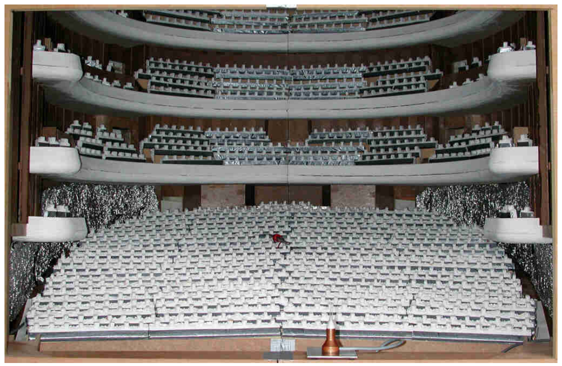
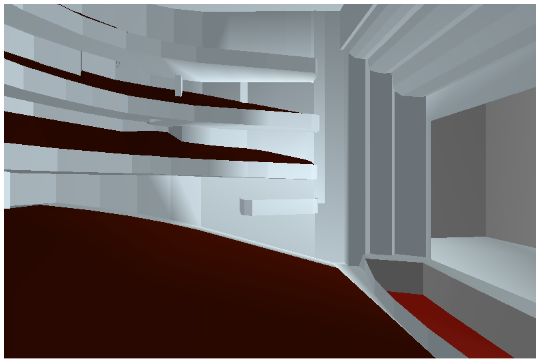
Room acoustic modelling techniques: A comparison of a scale model and a computer model for a new opera theatre





Jens Holger Rindel
Odeon A/S

Outline

- The project
- Computer model
- Results from computer simulations
- Scale model and measurement technique
- Materials and adjustment of absorption
- Results from scale model measurements
- Comparison of results and methods
- Conclusion

The project

Ankara Congress and Cultural Centre

Opera theatre with approx 1400 seats

Architect: Özgür Ecevit, Turkey

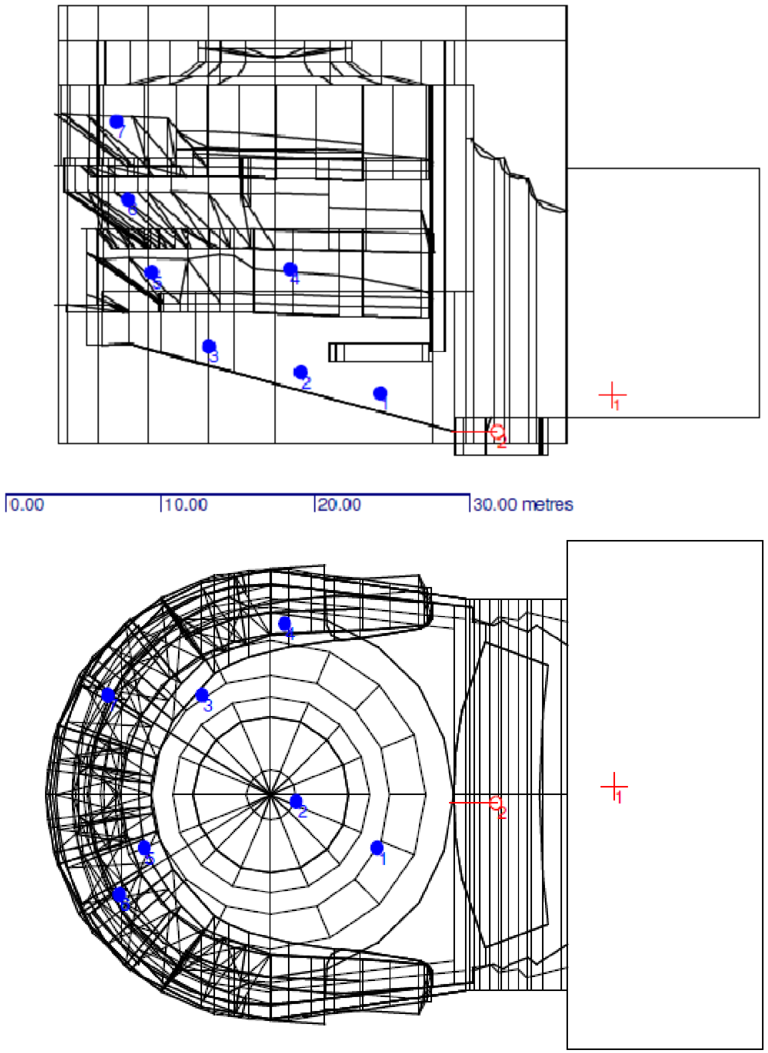
Acoustic consultant: Jordan Akustik and J.H. Rindel

Design goals

ISO 3382 parameters (with full audience)

Parameter	Recommended range	Just noticeable difference
T30	1.5 to 2.2 s	5%
EDT	1.5 to 2.2 s	5%
G	-2 to +6 dB	1 dB
C80	-2 to +4 dB	1 dB
LF	0.2 to 0.4	0.05

Computer model – room model

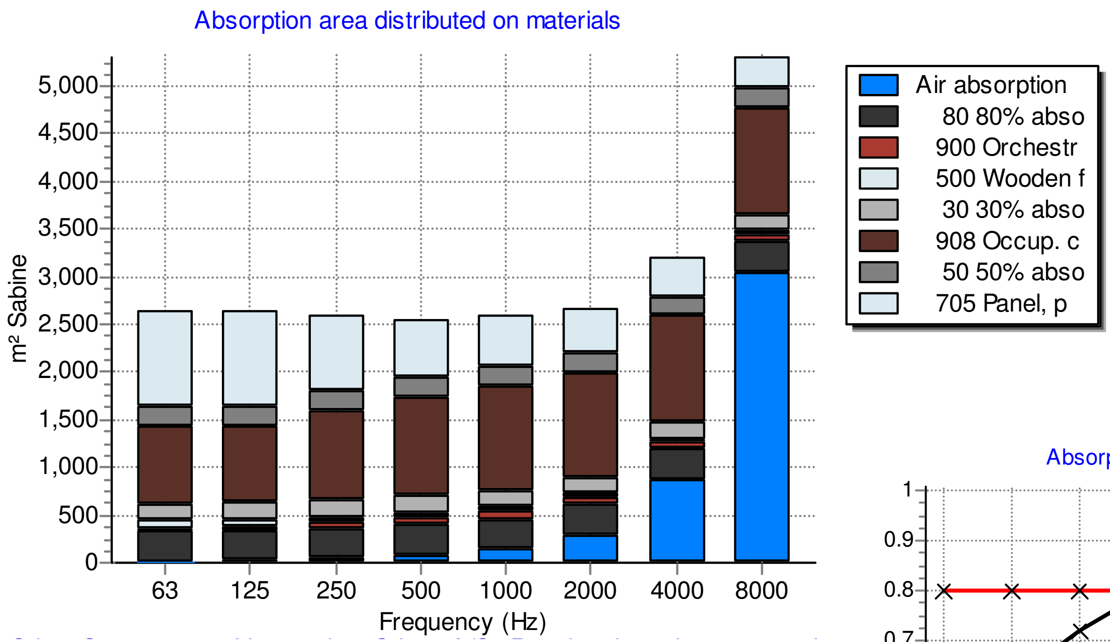


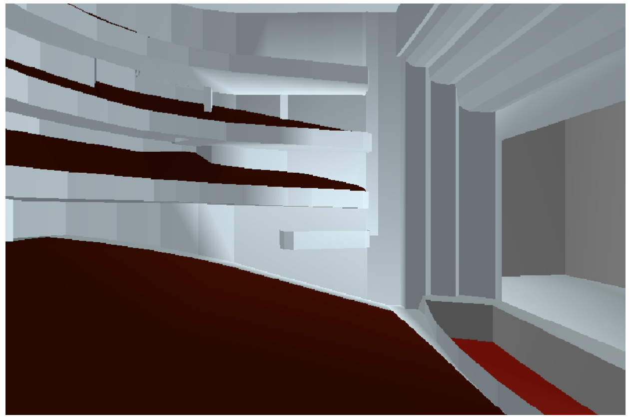
Model in the final phase 3. Design and materials were adjusted according to results from the previous phases.

