La Philharmonie de Paris – Acoustic Scale Model Study

MARSHALL DAY Acoustics · Limsi · KahleAcoustics

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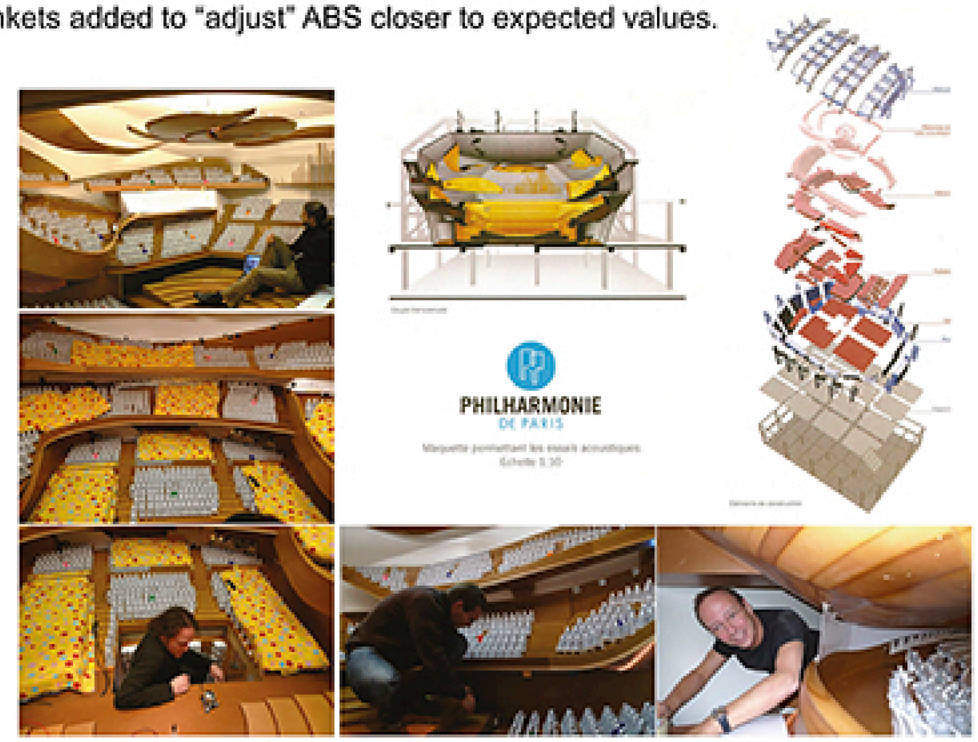
Design Overview & Test Objectives

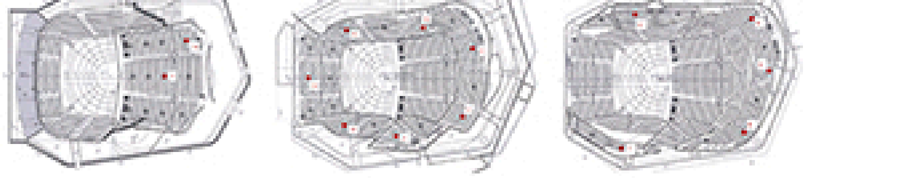
- Design brief for a 2400 seat concert hall demanding:
  - "innovation and modernity in concert hall design"
  - "acoustic design should not be conservative and rigidly attached to conventions"
- Importance for both ***clarity*** and ***reverberance***, leading to some form of interconnected volume design.
- Proposed design by architect Jean Nouvel and acoustician Harold Marshall was far from conventional.
- A Scale Model study was included in the "toolbox" of the design team to refine the details of the design over the course of the project.
- The scale model results were required to:
  - Aid in the calibration of the computer simulation model
  - Investigate the acoustic coupling between the inner and outer volumes
  - Determine if the design would achieve the acoustic goals

Philharmonie de Paris 1:10

- Scale model constructed in varnished laminated wood
- Designed air-tight for Nitrogen testing (used by other testing team)
- Coupling areas were varied by installing semi-rigid plastic plaques
  - Based on the 3D computer model
  - Modify coupling areas between 1st & 2nd balcony, 2nd balcony & ceiling
  - Coupling area were varied [0, 50, 70, 100%] of the concerned surfaces
- Blankets added to "adjust" ABS closer to expected values.

