Innehåll

- Något om Ecophon
- Rumsakustik i praktiken
- Betydelsen av god akustik
- Rumsakustik och ljudabsorption
- Ljudspridning
- “Activity based acoustic design”
- Rumsakustiska mått
- Effekt av akustikreglering i klassrum
- Öppna kontorslandskap
- Beräkning av rumsakustiska mått

Fö 2020-05-13, 13-15
Öv 2020-05-14, 10-12

Fö 2020-05-18, 10-12
Öv 2020-05-18, 13-15

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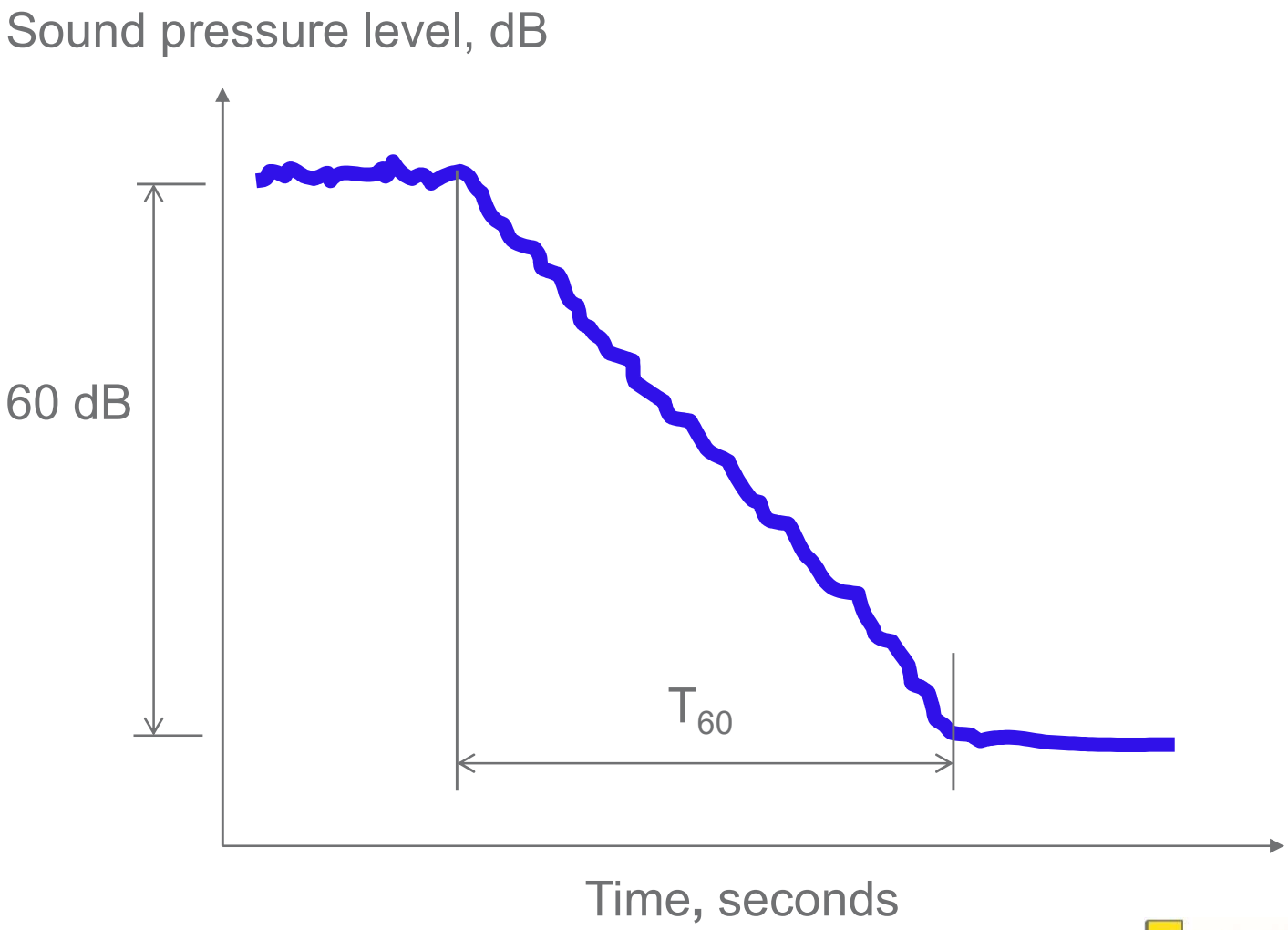
Definition: Reverberation time



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where

His formula

$$T = 0.16\left(\frac{V}{A}\right) \quad \text{or} \quad A = 0.16\left(\frac{V}{T}\right)$$

where

T=the reverberation time (s)
V=the room volume (m^3)
A=the total equivalent absorption area (m^2 sabin)

The equivalent absorption area A for a surface with area S m^2 is equal to α x S where α is the absorption coefficient for the surface

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Acoustic design with Sabine formula

Example: The reverberation time in a room with a volume of 200 m^3
is 2,5 s at 1000 Hz.
Target value for the reverberation time is 0,40 s at 1000 Hz

- A(before treatment)=0,161xV/T= 0,161x200/2,5=12,9 m^2 sabin
- A(needed to fulfil 0,40 s)= 0,161xV/T=0,161x200/0,40=80,5 m^2 sabin
- A(to be added to fulfil 0,40 s)=A(needed)-A(before)=80,5-12,9=67,6 m^2 sabin

If e.g. the absorption coefficient for a ceiling absorber is 0,90 at 1000 Hz we will need S= A/α=67,6/0,90=75 m^2

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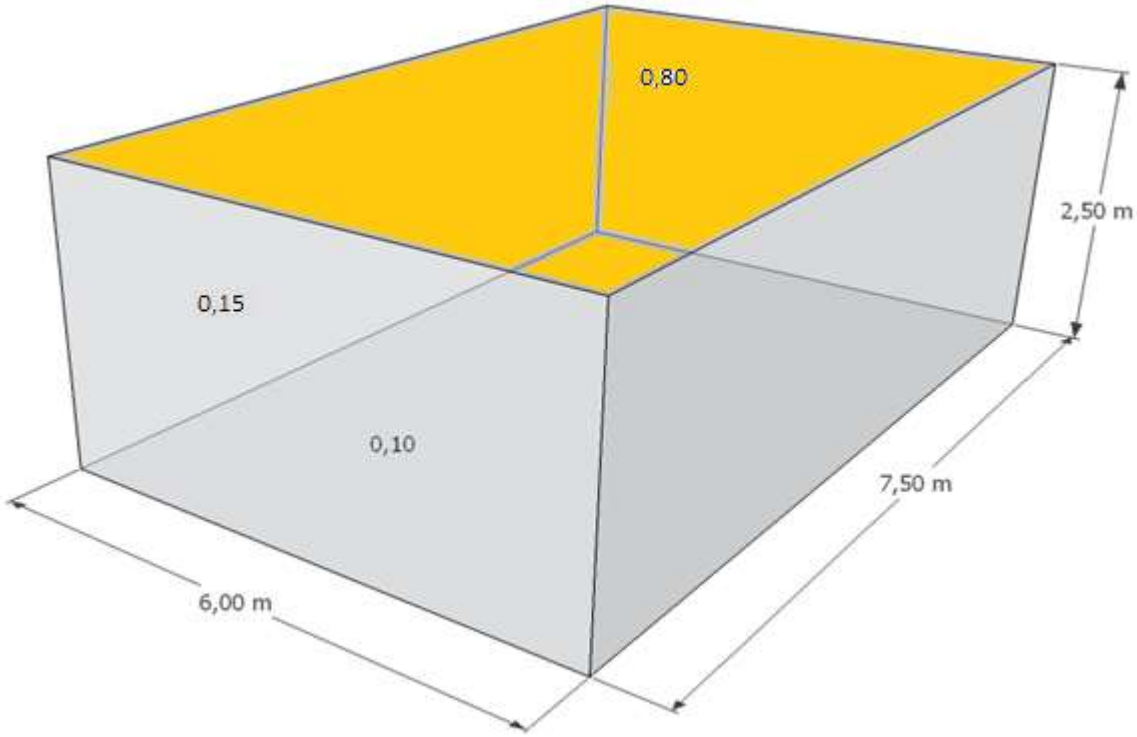
Sabine formula: How it works in theory



Absorption coefficients (500 Hz):

Walls=0,15
Ceiling=0,80
Floor=0,10

$A=\sum \alpha_i \times S_i = 0{,}10x6x7{,}5+2x0{,}15x7{,}5x2{,}5+2x0{,}15x6x2{,}5+0{,}80x6x7{,}5=51\ m^2$ sabin

$T_{60}=0{,}161x(V/A)=0{,}161x112{,}5/51\approx0{,}36$ s

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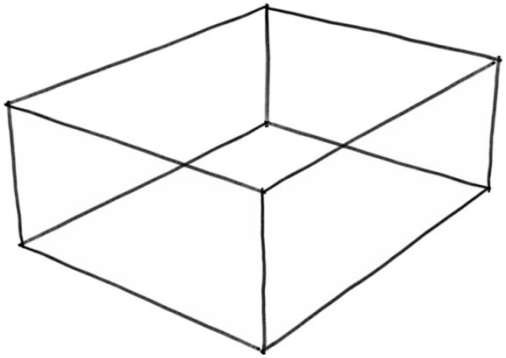
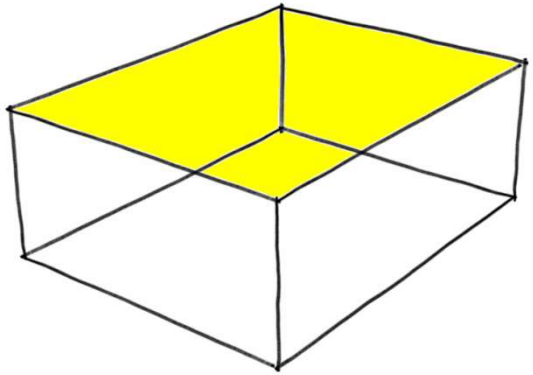
Room types

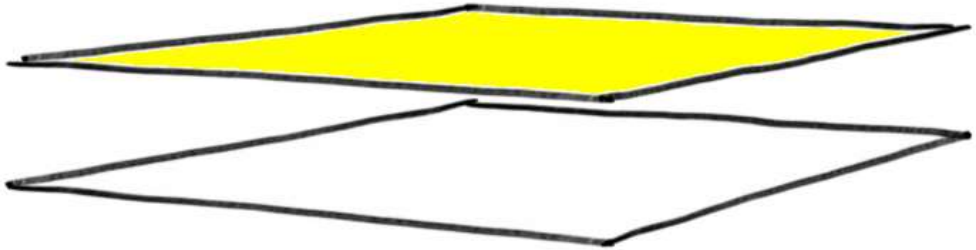
Reverberant room (Sabine room)



Room with absorbent ceiling



*Open-plan **spaces***



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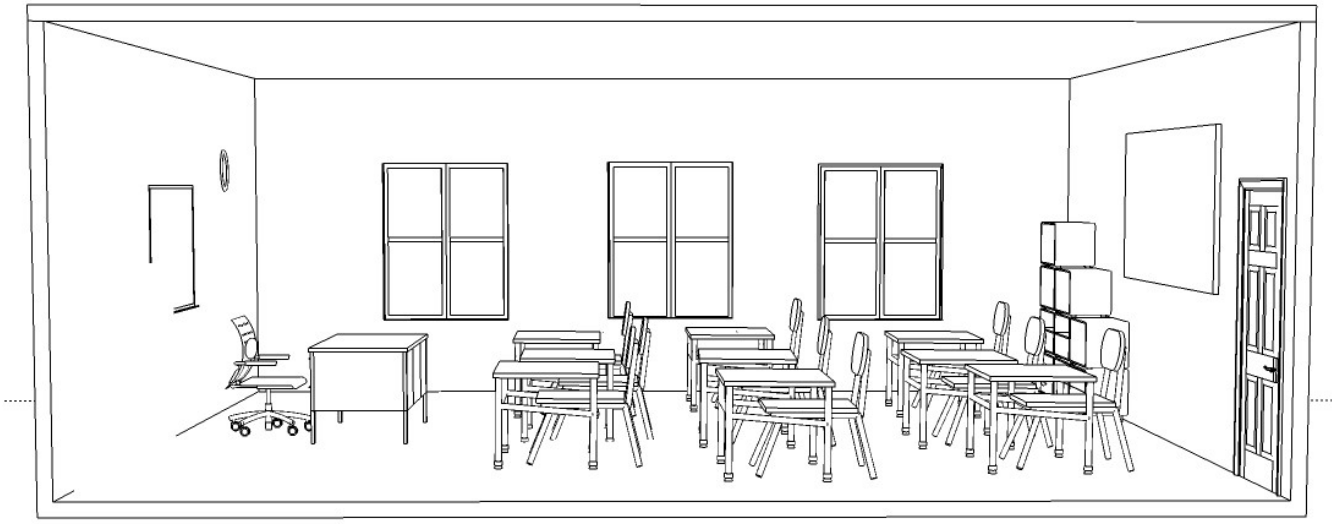
Typical classroom



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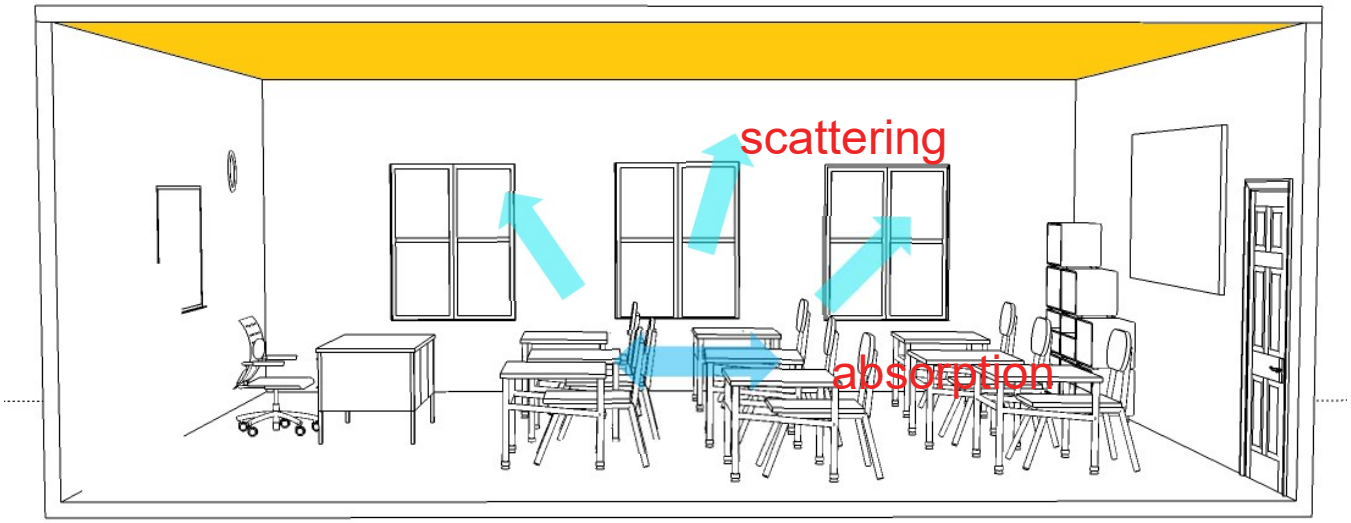
Effect of furniture



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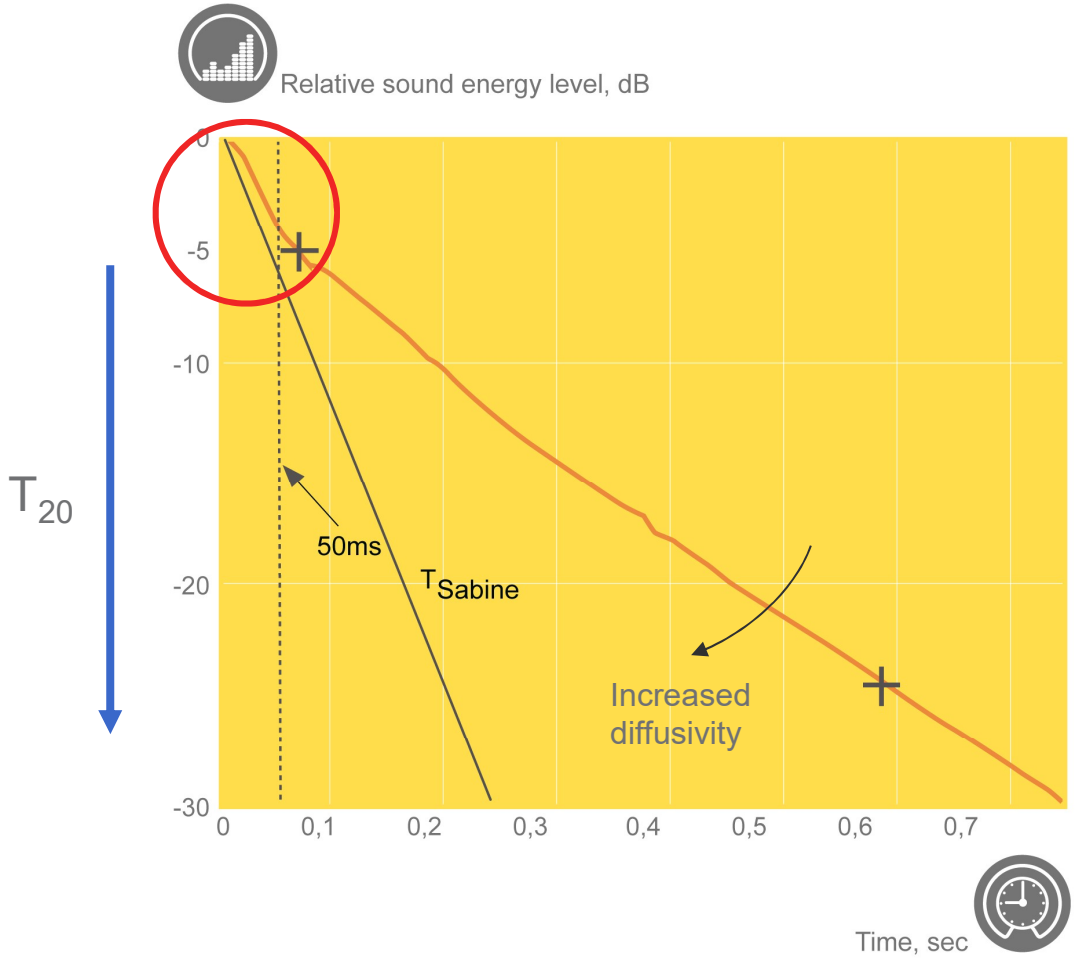
Reverberation decay in rooms with suspended absorbent ceiling



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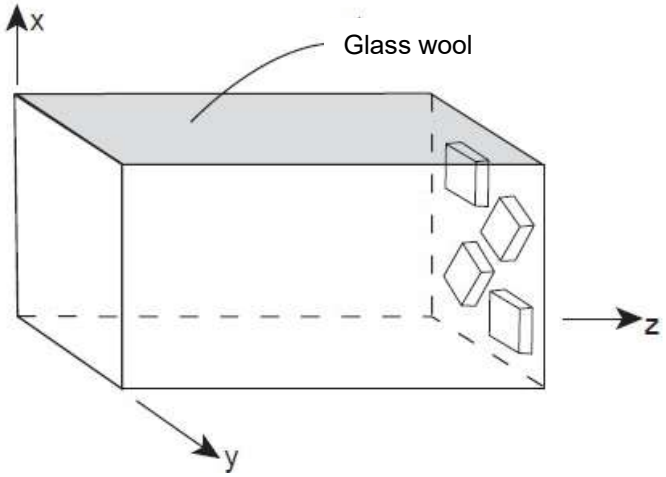
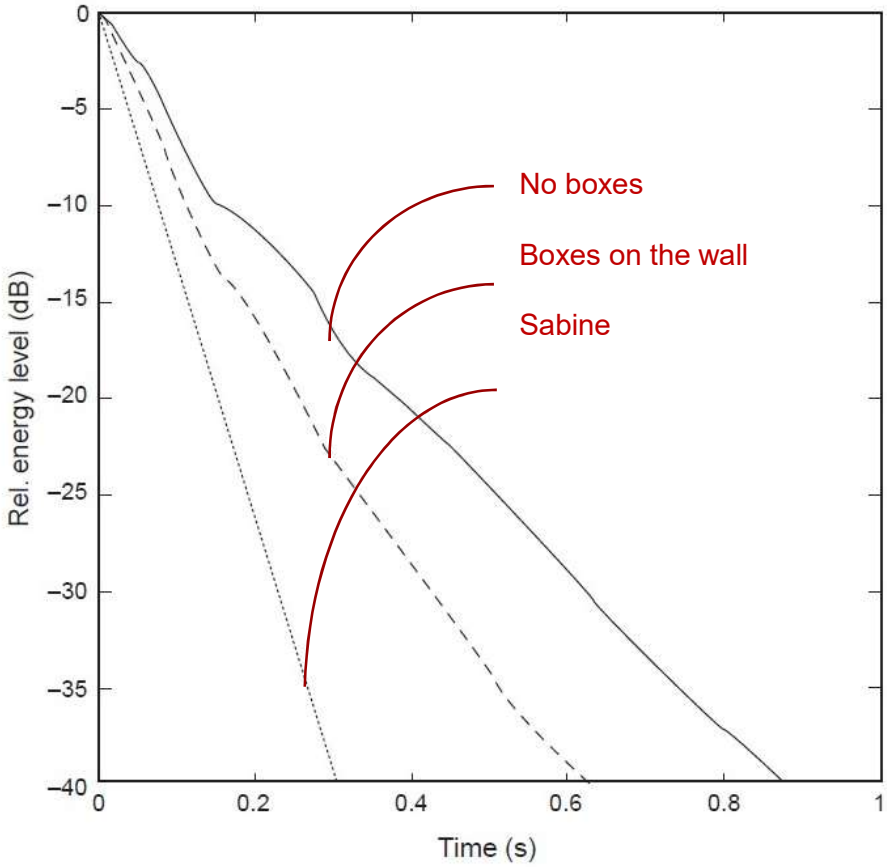
Scattering – why is it important?