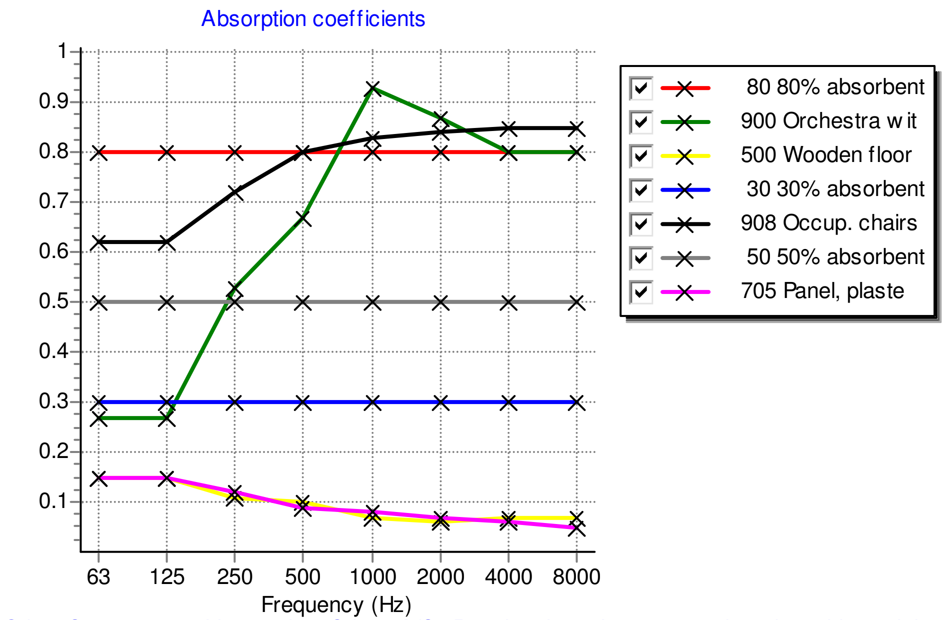
2 source positions
- stage
- pit

7 receiver positions
- main floor
- balconies

Materials

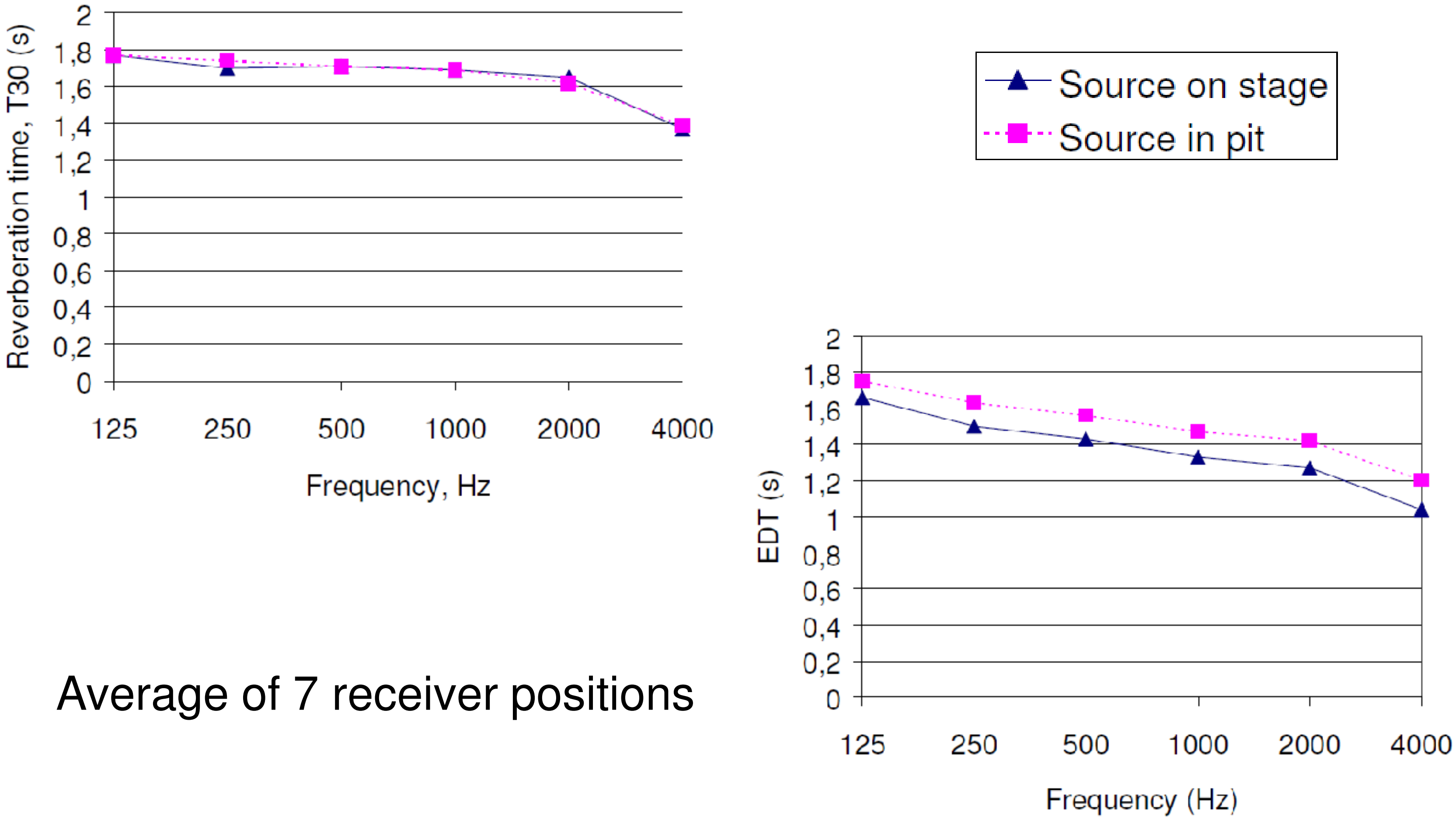






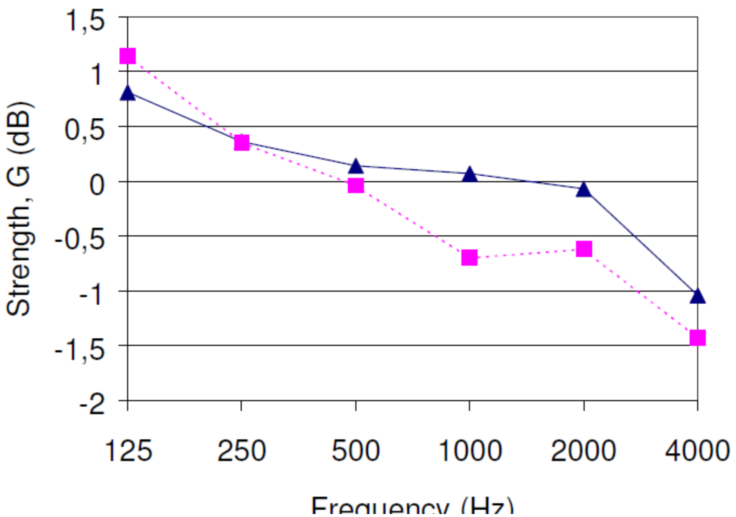
Scattering coefficients (500 1000 Hz):
0.6 – Audience, orchestra, back walls, balcony bottoms
0.1 – All other surfaces