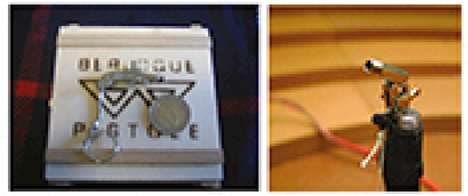


Tested receiver positions (red) from available receiver access points (gray)

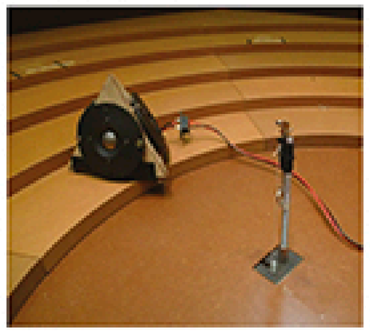


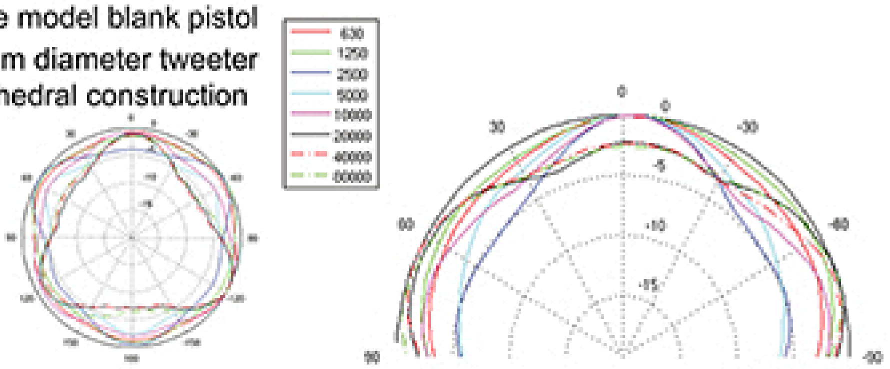
Sound sources

- Various sound sources exist for room acoustic measurements at full-scale.
- Scale model acoustical sources are often limited in sound power or performance, making high SNR measurements difficult to obtain.
- Investigation of coupling area effect requires analysis of the ***late*** RIR tail, therefore ***high*** SNR is required.
- Pro-audio Samson Servo 120a amplifier surprisingly offering only a 10 dB drop from 10 - 90 kHz
- Several sources were tested:
  - 12.5 mm diameter dome tweeter
  - Scale model blank pistol
  - 25 mm diameter tweeter tetrahedral construction



Scale-model pistol



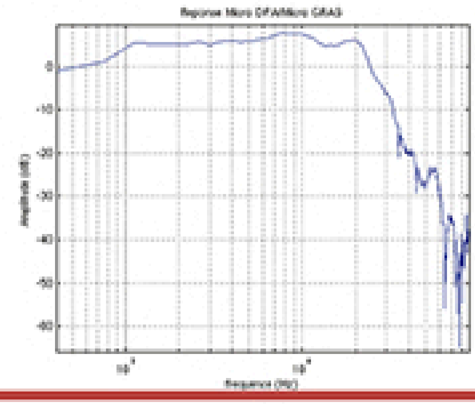


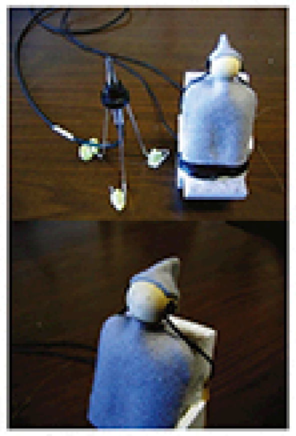
Octave band center frequency, Hz		1250	2500	5000	10000	20000	40000	
ISO permissible variations, dB (1:10 scale correspondence)		± 1	± 1	± 1	± 3	± 5	± 6	
Oct center Frequency, Hz	630	1250	2500	5000	10000	20000	40000	8000
Measured variations, dB	± 2.5	± 3	± 5	± 5	± 3	± 7	± 7	± 7

Tetrahedral-tweeter source directivity analysis rel. to ISO standard

Microphones

- Common practice has favored the use of standard measurement equipment for scale models.
- While providing very flat frequency responses, stable under many conditions, such microphones often suffer from high background noise, i.e. ***low*** SNR.
- High grade pro-audio miniature microphones (DPA 4060), combined with the pro-audio signal converters (RME, Fireface 800, 24-bit, 192kHz) have proven to be more sensitive, with higher SNR.
- For this study, a Dummy-head was made from a DPA4060 pair & wooden sphere on a scale model listener's body.