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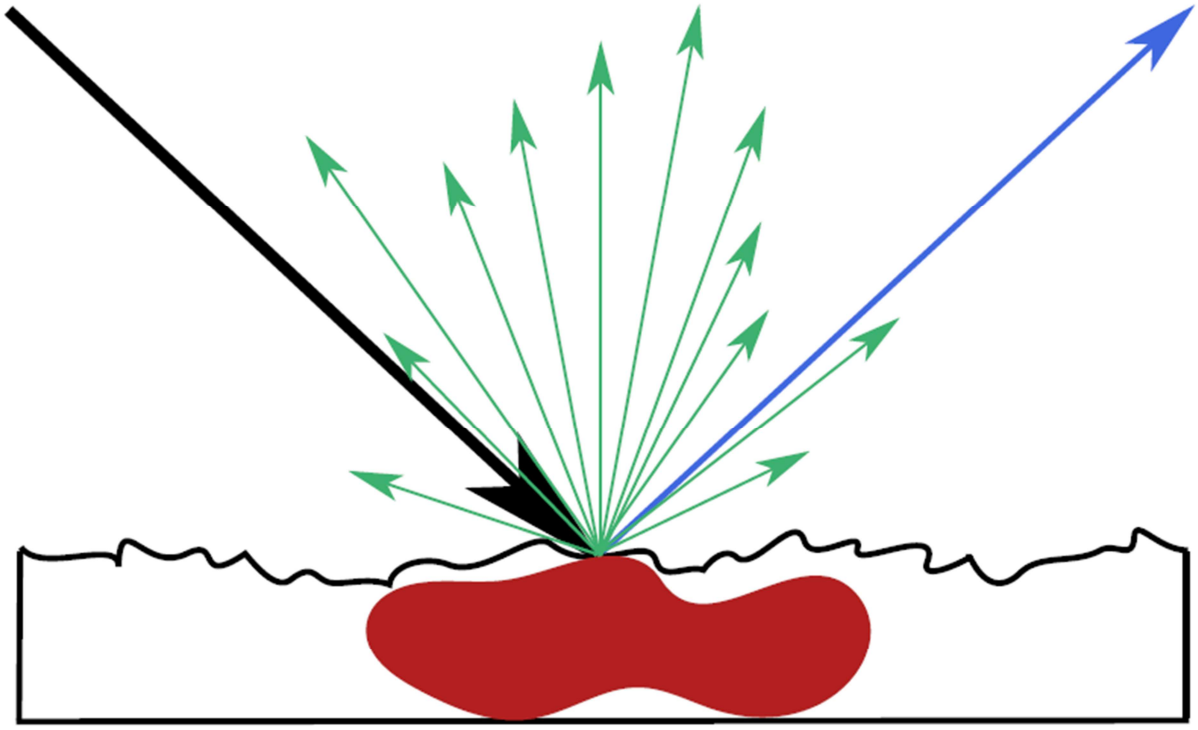
Absorption and scattering



$$\alpha + (1-\alpha)\cdot(1-s) + (1-\alpha)\cdot s = 1$$

absorbed — specularly reflected — diffusely reflected

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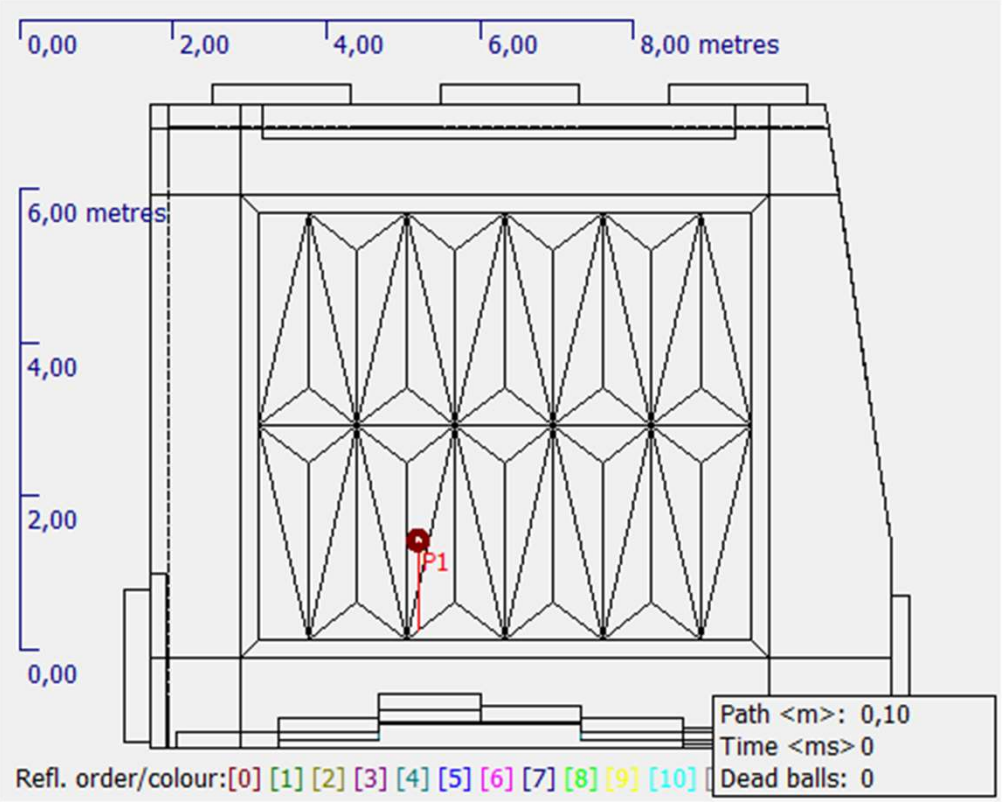
Simulation of sound fields



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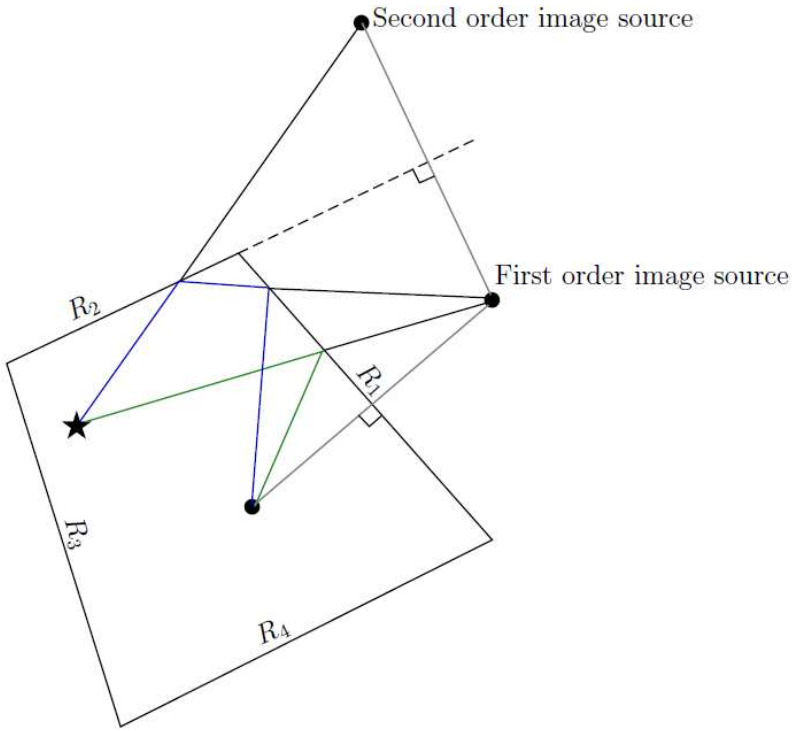
PARISM – simulation tool for ordinary rooms

Industrial PhD project together with DTU

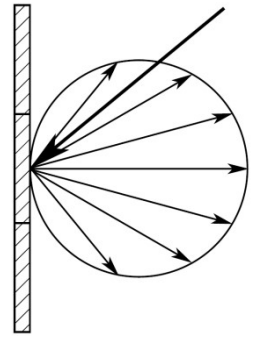
The image source method

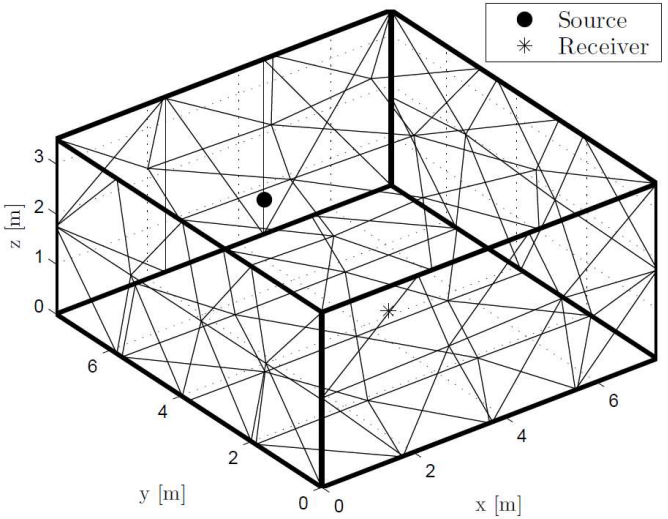


Acoustical radiosity

Lambert's law:

$$I(\theta) = I(0)\cos(\theta)$$





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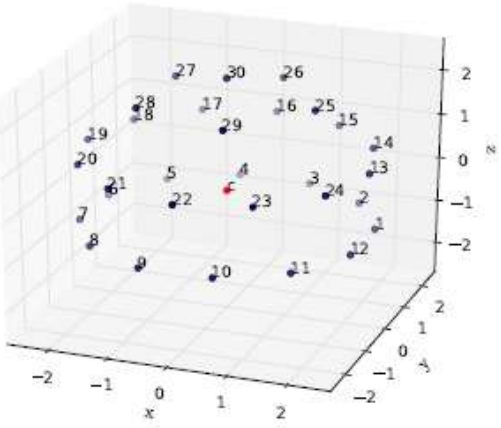
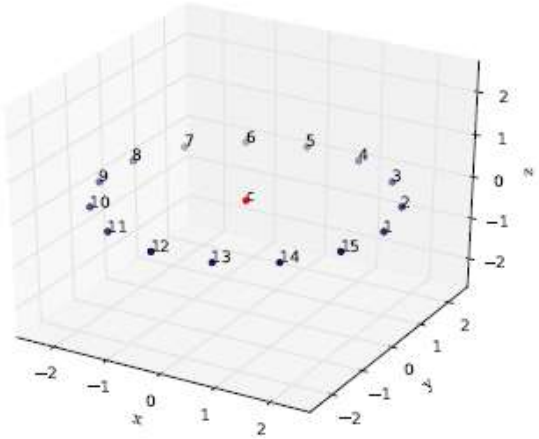
Auralisation with loudspeaker array using higher order ambisonics





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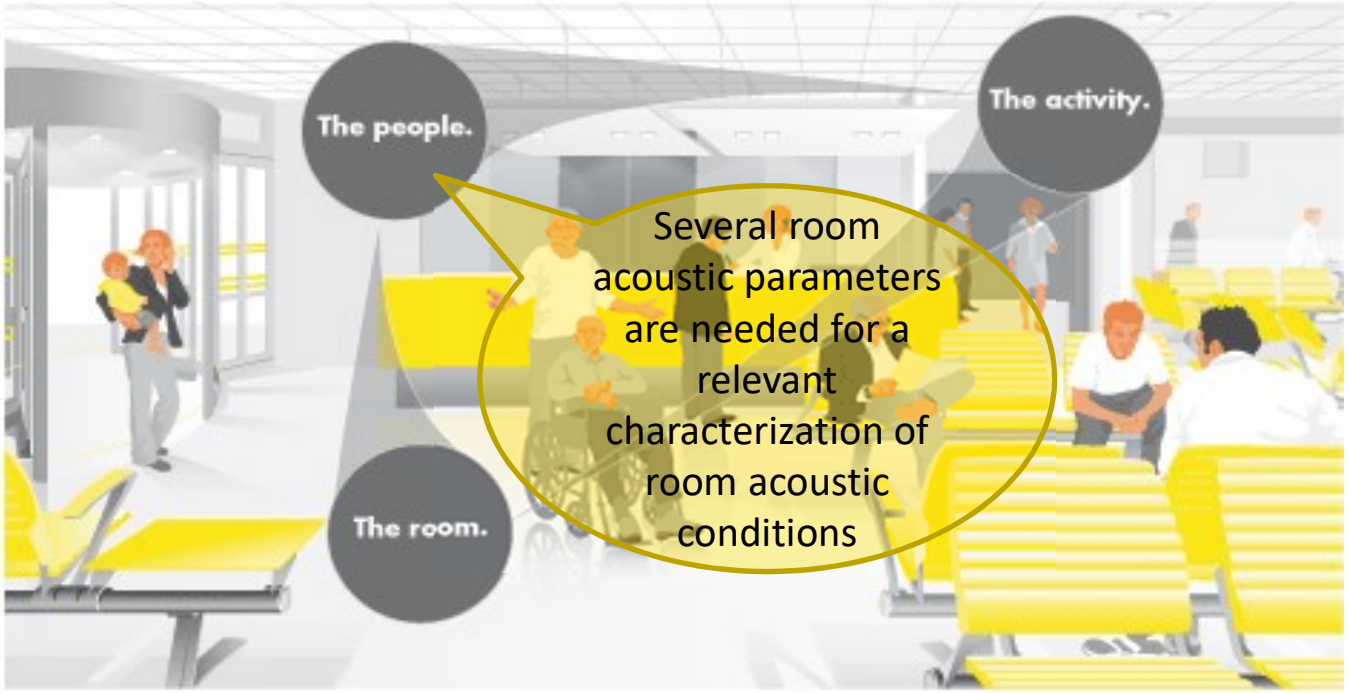
Activity based acoustic design – a method to approach room acoustic design



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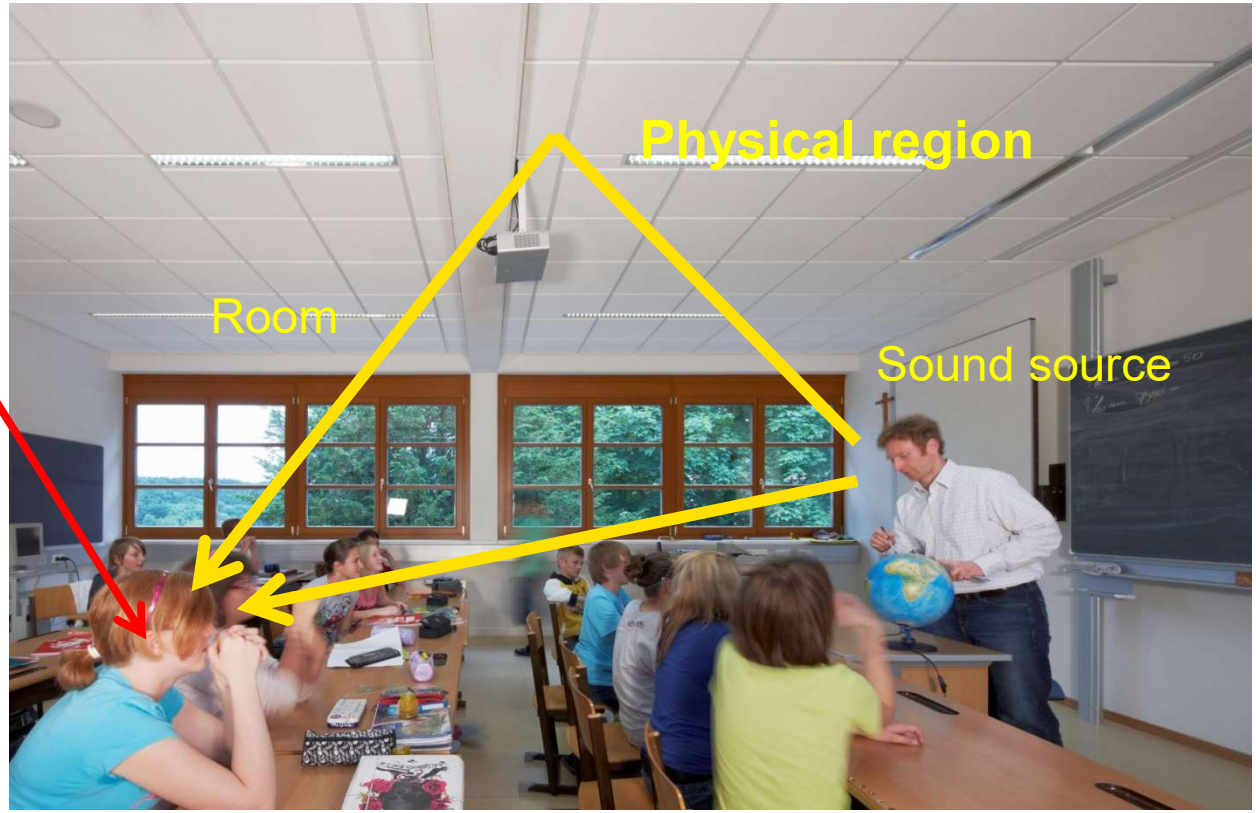
Assessment of sound in rooms

Physiological and psychological region

Sensation
- Sound strength
- Clarity
- Sharpness
- …

Preference



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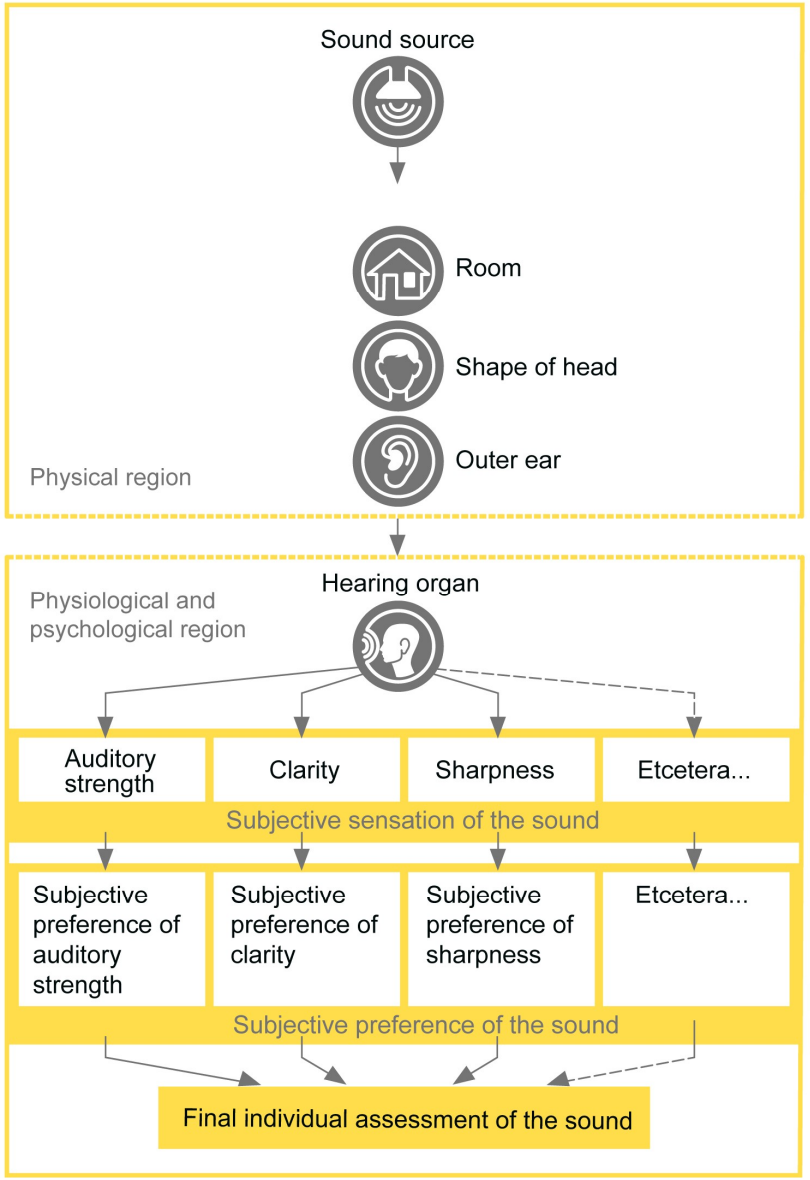
Assessment of sound in rooms



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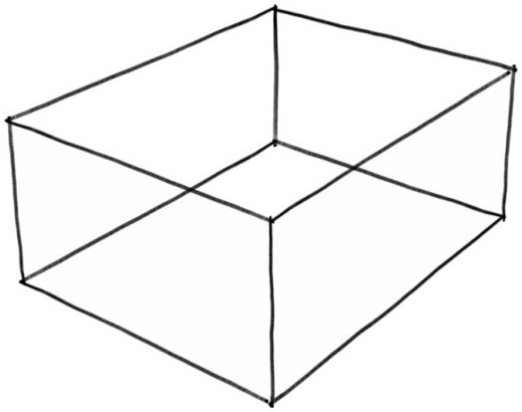
Room types

Reverberant room (Sabine room)

Reverberation time

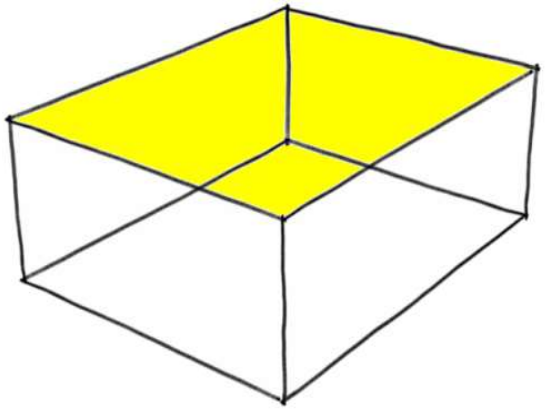


Room with absorbent ceiling

Speech clarity

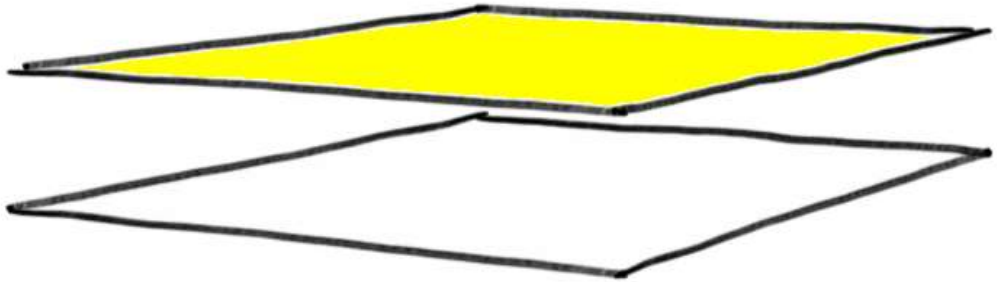
Sound strength

Reverberation time



Open-plan spaces

Spatial decay



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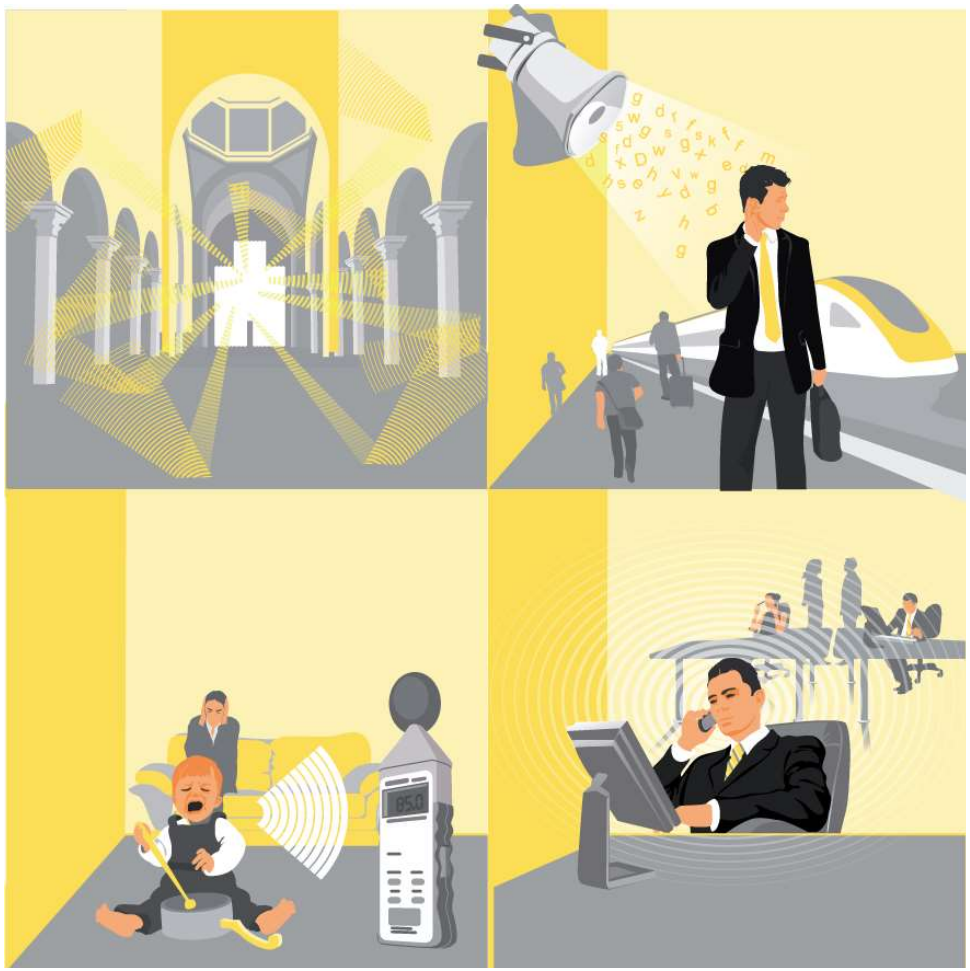
Room acoustic quality aspects