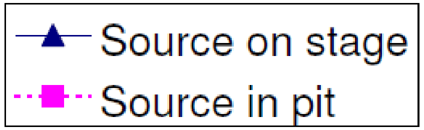
Calculation results



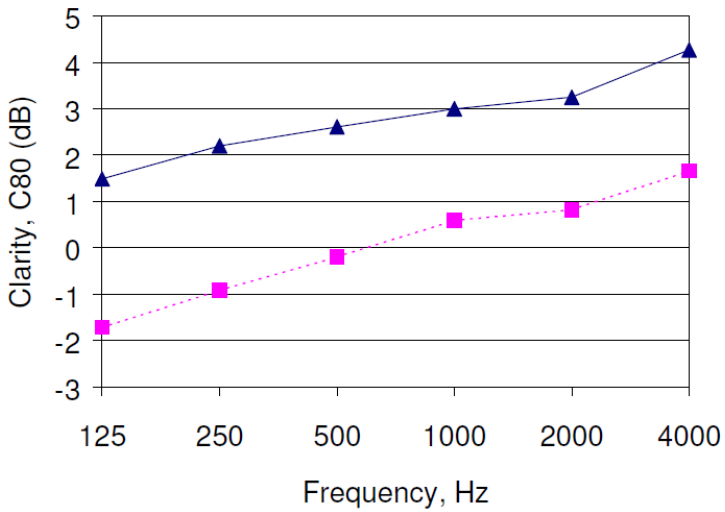
Average of 7 receiver positions

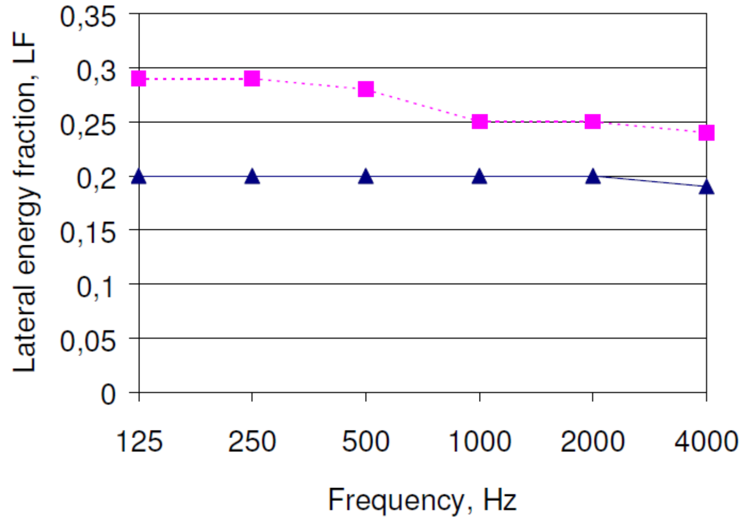
Calculation results





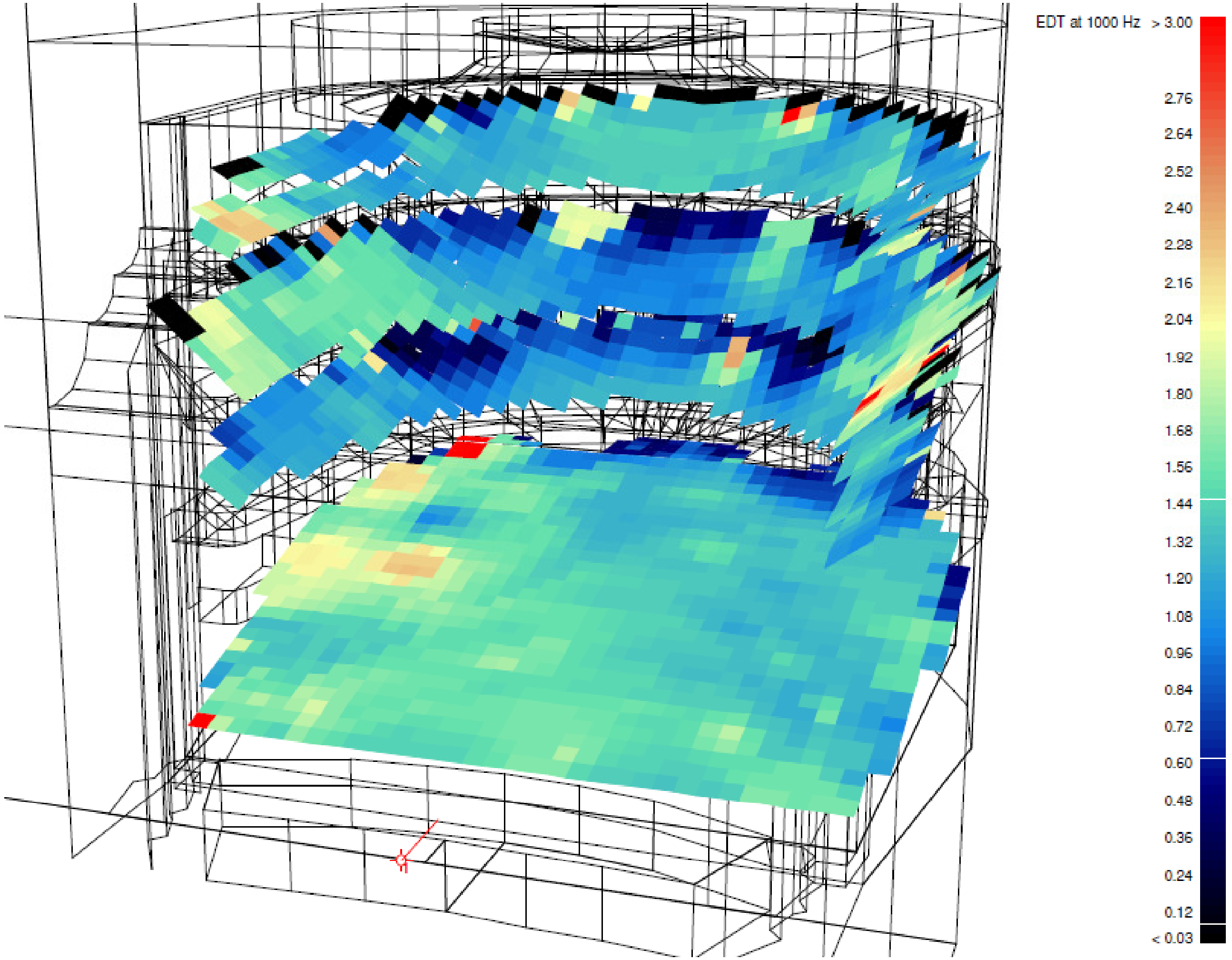
Average of 7 receiver positions





EDT – Grid response

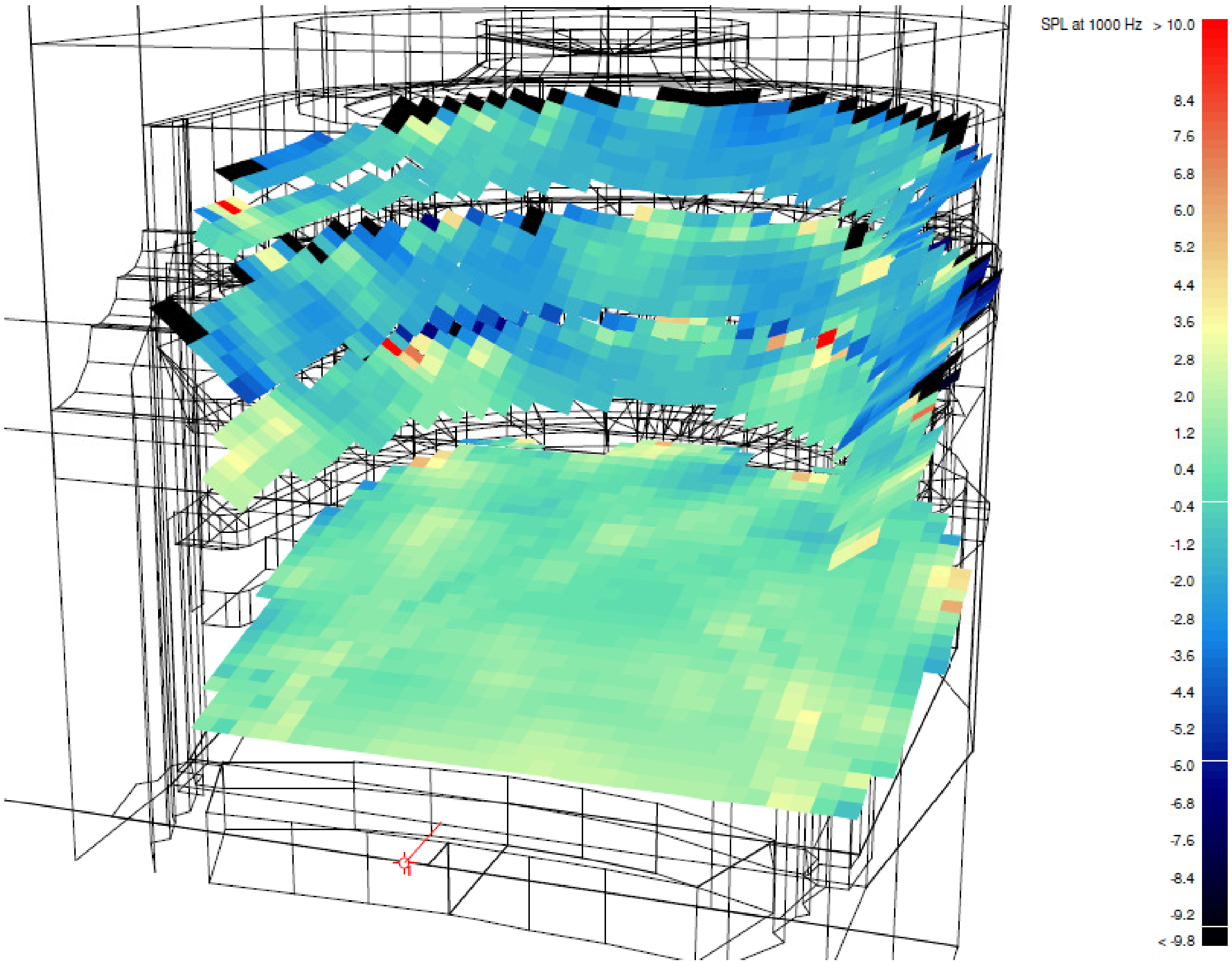
1 kHz octave
Source on stage



Odeon
Room Acoustics Software

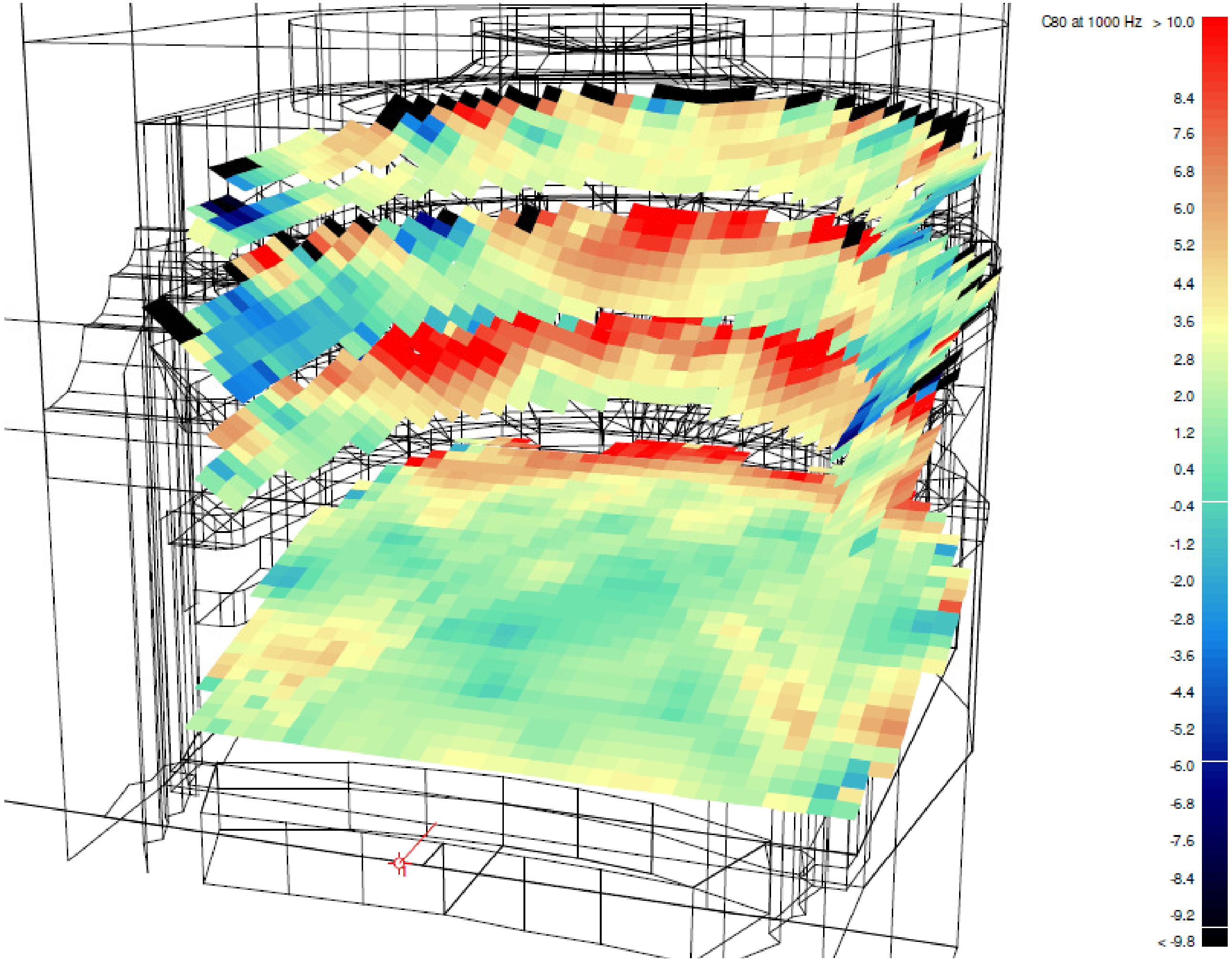
Strength G – Grid response

1 kHz octave
Source on stage



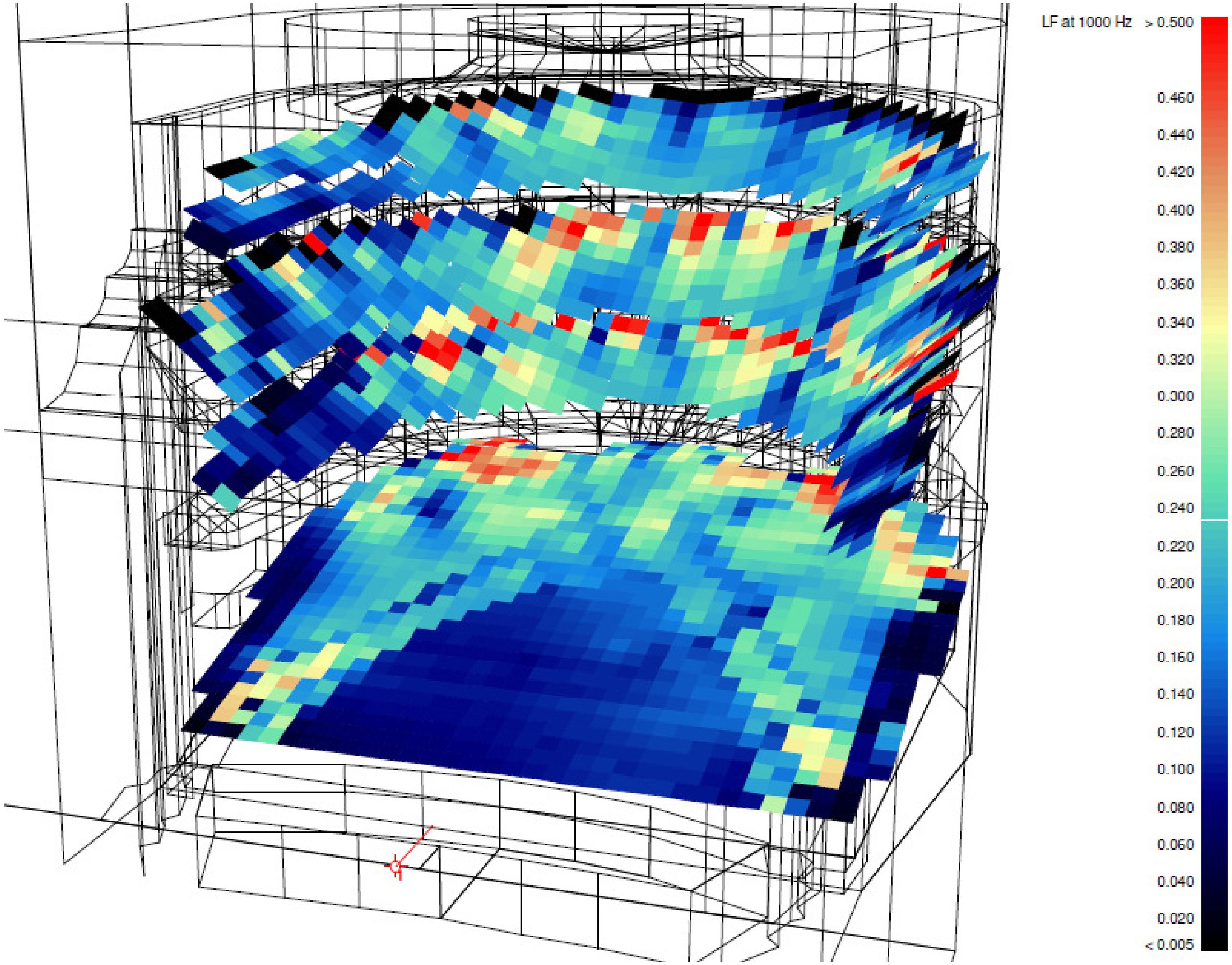
Clarity C80 – Grid response

1 kHz octave
Source on stage

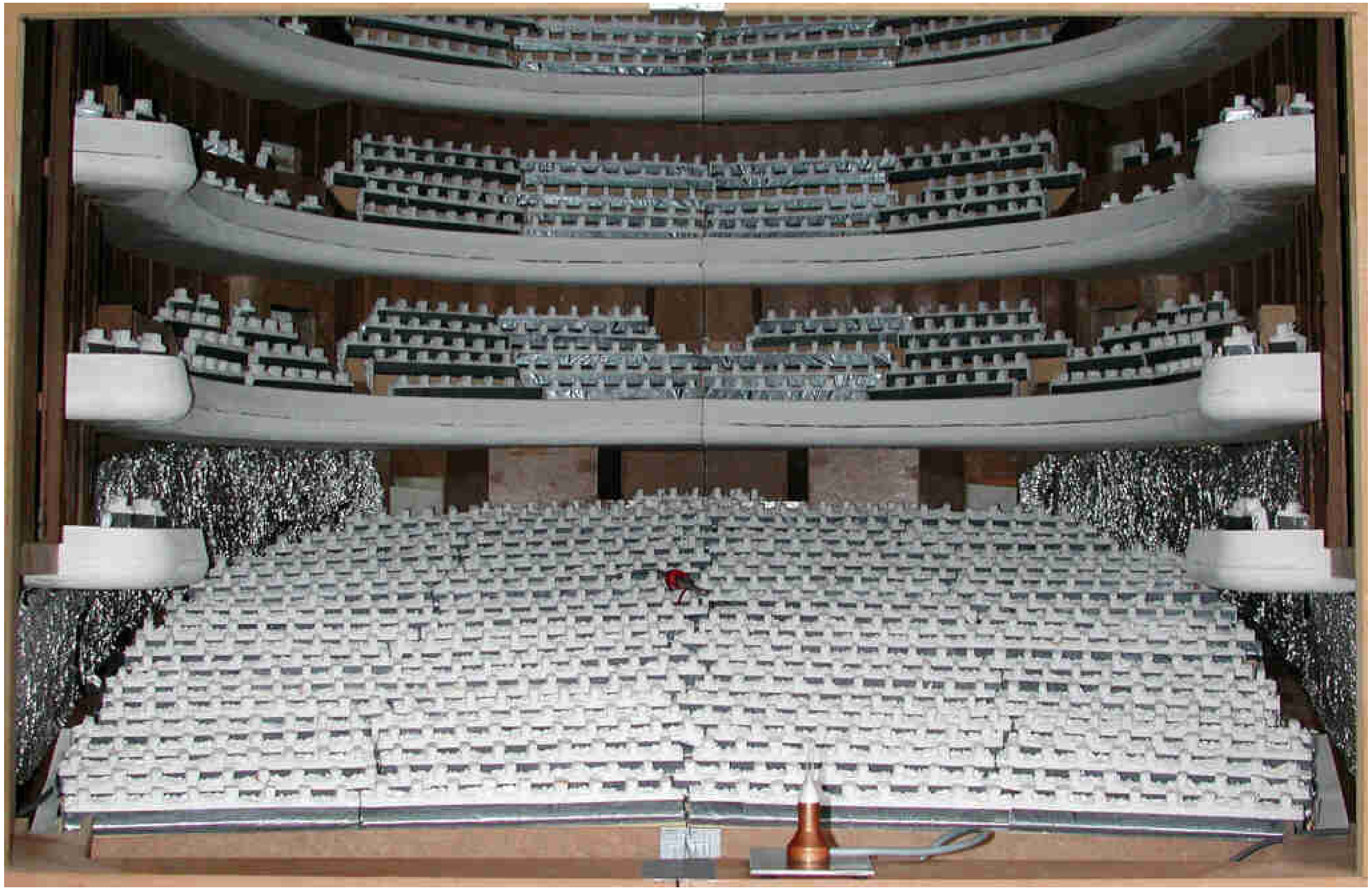


LF – Grid response

1 kHz octave
Source on stage



Scale model 1:20

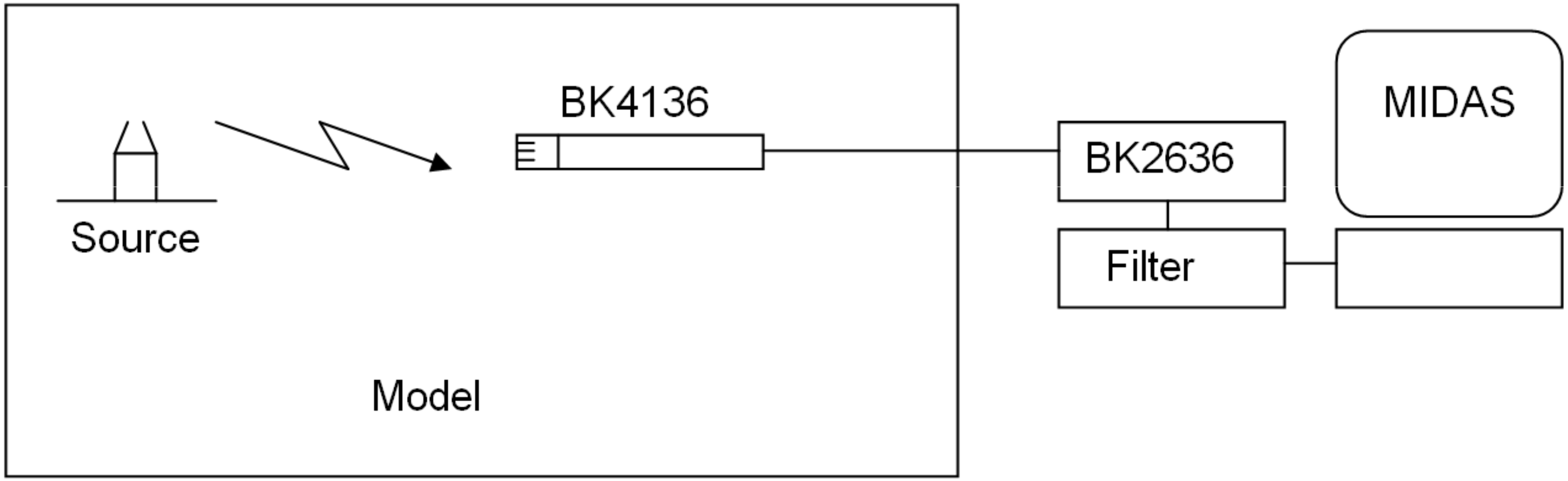


Equipment

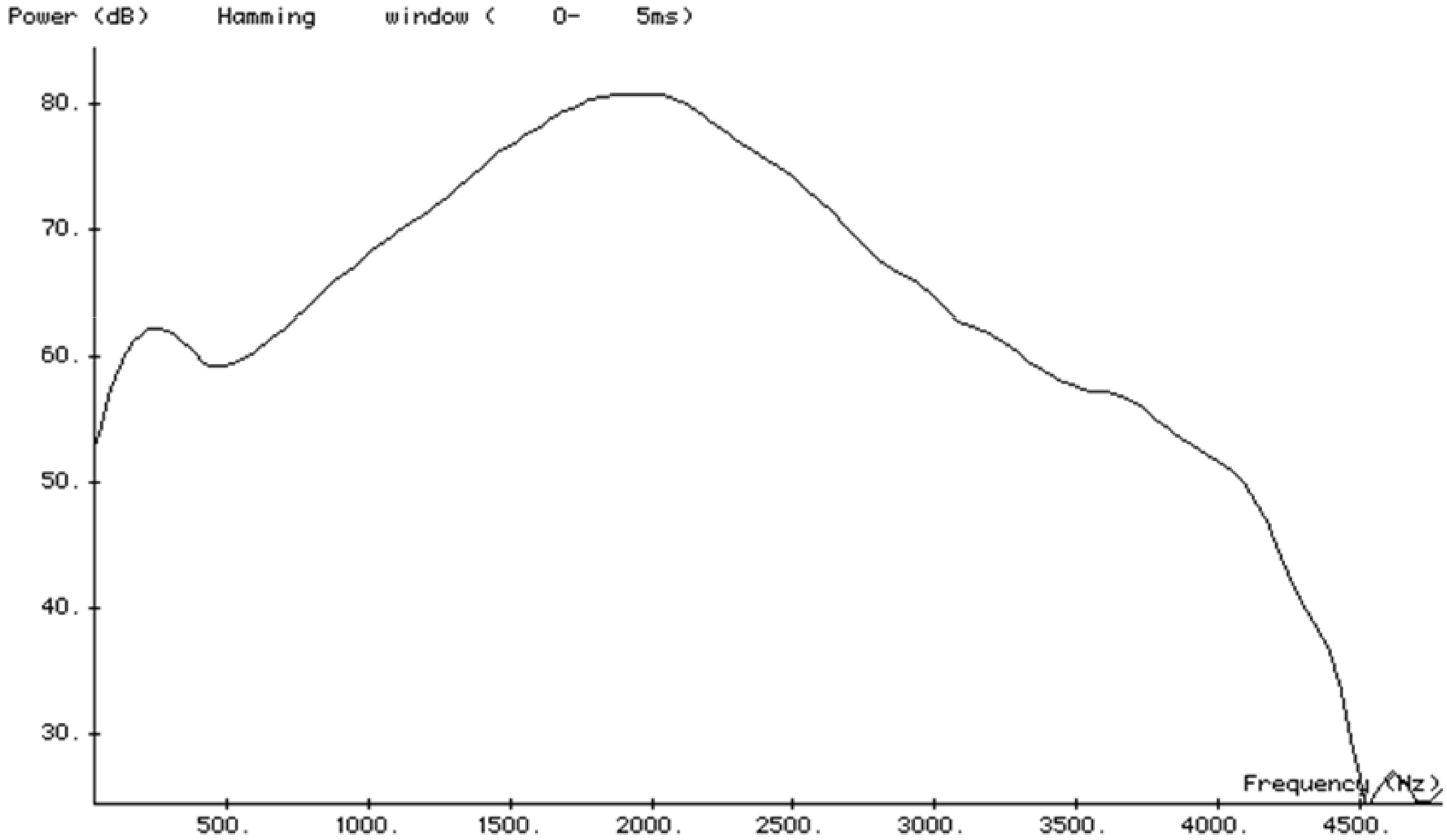
- Sound source: Electric spark source (designed at DTU)
