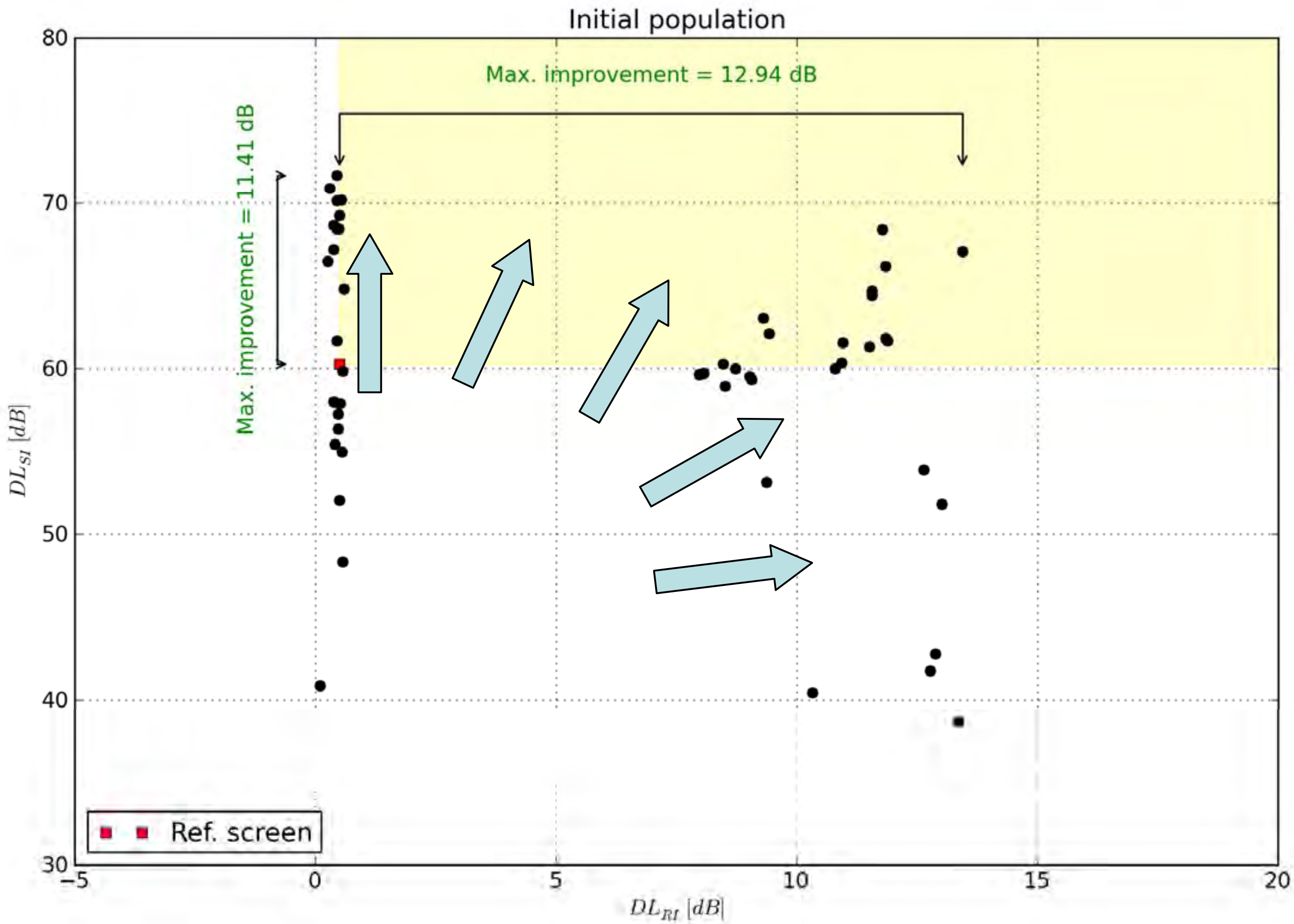
T5.3: Single-objective optimisation of DL_{SI}