- Reverberation
- Speech clarity
- Auditory strength
- Spatial decay

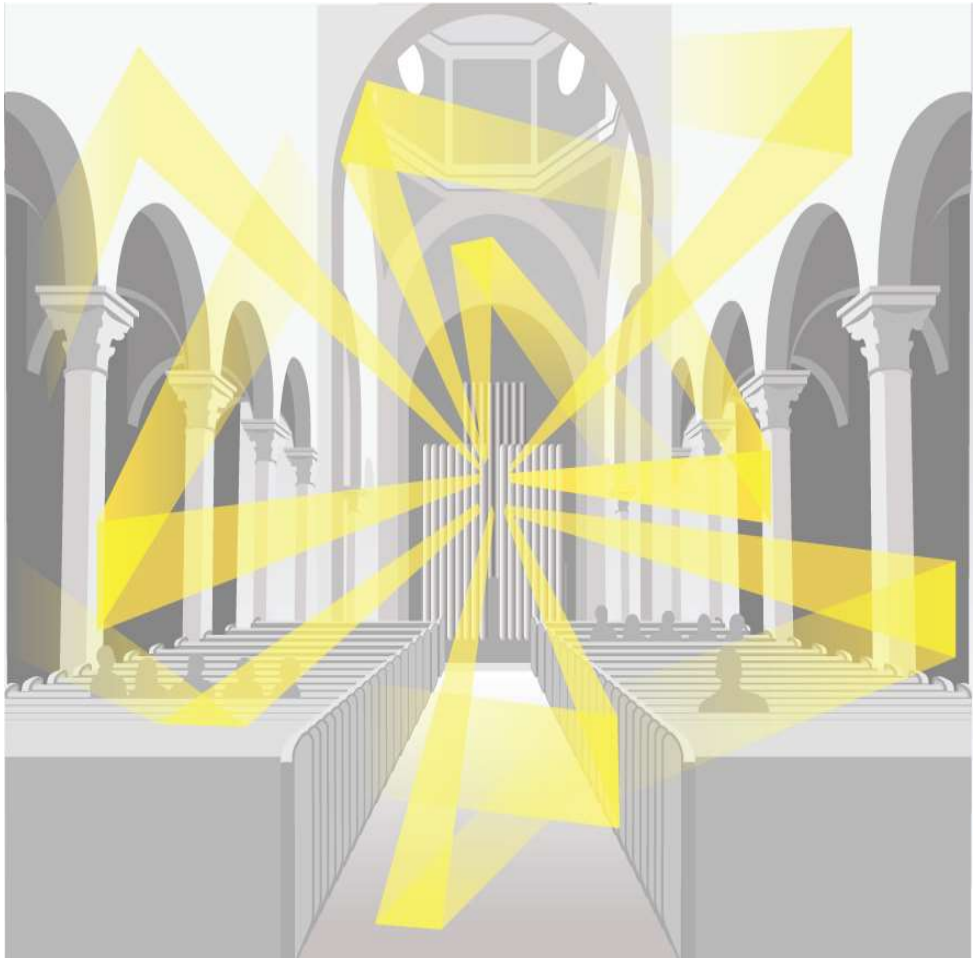


Efterklang

- **Relaterar till hur snabbt ljudenergin försvinner i ett rum**

Lång efterklang

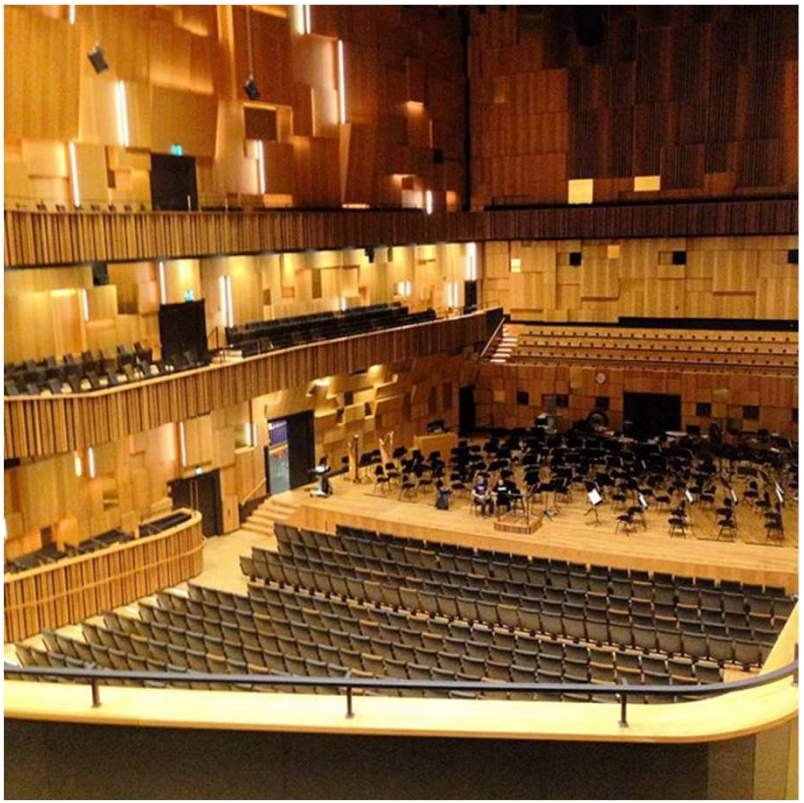
Kort efterklang



Parameters for performance spaces ISO 3382-1

Subjective quality	**Objective measure**
Clarity	Clarity index (C_{80})
Reverberance	Early decay time (EDT))
Intimacy	Sound strength (level)
Source broadening	Early lateral fraction and strength
Loudness	Sound strength and source-receiver distance

M. Barron, The development of concert hall design – A 111 year experience, Proce edings of the Institute of Acoustics, Vol. 28. Pt. 1. 2006



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ISO 3382-2: Reverberation time in ordinary rooms

ISO 3382-3: Open plan offices (T_{20} not included)

Schools

Offices

Hospitals

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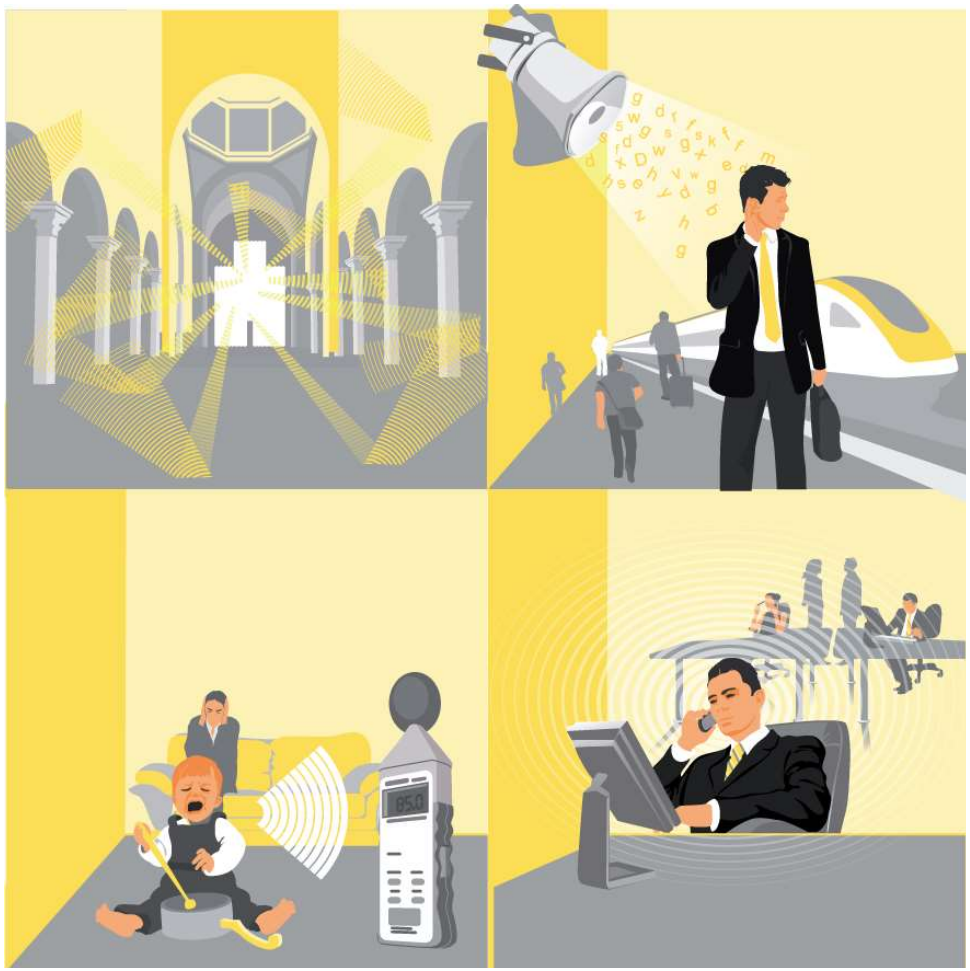
Room acoustic quality aspects and parameters

Ordinary rooms:

- Reverberation: T_{20} (s), ISO 3382-2
- Speech clarity: C_{50} (dB), ISO 3382-1
- Auditory strength: G (dB), ISO 3382-1

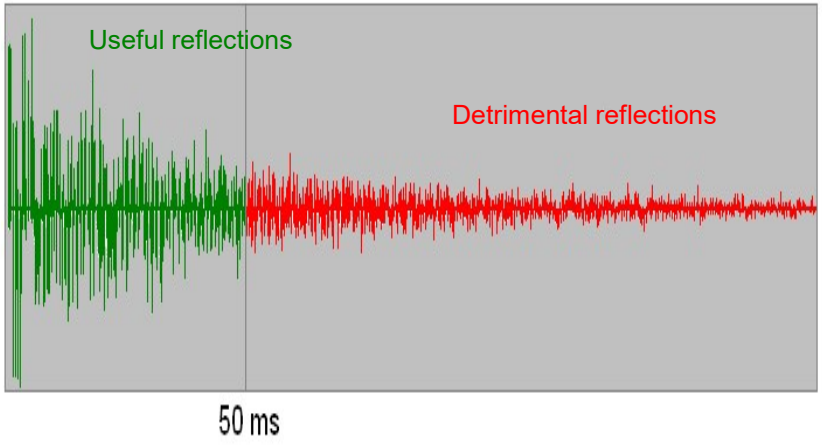
Open plan spaces:

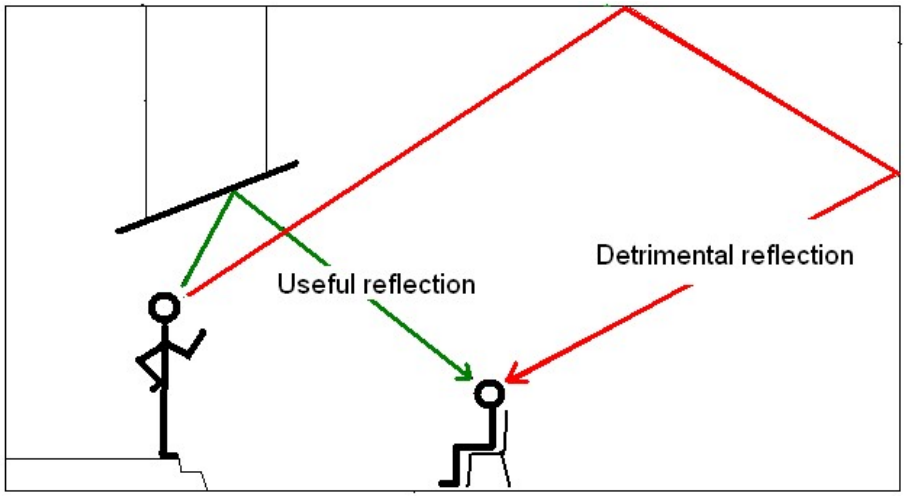
- Spatial decay: according to ISO 3382-3



Definition of room acoustic measures: Speech Clarity C_{50} (dB)

$$C_{50} = 10 \times \log\left(\frac{\text{Energy}(0-50\text{ms})}{\text{Energy}(50-\text{end})}\right) \quad \text{, dB}$$





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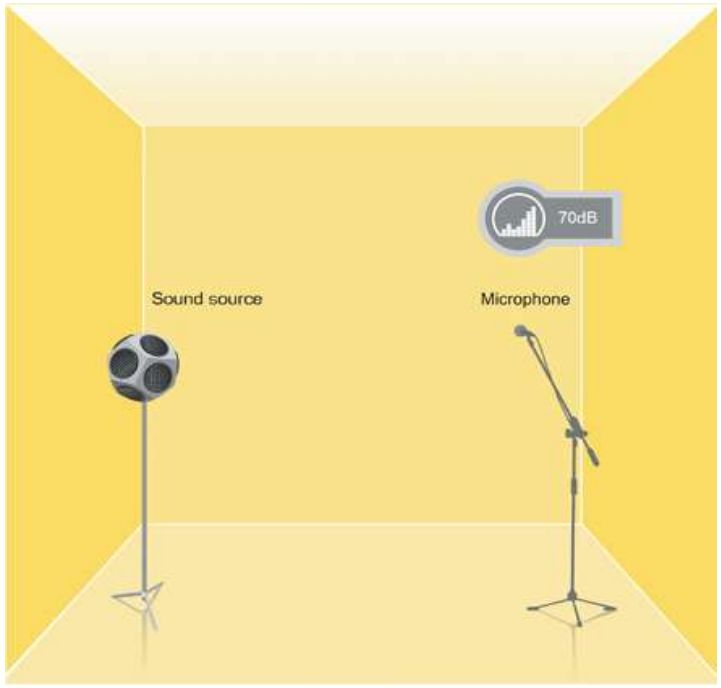
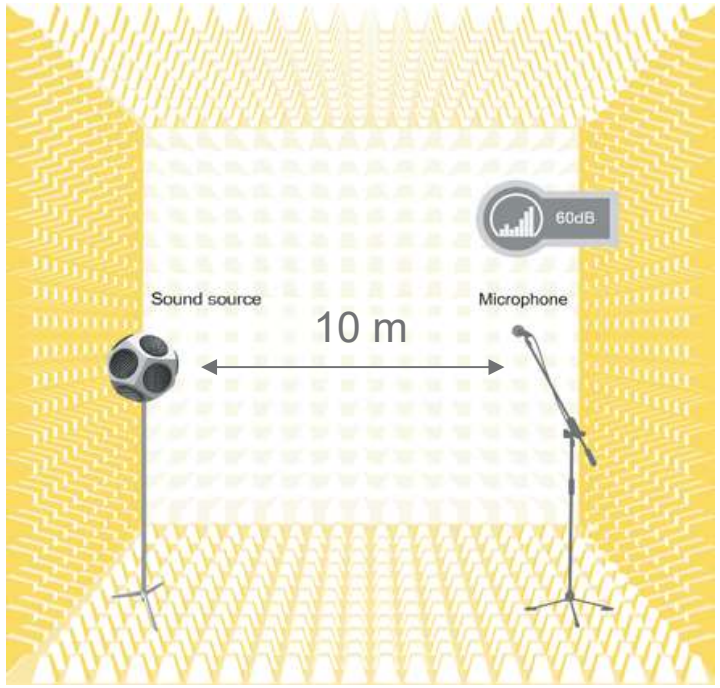
Room acoustic measures: Sound strength G (dB)

$G = Lp_{Room} - Lp_{10m} = Lp - Lw + 31$ dB (omni-directional sound source)





G=70 dB - 60 dB= 10 dB

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Calibrated Sound Power Source

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Just noticeable difference of room acoustic quantities according to ISO 3382-1

Subjective listener aspect	Room acoustic quantity	Just noticeable difference
Subjective level of sound	Sound Strength G in dB	1 dB
Perceived reverberance	Reverberation time T_{20} in seconds	5%
Perceived clarity of sound	Speech Clarity C_{50} in dB	1 dB

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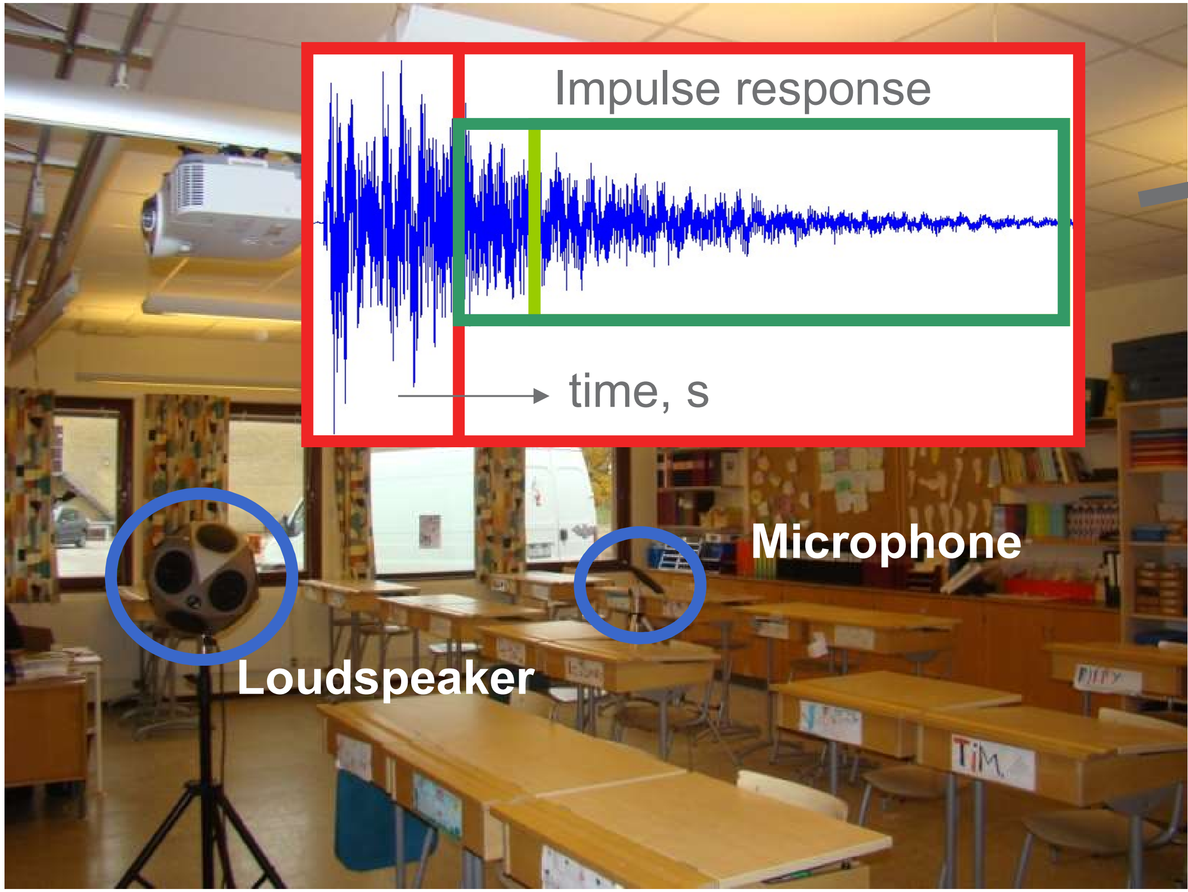
Room acoustic measurements



Reverberation time, T_{20}
Speech clarity, C_{50}
Strength, G

Small meeting rooms

Two similar rooms with different ceiling treatment.