- Useful frequency range: 1,6 – 110 kHz, corresponding to 80 – 5500 Hz, i.e.

  125 – 4000 Hz octave bands in scale 1:20
- Microphone: BK4136 ¼”-microphone, a BK2636 measuring amplifier and a Rockland 852 dual high/low-pass filter
- MIDAS software for measurements and analysis

Measurement setup



Spectrum of spark source
(Frequency / 20)



Air conditions

- Temperature and humidity was kept very stable. RH around 60%
- The MIDAS measurement system adjusted the impulse response to compensate for the excessive air attenuation at the high frequencies

Room Acoustics Software

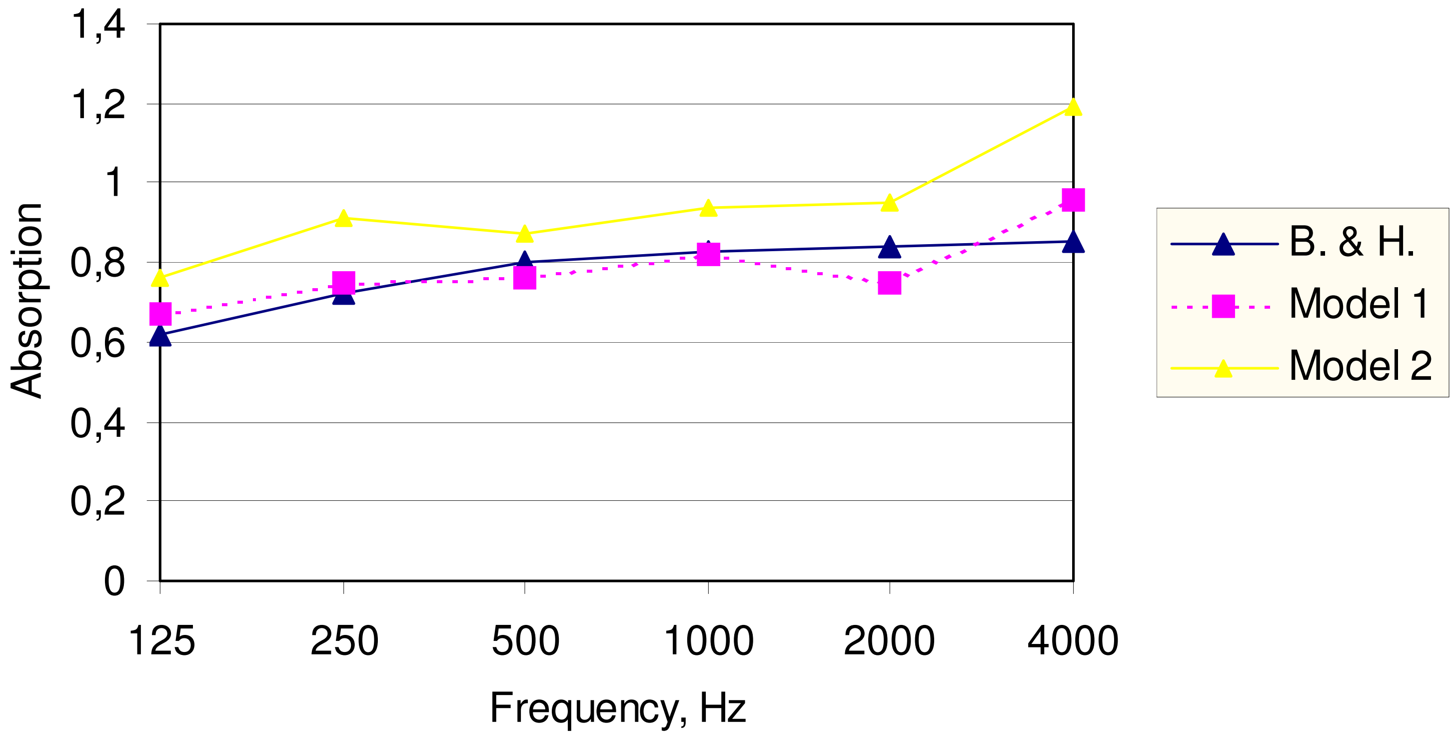
Audience

- Wooden fibre plate glued to a styrofoam back, in which the shapes of the "heads" of the audience are cut out.

Some of the surfaces of the front and back were covered with a layer of tape, in order to adjust the absorption.