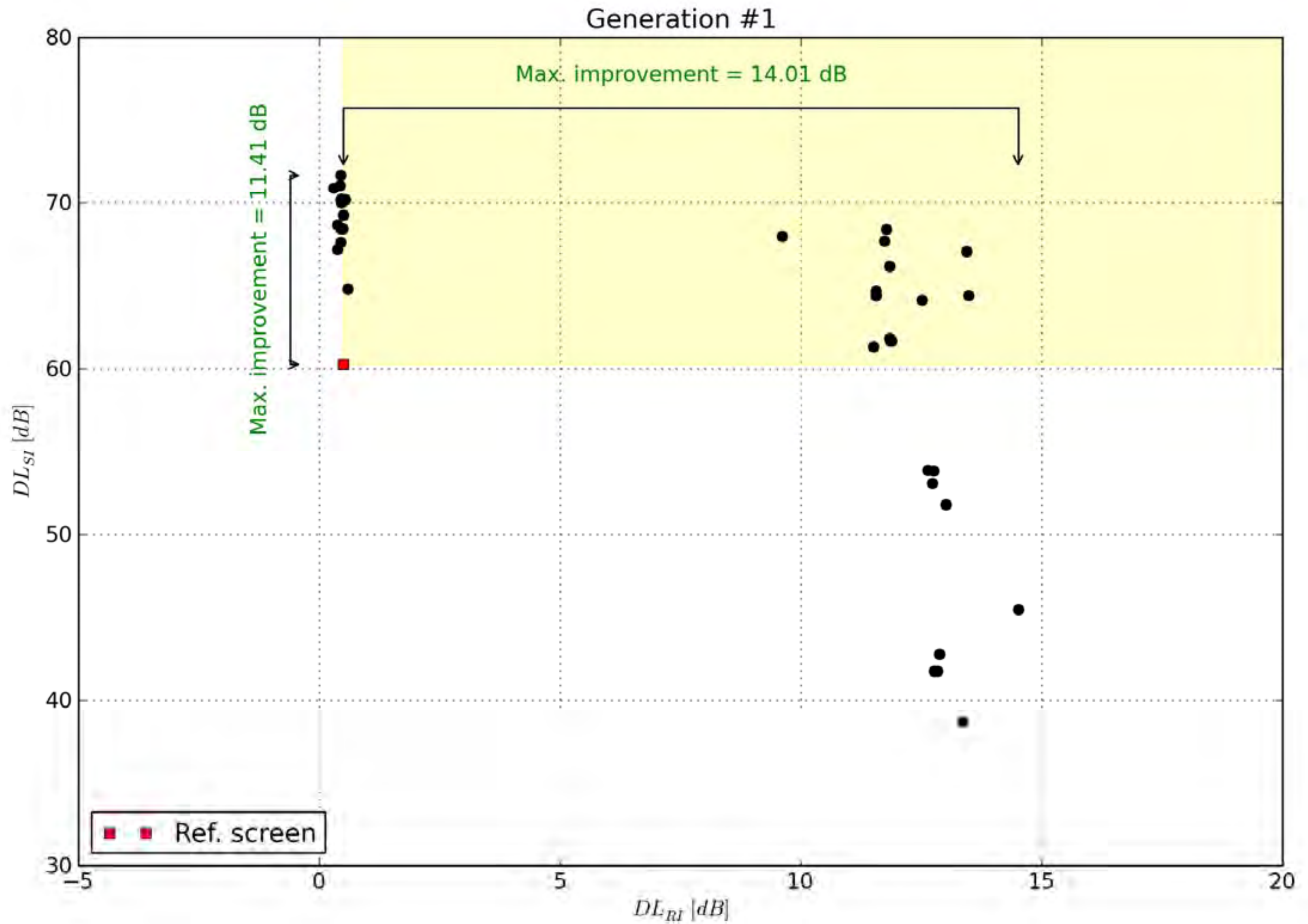
T5.3: Single-objective optimisation of DL_{RI}



