Using a Spherical Microphone Array to Analyze Stage Acoustics

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Stage Acoustics: Precedents

- A.C. Gade (1981,1982,1989)
  - ST1, EDT
- Jens Jorgen Dammerud (2010)
  - G, H/W
- Yann Jurkiewicz (2005)
  - ST1, G, EDT

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Research Goals

- Increase accuracy of measurement using real impulse responses measured with spherical microphone array
- Increase accuracy of reproduction using 2nd-order ambisonic decoding

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Research Goals

- Build and validate spherical microphone array for 2nd-order ambisonics
- Record onstage impulse responses in multiple venues
- Analyze impulse responses for possible stage acoustic parameters

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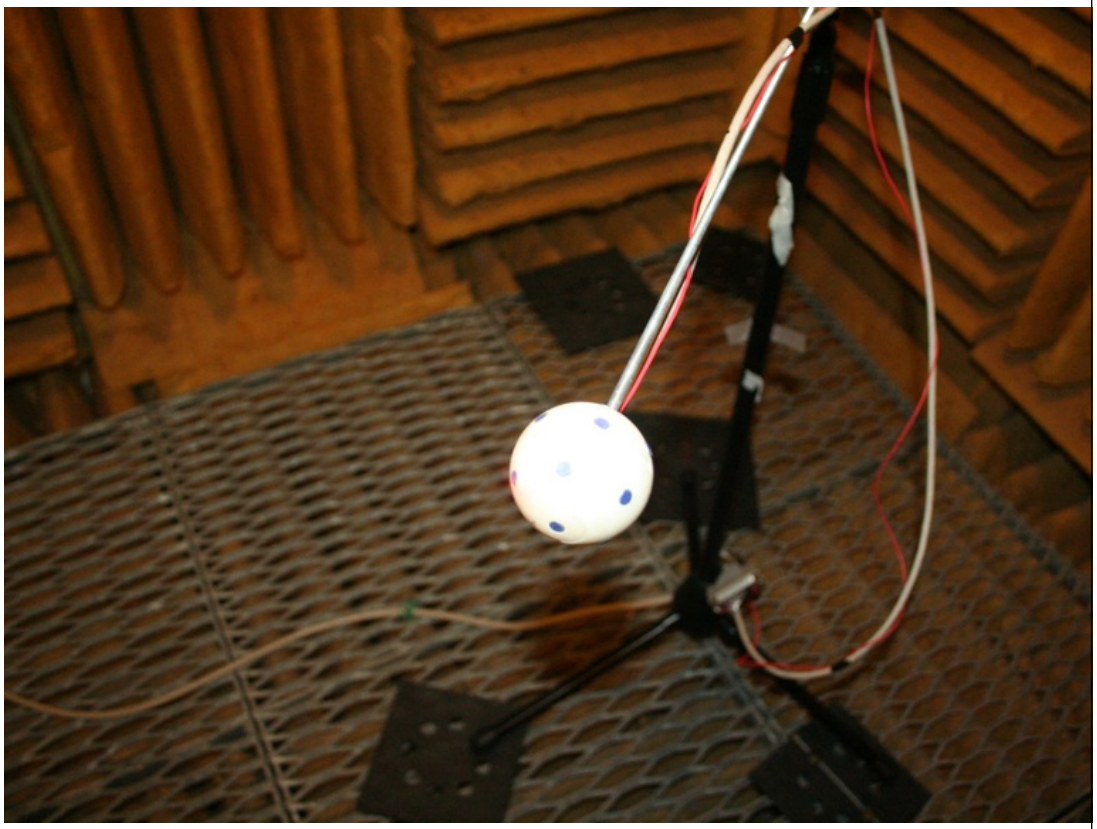
Building the Microphone

- 3D Rapid-prototype for shell
- Panasonic omnidirectional capsules



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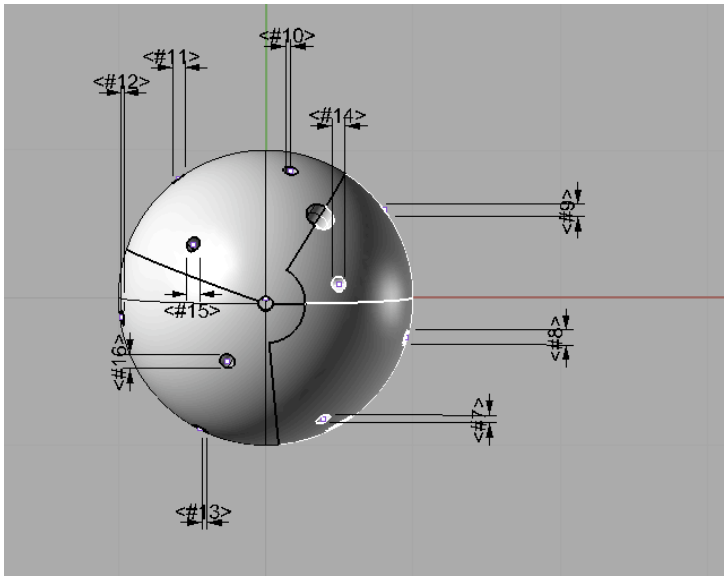
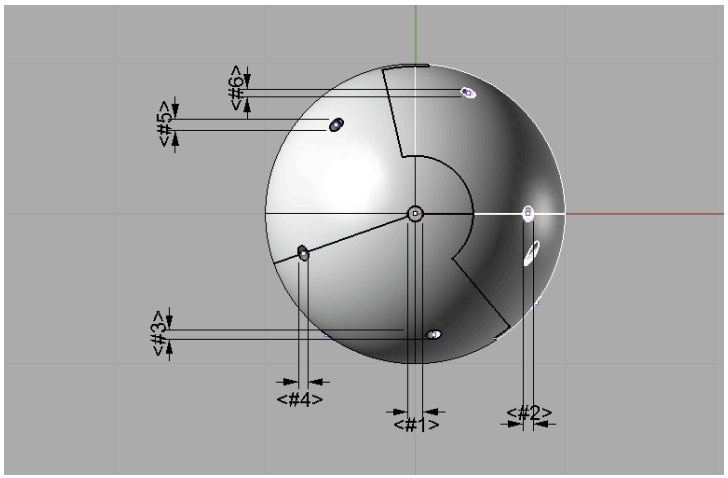
Designing the Microphone

- 2nd Order – 9 harmonics
- Sampling types:
  - Gaussian: $2(N+1)^2$
  - Equiangle: $4(N+1)^2$
  - Nearly Uniform: flexible, approx $1.5(N+1)^2$
- Jörg Fliege – A Two-Stage Approach for Computing Cubature Formulae for the Sphere
- 16 nearly-equally-spaced nodes with α weights
- Sphere radius determined by aliasing frequency