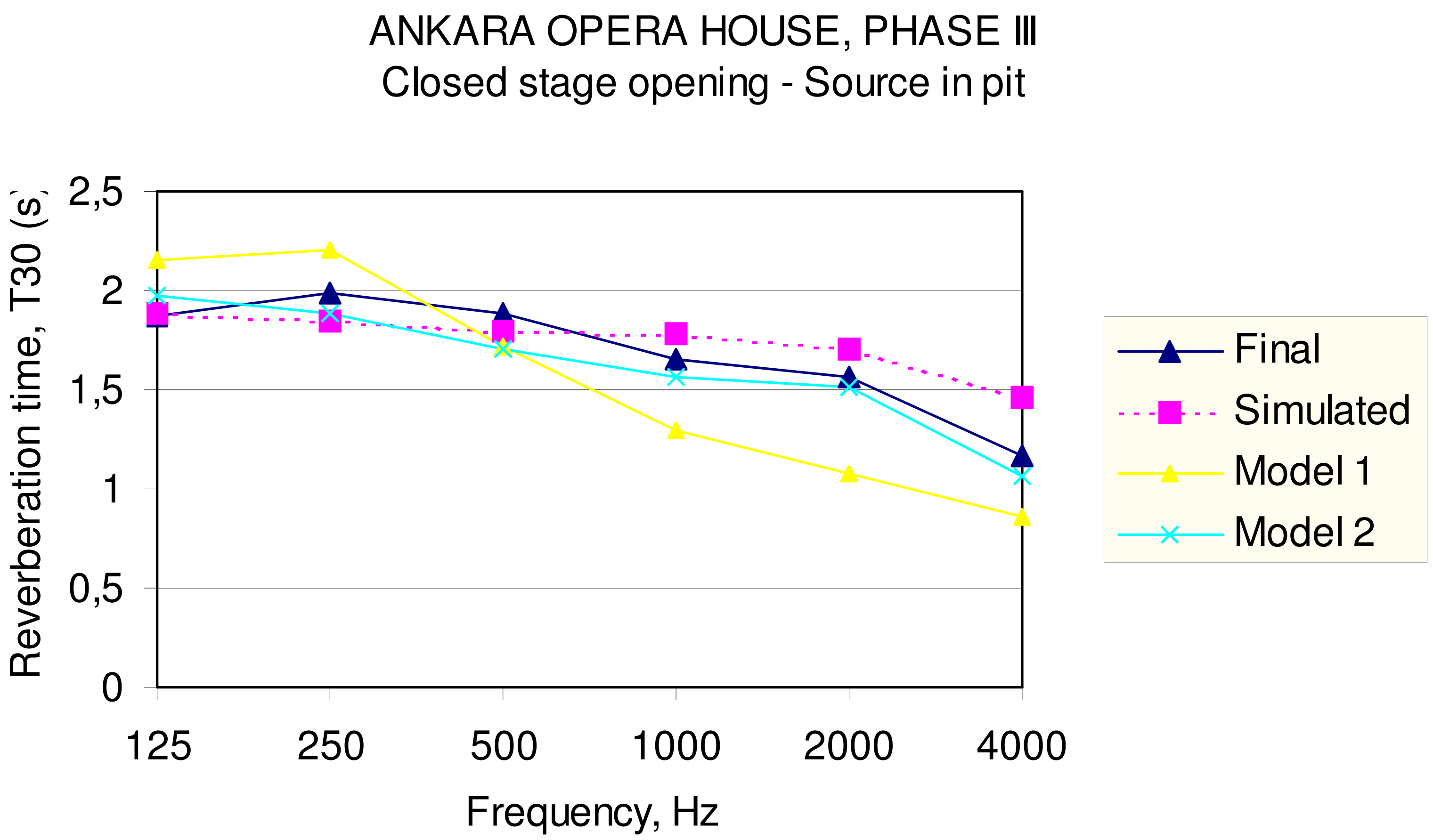
Absorption of model audience

Audience on occupied chairs, medium upholstered

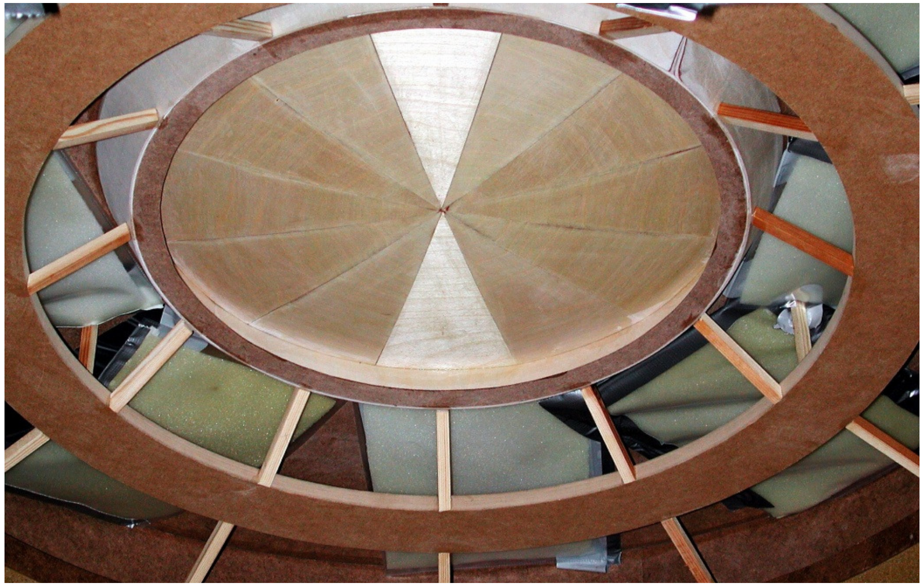


Ref: Beranek & Hidaka, J. Acoust. Soc. Am., Vol. 104, No. 6. 1998

Adjustment of absorption



Adjustment of absorption



Low frequency absorption added

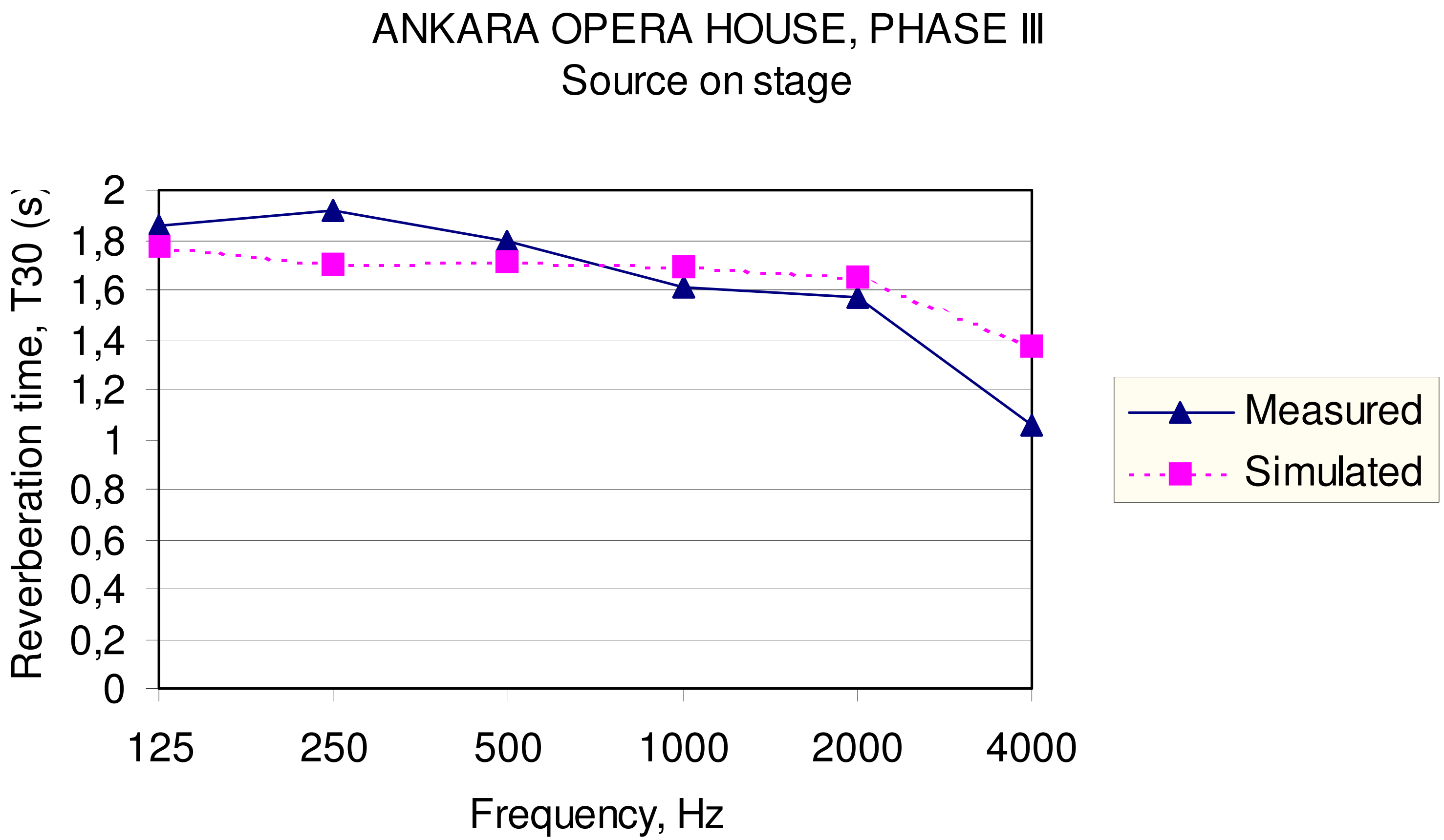
Ceiling in the auditorium with additional absorption

- Principle: To obtain the correct reverberation time in the relevant frequency range, although the contribution from air attenuation is higher in the model than in the real hall

Adjustment of scattering

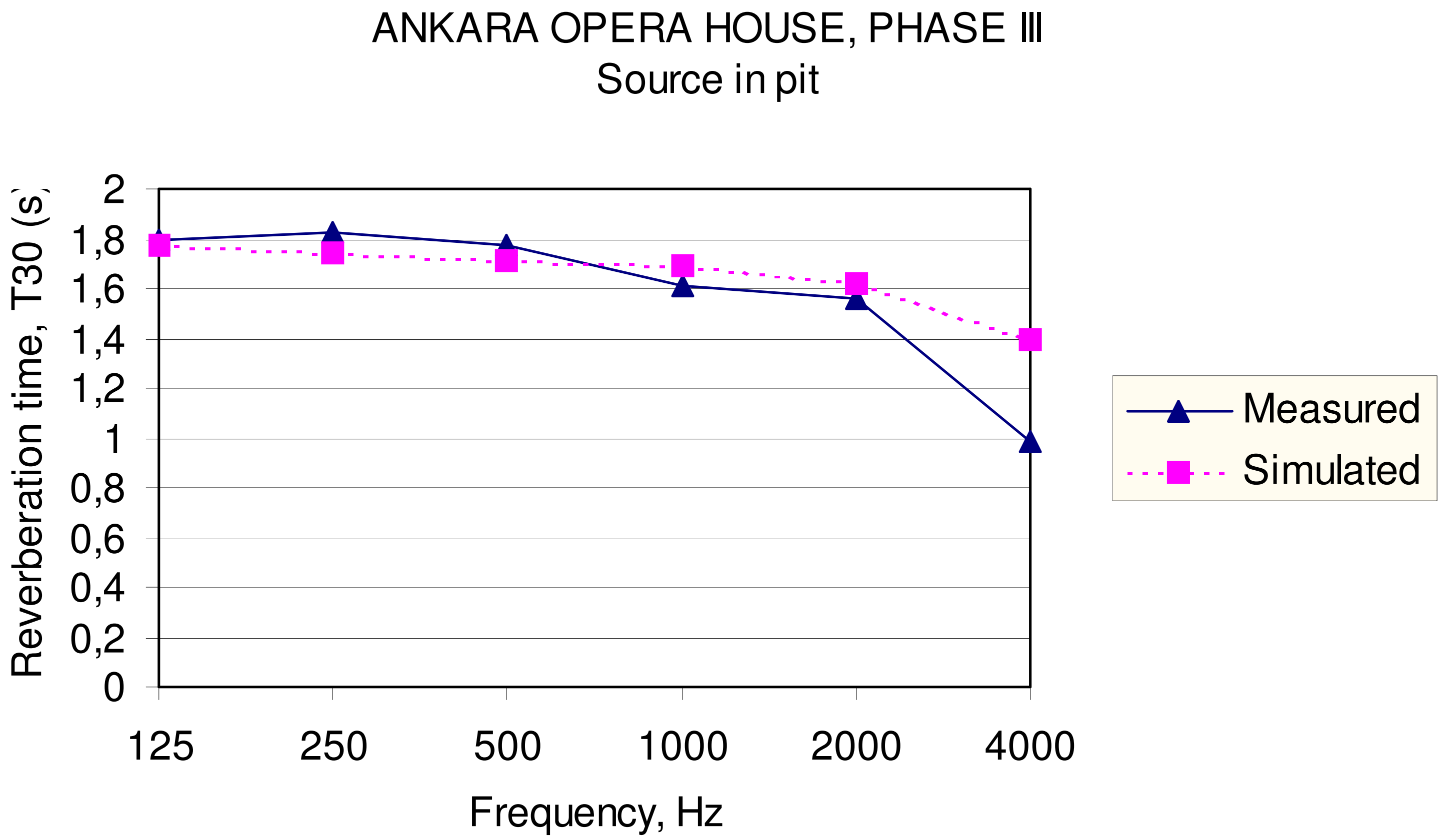
Wrinkled foil attached to the walls to represent a diffusing treatment

