Sound Absorbers and Diffusers

Acoustic analysis and solutions for listening spaces

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Overwiew

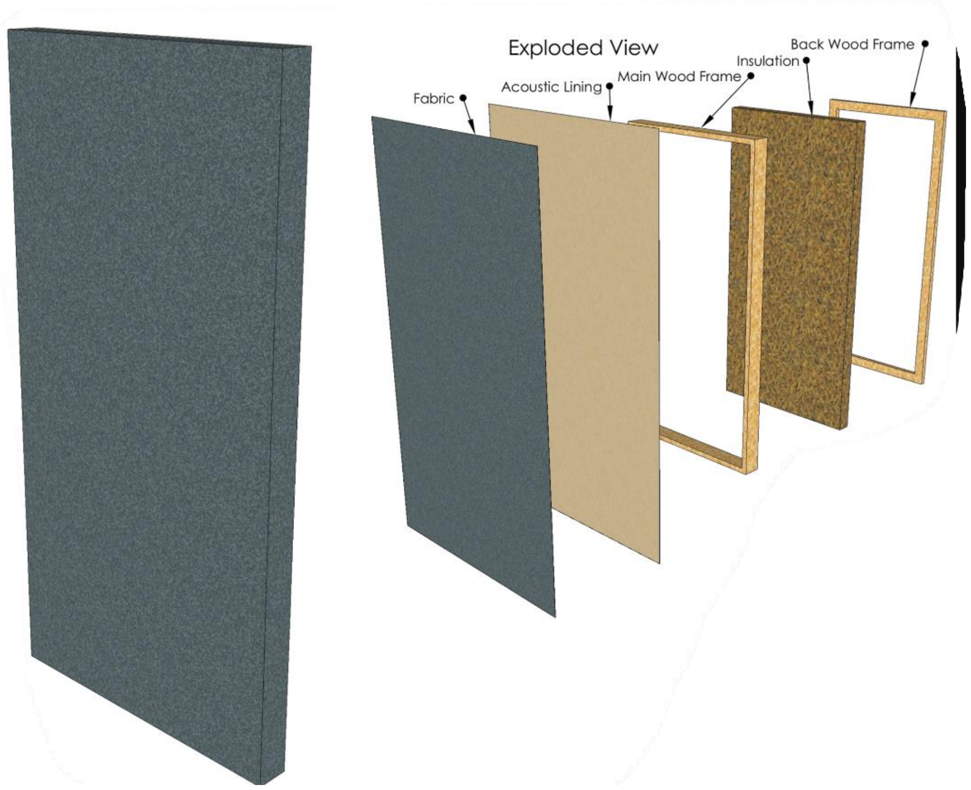
- Porous absorbers
- Diffusers
- Simulated and experimental positioning techniques

Acoustic panels and diffusers are used to control and improve the acoustic environment in various settings. They are designed to absorb, diffuse or reflect sound waves to achieve specific acoustic goals.

Different types with respective working principles

Absorbers

Porous sound absorbers



Working principle: part of the incident wave is reflected and part is absorbed and dissipated into heat by friction and viscous losses

The **porous structure** acts like a labyrinth for sound waves and is responsible of the energy dissipation

The **impedance** of the panel must therefore match the one of air as to absorb the wave rather than reflecting it

Absorption coefficient

- $\alpha = \frac{I_i - I_r}{I_i} = 1 - |R|^2,$ where $I_i = \frac{\hat{p}^2}{2Z_0}$ and $I_r = \frac{|R|^2 \hat{p}^2}{2Z_0}$

- $R = \frac{Z\cos(\theta) - Z_0}{Z\cos(\theta) + Z_0},$ where $Z = \left(\frac{p}{v_x}\right)_{x=0}$ wall impedance