Room 1: Ceiling absorber $\alpha_w = 1.0$

Room 2: Ceiling absorber $\alpha_w = 0.1$

Floor area = 12 m^2

Height = 2.7 m

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Semantic differential questionnaires

	Extremely	Very	Fairly	Partly	Fairly	Very	Extremely	
Distinct							X	Indistinct
Pleasant								Unpleasant
Dry								Reverberant
Best possible listening environment								Worst possible listening environment
Best possible speaking environmen								Worst possible speaking environmen

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Semantic differential questionnaires

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Best possible listening environment								Worst possible listening environment
Best possible speaking environmen								Worst possible speaking environmen

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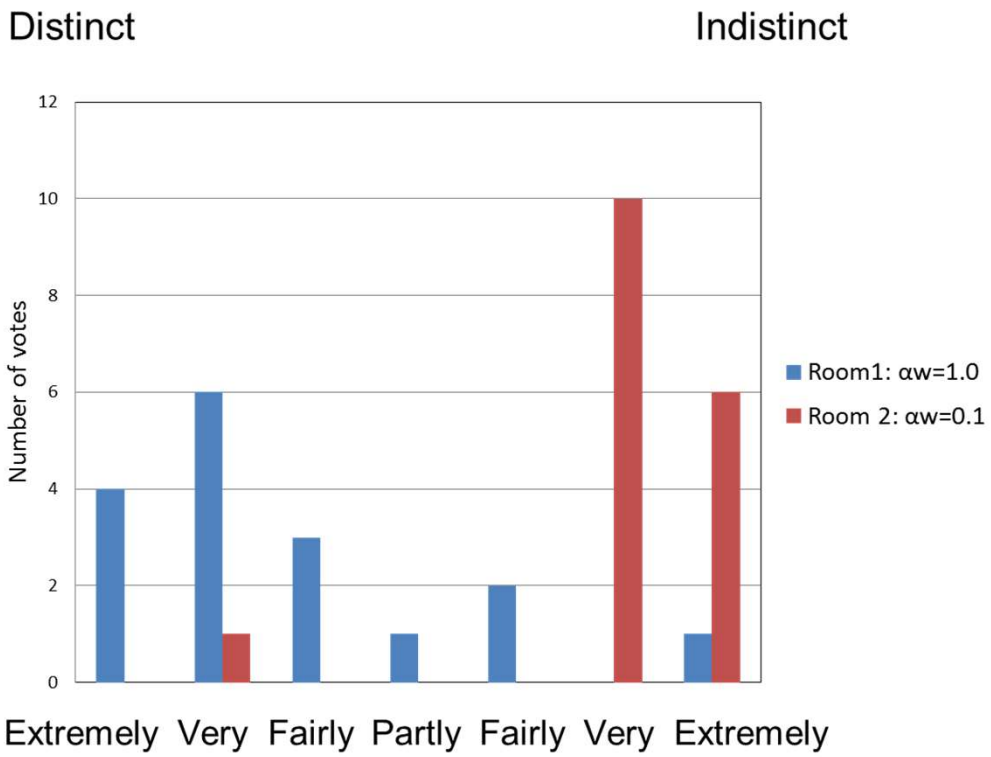
Listening test



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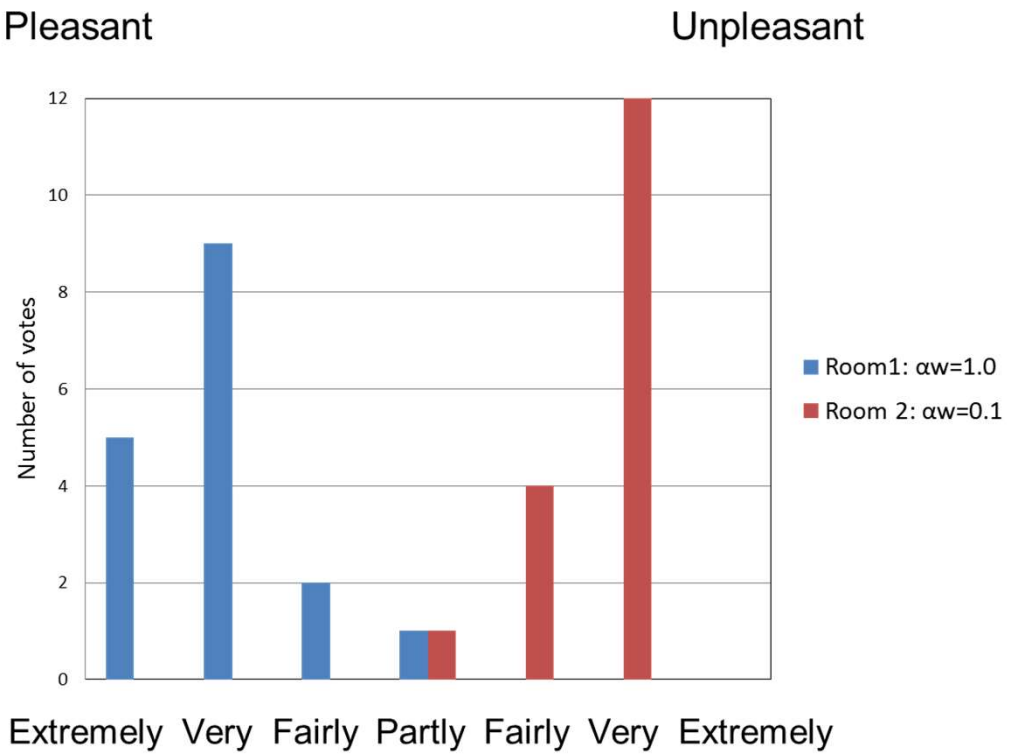
Listening test



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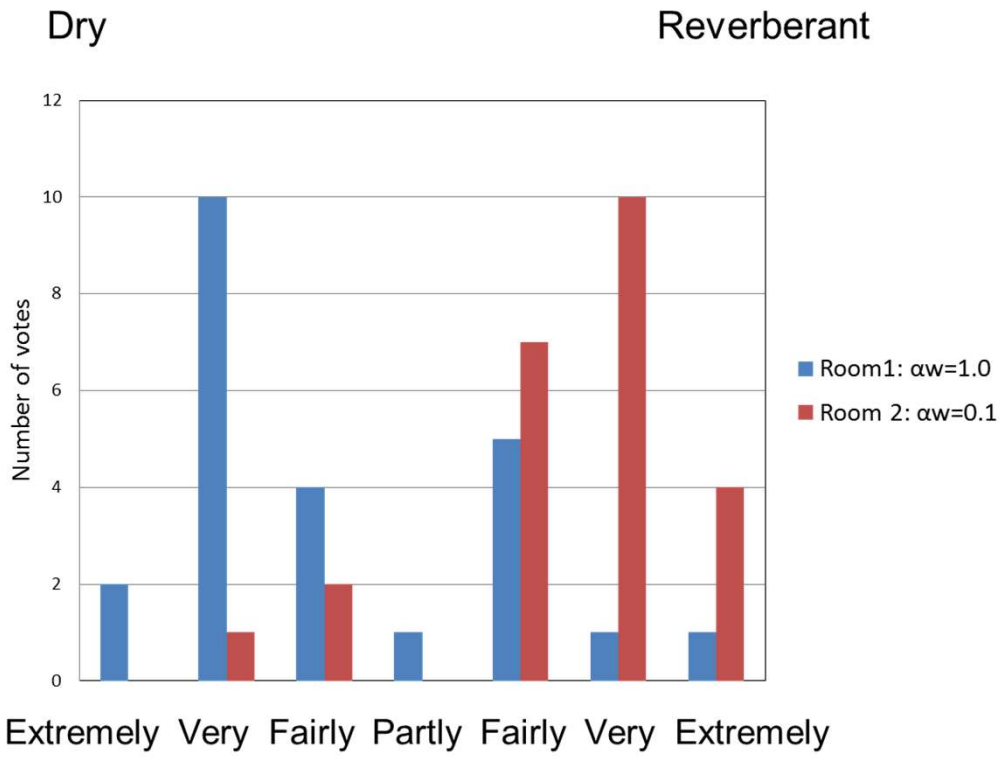
Listening test



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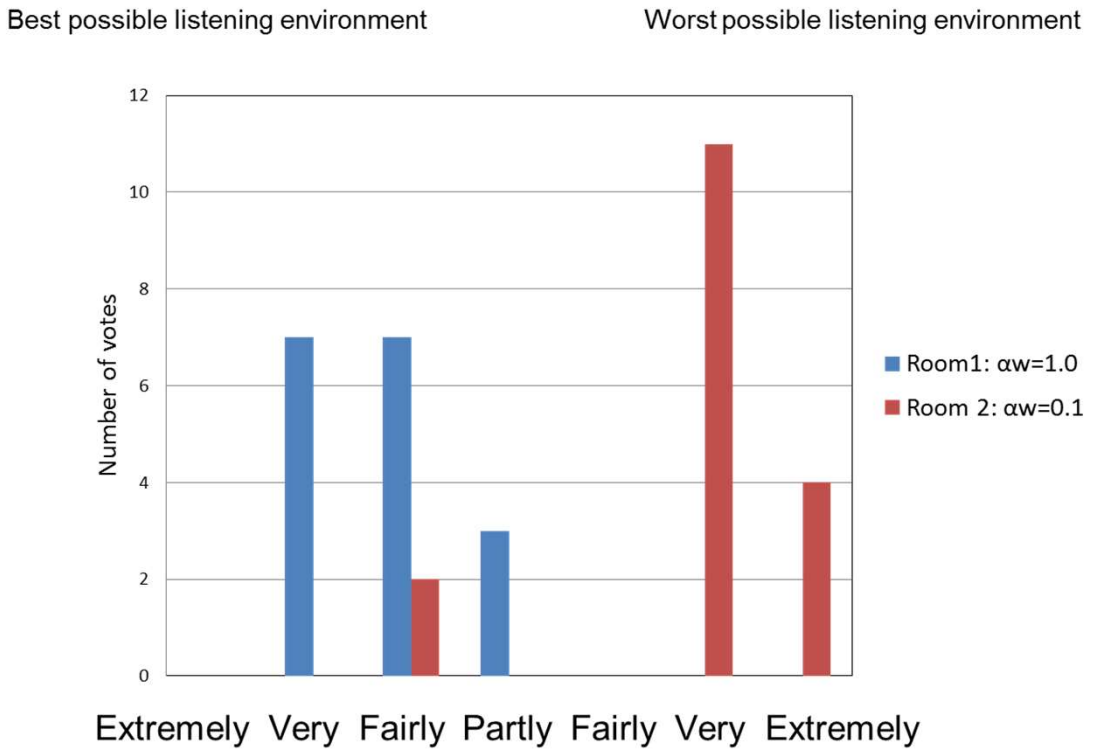
Listening test



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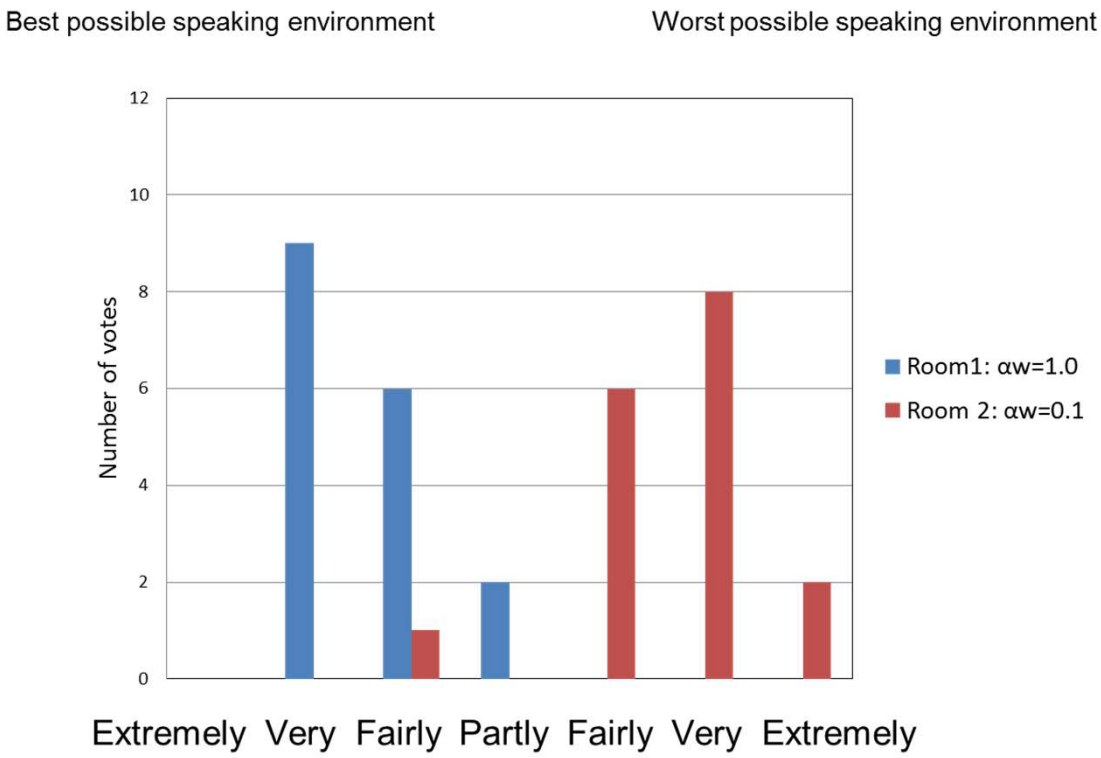
Listening test



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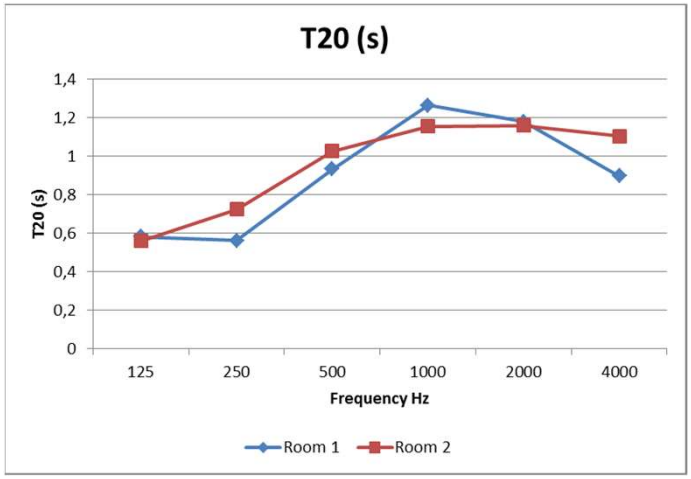
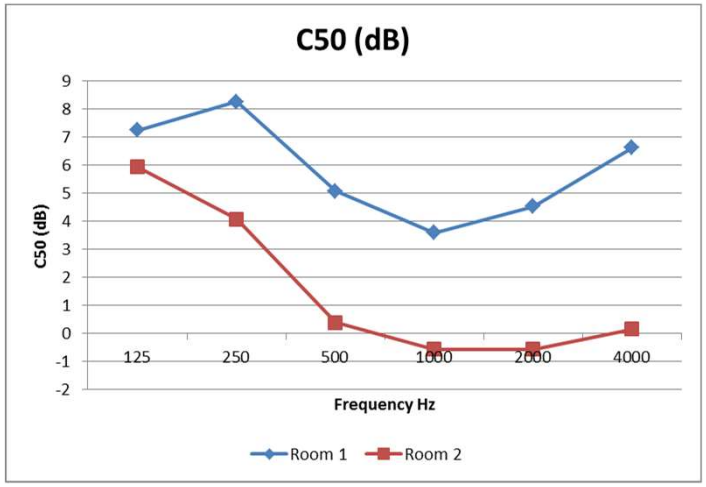
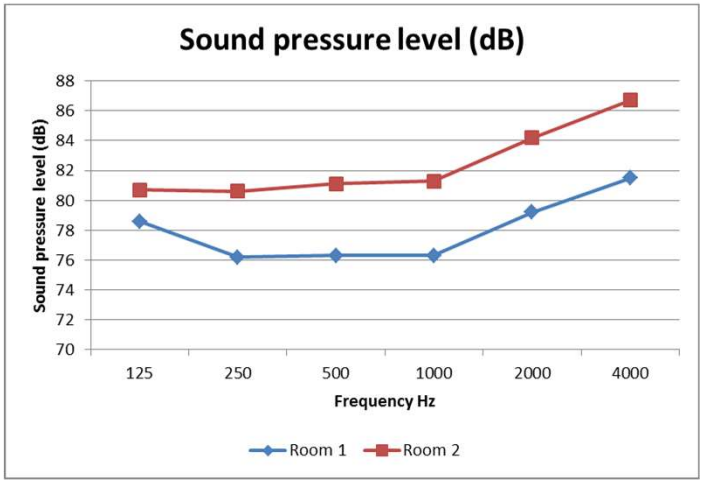
Measurement results







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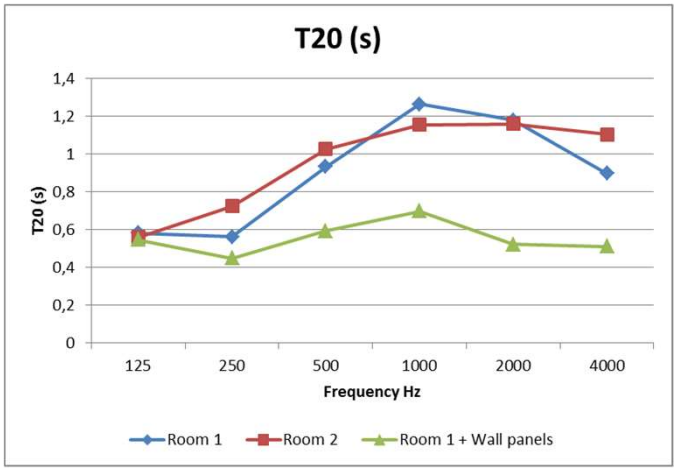
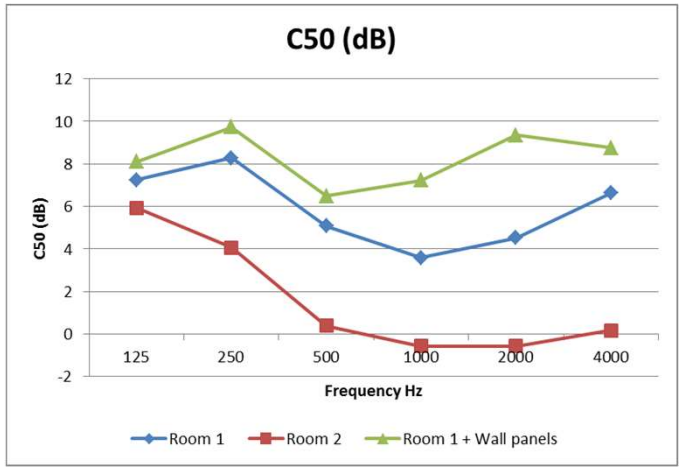
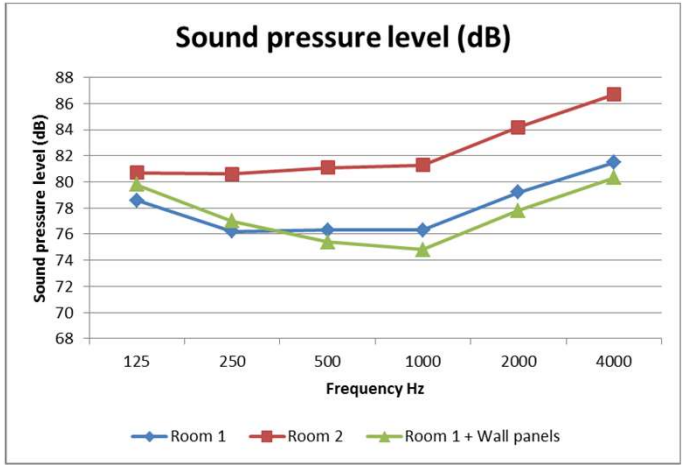
Measurement results, with wall panels







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Ecophon recommendation: Schools

Criteria	Parameter*	Target values
Speech clarity	C_{50} (dB)	6 – 8 dB
Sound strength	G (dB)	15 – 17 dB
Reverberation	T_{20} (s)	0,40 – 0,50 s

** Average 125 to 4000 Hz*

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The effect of different acoustical treatment

Volume= 150 m3, Floor area=55 m2, ceiling height=2,70 m

- No ceiling treatment, no furniture
- Ceiling treatment, no furniture
- Ceiling treatment, furniture
- Wall panels
- Extra low frequency absorption

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Classroom in different configurations

Without furniture and ceiling

Without furniture, with ceiling

With furniture and ceiling

With furniture, ceiling and wall panels

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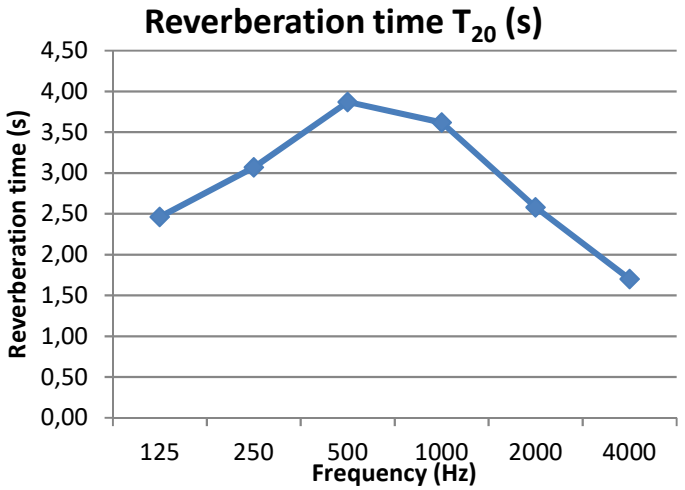
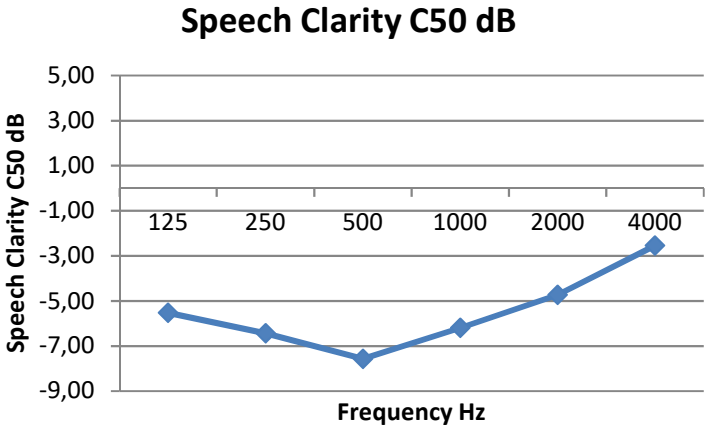
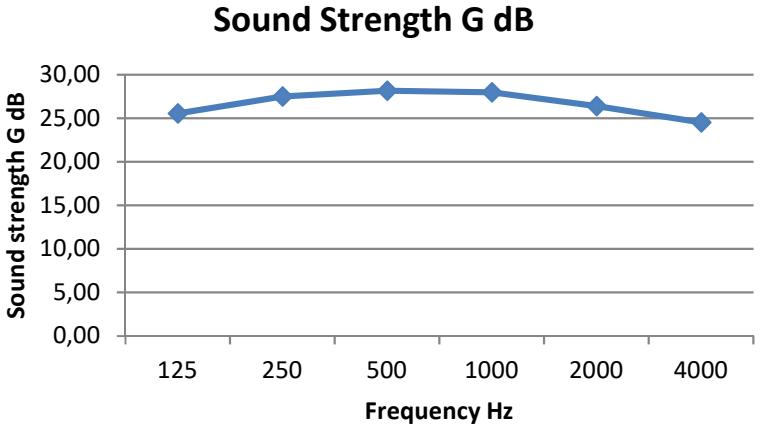
Without furniture and ceiling

Average absorption coefficient of the room surfaces is 0,05







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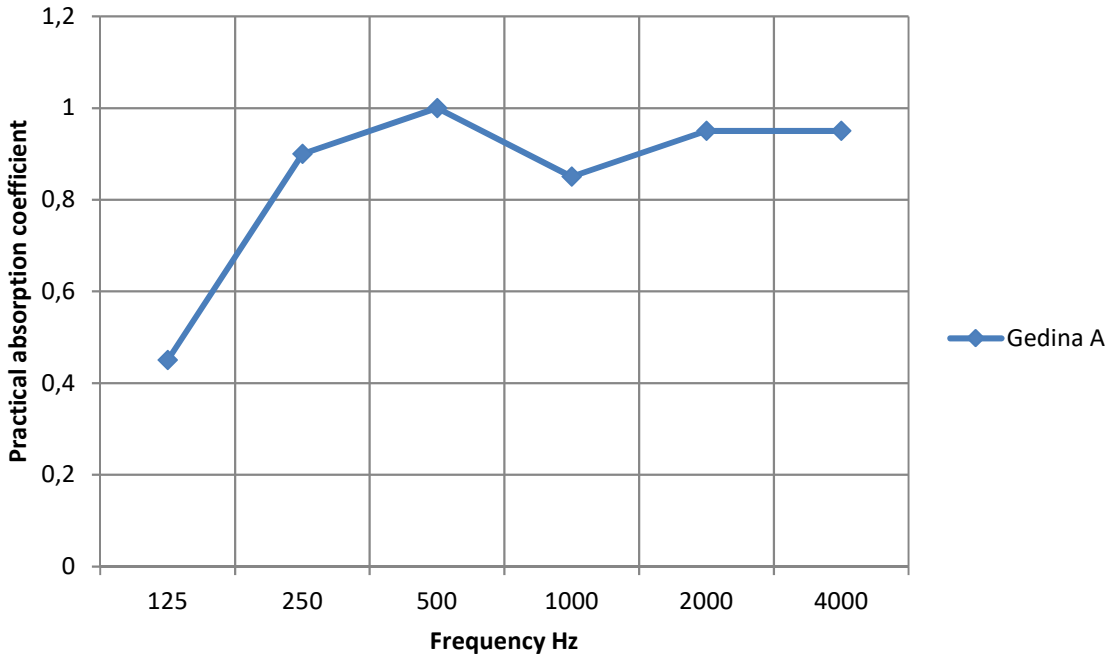
Practical absorption coefficient of Gedina A