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Spatial Fourier Transform

- B. Rafaely, Z. Li, R. Duraiswami, S. Moreau et al.
- Decompose sampled soundfield into orthogonal components (spherical harmonics), combine to form beam patterns

$$f_{nm} = \int_{\Omega \in S^2} f(\Omega) Y_n^{m*}(\Omega) d\Omega$$

$$Y_n^m(\theta,\phi) = \sqrt{\frac{(2n+1)(n-m)!}{4\pi(n+m)!}} P_n^m(\cos\theta) e^{im\varphi}$$

$$p_{0nm} = \mathrm{B_n}(kr) Y_n^{m*}(\Omega_0)$$

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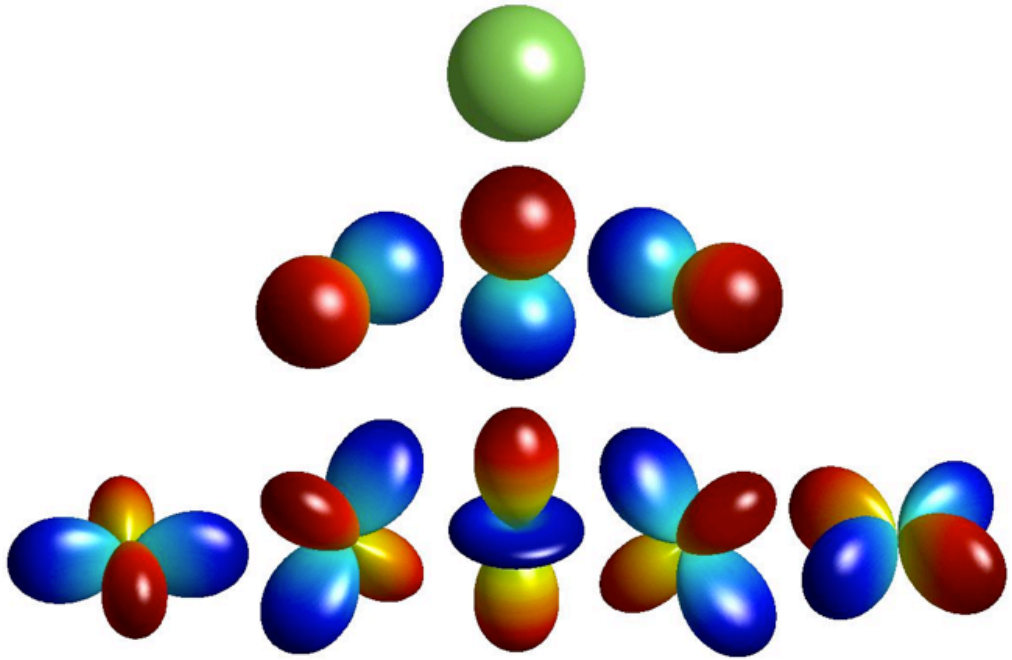
Spherical Harmonics

- For order N, $(N+1)^2$ harmonics
- 0^{th} Order
- 1^{st} Order
- 2^{nd} Order



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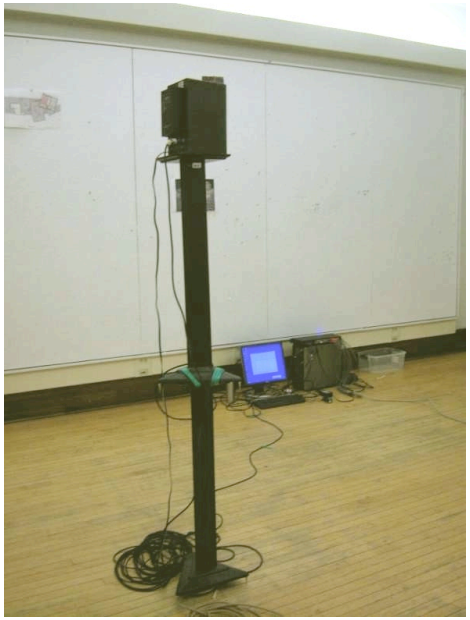
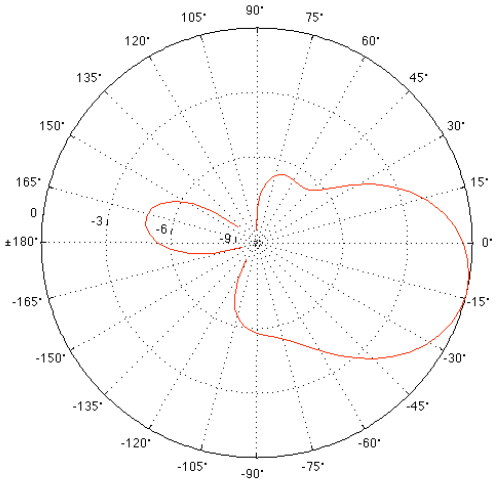
Calibrating the Microphone

- Capsules measured with shell in far field
  - 15 degree increments, 2 m from all surfaces, 2 m from source



Beam Patterns in dB (Normalized)



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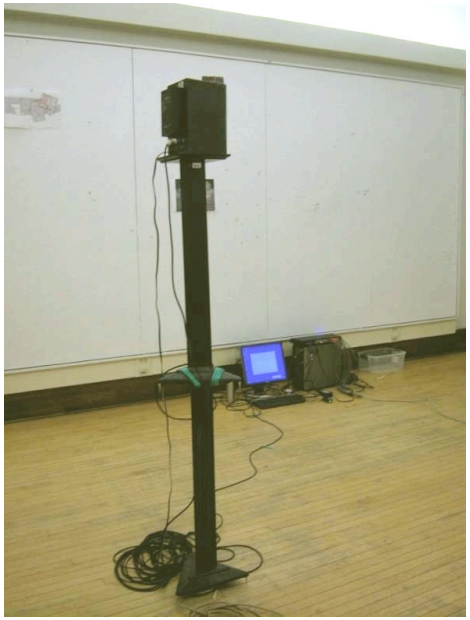

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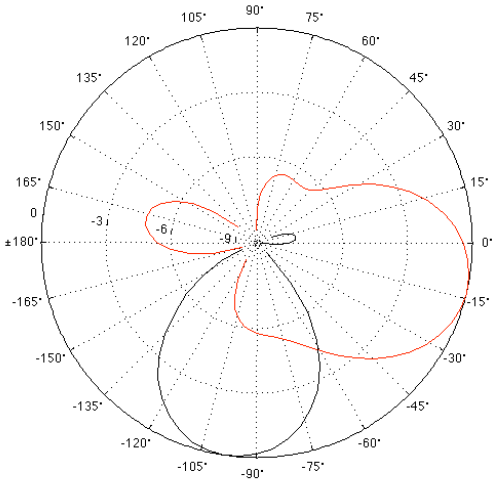

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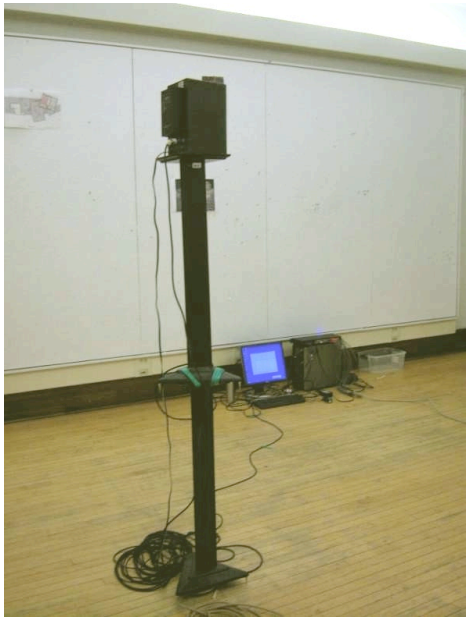

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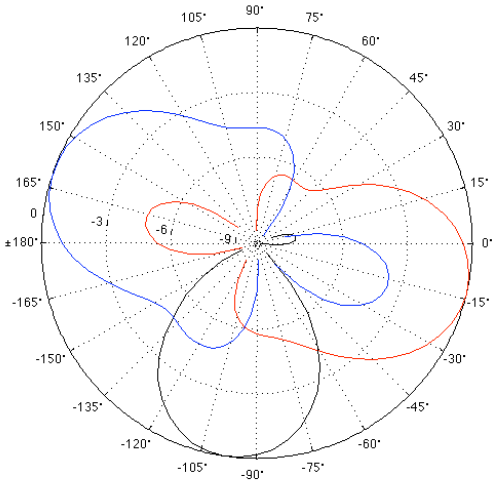