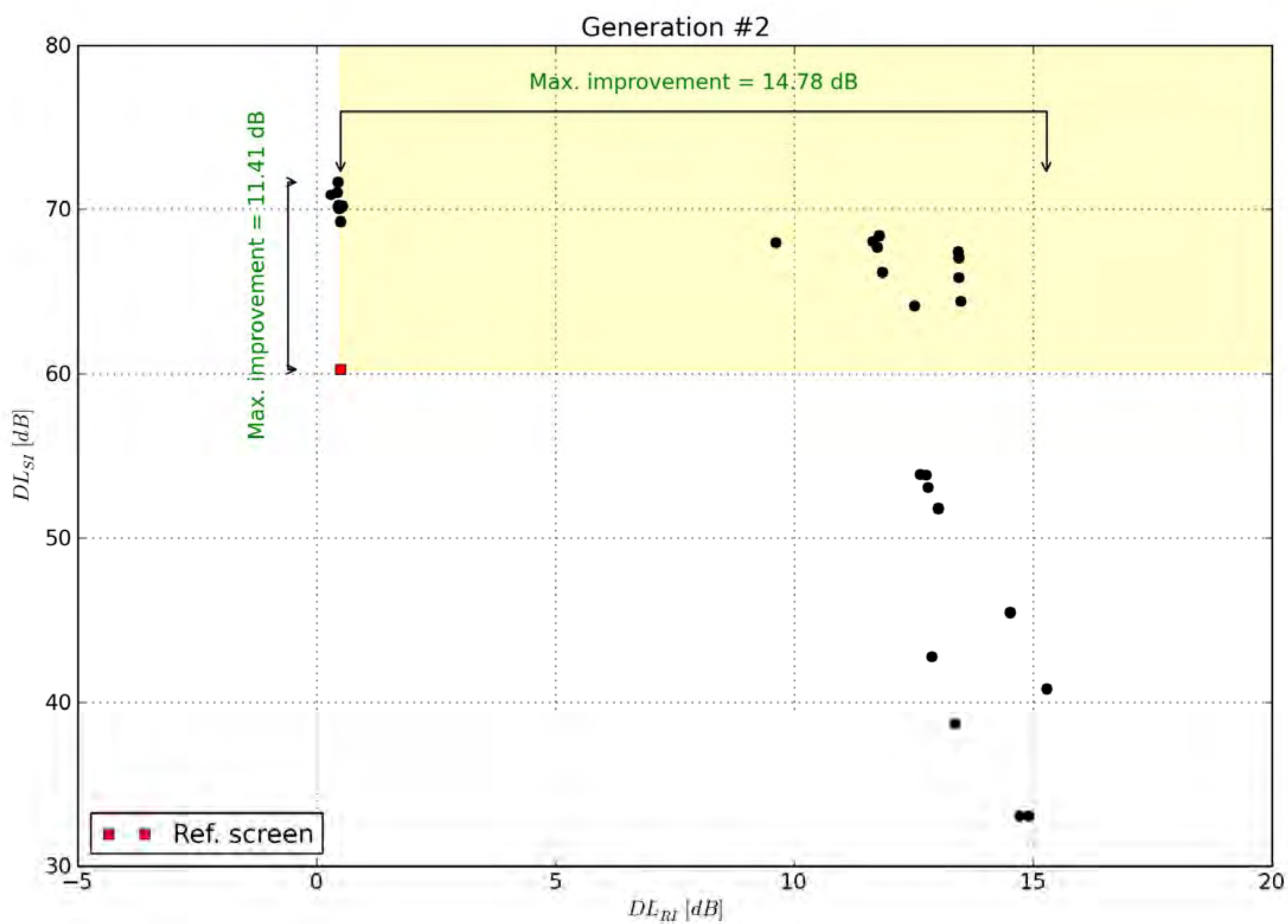
T5.3: Multi-objective optimisation of DL_{SI} and DL_{RI}