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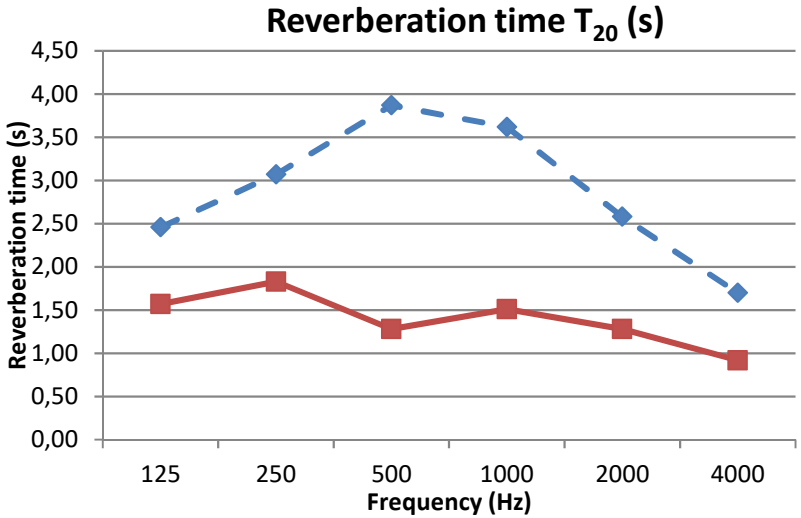
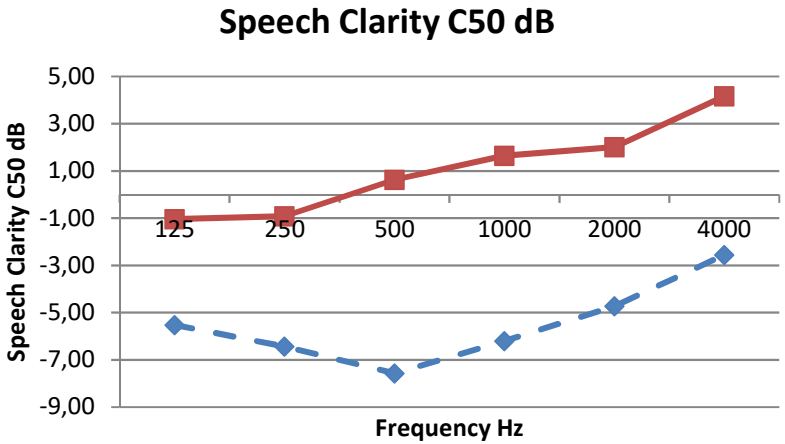
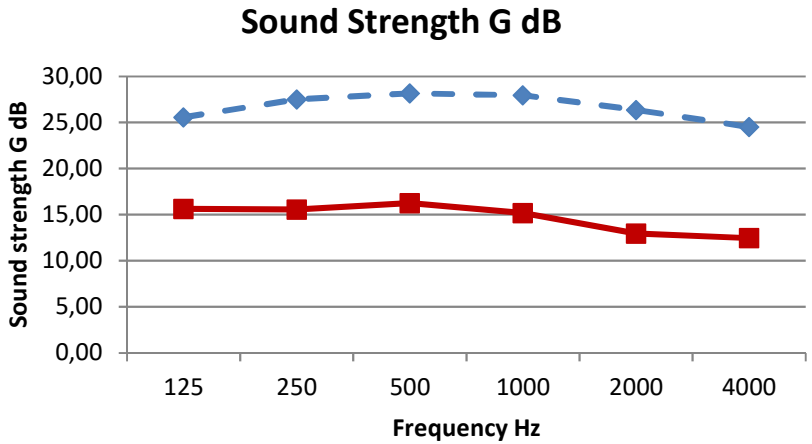
A SOUND EFFECT ON PEOPLE

Without furniture with ceiling







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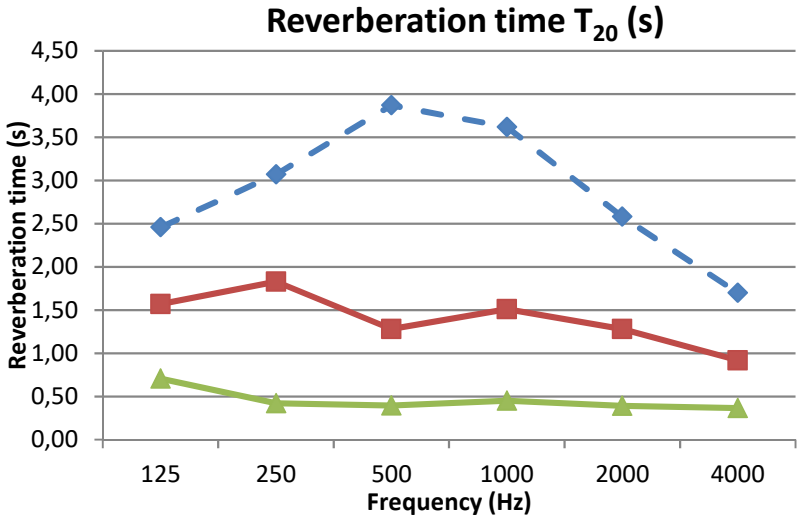
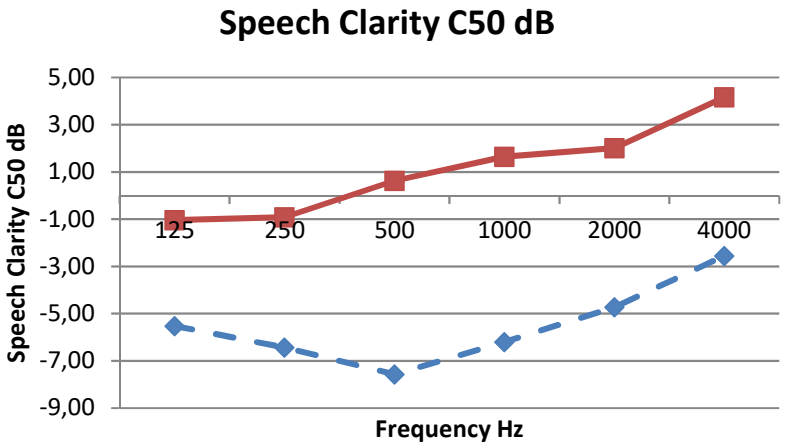
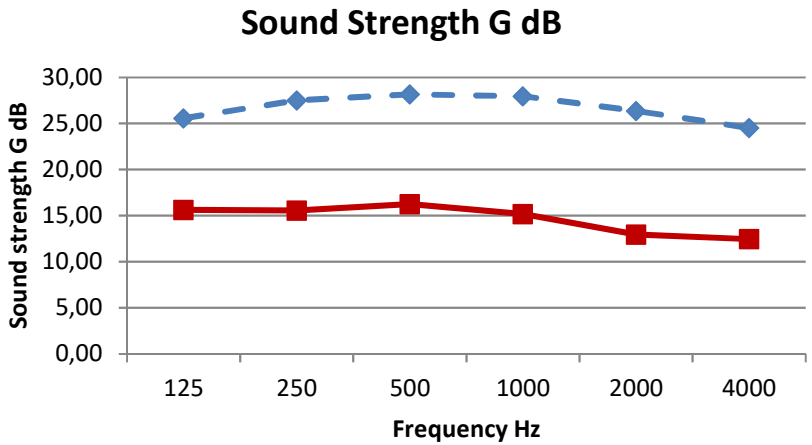
Without furniture with ceiling



Calculation according Sabine formula





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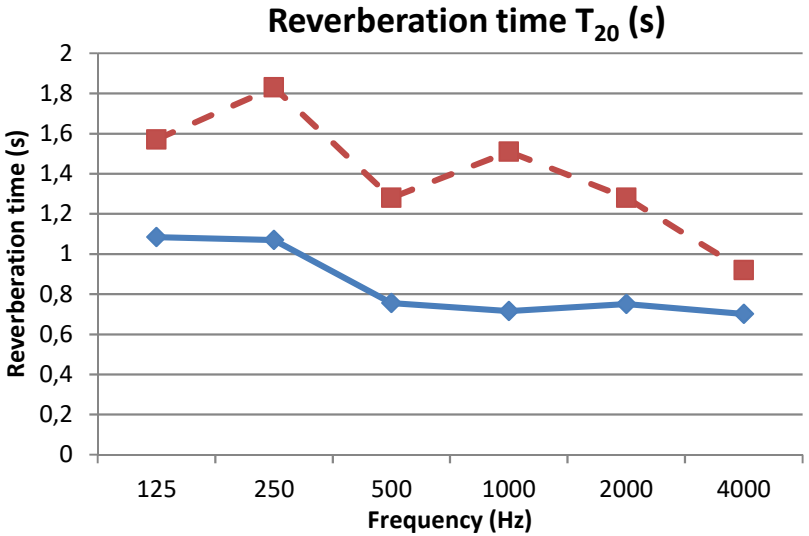
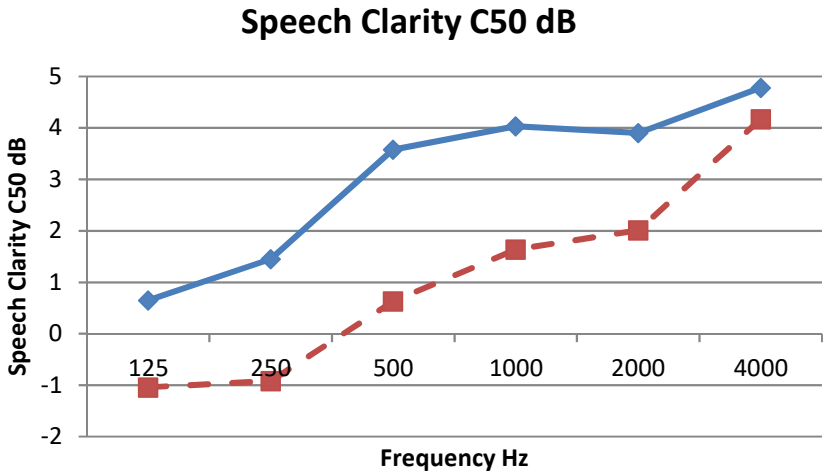
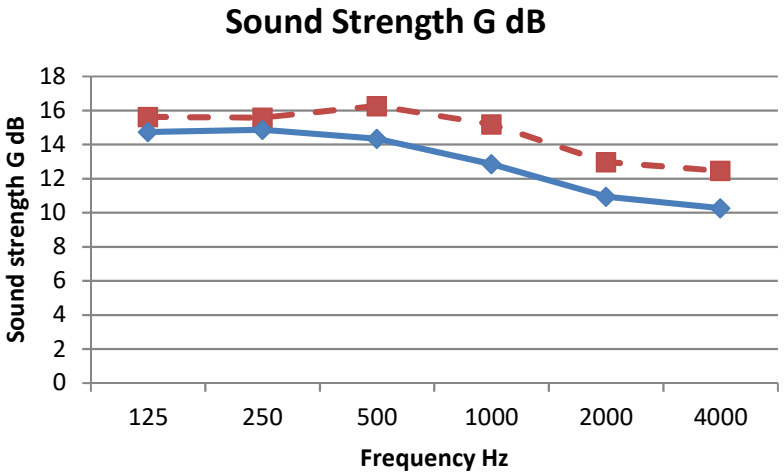
With furniture and ceiling







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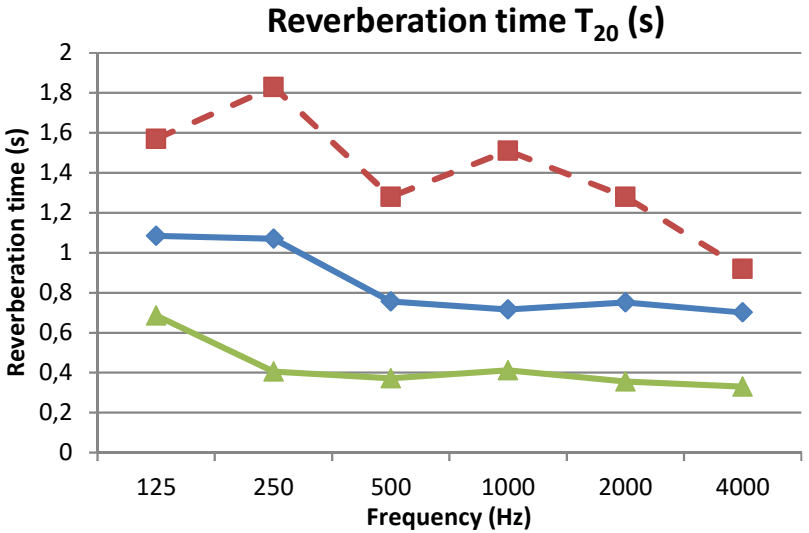
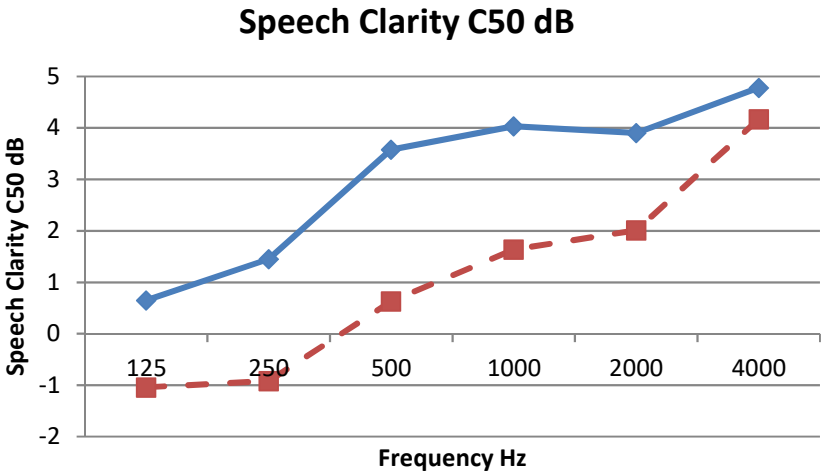
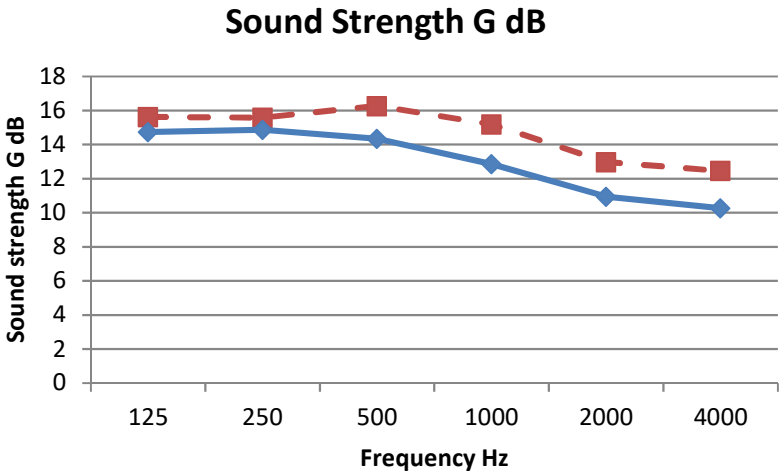
With furniture and ceiling







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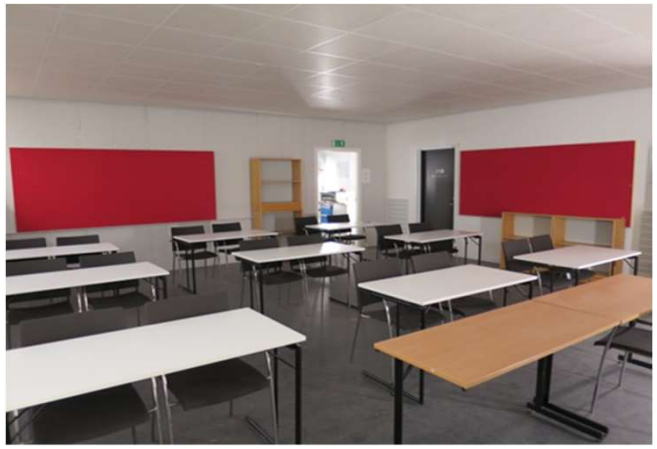
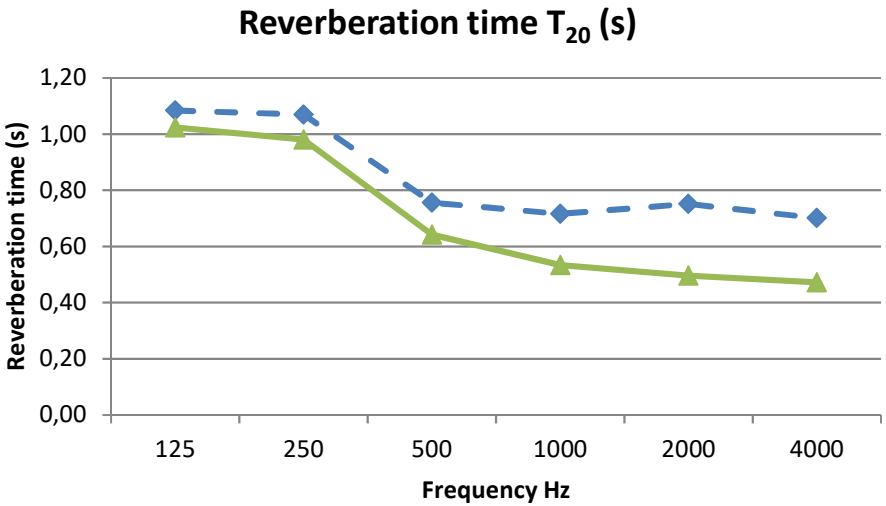
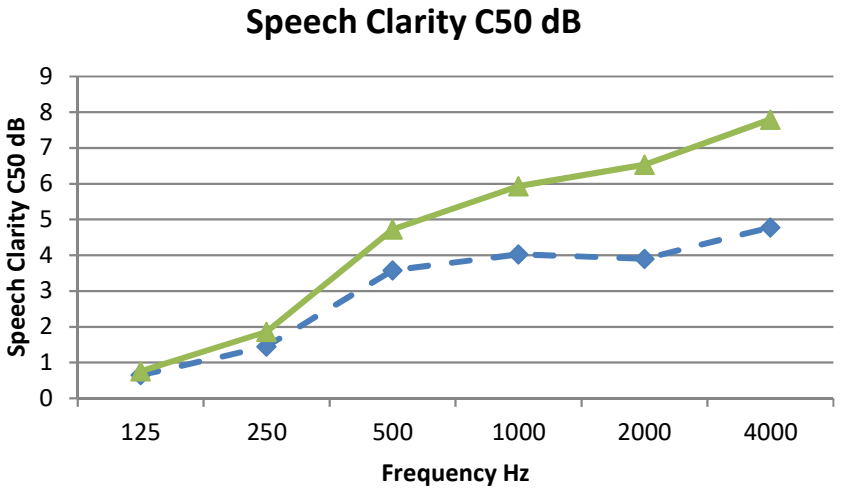
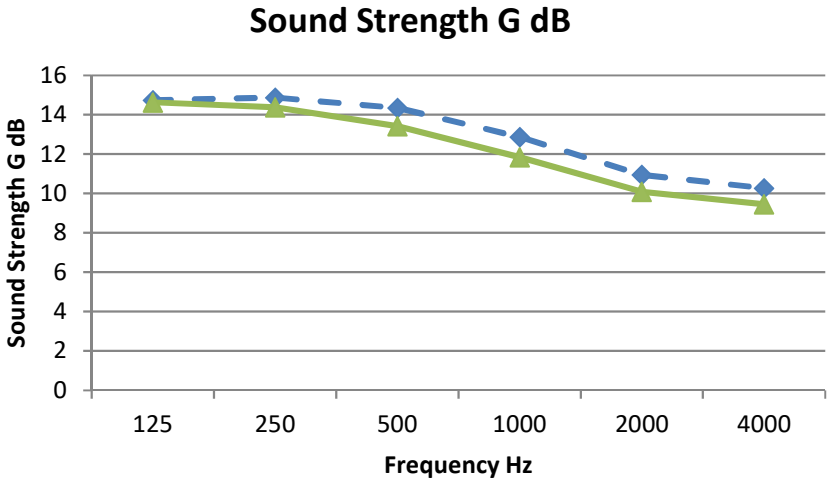
The effect of wall panels









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Ecophon Gedina A with Extra Bass

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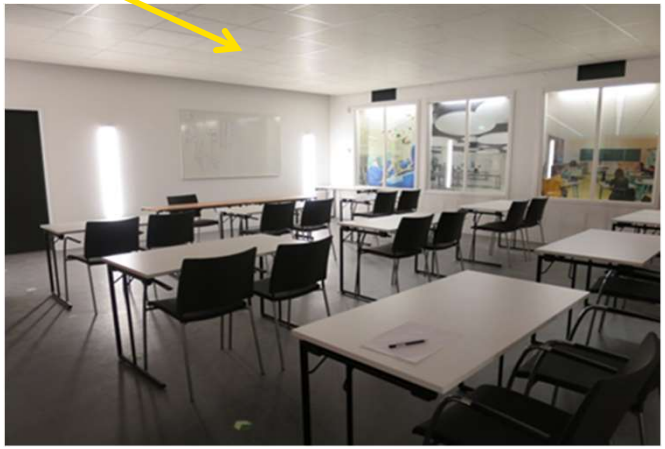
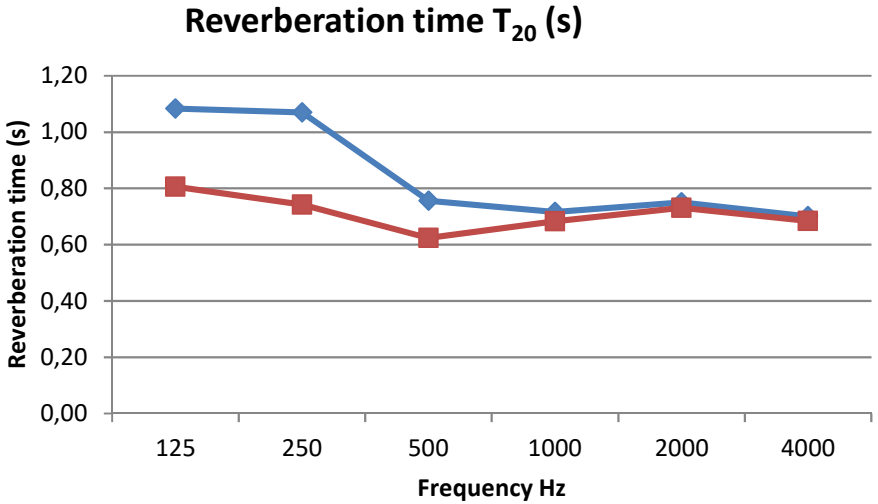
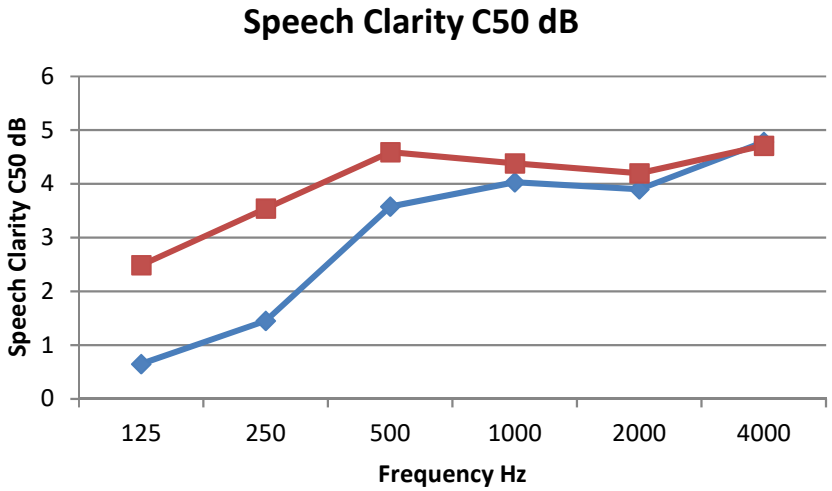
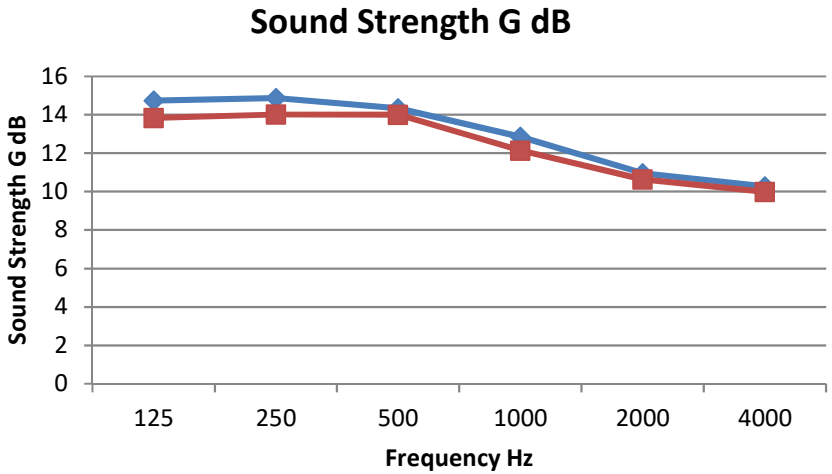
The effect of extra low frequency absorption

