

# Improving the intelligibility of a heritage-constrained university room using acoustic treatment and line arrays

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# AULA AFFRESCHI



Cultural heritage classroom

Philosophy and Literature, University of Bologna

Multimedia course *Digital Humanities*



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- Aula Affreschi
- Acoustic qualification (ISO 3382, IEC 60268, DIN 18041)
- Design proposal (numerical simulation)
- Post-operam measurements

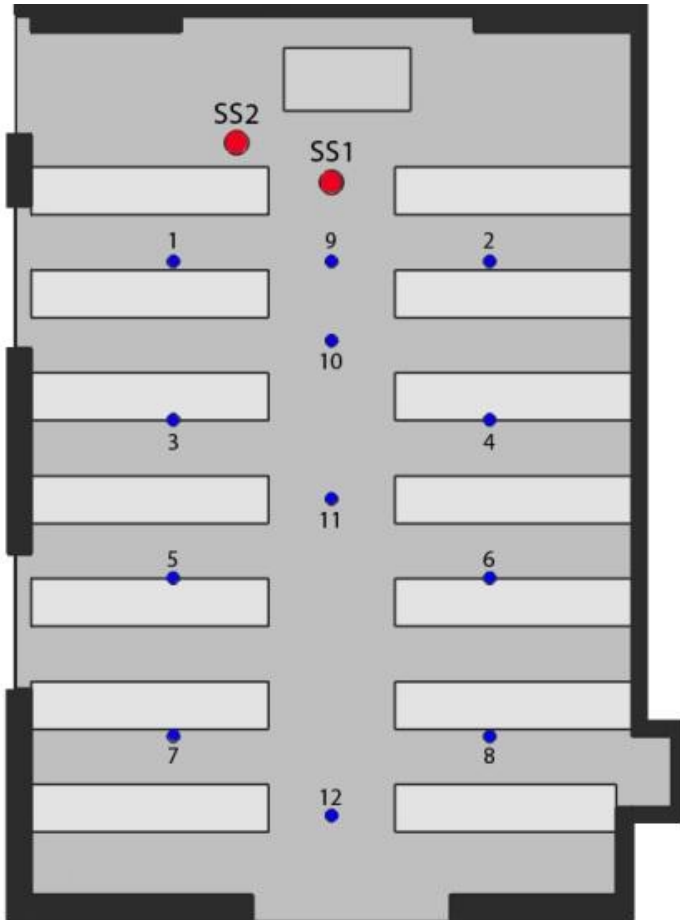


# AULA AFFRESCHI

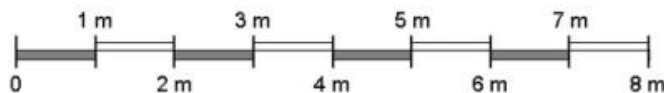


- Occupation = 56 people
- Volume = 550 m<sup>3</sup>
- Floor area = 84 m<sup>2</sup>

# ACOUSTIC QUALIFICATION



- ISO 3382, IEC 60268
- Omni sound source (ISO 3741)
- Grid of monaural receivers
- D<sub>2,S</sub> spatial decay
- L<sub>p,B</sub> background noise



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# ACOUSTIC QUALIFICATION

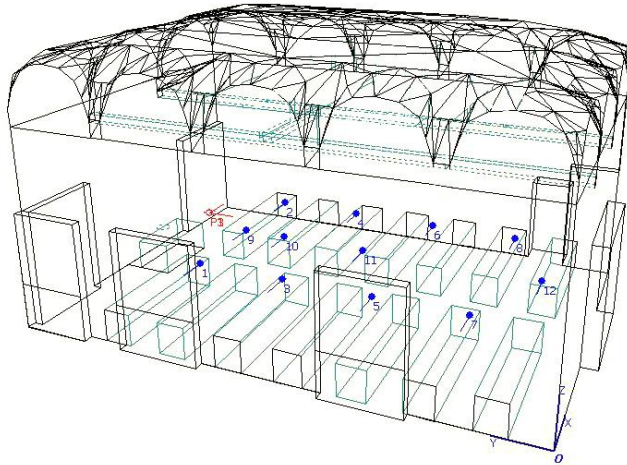
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	Measured mean values	Target values (UNI 11352, BB93, DIN 18041)
$C_{50,3}$ (dB)	<b>-2.4</b>	$\geq 0$
STI	<b>0.48</b>	$\geq 0.60$
$T_{M,occ}$ (s)	<b>1.20</b>	$\leq 0.85$