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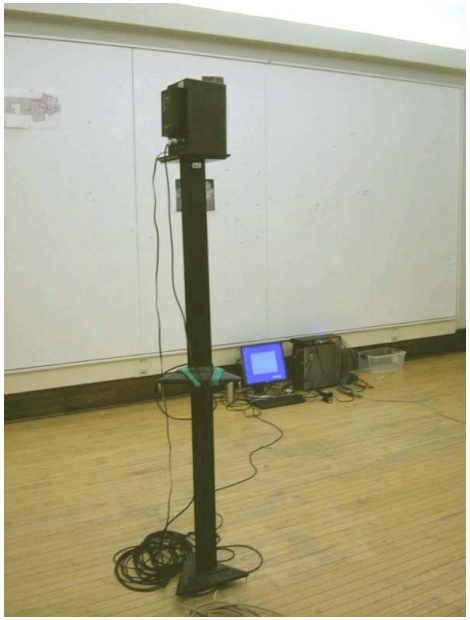

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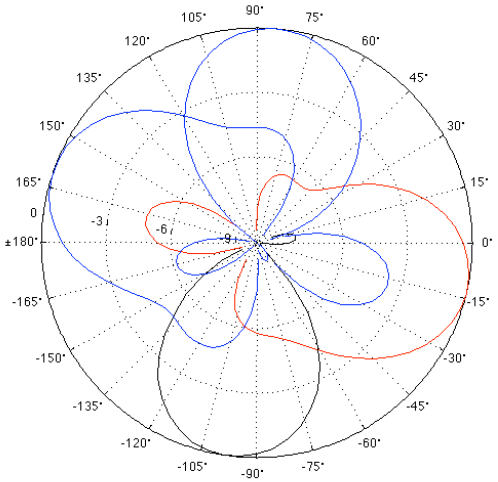

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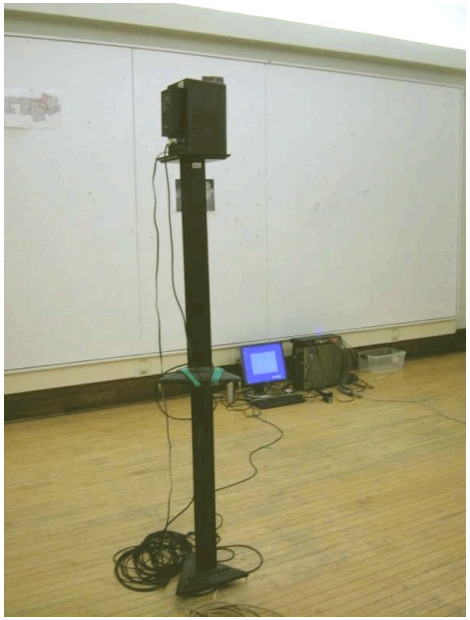

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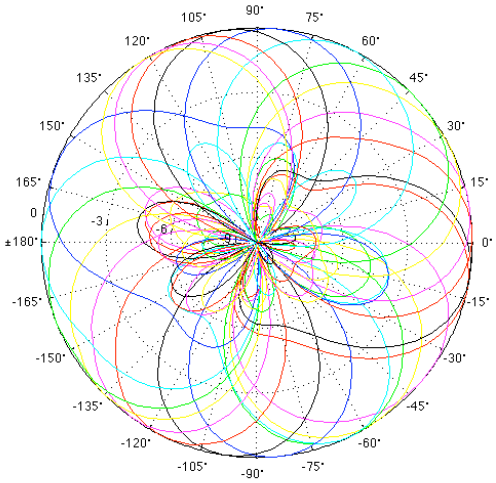
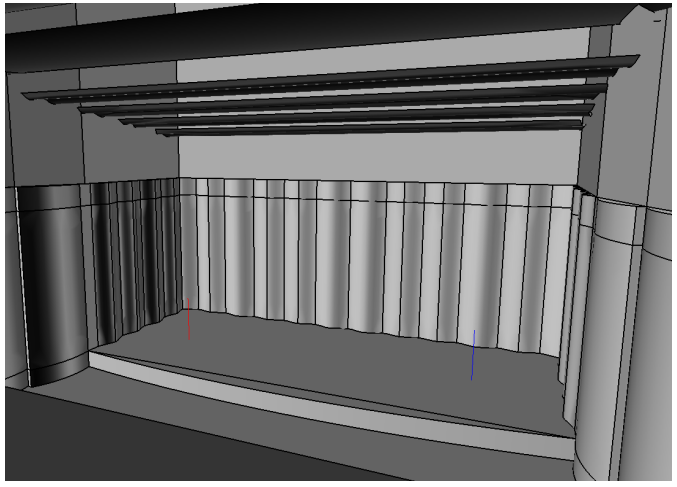


Picotte Hall, College of St. Rose (400 Seats)