With 50% Ecophon Extra Bass









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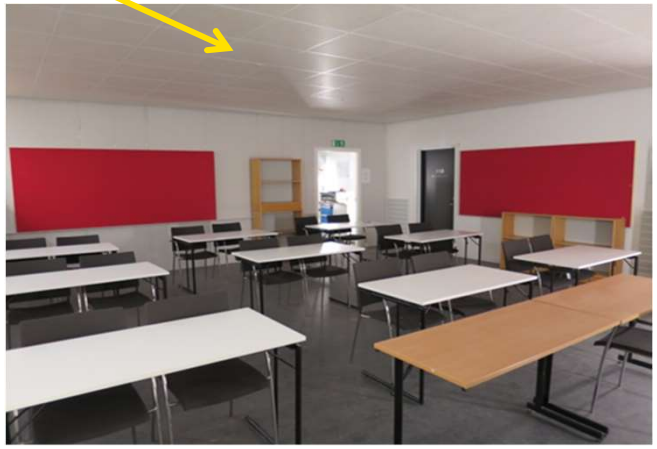
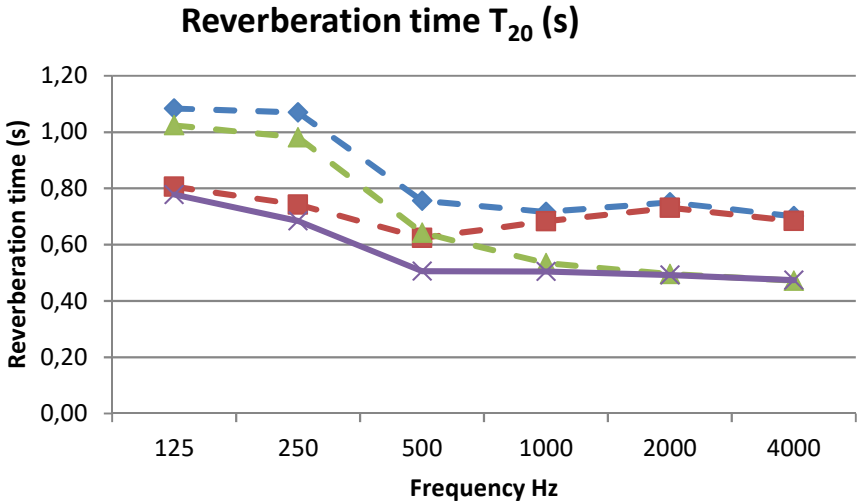
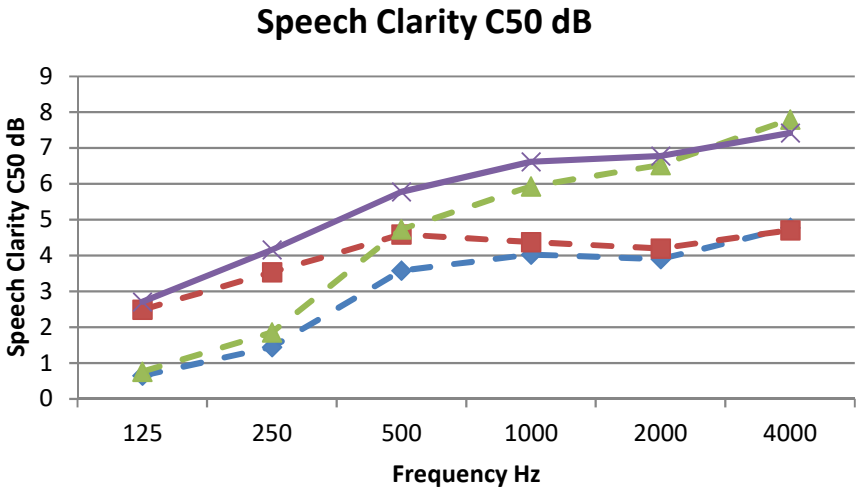
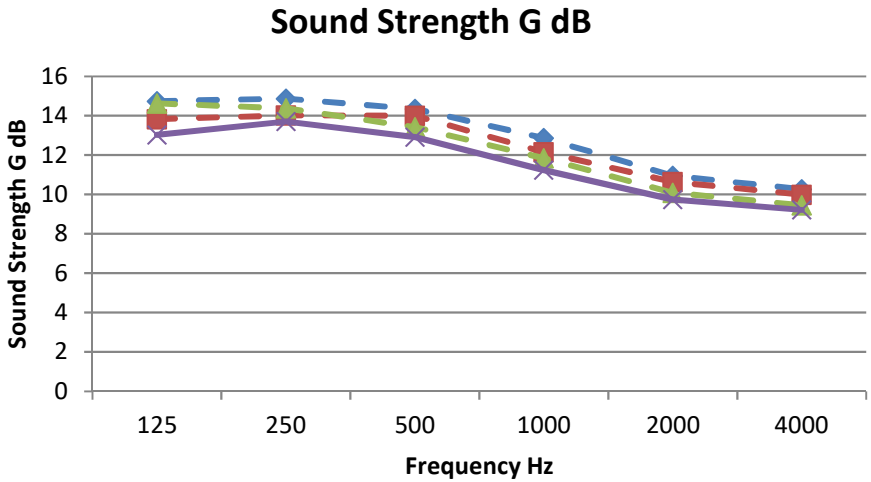
Wall panels and Ecophon Extra Bass

With 50% Ecophon Extra Bass









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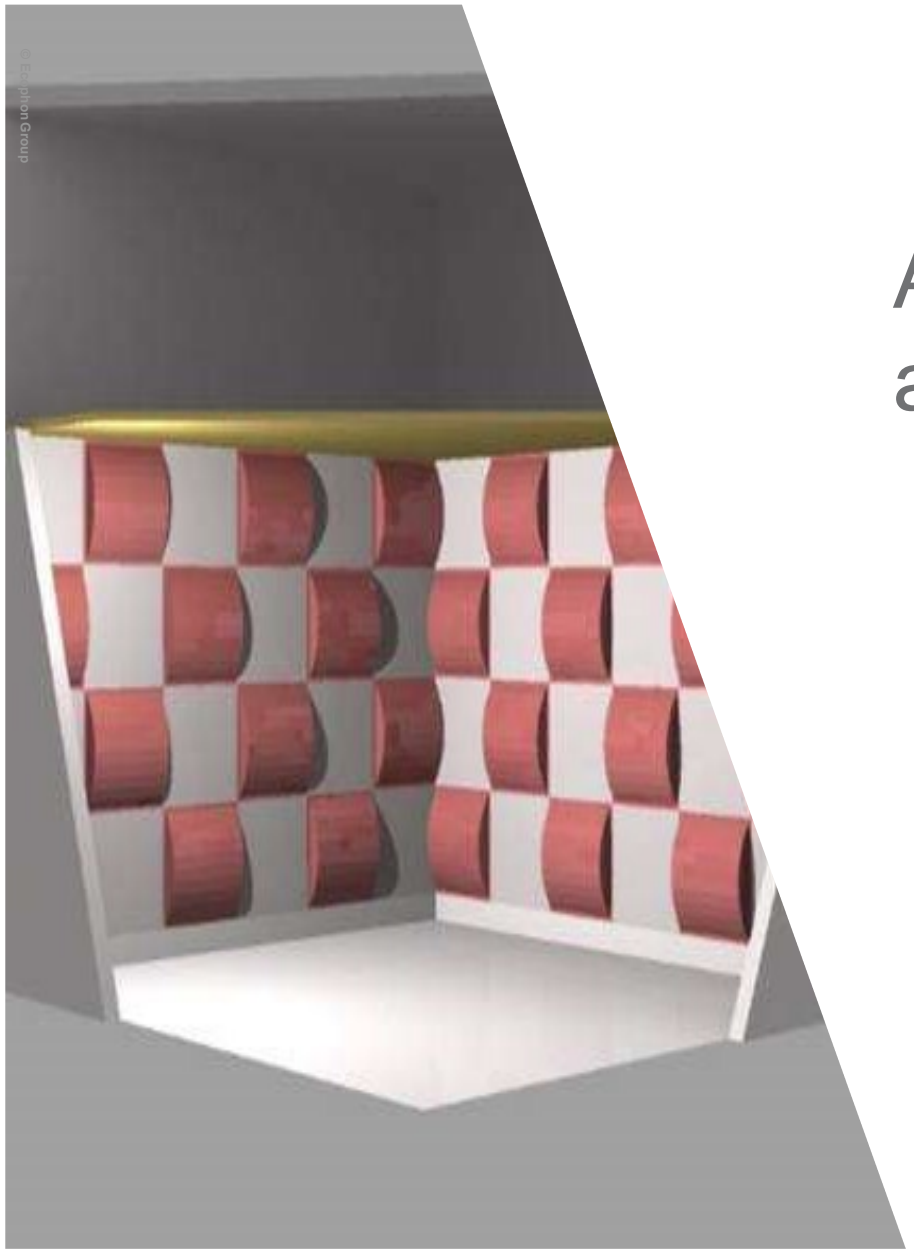

Acoustic design and architecture

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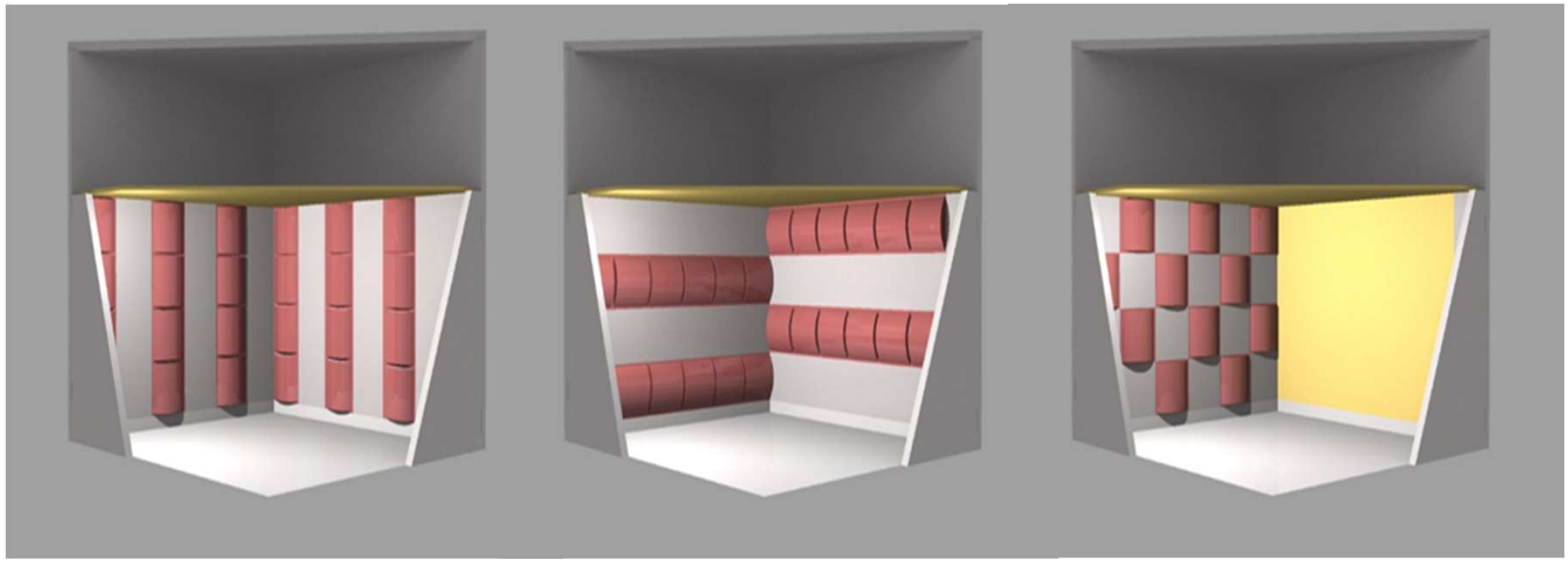
Effects of directional diffusion in a room with absorbing ceiling

Internship: Tim Näsling 2017



40 different configurations

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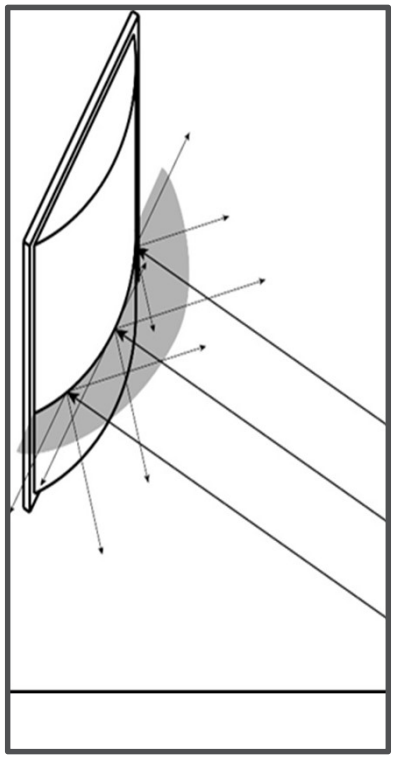

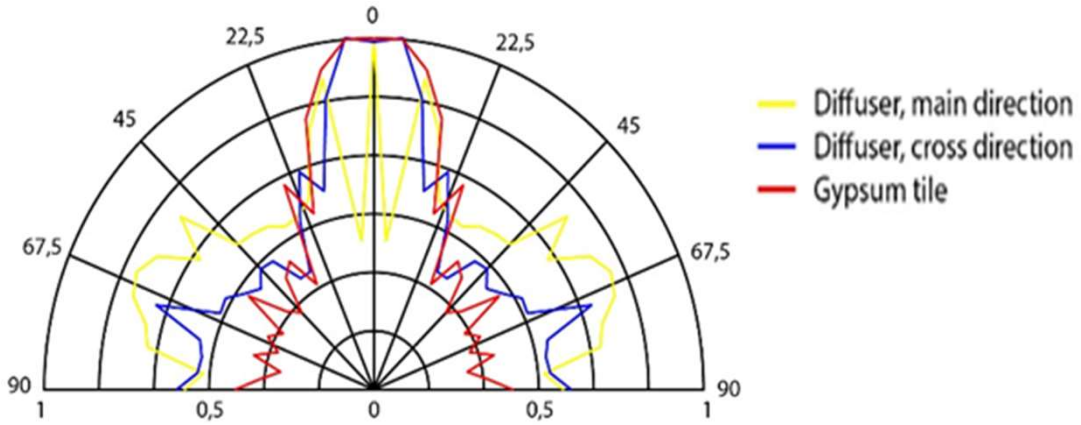

Diffusion at 4000 Hz

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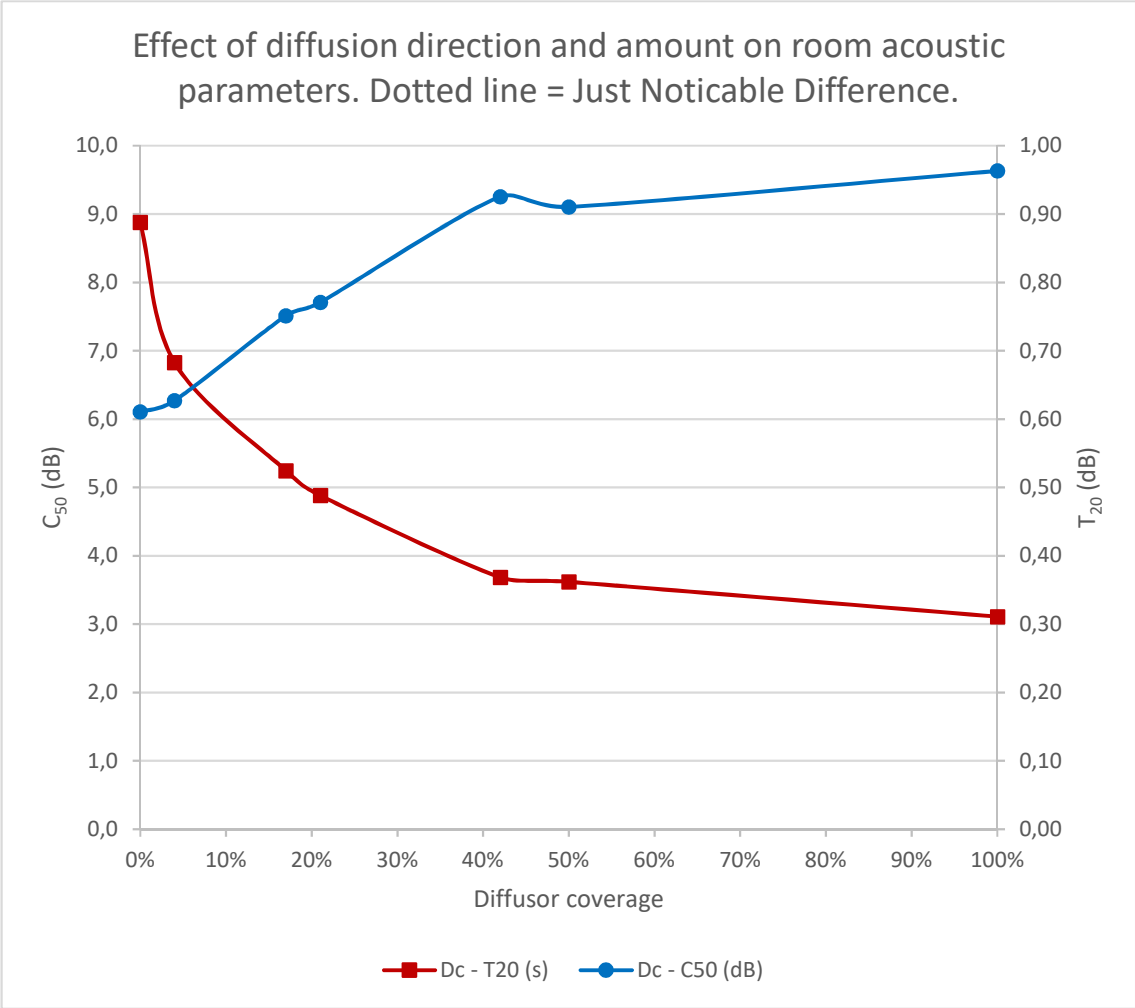

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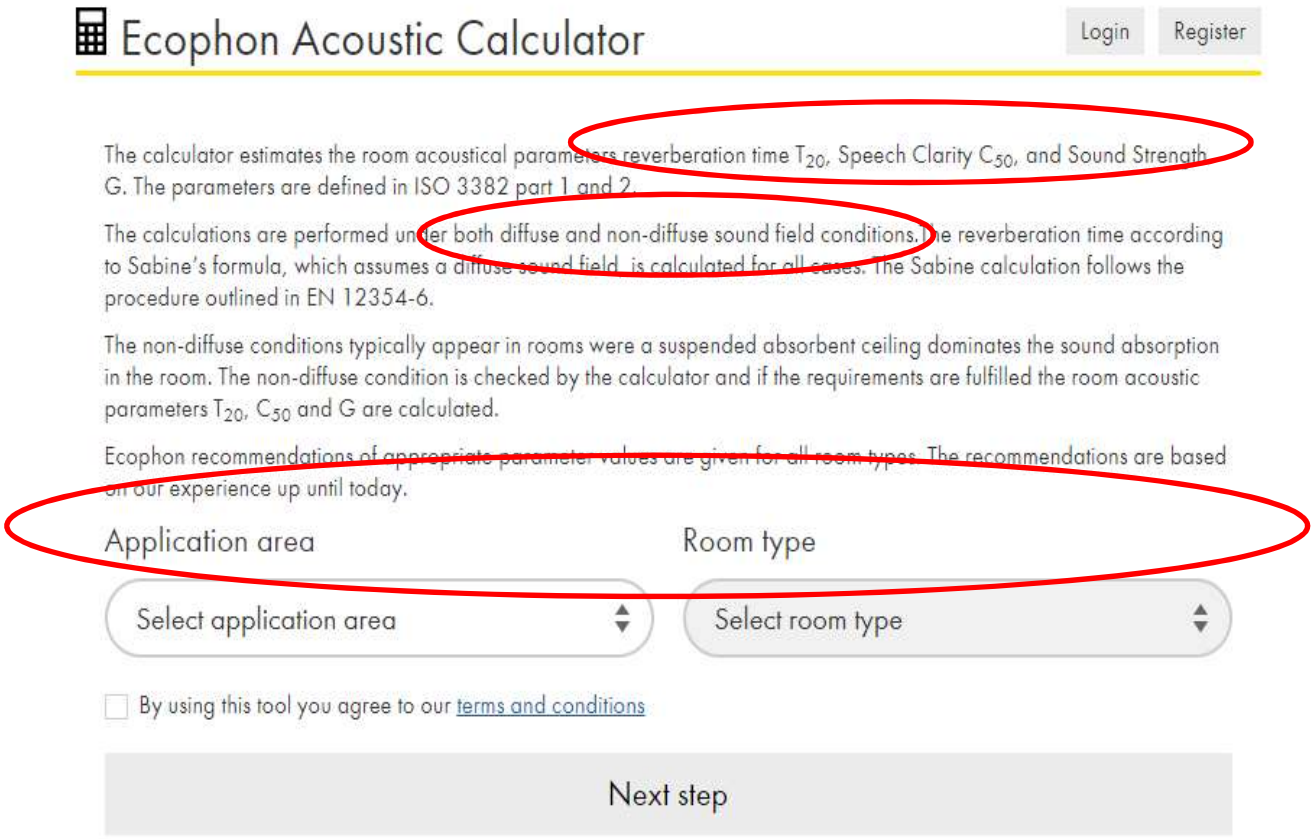

http://www.ecophon.com/en/about-ecophon/e-tools/ecophon-acoustic-calculator/

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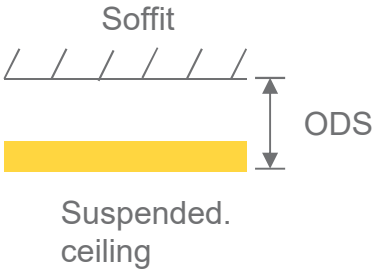
EAC example: Classroom with normal furnishing

Dimension: Height x Length x Width = 3,5 x 8 x 7 meter

Component	Input data	Ods (mm)	Area (m^2)	Amount
Suspended ceiling	Master Rigid + Extra Bass	800	-	
Walls	Gypsum with min-wool (2 layers)	-	-	
Doors (1.9 m2) on wall 3	Door, wood		3.8	2
Windows (1.5 m) on wall 1	Window glass		3.0	2
Soffit	Concrete	-	-	
Floor	Linoleum or vinyl on concrete			



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The calculator estimates the room acoustical parameters reverberation time T_{20}, Speech Clarity C_{50}, and Sound Strength G. The parameters are defined in ISO 3382 part 1 and 2.