Analogy with discontinuities in pipes

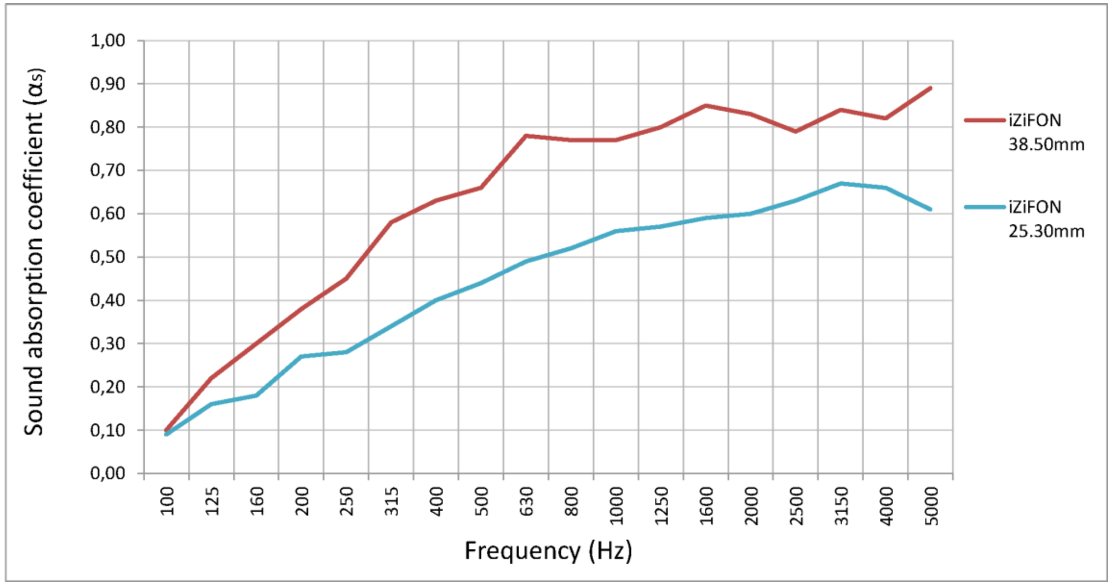
Porous sound absorbers

$Z = -jZ_0'\cot(k'd)$ ← for porous layers backed with a rigid wall

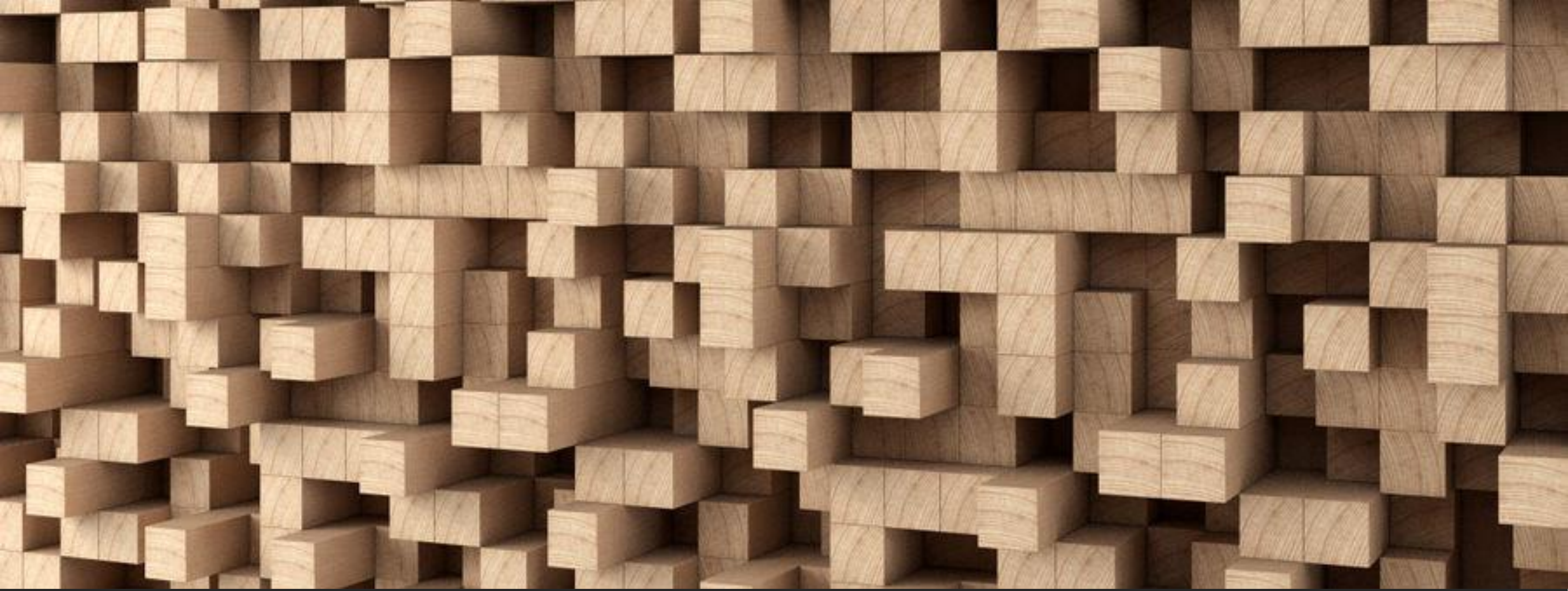
$$Z_0' = \frac{Z_0}{\sigma}\sqrt{1 - j\frac{\sigma\Theta}{\rho_0\omega}},$$