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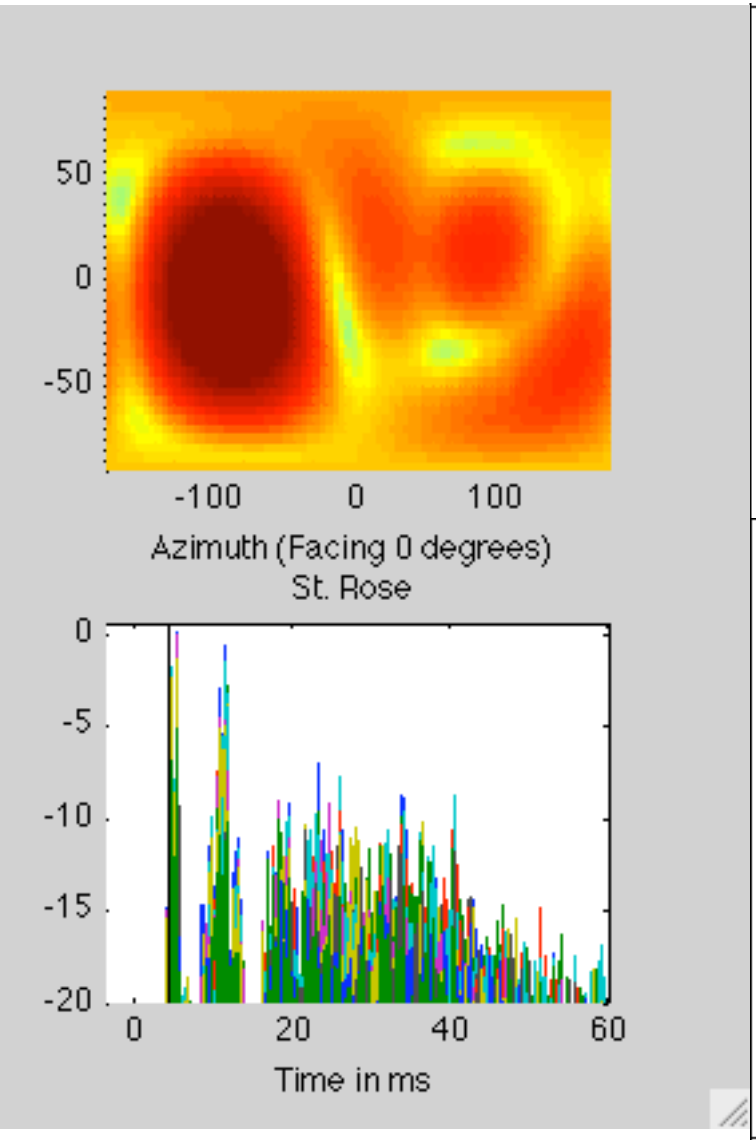
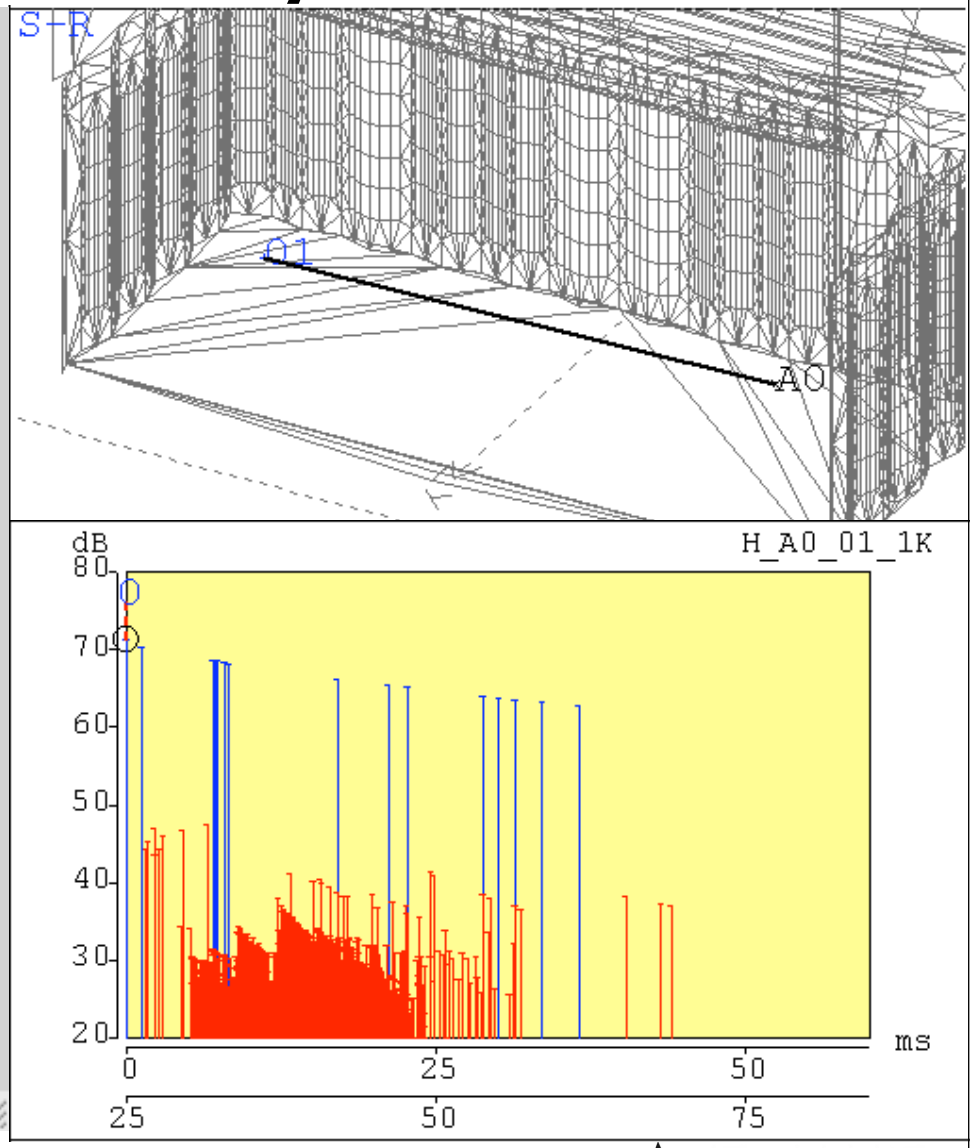
St. Rose Analysis



Measured Data



Simulated Data

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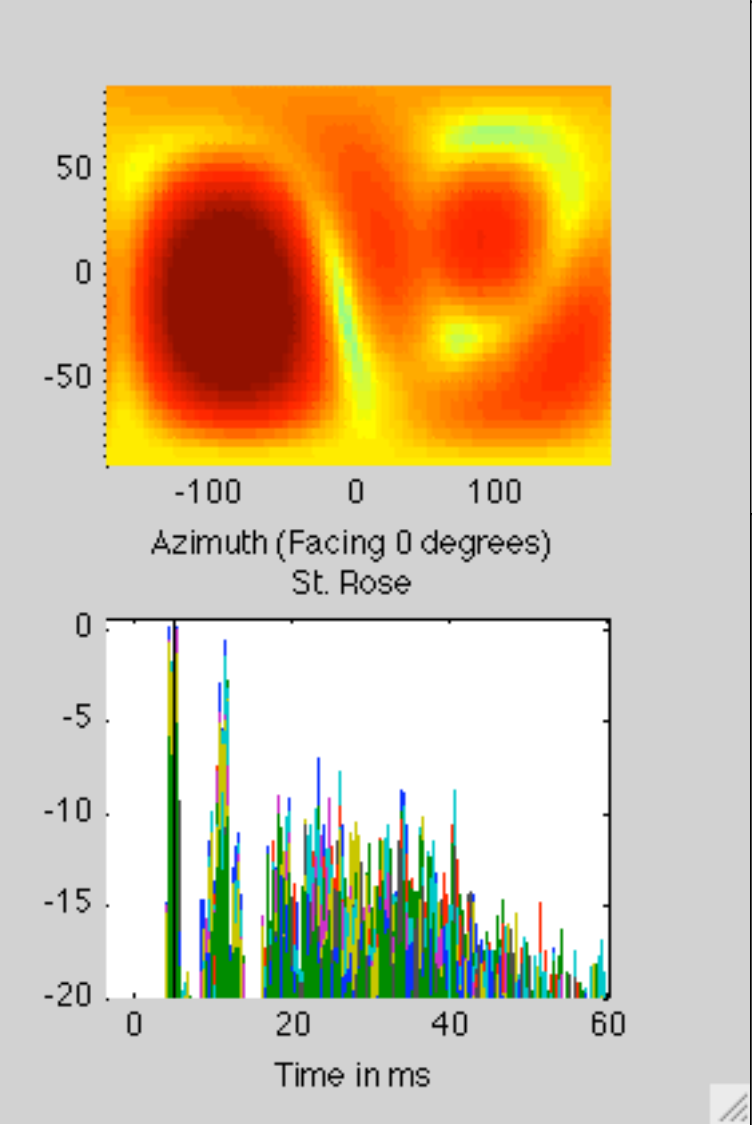