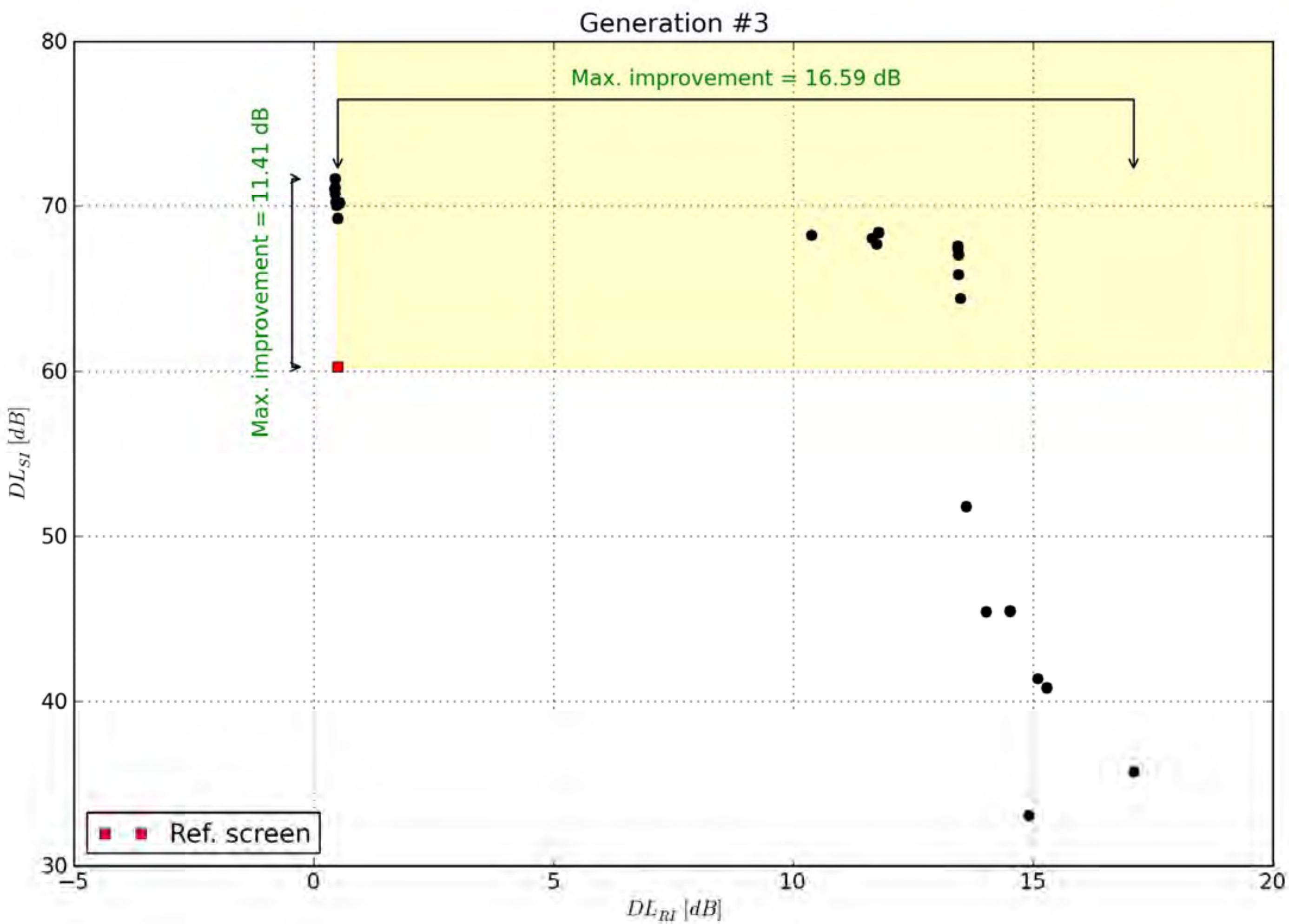
T5.3: Multi-objective optimisation of DL_{SI} and DL_{RI}