where σ is the porosity of the matherial and Θ is the specific flow resistance

$$k' = \frac{\omega}{c}\sqrt{1 - j\frac{\sigma\Theta}{\rho_0\omega}}$$



https://alphacoustic.com/en/product/sound-absorption-slab-polyester-fiber-izifon/



Diffusers

Working principle

- Acoustic diffusers are designed to scatter sound waves in various directions.
- They consist of complex surfaces or structures that break up and redirect sound reflections in a controlled manner.
- This scattering effect helps to distribute sound energy more evenly in a space, reduce sound reflections, and decrease echoes.
- Temporal and spatial diffusion
- They do not dissipate energy like absorbers do

- Skyline Diffusers

- Schroeder’s well diffuser

Scattering

Schroeder's formula to calculate well depth sequence:

$$S_n = (well\ position)^2\ mod\ N$$

where N is a prime number.

Intensity of the scattered sound at a distance *r* from a scattering wall element *dS*

$$I(r,\theta) = B(1-\alpha)\frac{\cos\theta}{r^2}dS$$

Irradiation density

Angle of incidence

(energy incident on unit area of the surface per second)

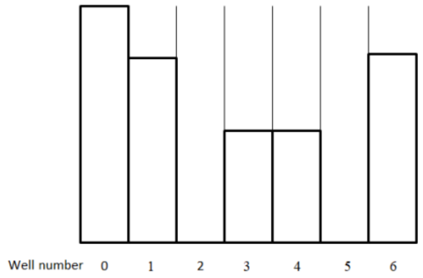


Figure 2. Well number configuration of QRD.

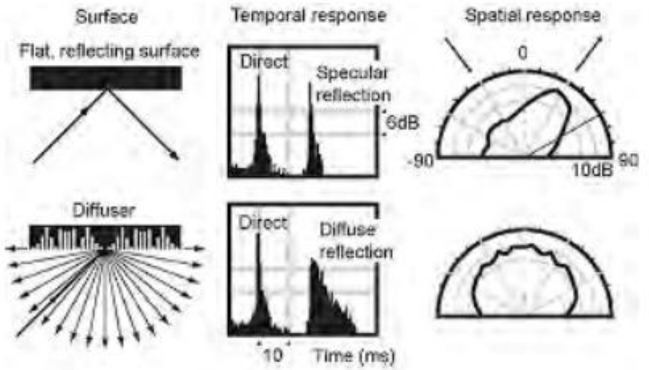


Fig 1. The spatial and temporal response of sound reflected from a plane flat surface and a diffuser. (After Cox and D'Antonio[15])