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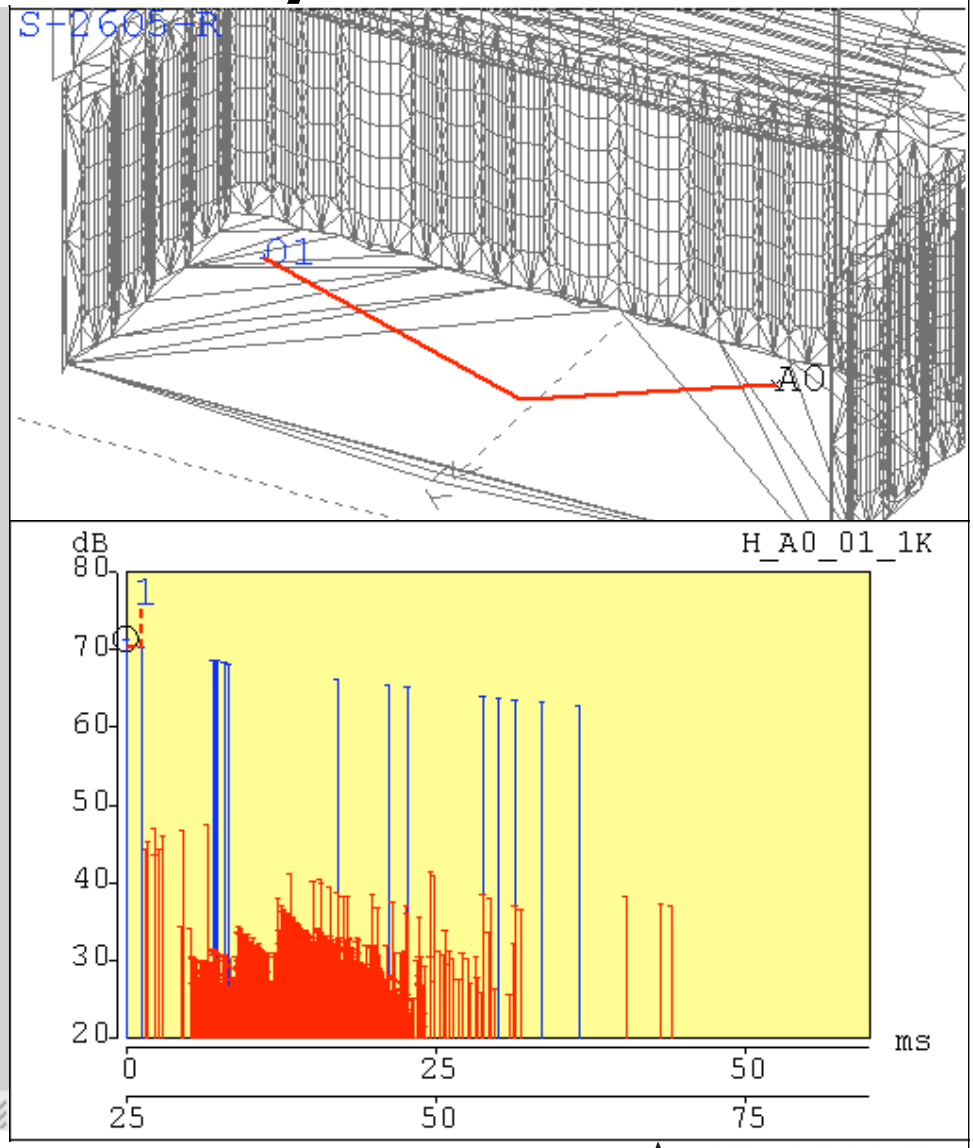

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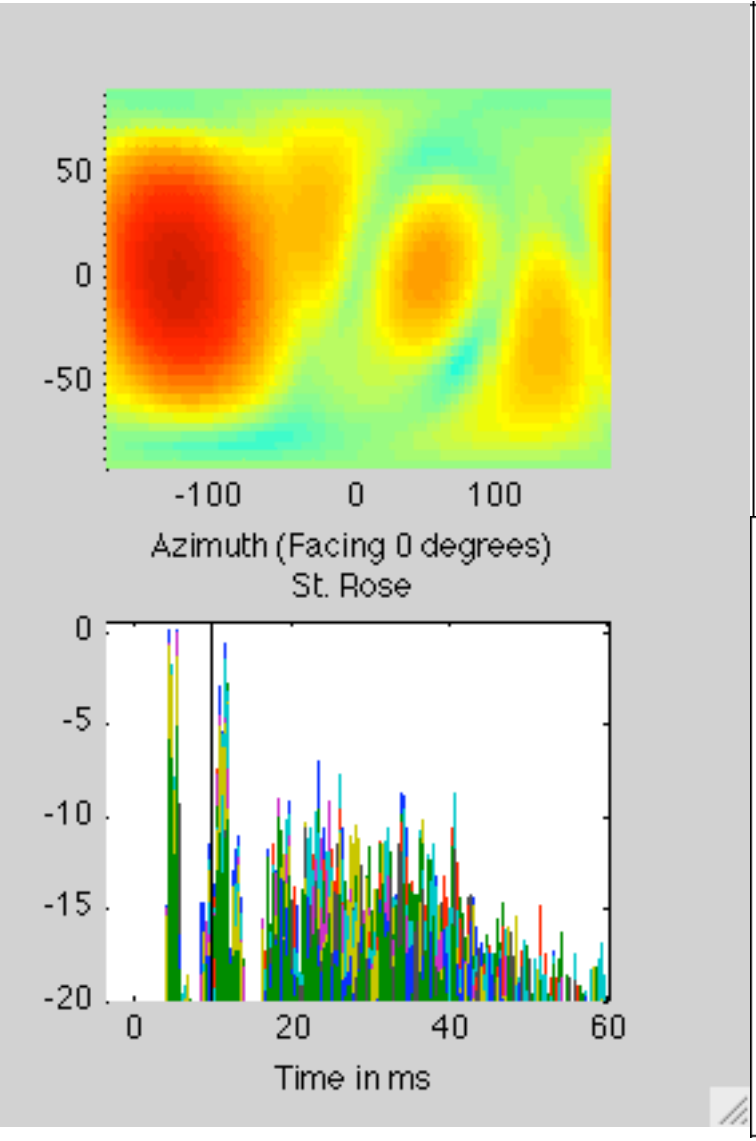

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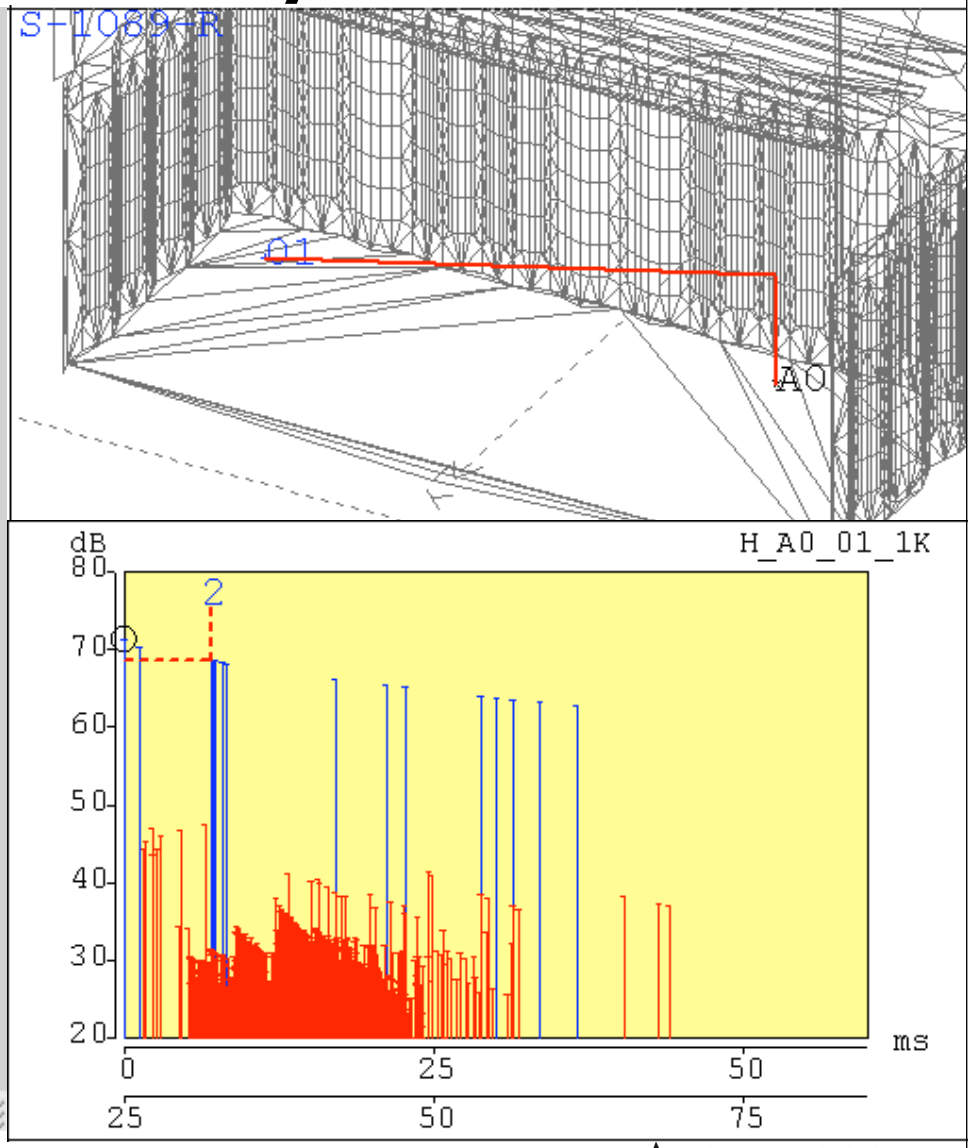