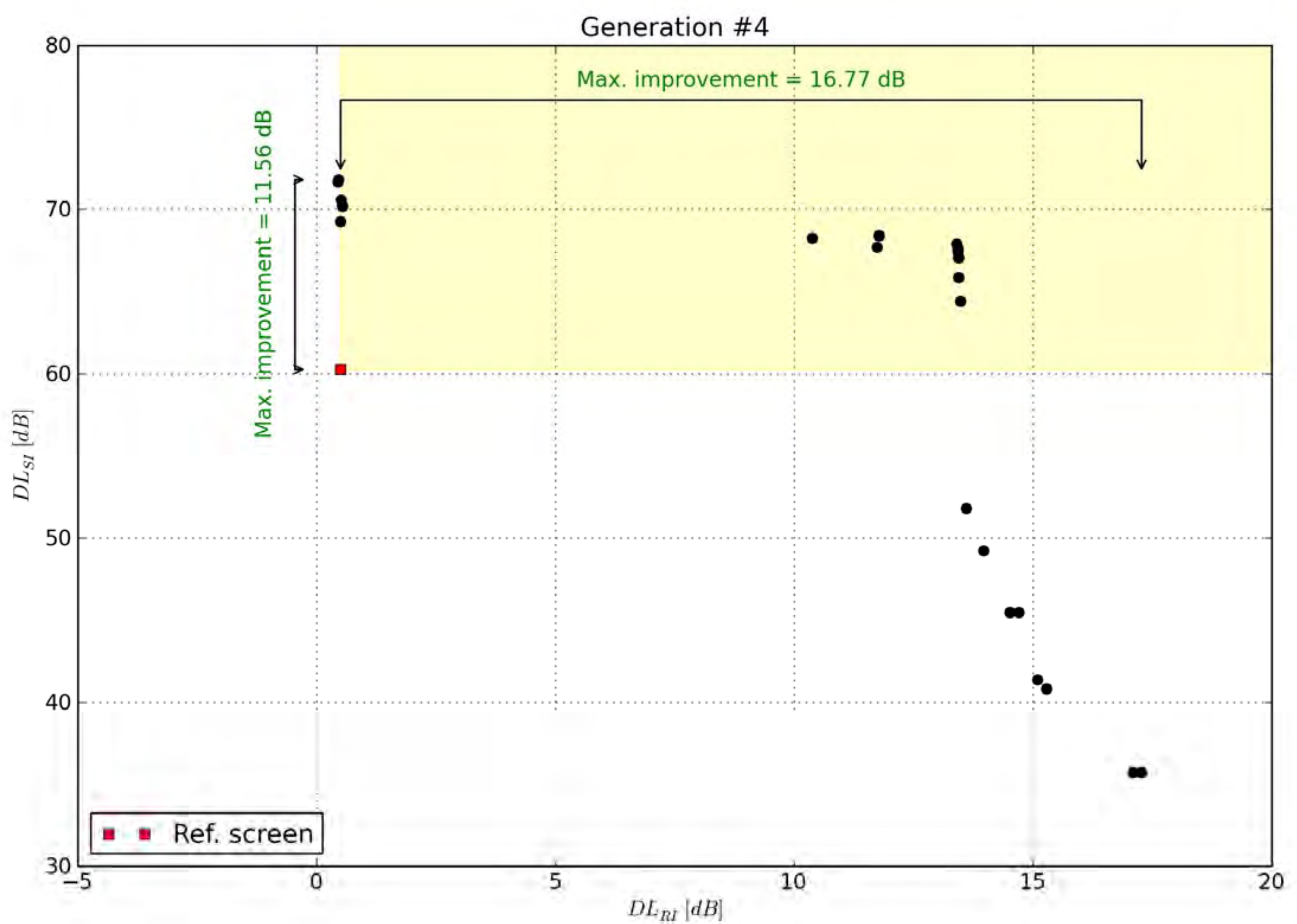
T5.3: Multi-objective optimisation of DL_{SI} and DL_{RI}