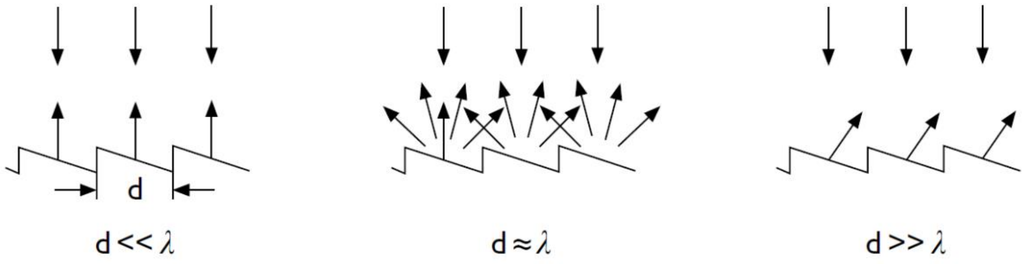
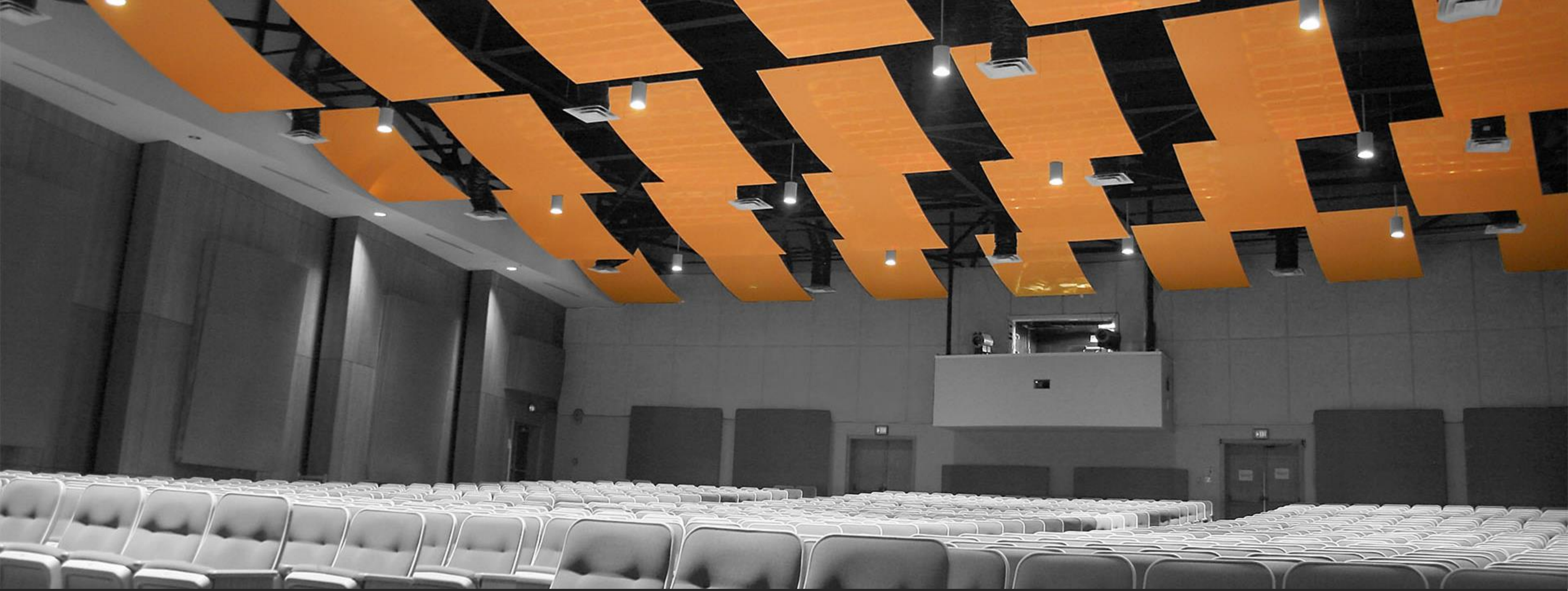