RT – Source on stage



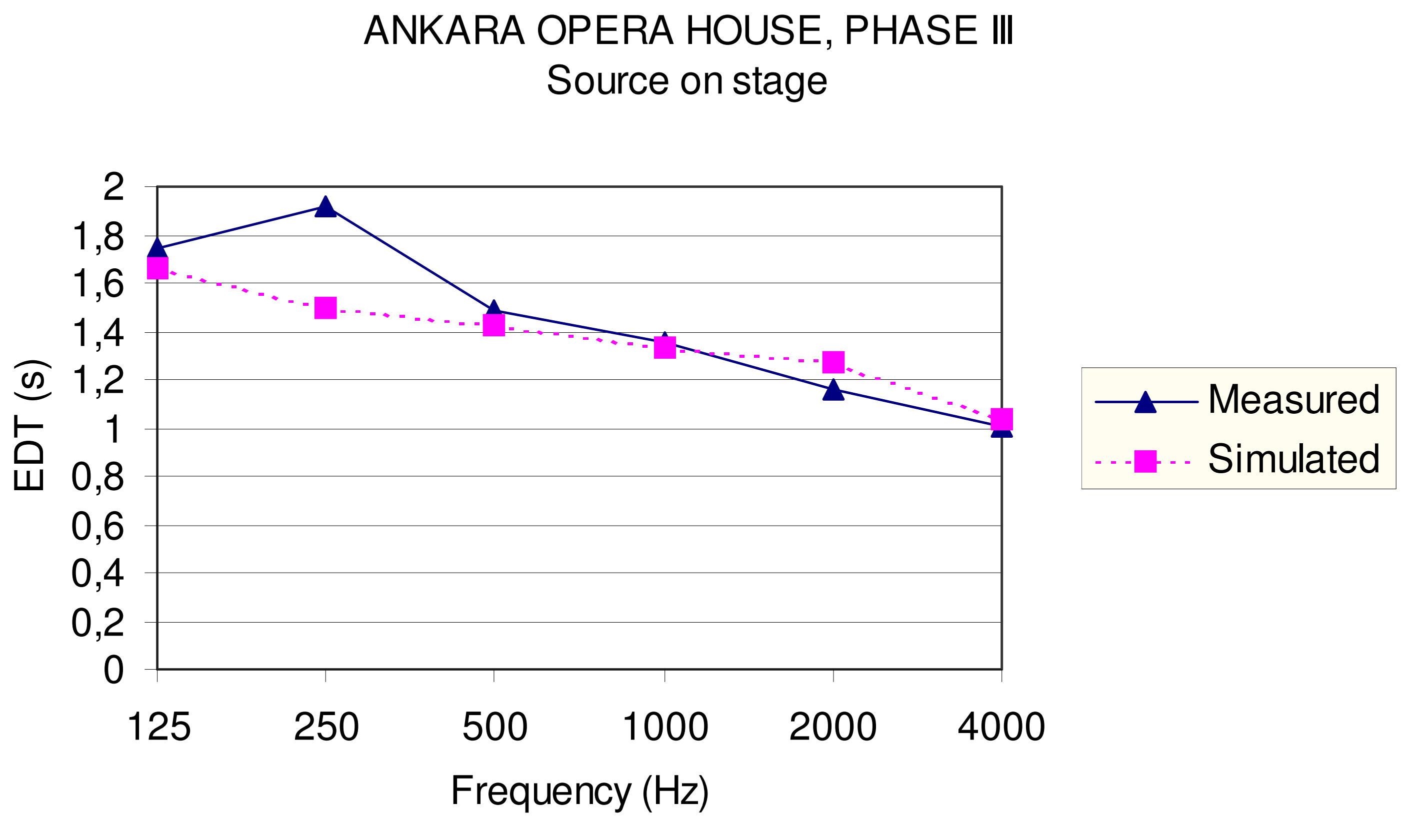
Average of 7 receiver positions

RT – Source in pit



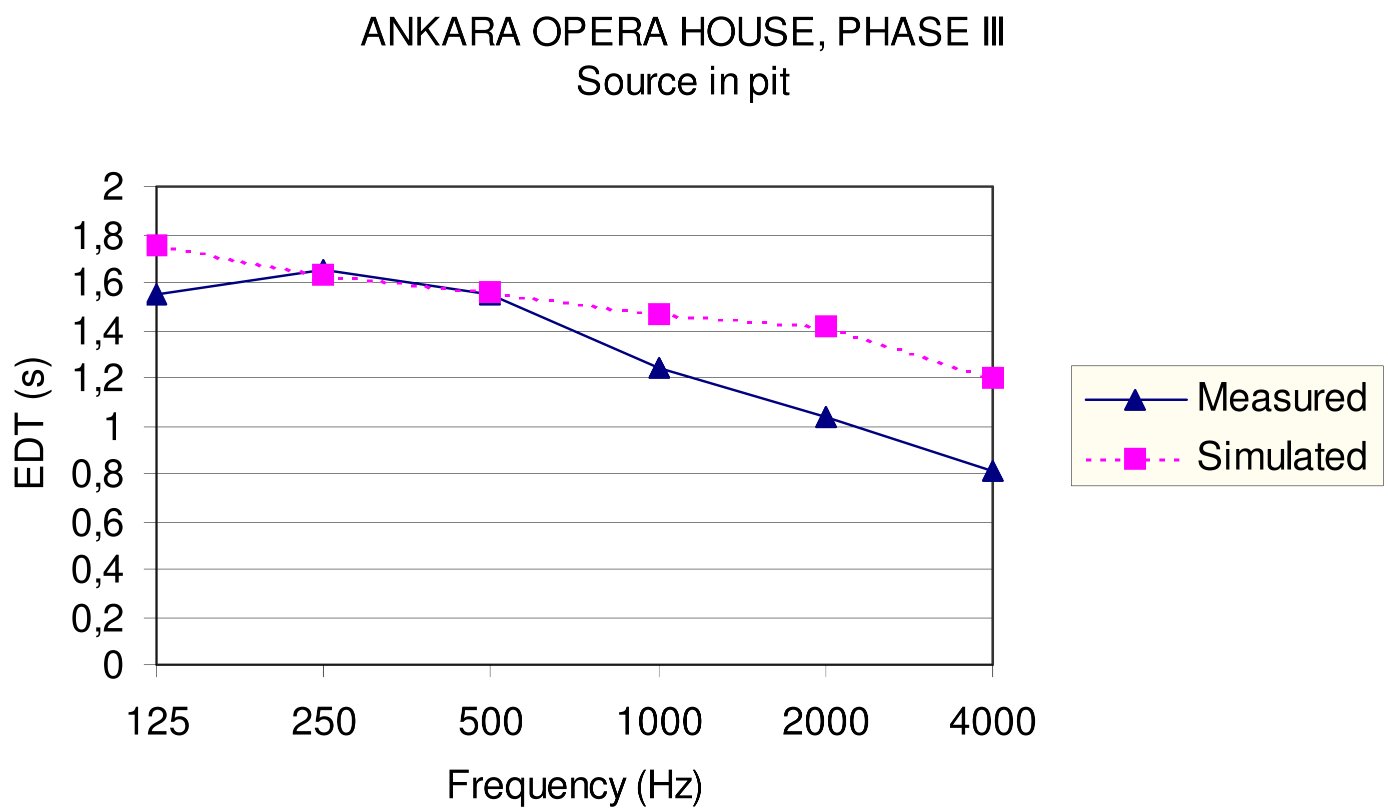
Average of 7 receiver positions

EDT – Source on stage



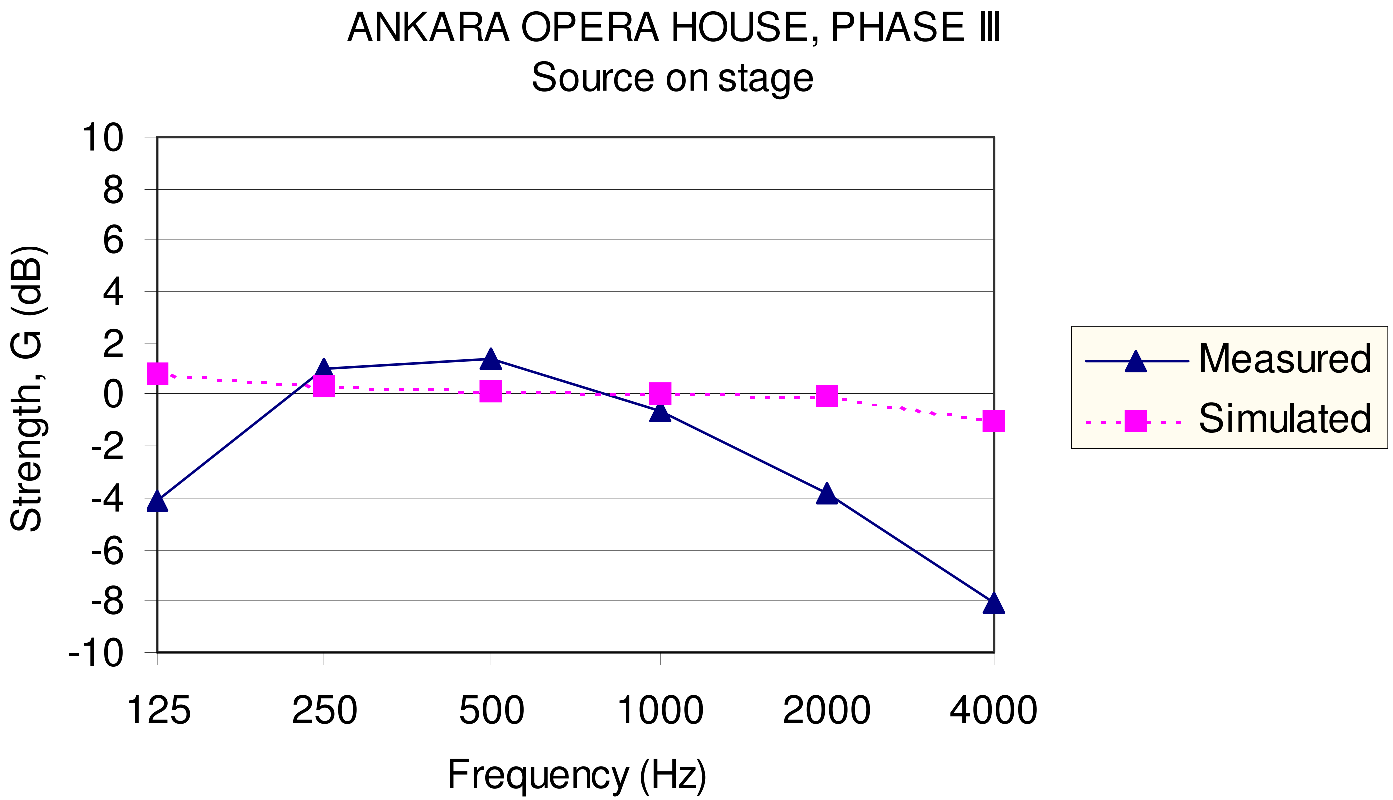
Average of 7 receiver positions

EDT – Source in pit



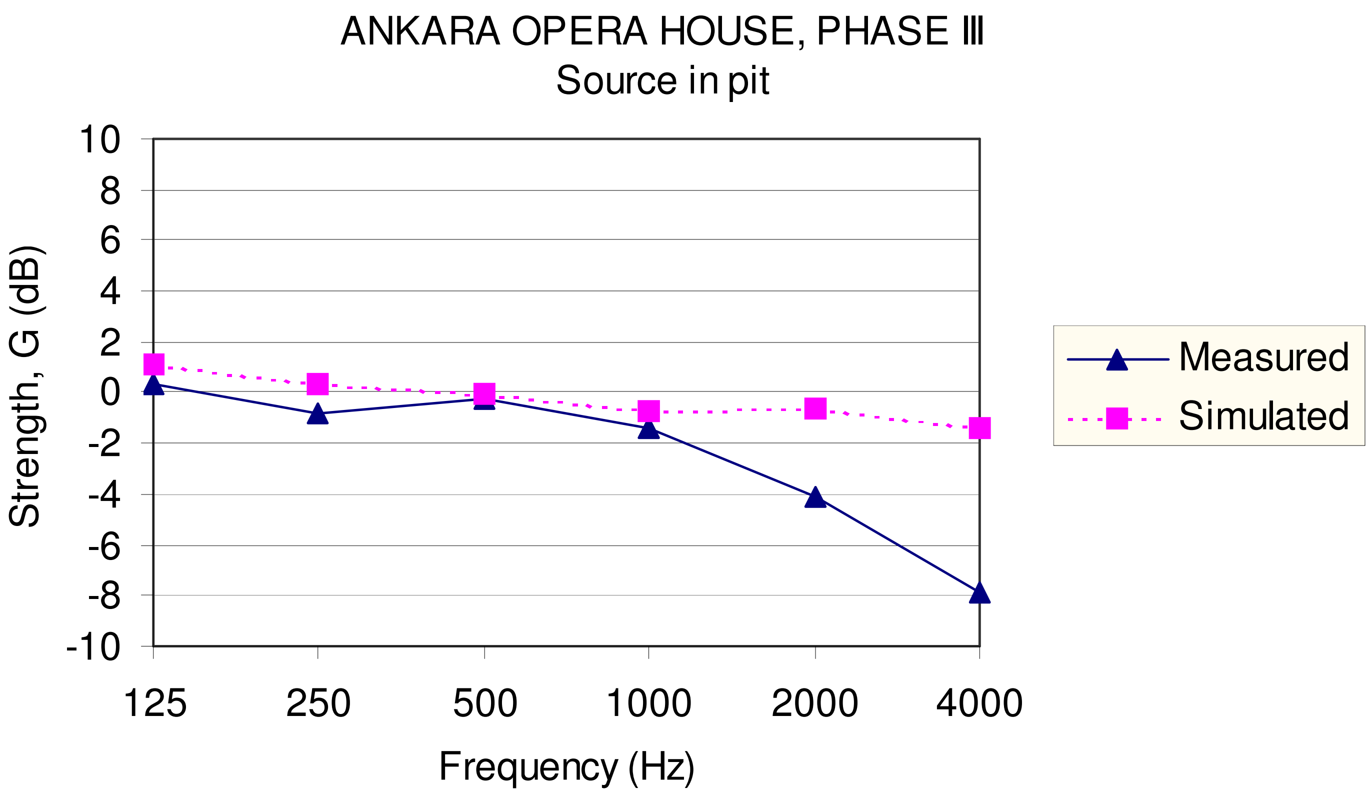
Average of 7 receiver positions

G – Source on stage



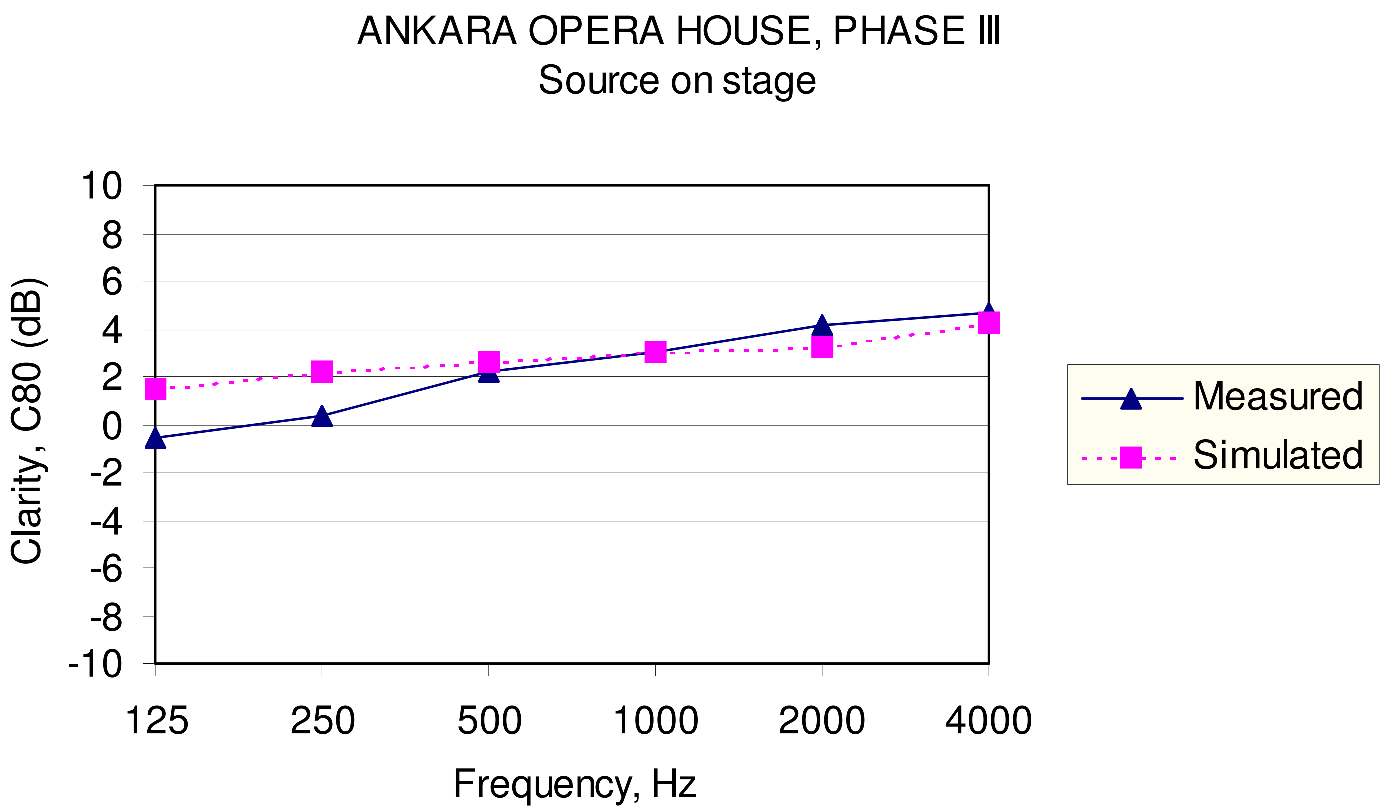
Average of 7 receiver positions

G – Source in pit



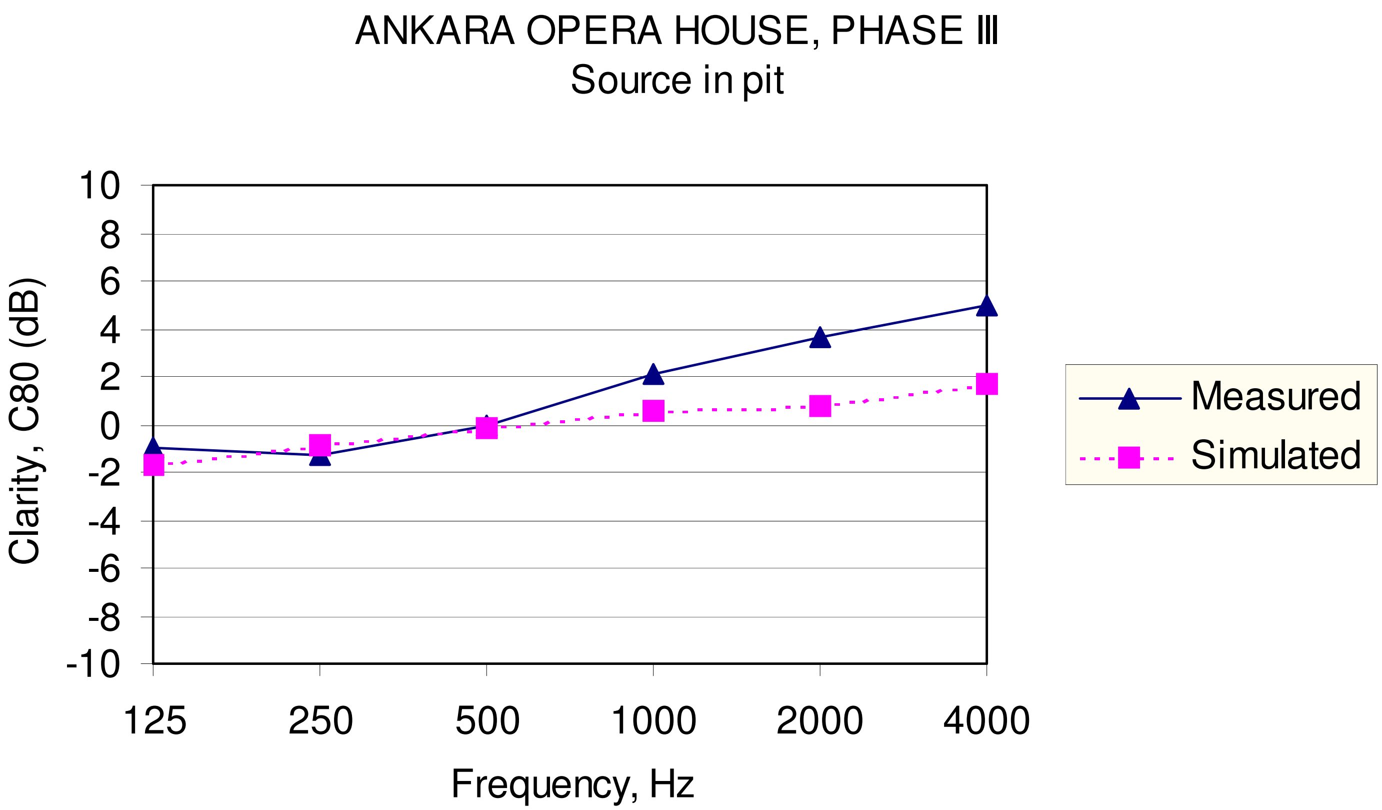
Average of 7 receiver positions

C80 – Source on stage



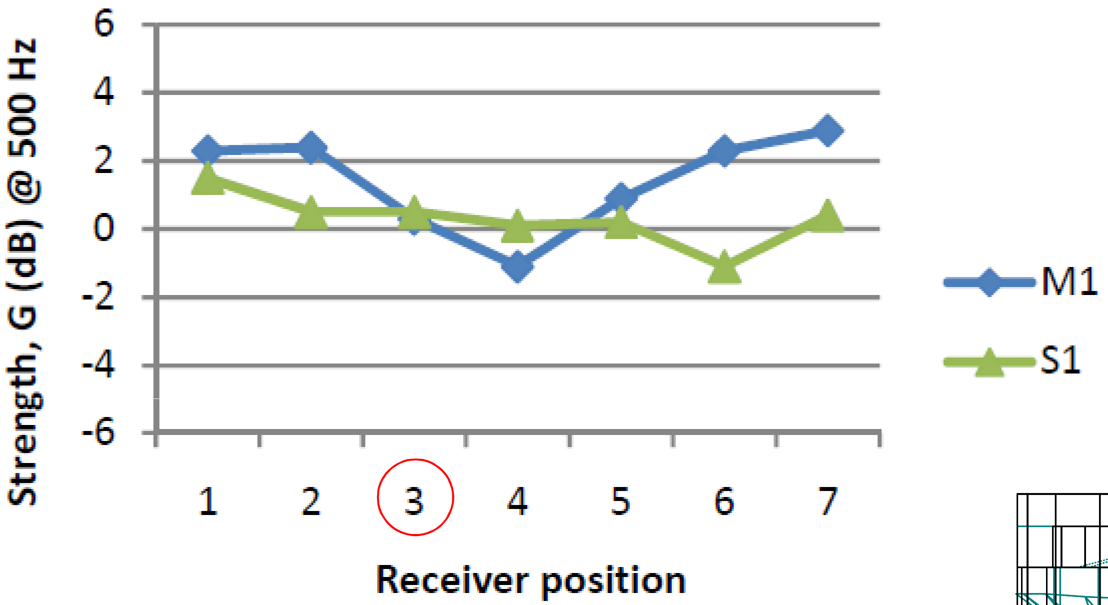
Average of 7 receiver positions

C80 – Source in pit

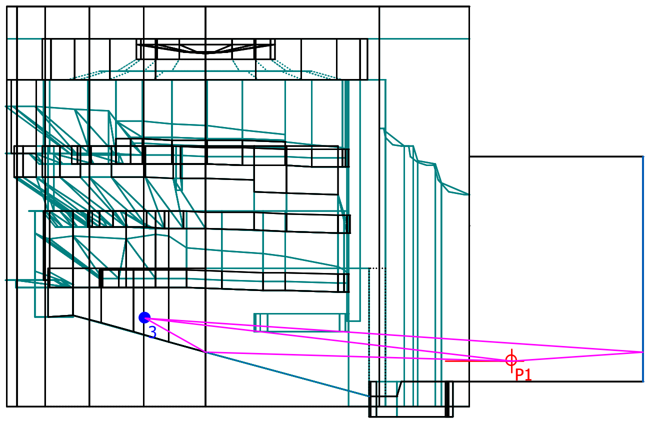


Average of 7 receiver positions

Comparison of methods

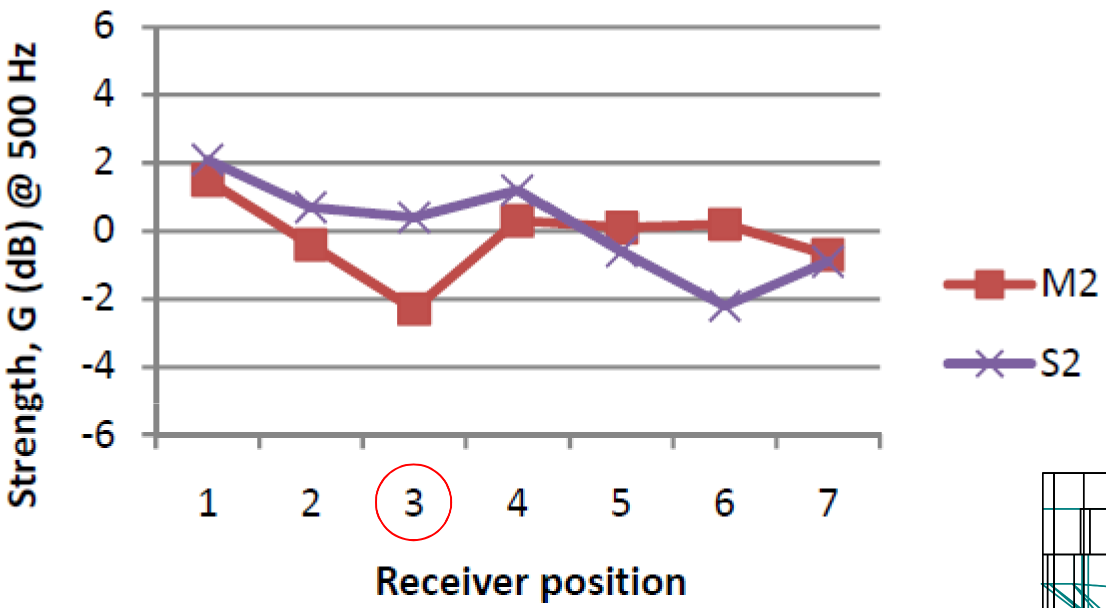


Source on stage

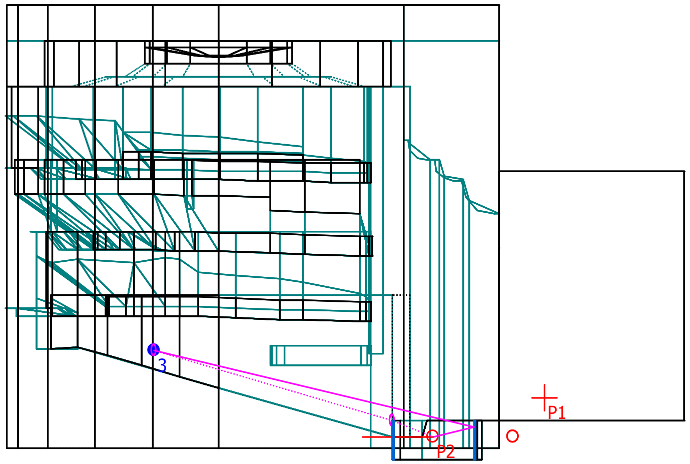


Receiver 3:
Sound propagation elevated over audience surface, no attenuation of direct sound
Reflection from audience surface

Comparison of methods

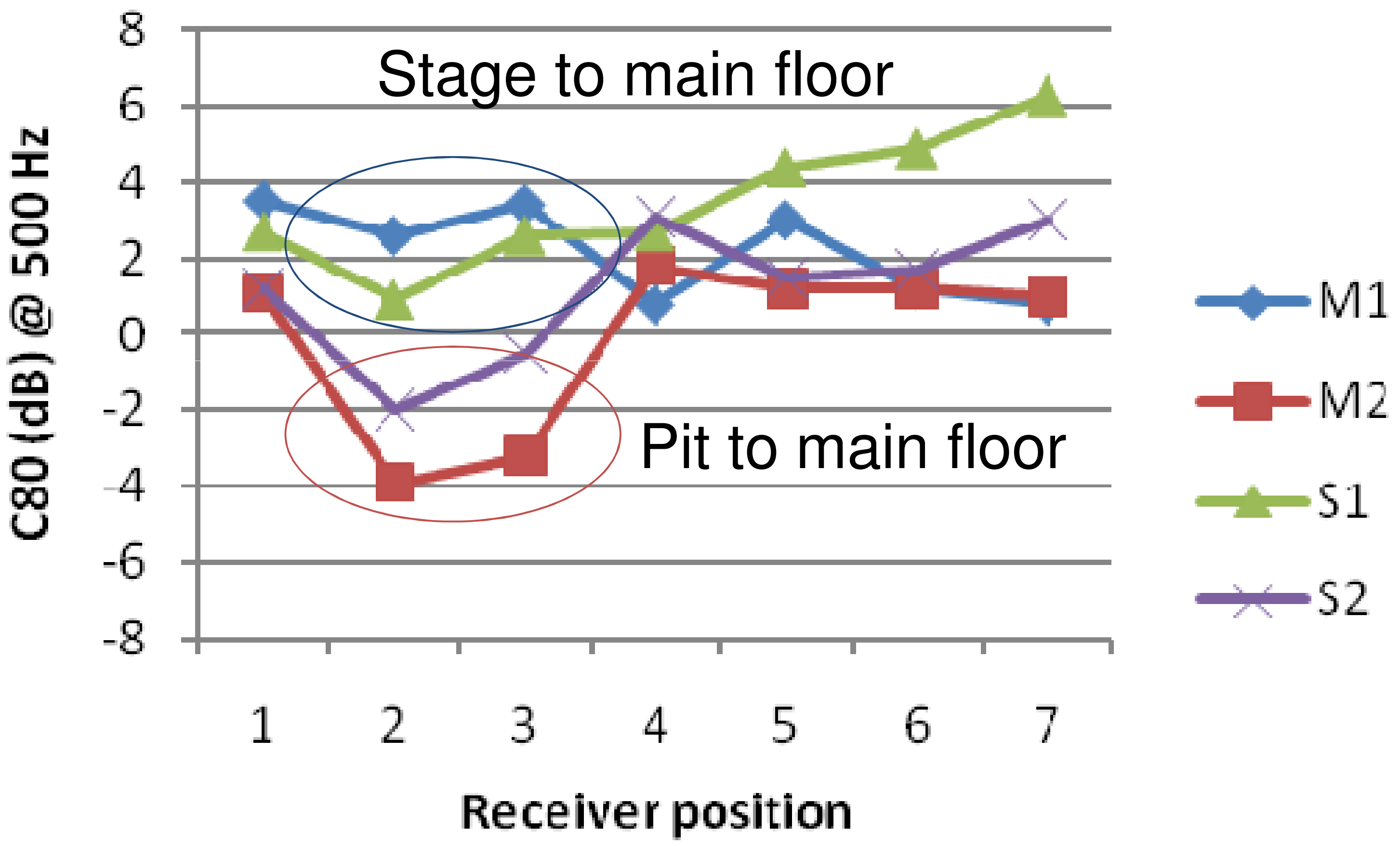


Source in pit



Receiver 3:
Sound propagation close to audience surface (attenuation missing in simulation)
No direct sound; Diffraction across pit wall (Odeon ver. 10)