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# NUMERICAL SIMULATION (ODEON V.12)



	S	$\alpha$					
		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Plaster and floor	0.05	0.02	0.02	0.03	0.03	0.04	0.05
Furniture	0.60	0.14	0.28	0.35	0.38	0.35	0.28

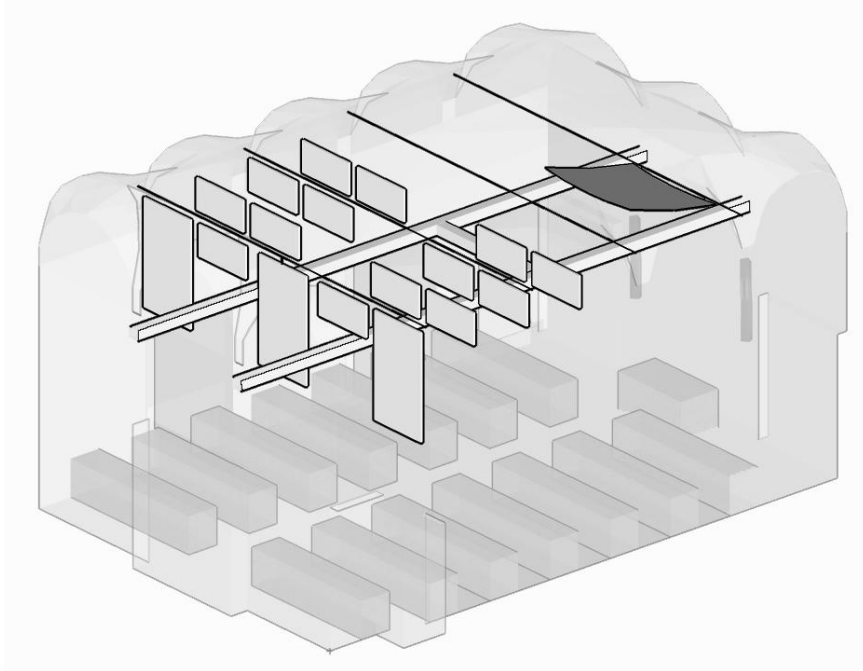
References for scattering and absorption coefficients: DIN 18041.

Calibration: differences between measured and simulated values within JND.