The calculations are performed under both diffuse and non-diffuse sound field conditions.The reverberation time according to Sabine's formula, which assumes a diffuse sound field, is calculated for all cases. The Sabine calculation follows the procedure outlined in EN 12354-6.

The non-diffuse conditions typically appear in rooms were a suspended absorbent ceiling dominates the sound absorption in the room. The non-diffuse condition is checked by the calculator and if the requirements are fulfilled the room acoustic parameters T_{20}, C_{50} and G are calculated.

Ecophon recommendations of appropriate parameter values are given for all room types. The recommendations are based on our experience up until today.

Application area

Select application area

- Select application area
- Health care premises
- Hotels and restaurants
- Office
- School

Room type

Select room type

xt step

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The calculator estimates the room acoustical parameters reverberation time T_{20}, Speech Clarity C_{50}, and Sound Strength G. The parameters are defined in ISO 3382 part 1 and 2.

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Ecophon recommendations of appropriate parameter values are given for all room types. The recommendations are based on our experience up until today.

Application area

Office

Room type

Select room type

- Select room type
- Canteen
- Cellular office
- Conference room
- Corridor
- Entrance
- Open plan office
- Reception

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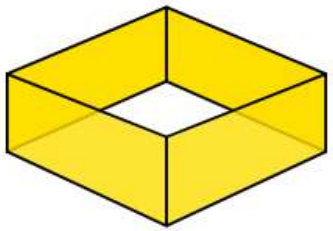
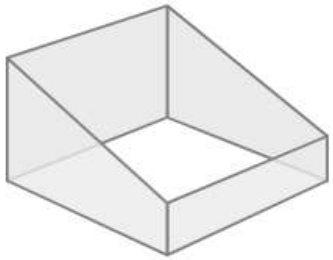
Room dimensions

Select room geometry



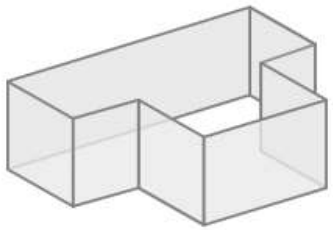
Rectangular

Rectangular room with horizontal soffit



Sloped

Rectangular room with a sloped soffit



Irregular

Rooms with more than four walls

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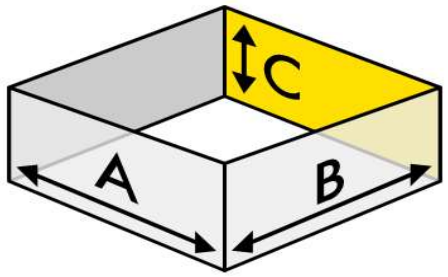

Room dimensions (in meters)

A: Wall length (meters)	B: Wall width (meters)	C: Wall height (meters)
7	5	3

Dimensions

Volume	105.00 m³
Wall area	72.00 m²
Soffit area	35.00 m²
Floor area	35.00 m²

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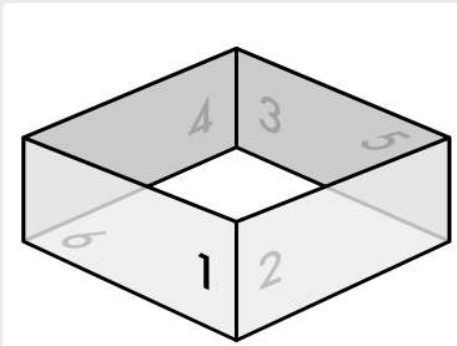

Room surfaces

Wall 1	Edit
Wall 2	Edit
Wall 3	Edit
Wall 4	Edit
Soffit	Edit
Floor	Edit

Wall 1 21.00 m²

Wall surface

Select wall surface

- Select wall surface
- Brick, plain painted
- Brick, unglazed
- Concrete
- Gypsum (1 layer) with min-wool
- Gypsum (2 layers) with min-wool
- Gypsum (2 layers) without min-wool
- Wood, 25 mm with airspace

Number of doors on wall

0

t wall

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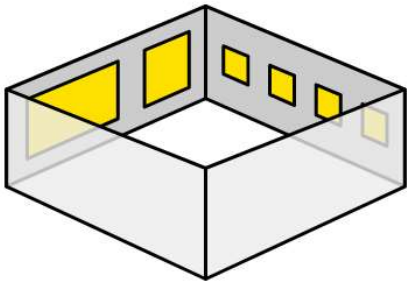

Adding absorption

2. Wall panels

Wall 1	21.00 m²
Panel	
Ecophon Akusto™ Wall C	
Akusto Wall C Akutex FT 40 mm, 5C	
Area (m²)	
3	

Wall 2	15.00 m²
Panel	
No wall panel	
Select product	

Wall 3	21.00 m²

Wall 4	15.00 m²

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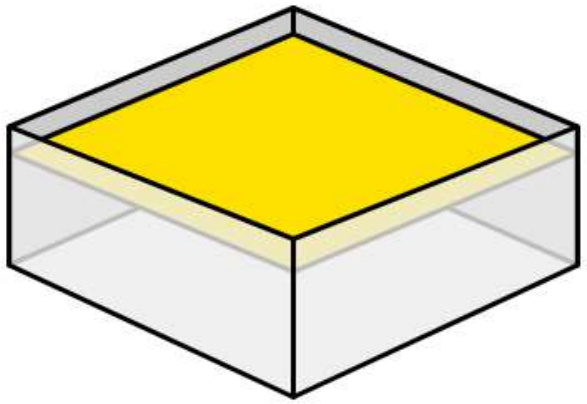

Adding absorption

1. Suspended ceiling

1: Family

Select family

2: Product

Select product

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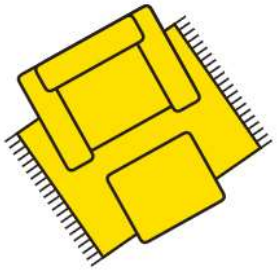
Furnishing

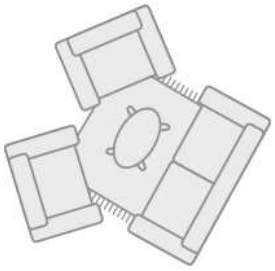
Sparse

A sparse room is characterized by a small amount of furniture or equipment and bare walls which are sound reflecting. A classroom, conference room or office mainly furnished with tables and non-upholstered chairs over the floor area and very few cupboards or shelfs along the walls may be an example.



Normal

A normal furnished room means a room with furniture over the floor area and along the walls. A classroom, office or conference room with tables and chairs over the floor area and shelfs and cupboards along the walls may be an example.



Dense

A dense furnished room is a room with a large amount of furniture and equipment and where some of the furniture's are upholstered like office chairs and sofas. A care room with beds in a hospital can be considered as a densely furnished room.

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Results and Ecophon recommendation

Reverberation time T_{20} (s)	Speech clarity C_{50} (dB)	Strength G (dB)
Sabine calculation 0.36	Sabine calculation 7.91	Sabine calculation 20.70
RAC calculation 0.50	RAC calculation 6.13	RAC calculation 19.42
Ecophon recommendation ≤ 0.6	Ecophon recommendation ≥ 6	Ecophon recommendation ≤ 17

Note: Average bonds over octave bands 125 to 4000Hz.

Ecophon recommendations are based on our experience up until today and might be subject to change in the future.

Room Acoustic Comfort (RAC) calculations for rooms with absorbing ceilings. This calculation will give a better correspondence to measurements than Sabine formula.

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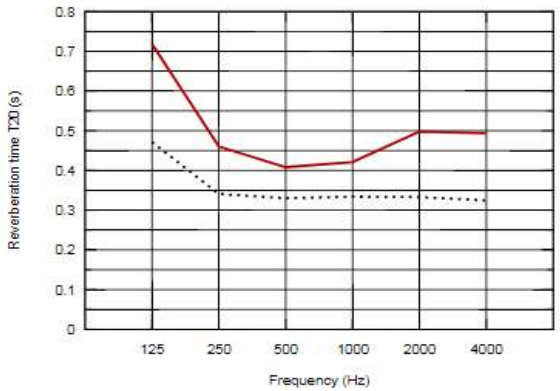
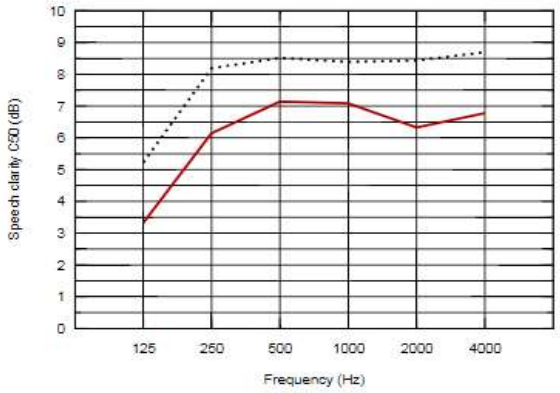
Reverberation time T_{20} (s)



··· Sabine calculation
— RAC calculation

125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
0.47	0.34	0.33	0.33	0.33	0.32
0.72	0.46	0.41	0.42	0.50	0.49

Speech clarity C_{50} (dB)



··· Sabine calculation
— RAC calculation

125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
5.22	8.19	8.51	8.39	8.43	8.70
3.32	6.15	7.14	7.08	6.33	6.78

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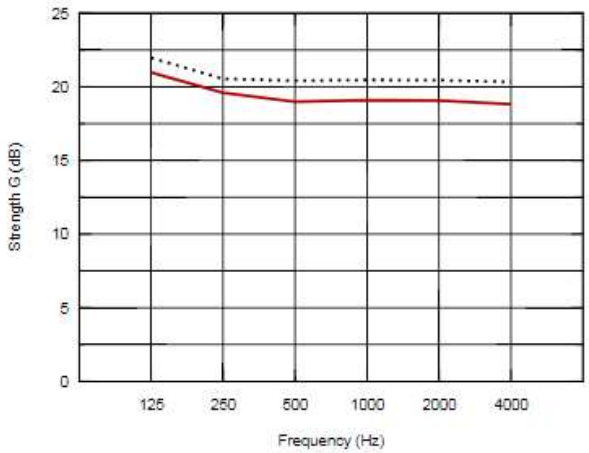
Strength G (dB)



··· Sabine calculation
— RAC calculation

125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
21.96	20.55	20.41	20.46	20.45	20.34
20.98	19.59	18.99	19.09	19.06	18.83

Back

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Save calculation

New calculation

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Purpose of RAC calculator

- Calculation of “true” T_{20}, C_{50} and G in rooms with ceiling treatment (non-diffuse conditions)
- Calculation of T_{20} with Sabine formula and C_{50} and G for diffuse sound field conditions.
- Guidance towards good solutions for sparsely furnished rooms.
- Promote the use of C_{50} and G

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Acoustic measurements in open-plan offices

ISO 3382-3

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Content

- ISO 3382-3
- Sound propagation in open-plan offices
- Room acoustic parameters for open-plan offices
- Radius of comfort
- The effect of ceilings, screens and wall panels in open-plan offices
- Conclusions

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Acoustic measurements in open-plan offices ISO 3382-3

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Open-plan Offices

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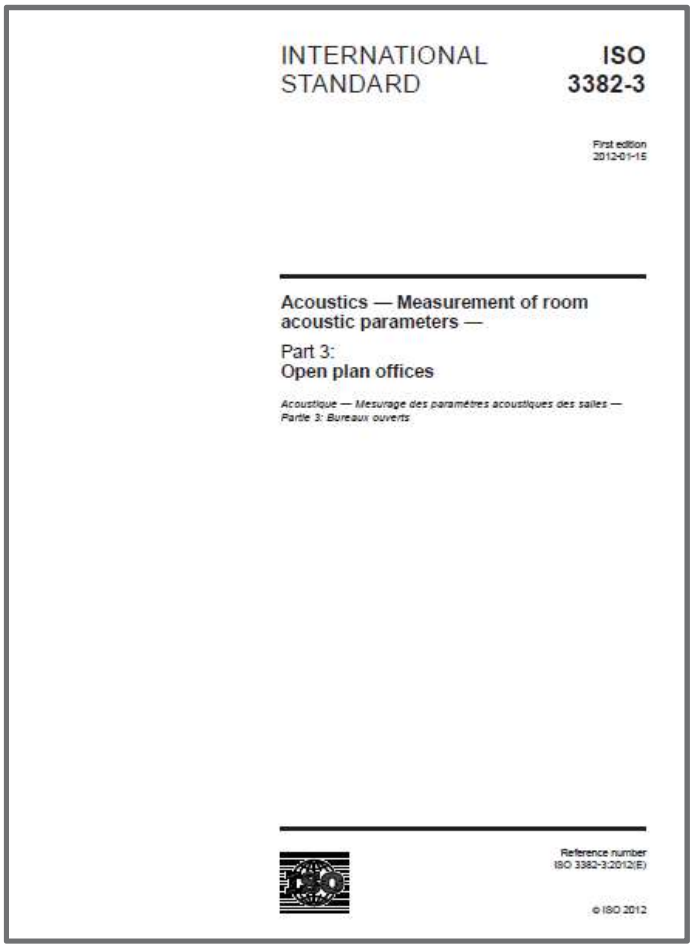

INTERNATIONAL STANDARD **ISO 3382-3**

First edition
2012-01-15

Acoustics — Measurement of room acoustic parameters —

Part 3:
Open plan offices

Acoustique — Mesurage des paramètres acoustiques des salles —
Partie 3: Bureaux ouverts

Reference number
ISO 3382-3:2012(E)

ISO 3382-3
Acoustics measurements in open-plan offices.

ISO 3382-1: Performance spaces

ISO 3382-2: Reverberation time in ordinary room

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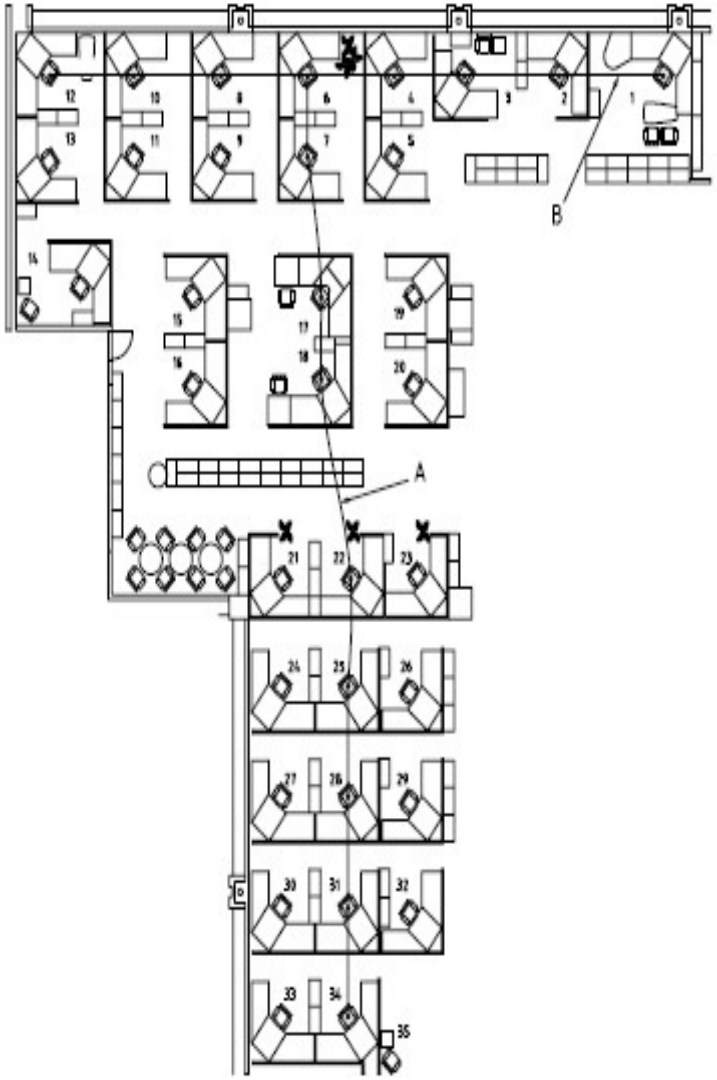

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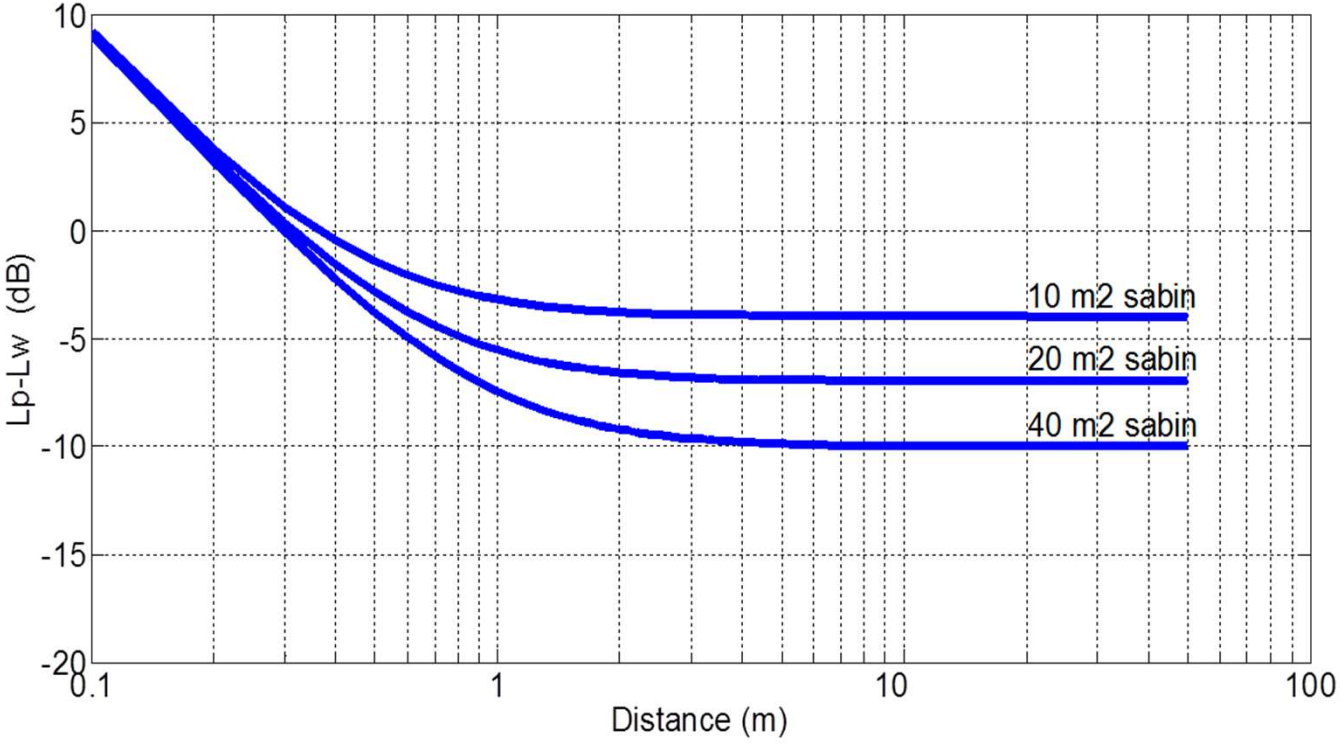
Sound propagation in reverberant rooms

$$L_p = L_W + 10 \cdot \log\left(\frac{1}{4\pi r^2} + \frac{4}{A_{eq}}\right)$$



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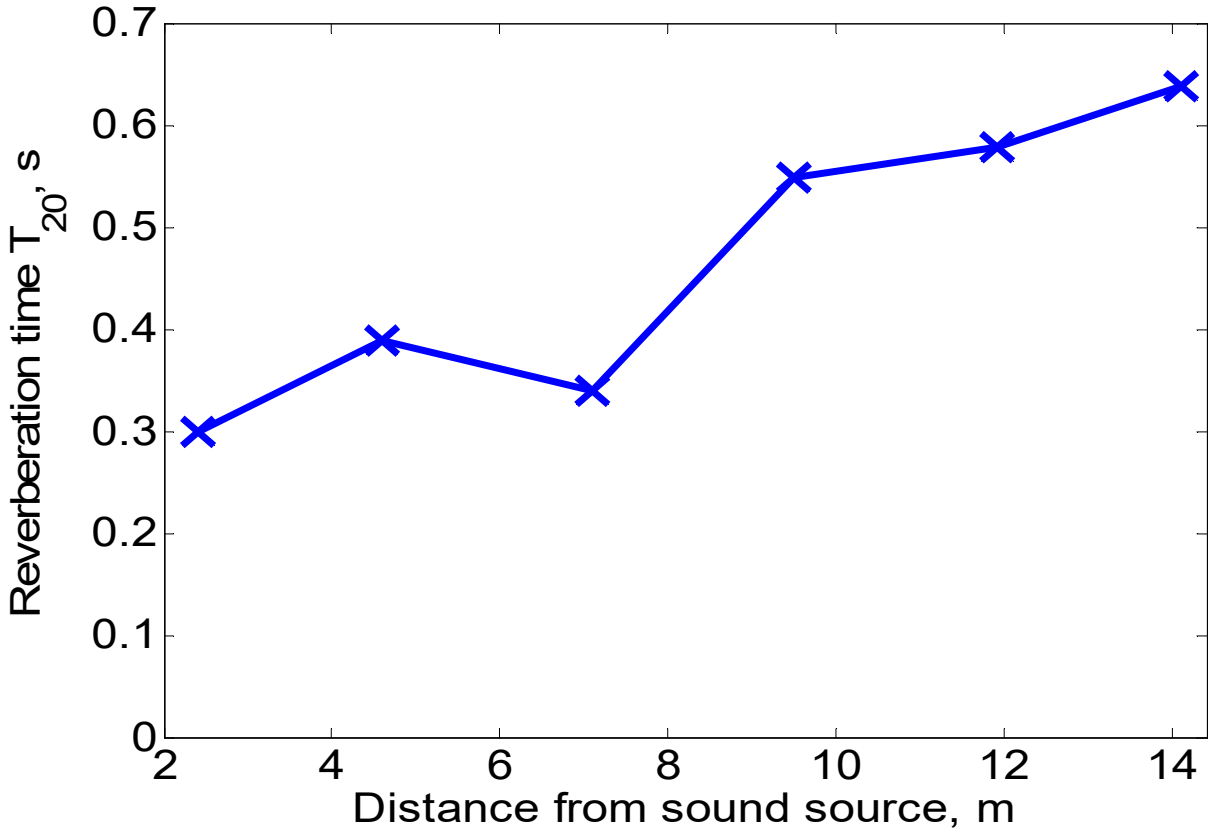
Reverberation time vs. distance