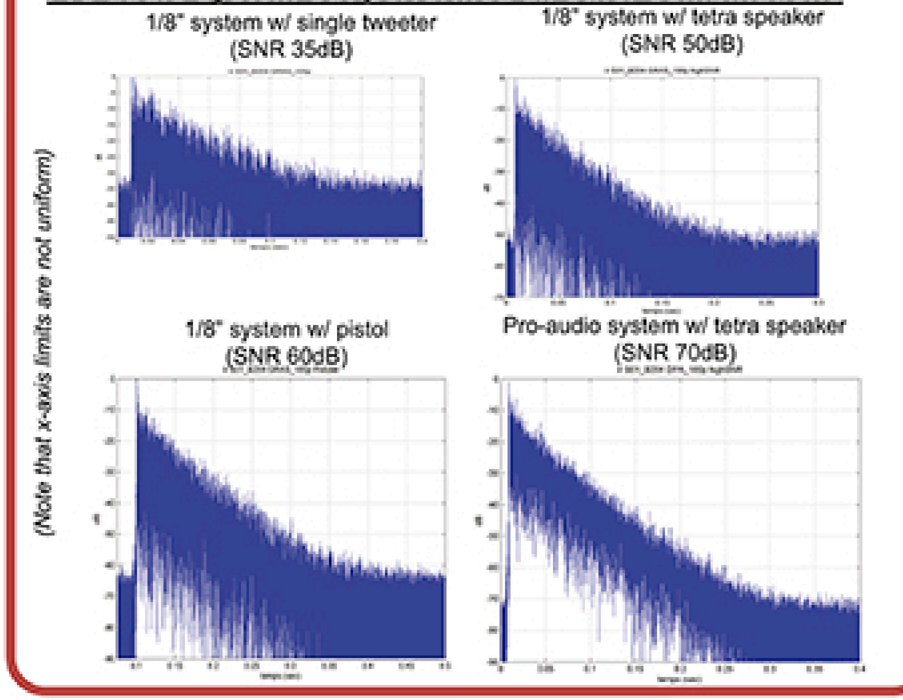
1:10 DPA Binaural head

Frequency response of Pro-audio DPA4060 compared to 1/8" diameter, GRAS 40DP

30dB down at 60kHz

Signal-to-Noise Gains

- Stimuli: 0.5 sec log sweep, 500 Hz - 90 kHz. 20 repetitions, time aligned and averaged
- ***Pro-audio system out-performed all other combinations***



Acoustic Design Results

Summary results at mid-freq. (average of 500 Hz and 1 kHz).
Symphony mode config. For stage risers and reflector "clouds"

Acoustic Parameter	Brief for Symphony Mode	1:10 Scale Model Semi-Occupied room & bare stage
RT - Occ. with orchestra	Mean 2.2 – 2.3 s	2.67 s
C80	Unoccupied –3 to 0 dB	–0.1 dB
G	Unoccupied 3 – 6 dB	3.5 dB
G_{late}	Unoccupied 0 to –4 dB	0.41 dB
G_{early} (80ms)	Unoccupied –2 to +2 dB	0.34 dB
1-IACC[E, mid]	Unoccupied Mean > 0.55 > 0.50 for at least 80% seats	Mean 0.71 >0.50 for 87% of seats measured

Summary results at mid-freq. for different coupling area conditions

	Coupling opening condition: All open	50% Closed	70% Closed	100% Closed
RT inner vol.	2.65 s	2.61 s	2.56 s	2.37 s
RT outer vol.	2.78 s	2.82 s	3.08 s	3.53 s
G	3.5 dB	3.5 dB	3.6 dB	3.3 dB
G_{late}	0.41 dB	0.37 dB	0.09 dB	–0.05 dB
G_{early}	0.34 dB	0.38 dB	0.79 dB	0.20 dB
C80	–0.1 dB	0 dB	0.7 dB	0.2 dB

- Results of these measurements :
  - Derivation of the objective parameters as specified in the Acoustic Brief.
  - Verification that the design functions as intended in the Acoustic Brief.
  - Determination of the appropriate balance between inner/outer volumes, coupling opening and absorption.
  - Comparison and validation of the design team's computer simulations.
- Due to the ABS conditions of the model, many other studies were performed in numerical simulations.
- **The final constructed hall is a result of numerous design iterations, for which the scale model was a significant one.**