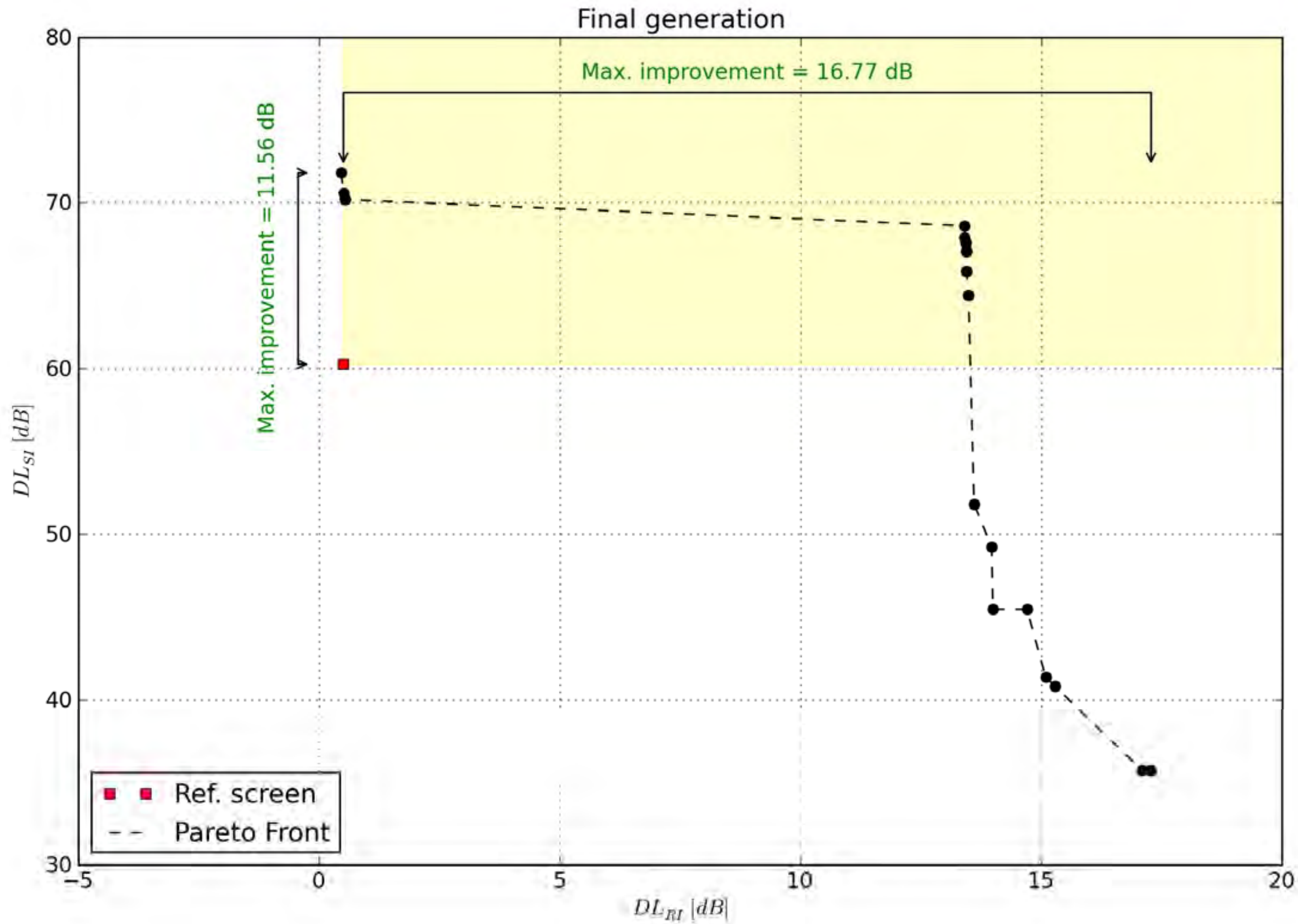
T5.3: Multi-objective optimisation of DL_{SI} and DL_{RI}