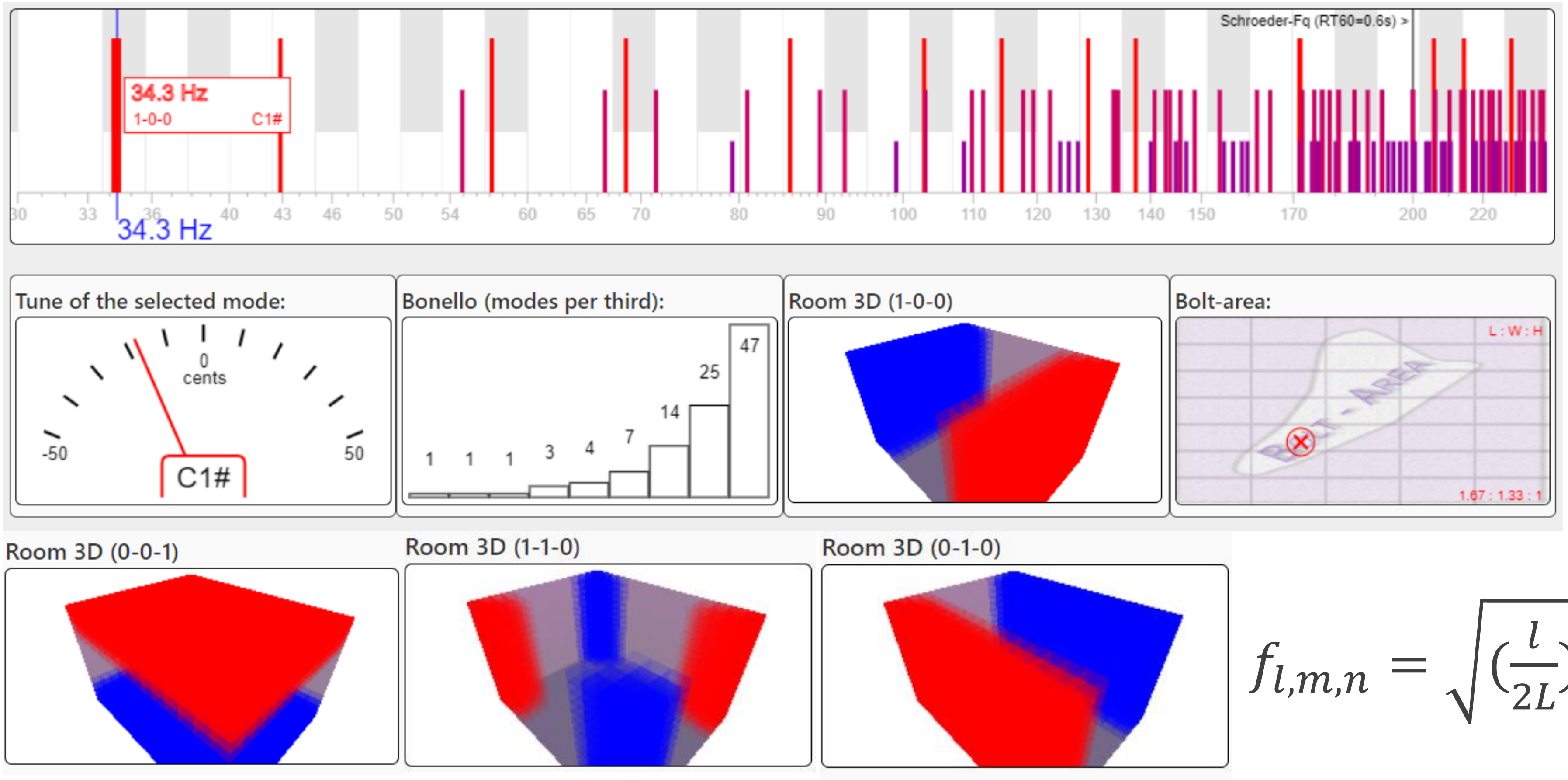