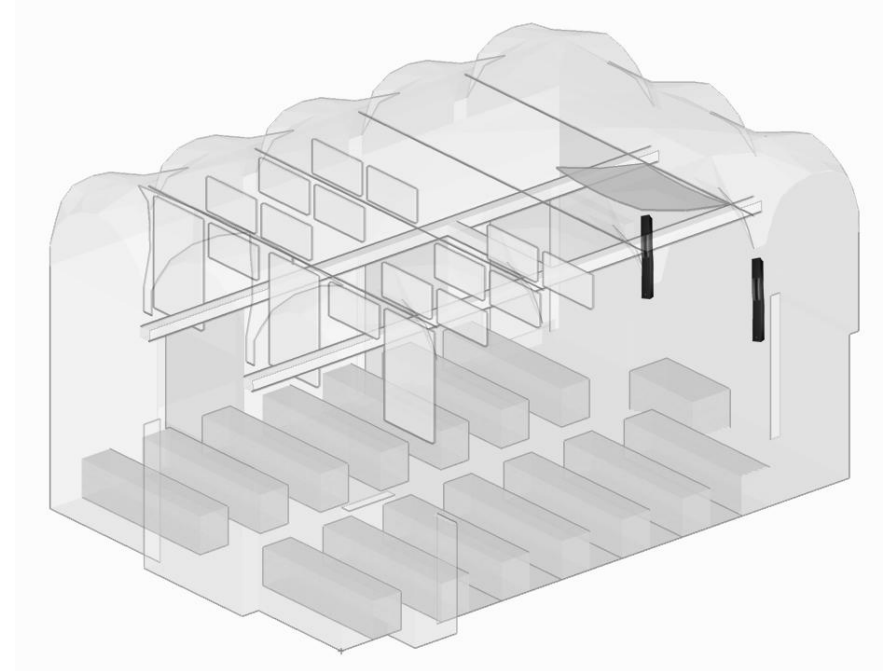




# DESIGN PROPOSAL



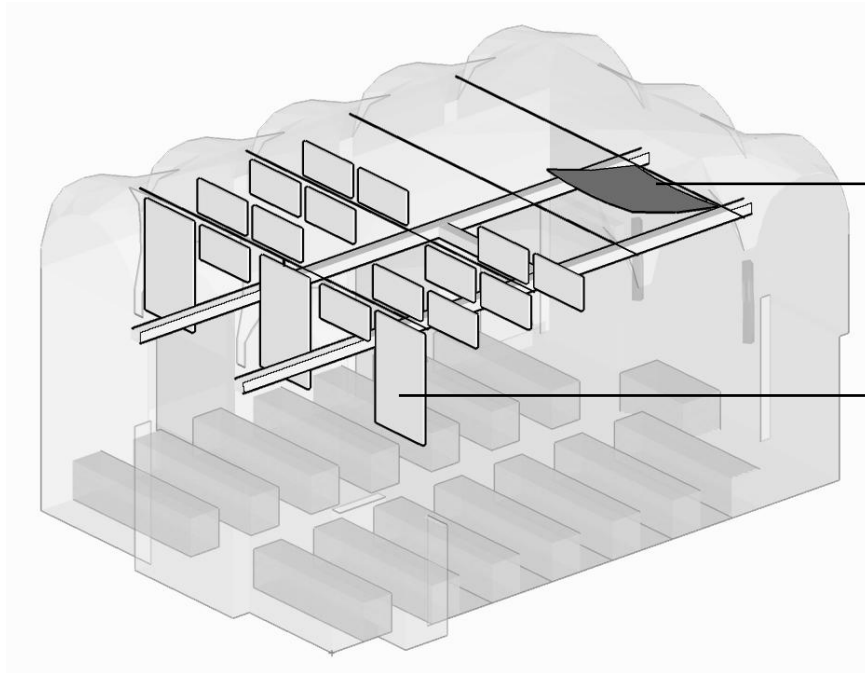
Passive acoustic  
**BAFFLES AND REFLECTOR**