T5.3: Multi-objective optimisation of DL_{SI} and DL_{RI}



T5.3: Multi-objective optimisation of DL_{SI} and DL_{RI}

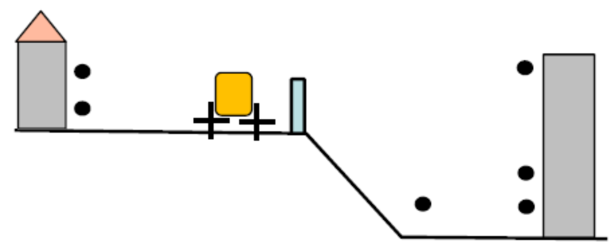


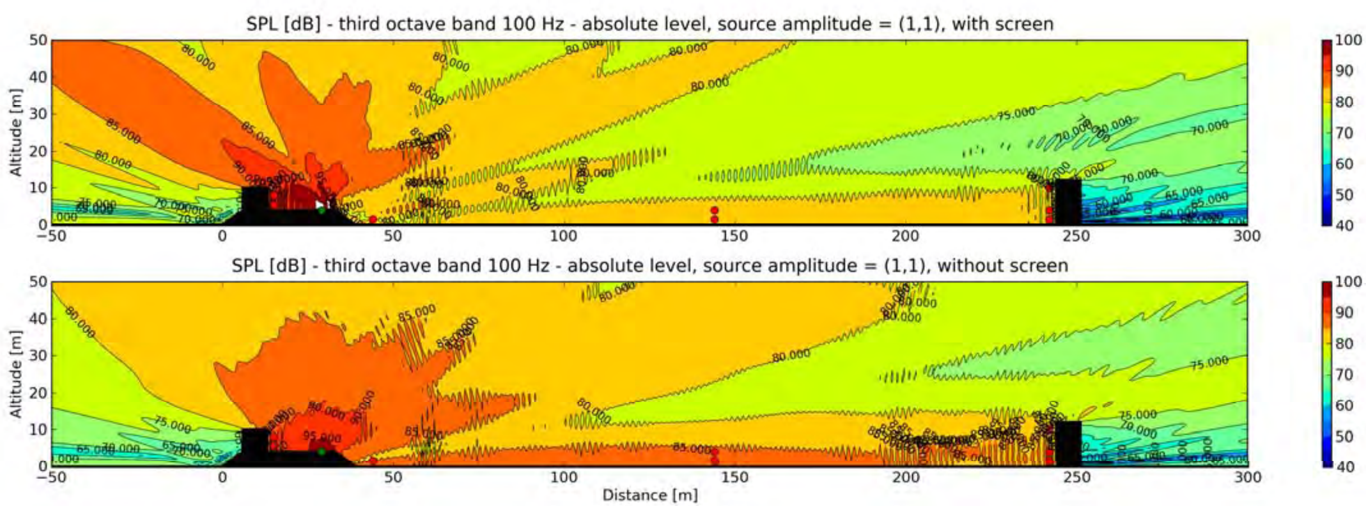
T5.3: Multi-objective optimisation of DLSI and DLRI

	Single-Objective	Multi-objective
Reflection	16,58 dB	16,77 dB
Transmission	11,67 dB	11,56 dB

Extrinsic optimizations:

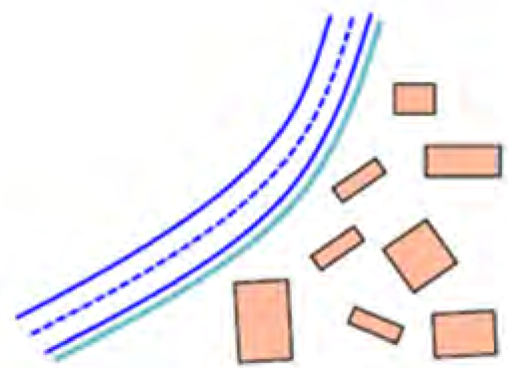
- Multi objective optimizations : Acoustical + Environmental + Economical parameters
- Acoustical performances:
  - the insertion loss IL
  - the sound pressure level difference ΔL





Global impact:

- Acoustical performances:
  - The gain in number of exposed people (ranges of 5 dB(A))
  - The gain in the number of highly annoyed people
- Environmental performances:
  - Complete LCA



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Journées techniques “Acoustique et Vibrations” 2011

Avancement des travaux au sein du WP5 du projet européen QUIESST

Aix-en-Provence
8 juin 2011