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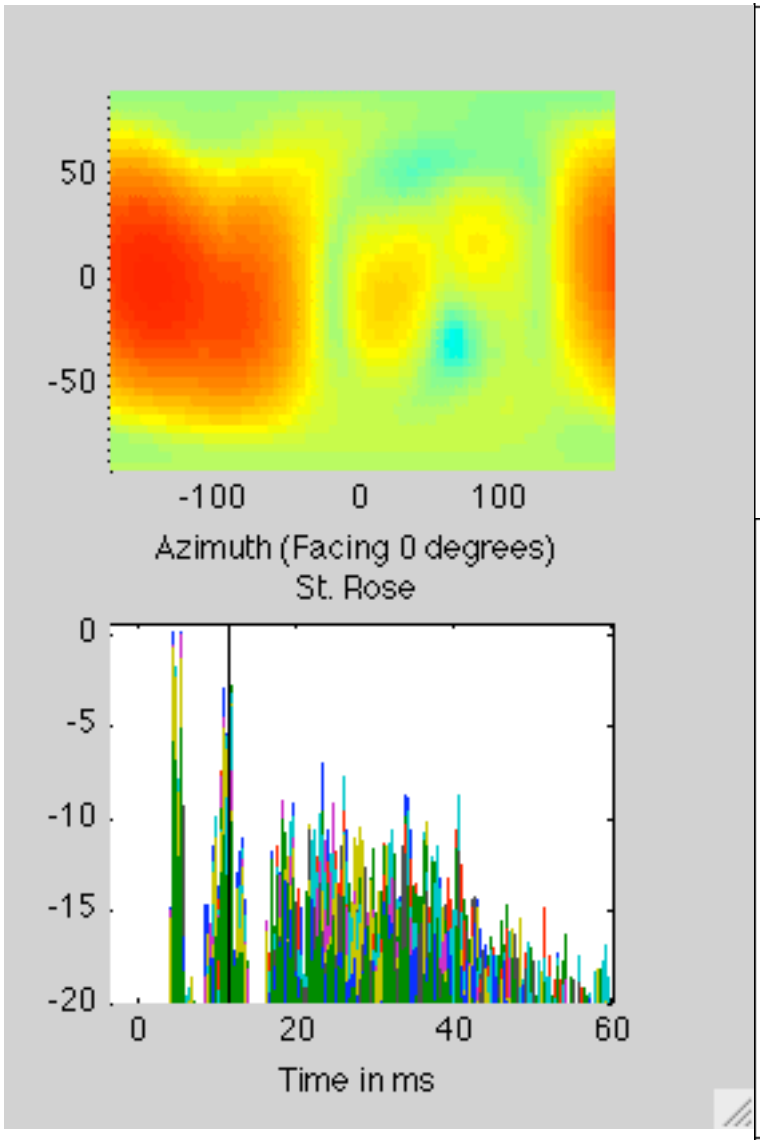

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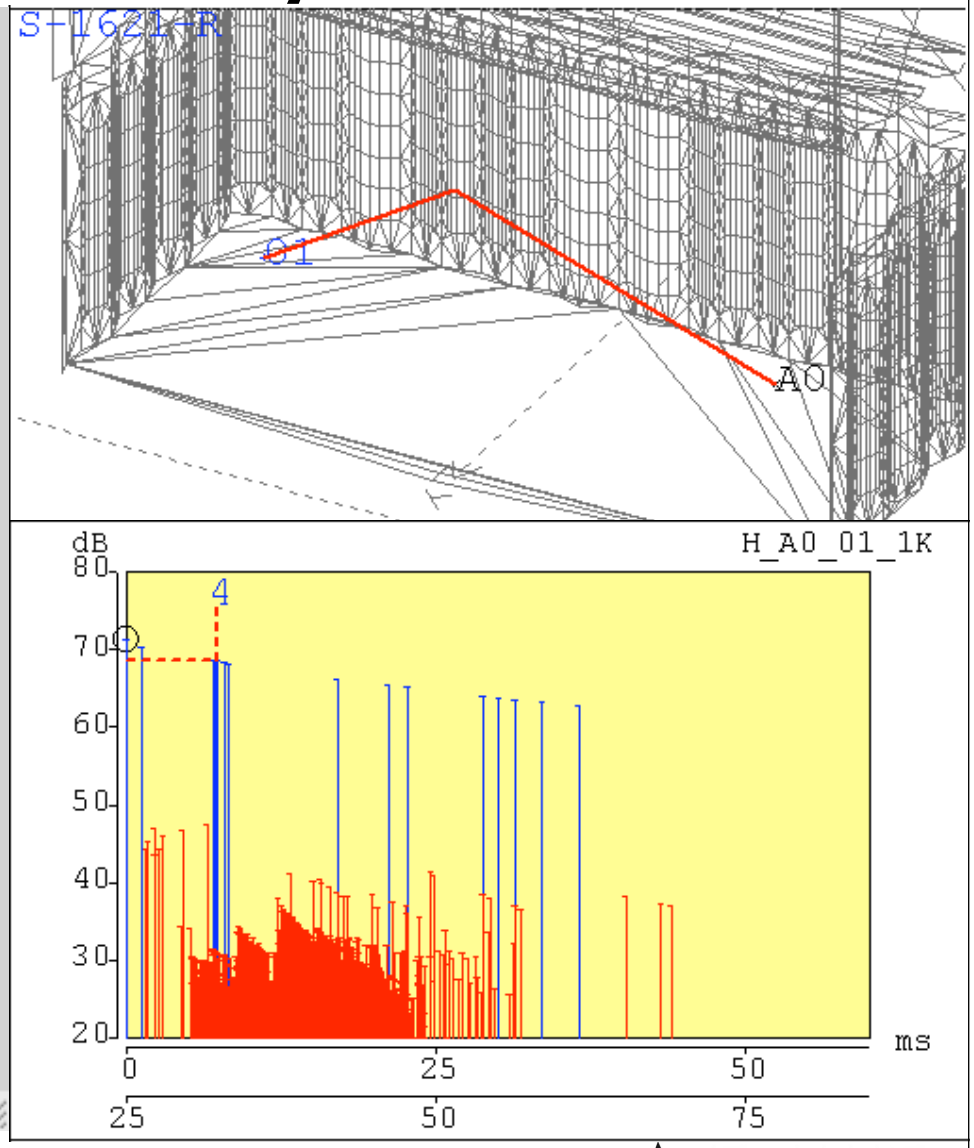