Active acoustic  
**LINE ARRAYS**



# DESIGN PROPOSAL: BAFFLES AND REFLECTOR



→ The reflector enhances the early reflections

→ Vertical baffles decrease the reverberation time

Passive acoustic

All the devices preserve the architectural value of the space

# DESIGN PROPOSAL: BAFFLES AND REFLECTOR



Baffles

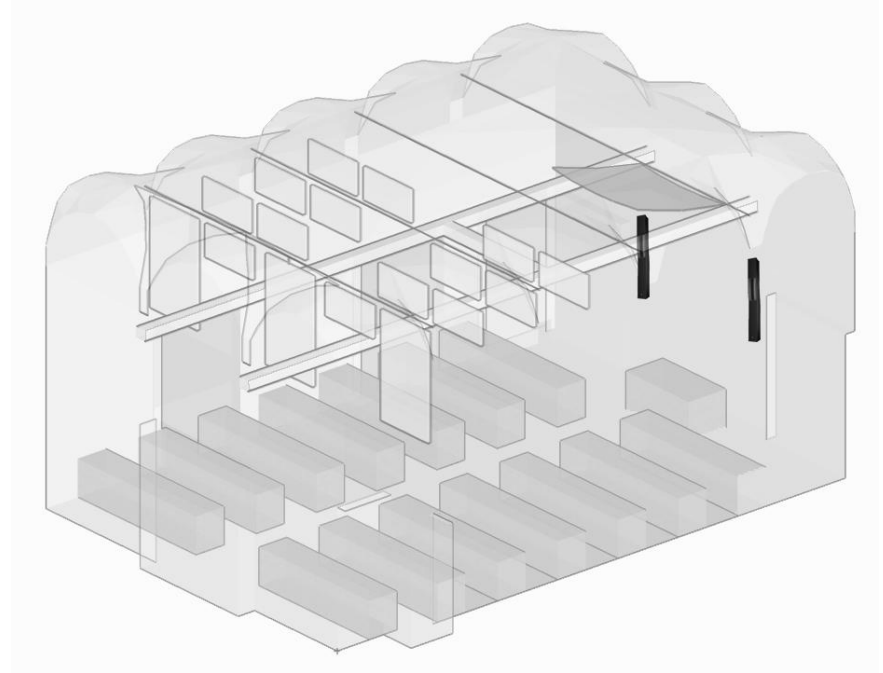


Reflector

	s	$\alpha$					
		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Vertical baffles	0.50	0.27	0.42	0.70	0.70	0.70	0.50
Reflector	0.50	0.18	0.15	0.03	0.03	0.02	0.02

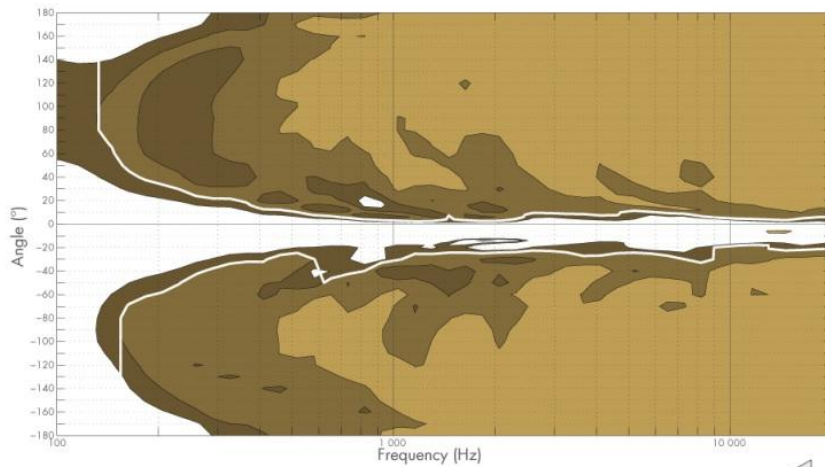
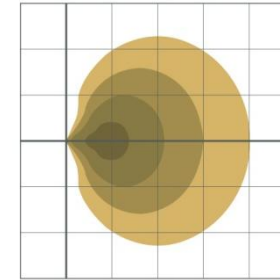
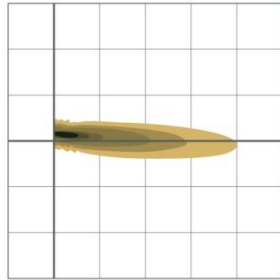
# DESIGN PROPOSAL: LINE ARRAYS

Line arrays improve the speech intelligibility in each row of the classroom, guiding the direct sound towards the audience area.