Figure 7.13 Sound scattering from a rough wall for three ranges of wavelengths.



Room acoustics

Room Modes and Eigenfrequencies



$$f_{l,m,n} = \sqrt{(\frac{l}{2L})^2 + (\frac{m}{2W})^2 + (\frac{n}{2H})^2}$$

https://amcoustics.com/tools/amroc

Positioning techniques

Finite element method:

- 3D simulations for different speakers/panels positioning configurations
- Approximative results due to the difficulty in evaluating the effect of objects in the room
- Possibility to evaluate many different configurations with ease

Experimental method:

- Measures the actual response of the room
- Optimal results
- Requires technical equipment
- Time and effort are required in order to evaluate the results for different positions

Finite Element Method

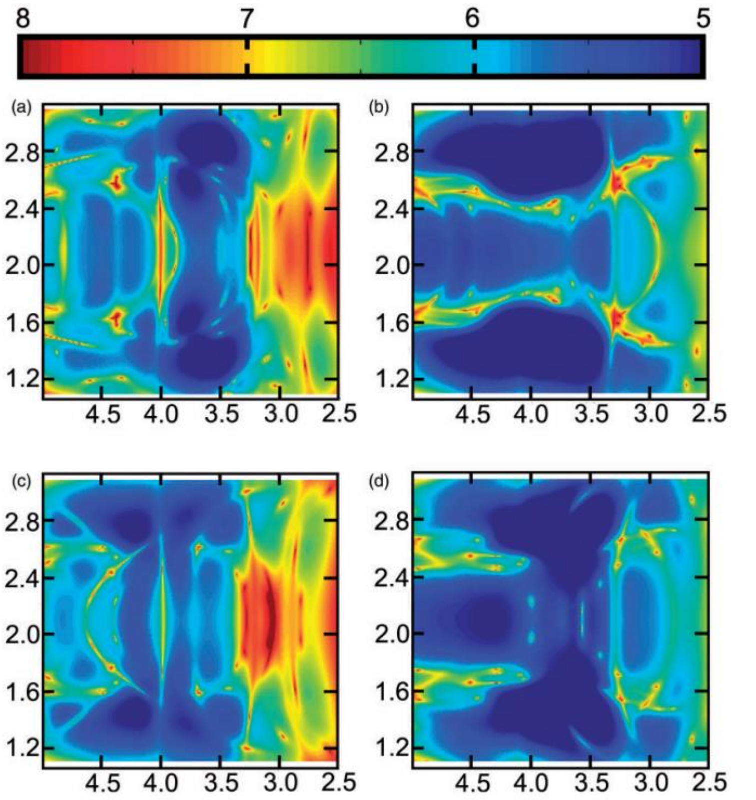
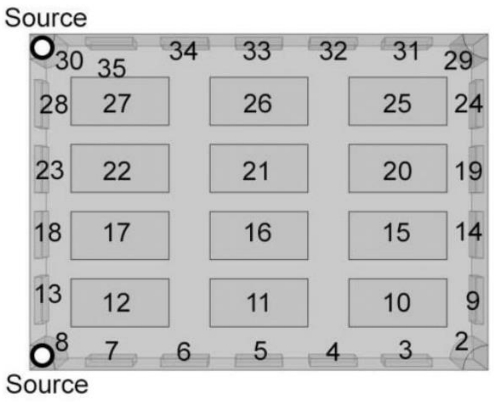


Figure 6. Standard deviation sound fields: The blue areas of the figures represent areas of low standard deviation and acceptable listening positions, while the red areas represent locations of higher standard deviation (Unit: dB).(a) No absorption. (b) All absorption. (c) Only corner absorption. (d) All absorption no corners.



"Effects of absorption placement on sound field of a rectangular room: A statistical approach Siu-Kit Lau and Eric A Powell"