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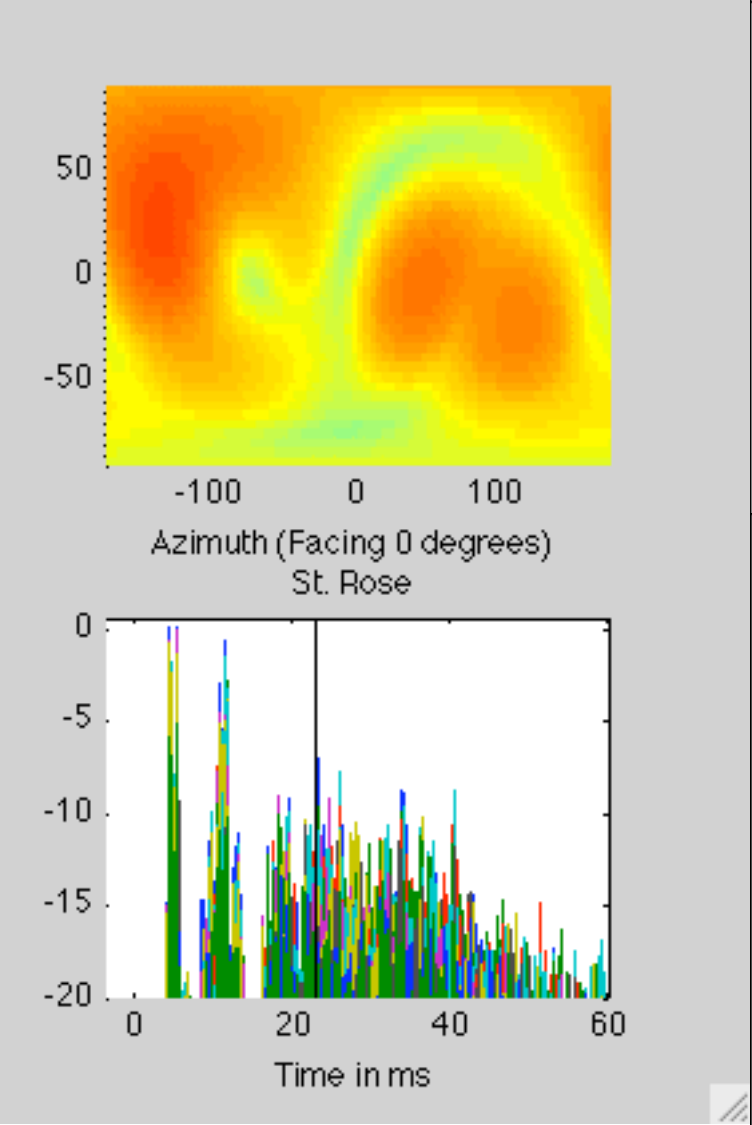

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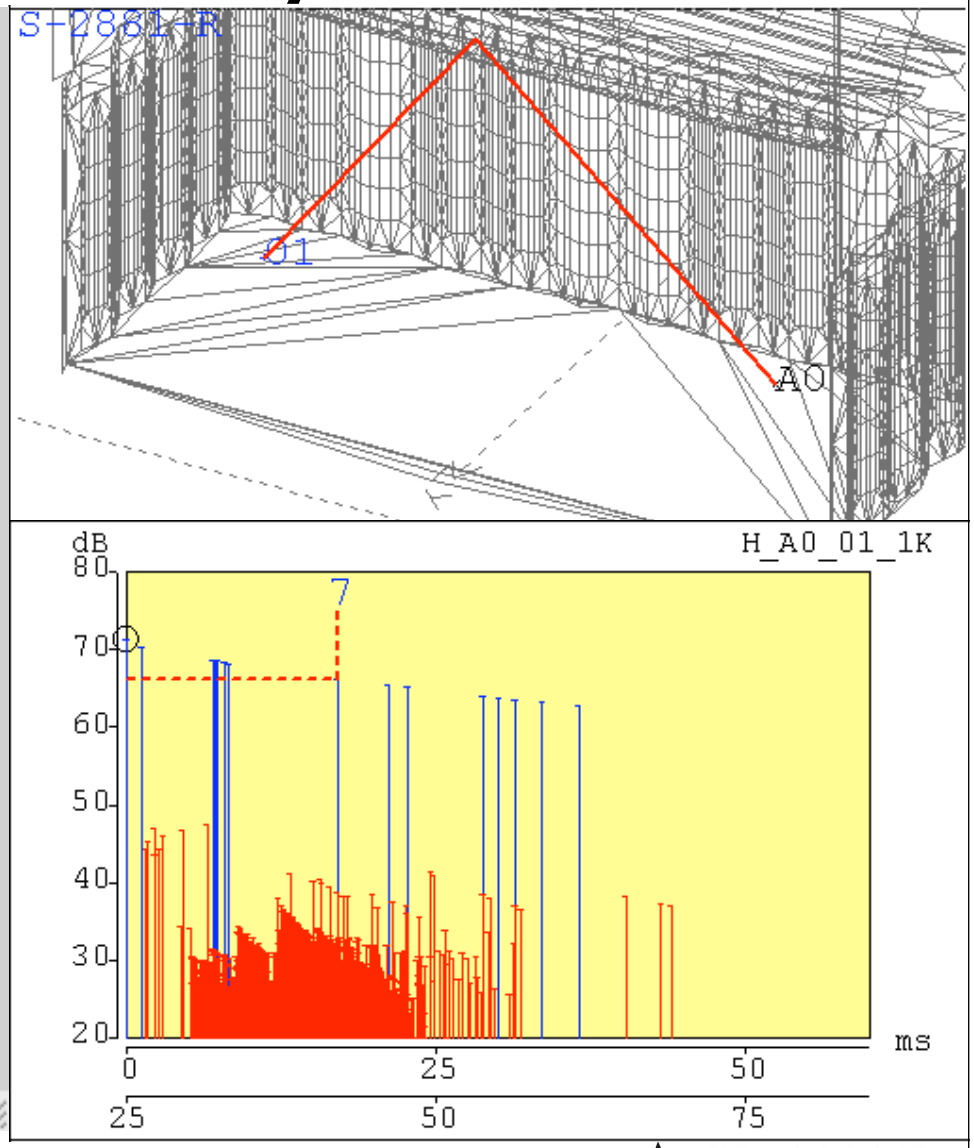