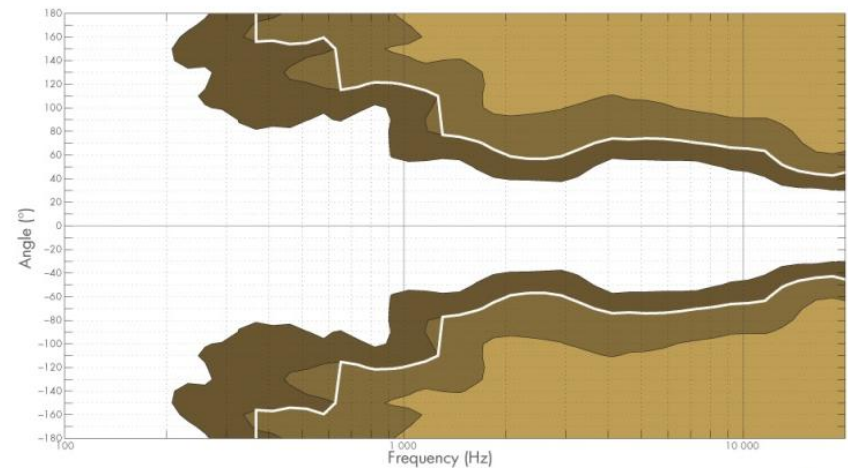


Active acoustic

# DESIGN PROPOSAL: LINE ARRAYS



Beamwidth Syva vertical 1/3 oct



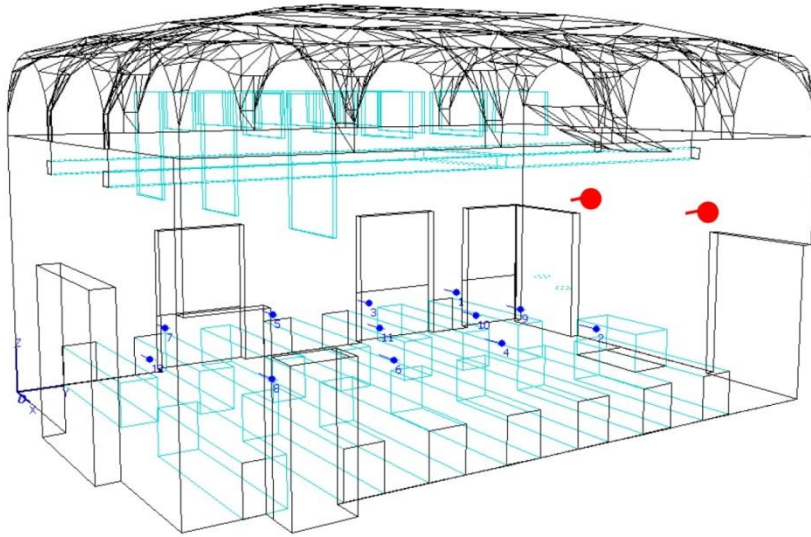
Beamwidth Syva horizontal 1/3 oct



Vertical directivity

Horizontal directivity

# DESIGN PROPOSAL: LINE ARRAYS



Balance between talker and PA system:  
line arrays set on normal vocal effort sound pressure level

$$L_p = 59.5 \text{ dB at 1 meter}$$



# POST-OPERAM MEASUREMENTS



# RESULTS

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	Post-operam mean values	Target values (UNI 11352, DIN 18041, BB93)
$C_{50,3}$ (dB)	<b>0.1</b>	$\geq 0$
STI	<b>0.60</b>	$\geq 0.60$
$T_{M,OCC}$ (s)	<b>0.83</b>	$\leq 0.85$

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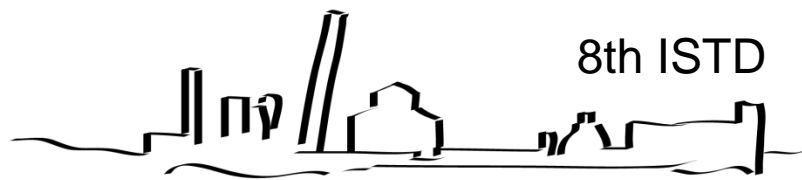


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# REMARKS

- The initial acoustic qualification was performed in order to classify the discomfort perceived within Aula Affreschi.
- Numerical simulations were used to calibrate the 3D model and to propose the acoustic correction design.
- Baffles and reflector led to the achievement of speech intelligibility target values provided by technical standards.
- Post-operam measurements showed how the good balance between the talker and PA system allows to reduce the talker's vocal effort and the students' distraction.





September 14-15, 2017, Bologna (Italy)



**THANK YOU FOR LISTENING!**