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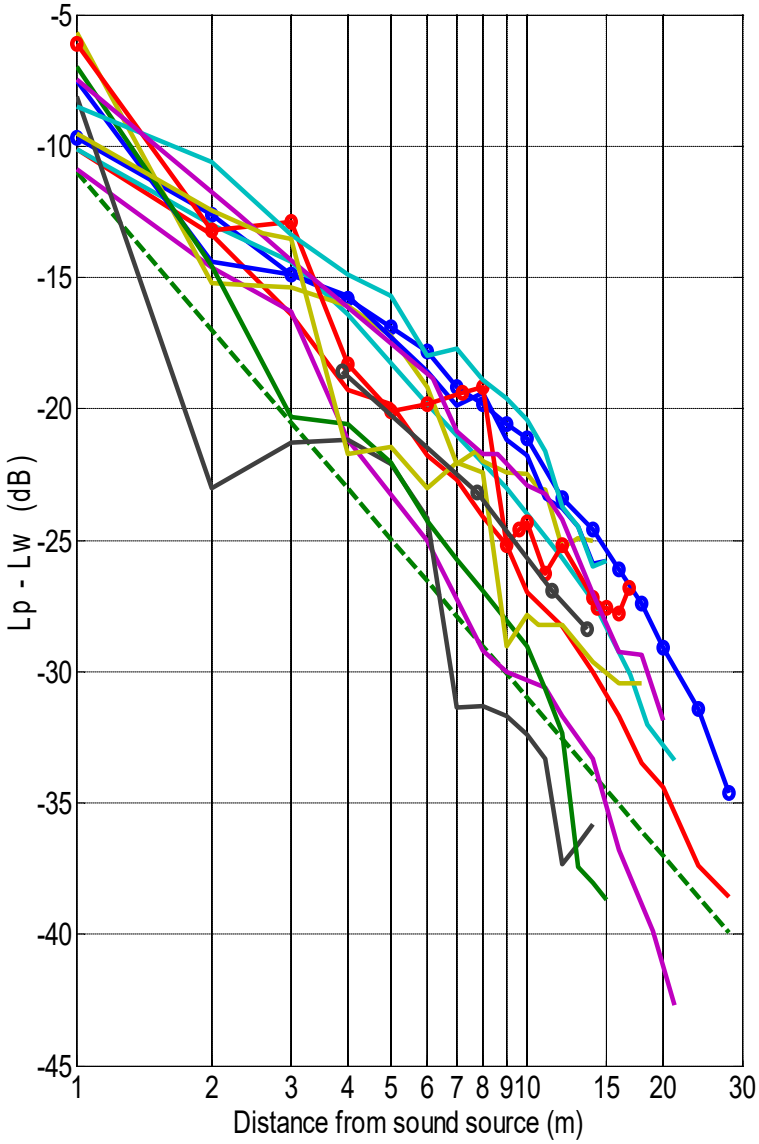

Sound propagation in open plan offices

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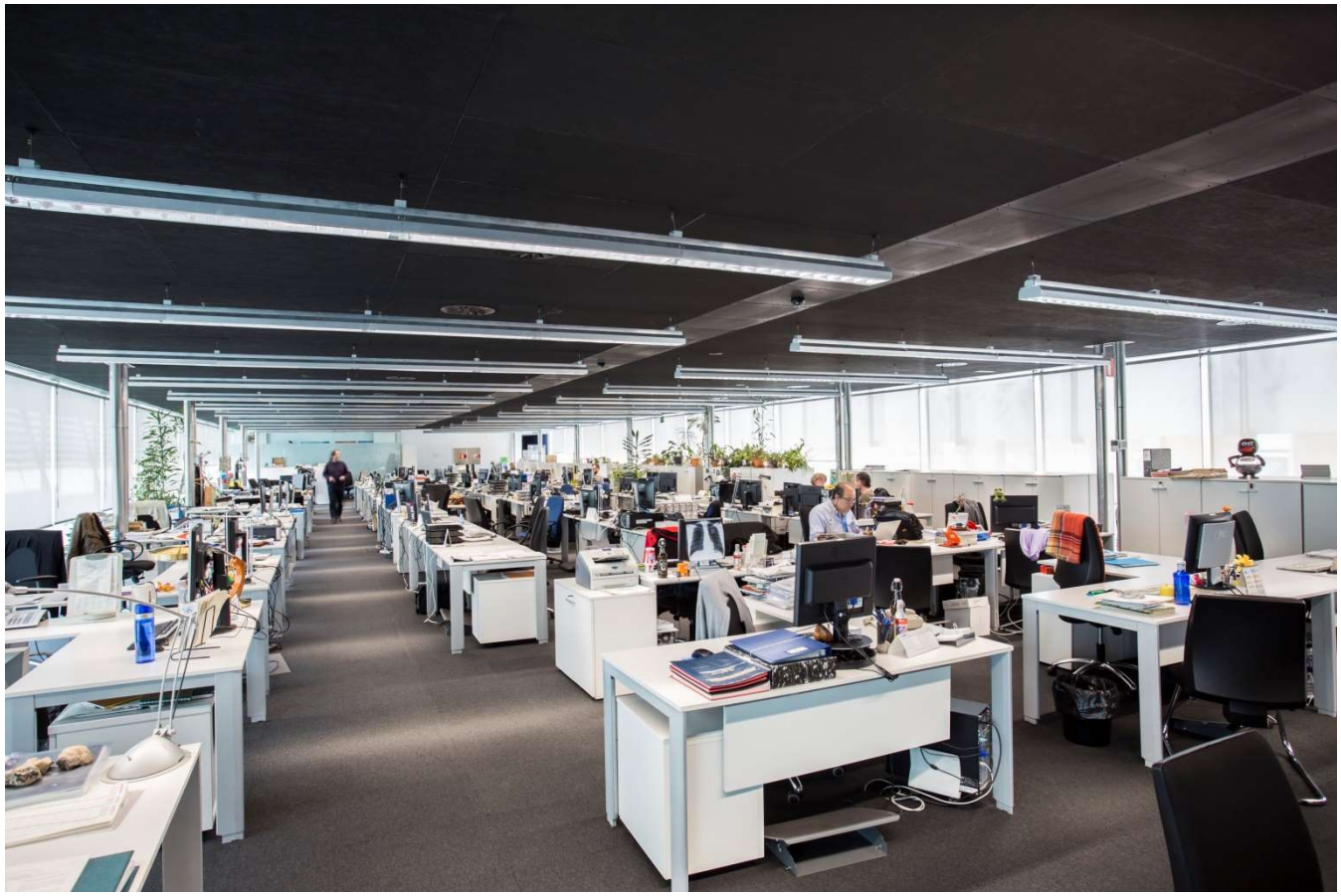
Sound propagation in an open plan office



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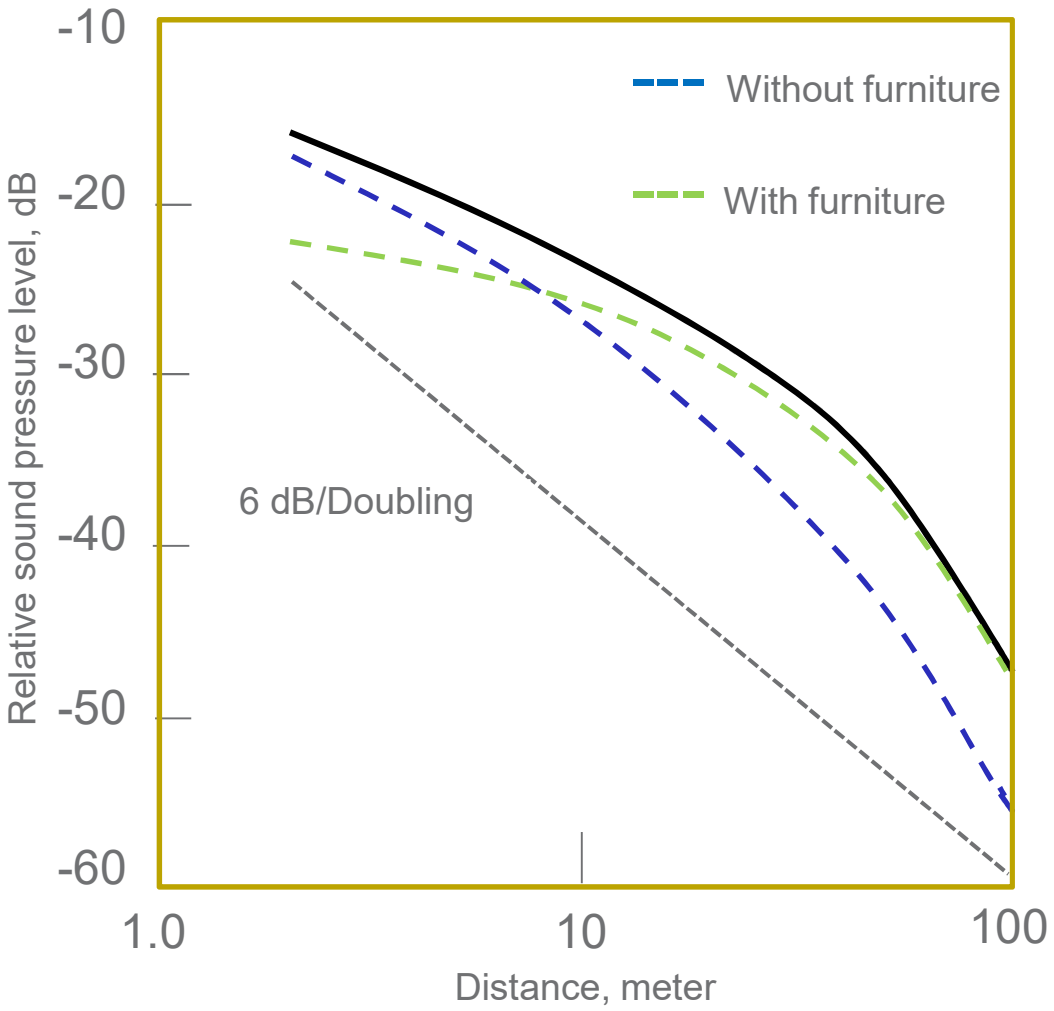
Sound propagation in open plan spaces



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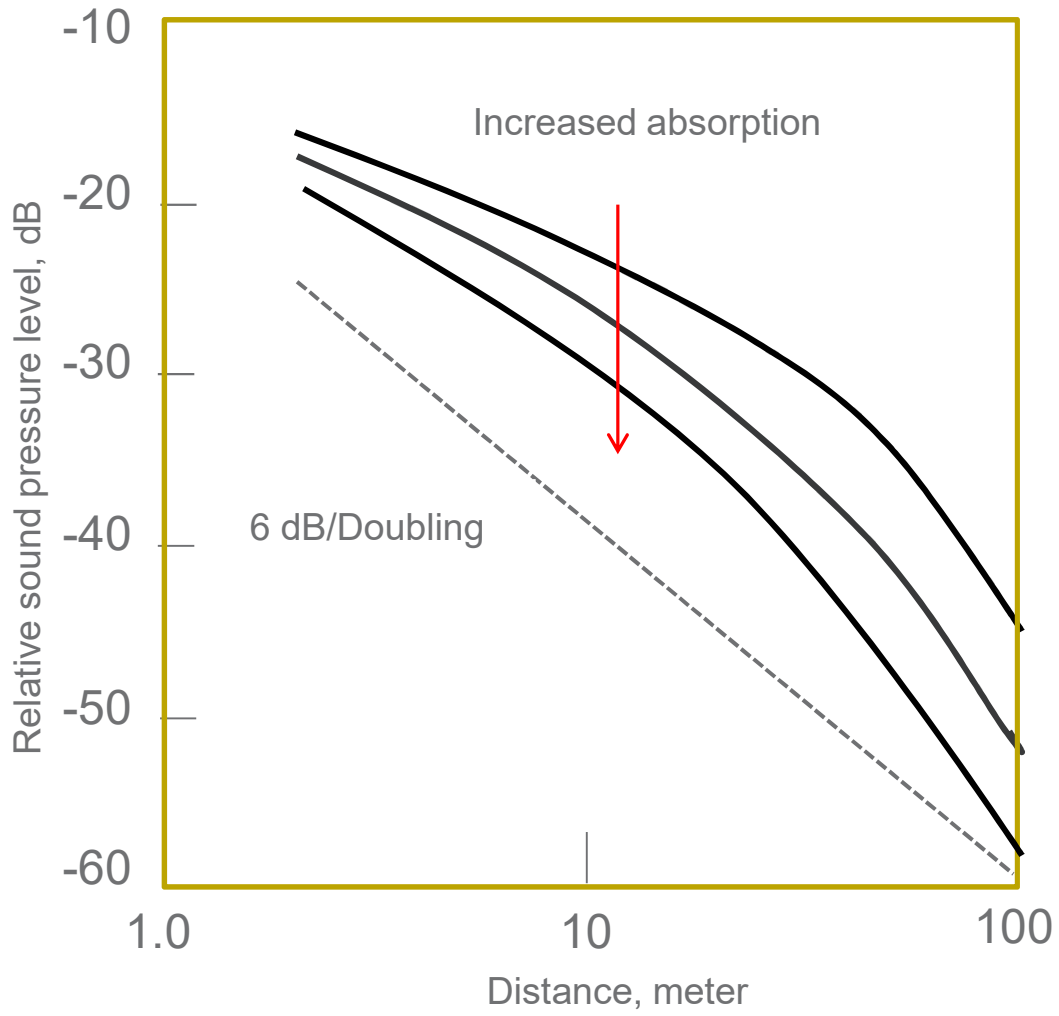
Sound propagation in open plan spaces



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Room acoustic parameters for open-plan offices

- Spatial decay rate of A-weighted SPL of speech $D_{2,S}$
- A-weighted SPL of speech at 4 meter, $L_{p,A,S,4m}$
- Distraction distance, r_D (STI)
- Average A-weighted background noise level, $L_{p,A}$

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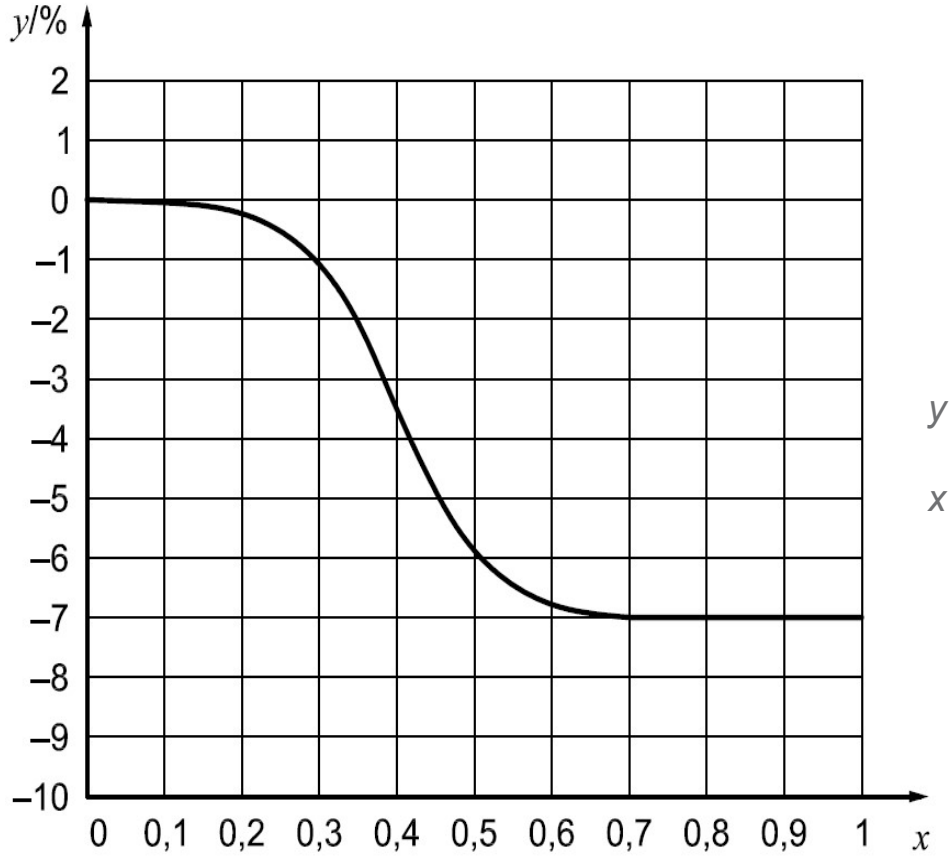
The effect of STI on the performance of cognitively demanding tasks



y minimum change in task performance

x speech transmission index

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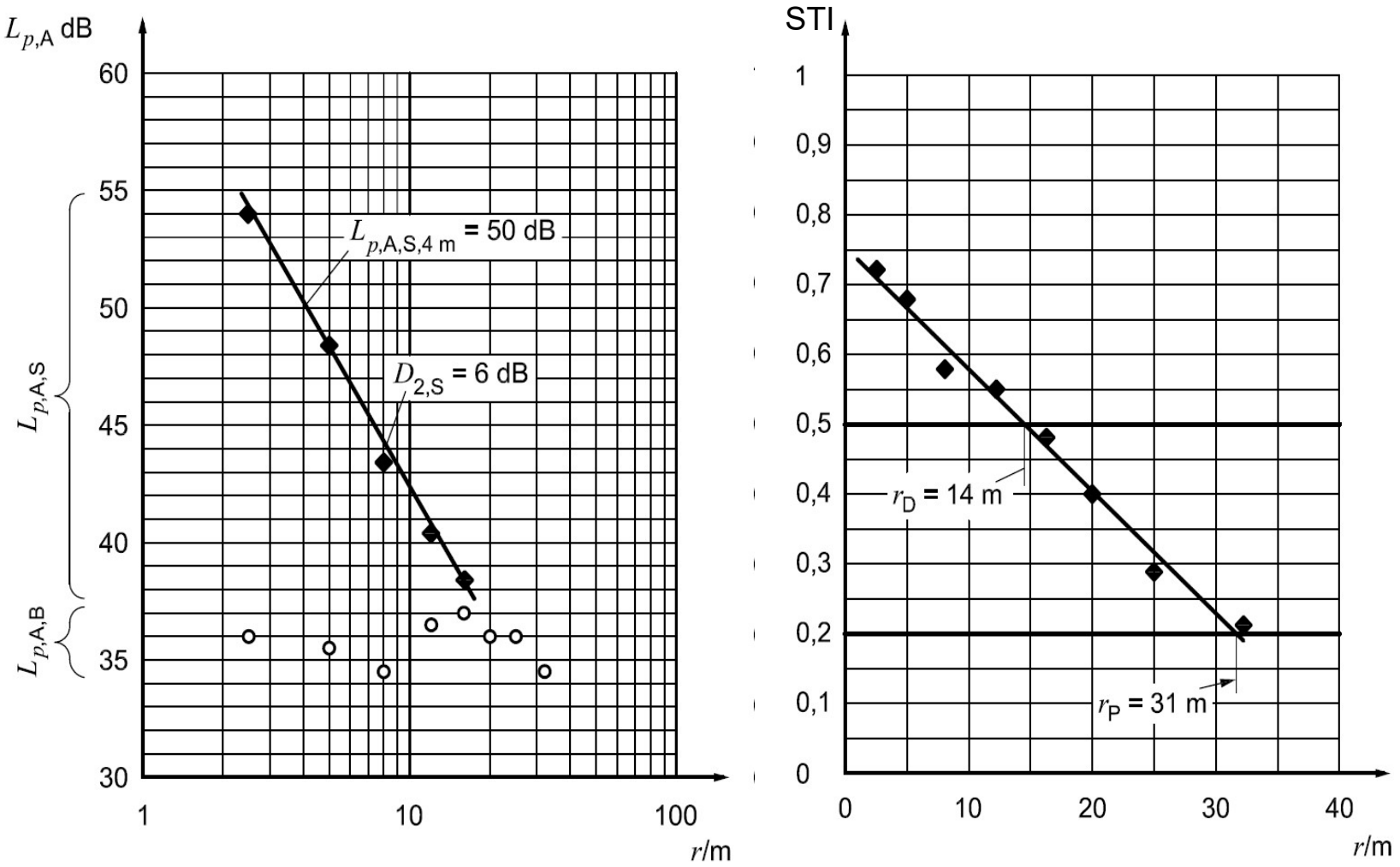
The determination of $D_{2,S}$, $L_{p,A,S,4m}$ and r_d



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Evaluation of office acoustics:

Single value - Radius of comfort r_c (m)

- Definition: the distance for a 10 dB decrease of normal “office” speech. Normal speech level in an office is about 58 dB(A) at 1 meter distance.
- r_c is calculated from parameters defined in the measurement standard for open-plan offices: ISO 3382-3.

$$r_c = 4 \cdot 10^{0.3(L_{p,A,S,4m} - 48)/D_{2,S}}$$

Interpretation:

short radius of comfort (r_c) means increased privacy
and less disturbance between workplaces

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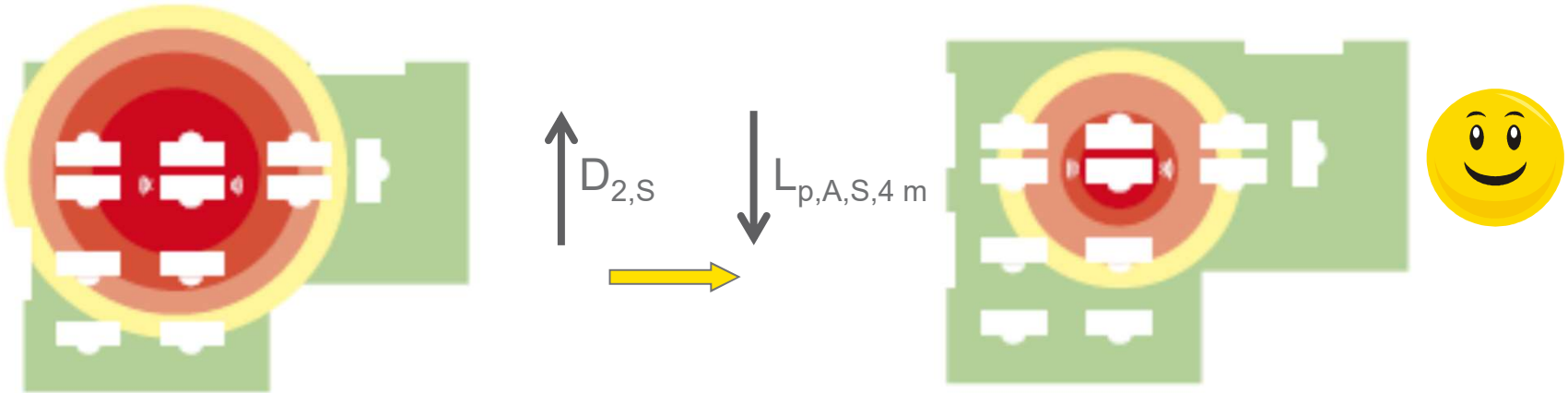
Distance of comfort r_c



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Master Thesis: Room Acoustic Design

Objectives

- Parametrical study of room acoustic parameters (stress test) of Ecophon Acoustic Calculator*
- Control of Ecophon recommendations and adjustments for large spaces

Method

- Setup of parametrical study concerning room dimensions and acoustical treatment
- Using the existing room acoustic calculator for calculations
- Validation with field measurements

Start date: Spring 2019

In collaboration with Ecophon

Supervisor: Emma Arvidsson, Erling Nilsson (Ecophon, LTH)

Examinator: Delphine Bard (LTH)

Contact: emma.arvidsson@ecophon.se

erling.nilsson@ecophon.se Erling Nilsson (Ecophon, LTH)

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Master Thesis: Characterization of porous materials

Objectives

- Characterization of acoustical and mechanical properties of mineral wool

Method

- Measurements of porous materials in Kundt's tube.
- Analysis of material properties
- Simulations in the software AlphaCell.

Start date: Spring 2019

In collaboration with Ecophon

Supervisors: Emma Arvidsson, Erling Nilsson (Ecophon, LTH)

Examinator: Delphine Bard (LTH)

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erling.nilsson@ecophon.se

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