Simulated Data

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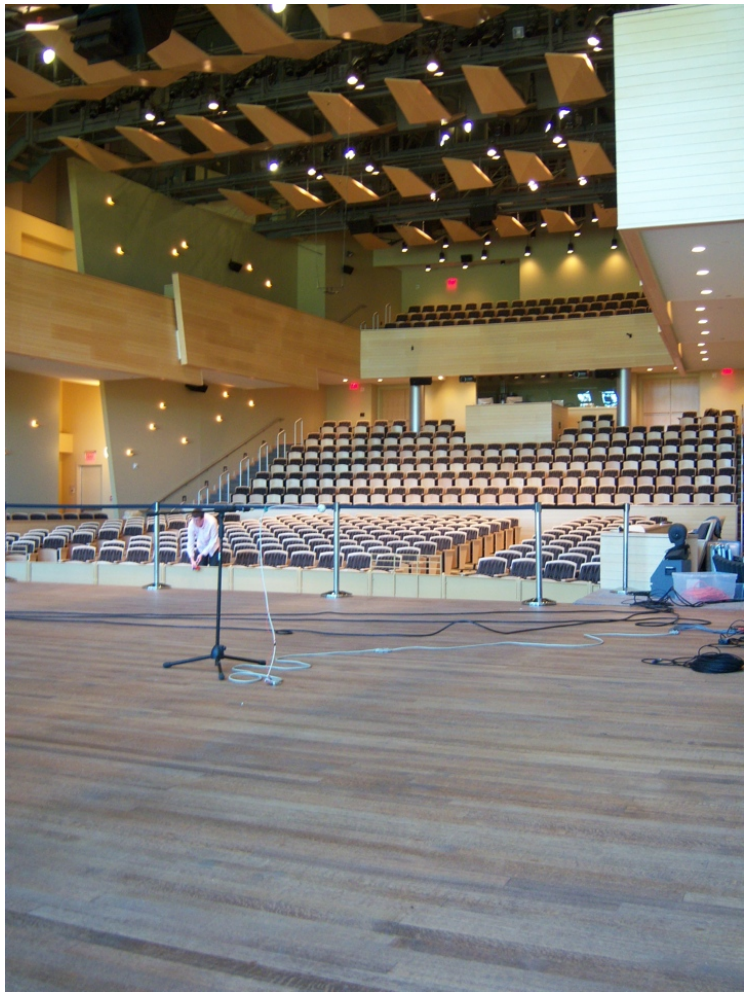
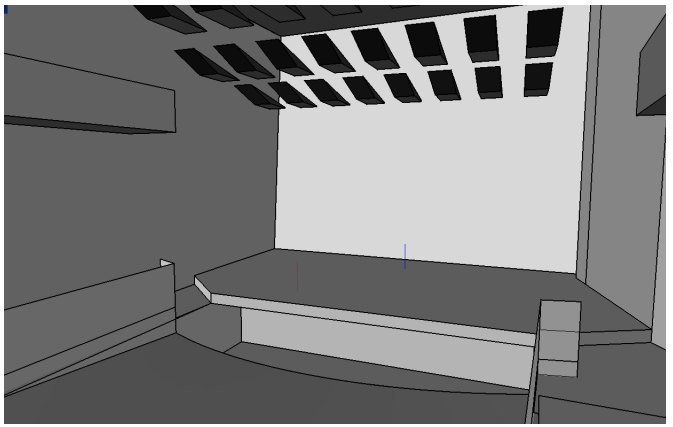
Zankel Hall, Skidmore (600 seats)





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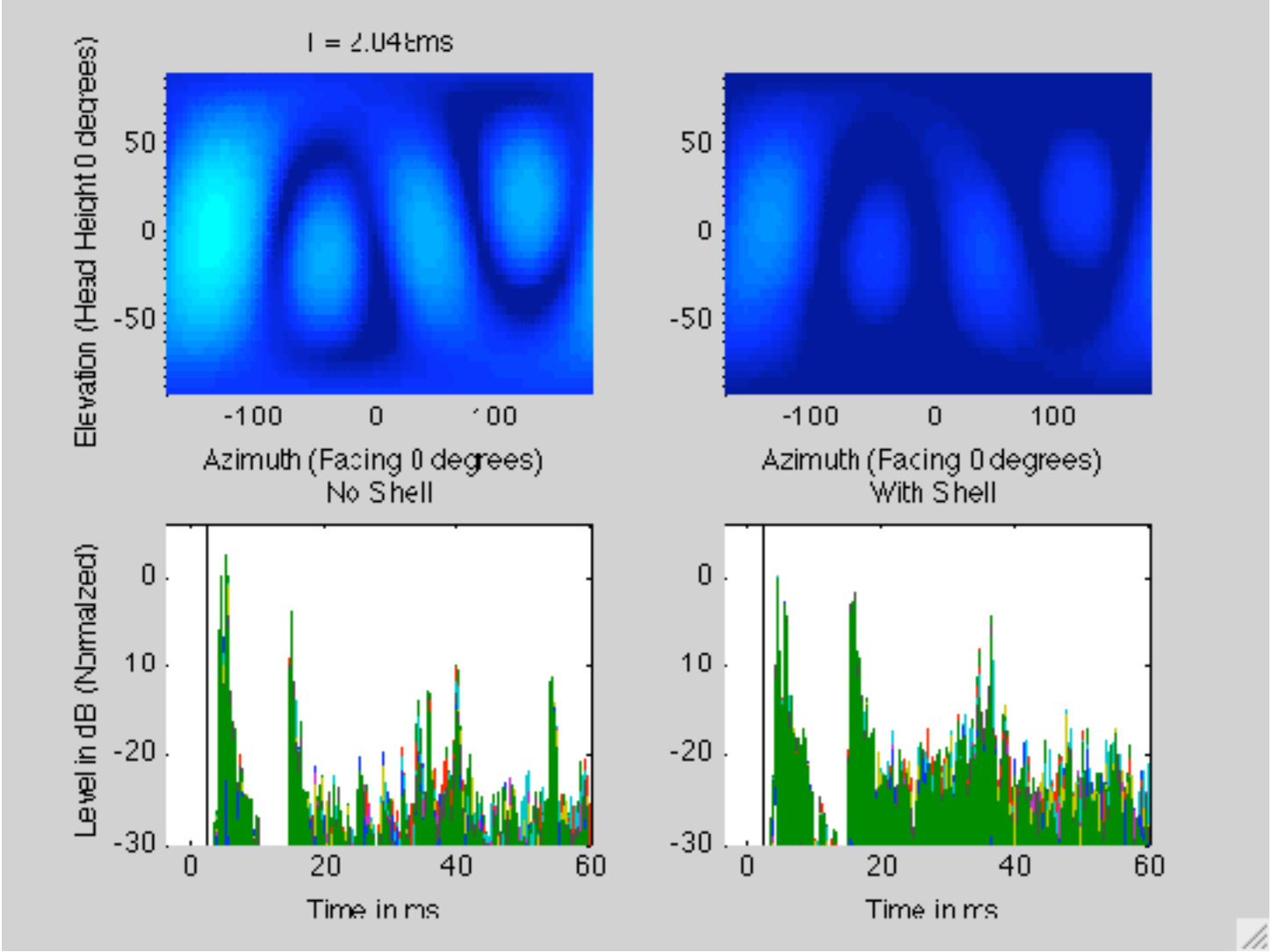
Skidmore Analysis



Measured Data

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Omni Parameter Comparison

Parameter	Skidmore	St. Rose
ST1 in dB	-12.5	-9.5
G in dB	8.9	15.9
EDT in s	2.13	1.68
H/W	0.50	0.52

Spatial parameter?

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Future Work – Auralization

- Arup SoundLab
- Max/MSP real-time auralization with musicians
- Multi-dimensional scaling on preference tests

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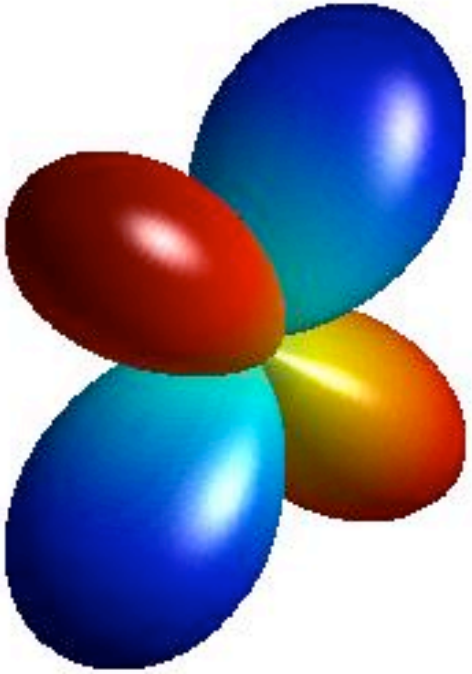
Application of Higher Order Ambisonics



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