C80 – comparison of methods



Discussion - 1

	Scale model	Computer model
Room model detailing	High degree of detail possible (but expensive)	Simplified geometry preferred High degree of detail possible
Materials	Absorption approximated	Absorption data accurate (if available)
Scattering	Included with detailed modelling	Scattering coefficients assigned to surfaces with simplified details
Diffraction	Included	Approximated or missing in some cases
Attenuation of sound propagating across audience area	Included with detailed modelling of audience	Not included (yet)

Discussion - 2

	Scale model	Computer model
Air attenuation	Compensation needed (less abs. in materials or impulse response boosted)	Accurate (calc. from temperature and RH)
Frequency range	Limited at low and high frequencies	Full audio range
Reverberation time	Used for calibration. Absorption of materials adjusted to meet expected RT	Predicted by simulation
EDT, G, C80 …	From measured impulse response	From calculated impulse response
LF, IACC	Special miniature transducers needed	From calculated impulse response (3D)

Discussion - 3

	Scale model	Computer model
Auralisation	Quality limited by transducers	High quality possible. Any HRTF may be applied
Reproduction through loudspeakers	Not possible	Ambisonics or n-channel surround
Sources with special directivity (musical instruments)	Possible, but difficult	Possible. Application of directivity data or multi-channel auralisation
3D analysis of early reflections	Possible with laser beam and light-reflecting surfaces	Easy, coupled to reflectogram

Discussion - 4

	Scale model	Computer model
Echo and flutterecho detection	Inspection of impulse response	Inspection of impulse response. Auralisation of impulsive sound
Colouration	Not possible	Possible with high quality auralisation
Detection of weak spots in the audience area	Not realistic to cover all seats by measurements	Possible through grid mapping of all parameters
Grid mapping of results	Not possible	High resolution grids possible (long calculation time)

Conclusion

- Both methods have weaknesses and advantages
- Results: No big difference between measured and simulated room acoustic parameters
- Main problems in scale models:
  - Transducers (directive sources, dummy head)
  - Auralisation with sufficient quality
- Main problems in computer models
  - Data for scattering surfaces; can be measured in scale model reverberation chamber (ISO 17497-1)
  - Simulation of the attenuation of sound propagation across the audience area