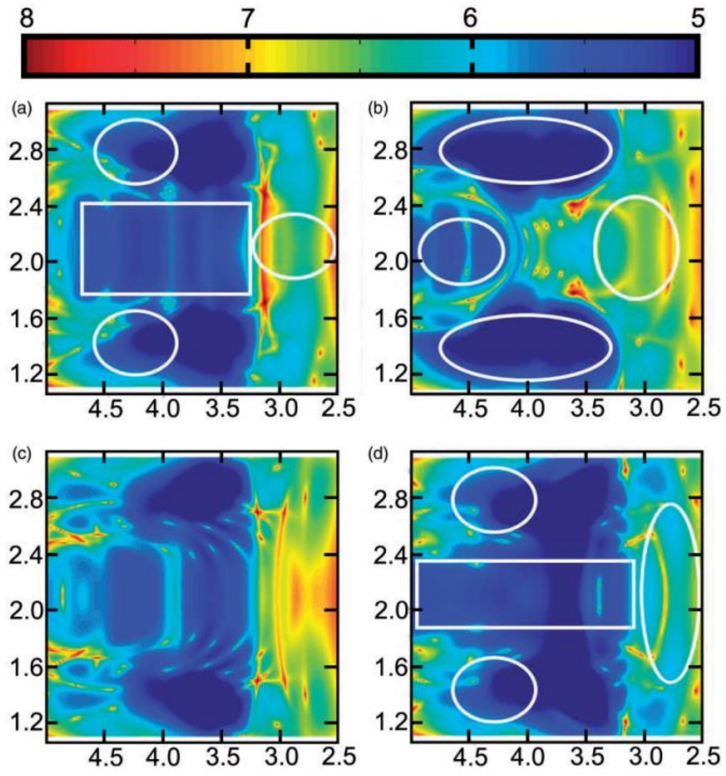
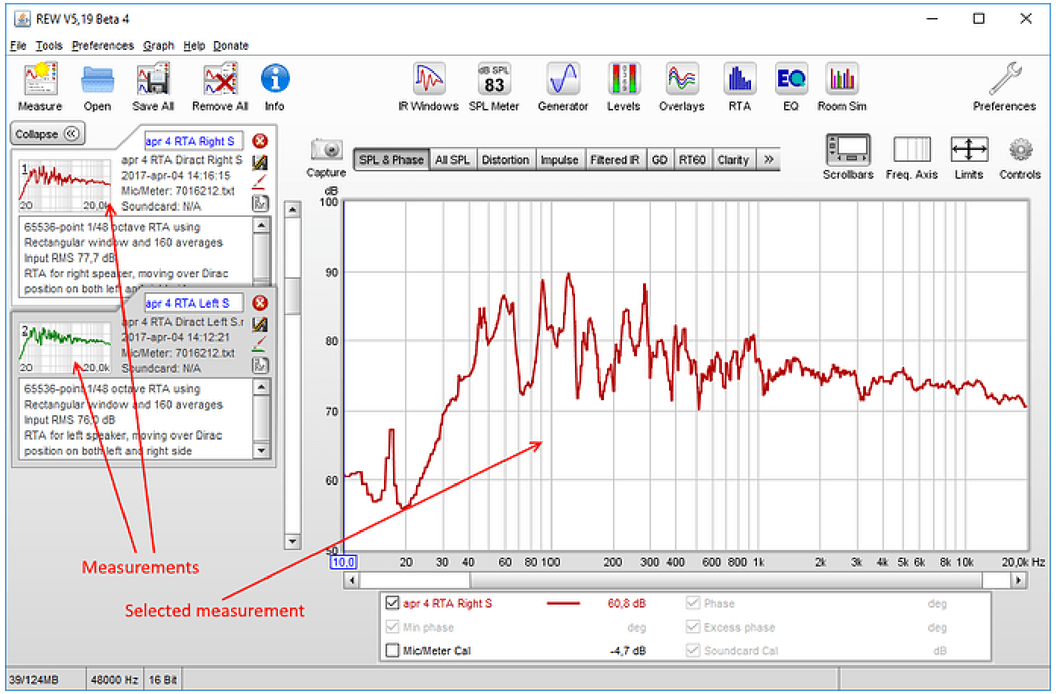


Figure 7. Standard deviation sound fields for the effects of ceiling absorption: The blue areas of the figures represent areas of low standard deviation and acceptable listening positions, while the red areas represent locations of higher standard deviation (Unit: dB). (a) Only ceiling absorption. (b) Ceiling absorption with corners. (c) Only side wall absorption. (d) Side wall absorption with ceiling.

Experimental Method

- Measurement microphone's calibration file
- Soundcard artifacts calibration
- Frequency sweeps to capture the response
- Filtering of the response based on human perception
- Response's analysis
- RT60 evaluation
- EQ compensation



https://www.roomeqwizard.com/help.html

Conclusions

- Sound absorption and diffusion play a fundamental role in the acoustic quality of a listening space
- Different needs for an acoustic environment are achieved by employing different techniques, analysis methods and configurations

References

- ”Heinrich Kuttruff, Acoustics - An introduction, Taylor & Francis”
- “Effects of absorption placement on sound field of a rectangular room: A statistical approach, Siu-Kit Lau and Eric A Powell”
- “A brief history of Room Acoustic Diffusers, Trevor J. Cox Peter D’Antonio”
- “Suyatno and M Lianto 2021 J. Phys.: Conf. Ser. 1896 012020”
- https://amcoustics.com/tools/amroc
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