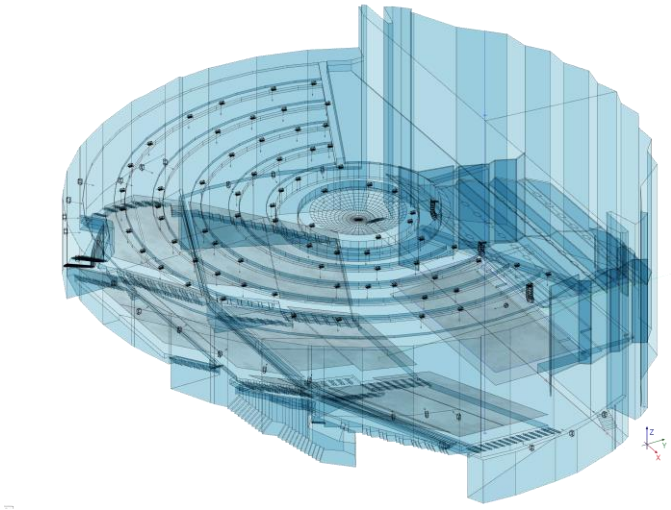
Simulation of room and electro-acoustics in EASE 5 with application examples

Pedro Lima, AFMG Technologies GmbH

Herbsttagung der SGA-SSA 2023

Overview

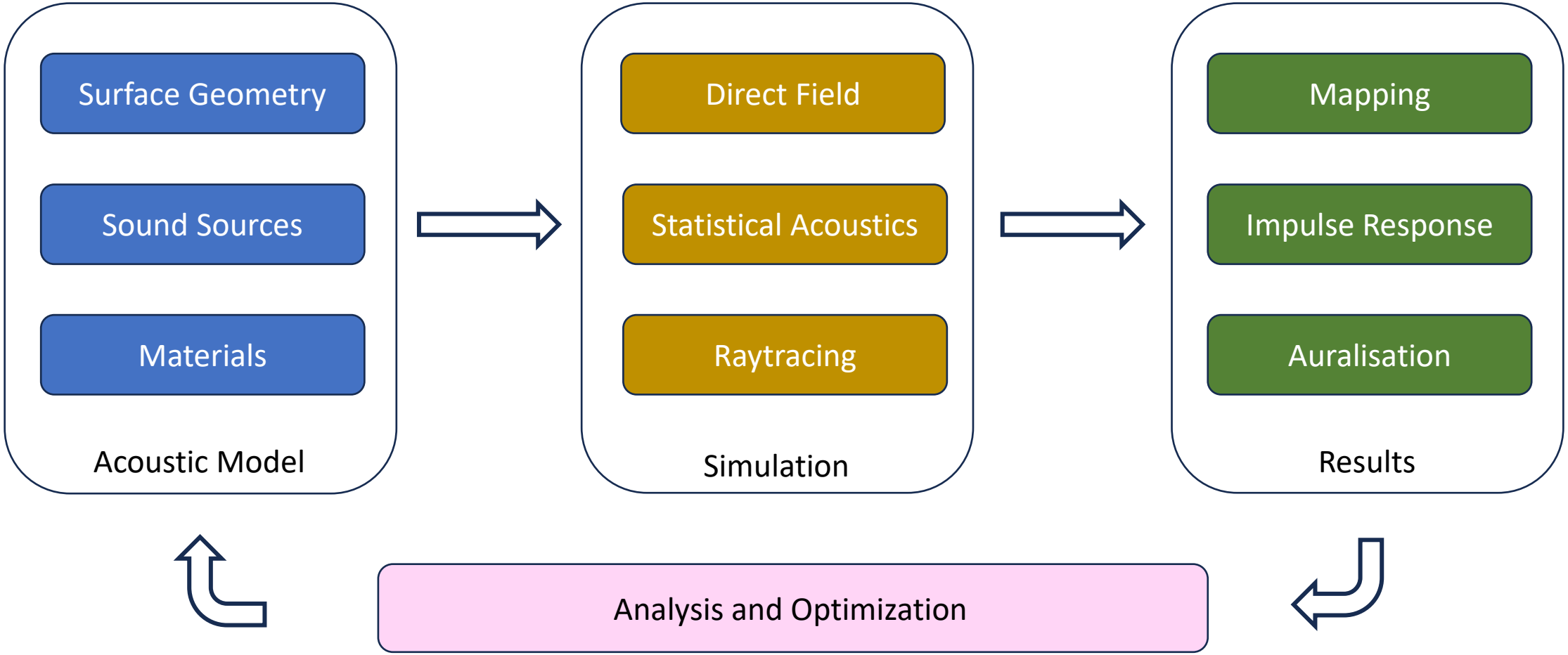
- EASE 5
  - Model entry
  - Assignment of materials
  - Audience areas and listener seats
  - Loudspeakers (GLL format)



- Calculation and Analysis
  - Acoustic parameters of the room
  - Room acoustic quantities
  - Calculation methods

- Application Examples
  - Church: comparison of digitally steered columns in reverberant space
  - Auditorium: optimized speech intelligibility with line arrays

Workflow Acoustic Simulation

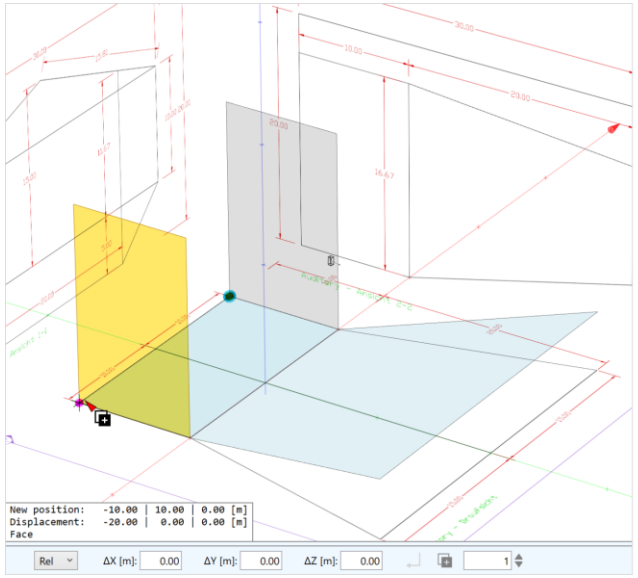


Model Entry

EASE 5 Room Model

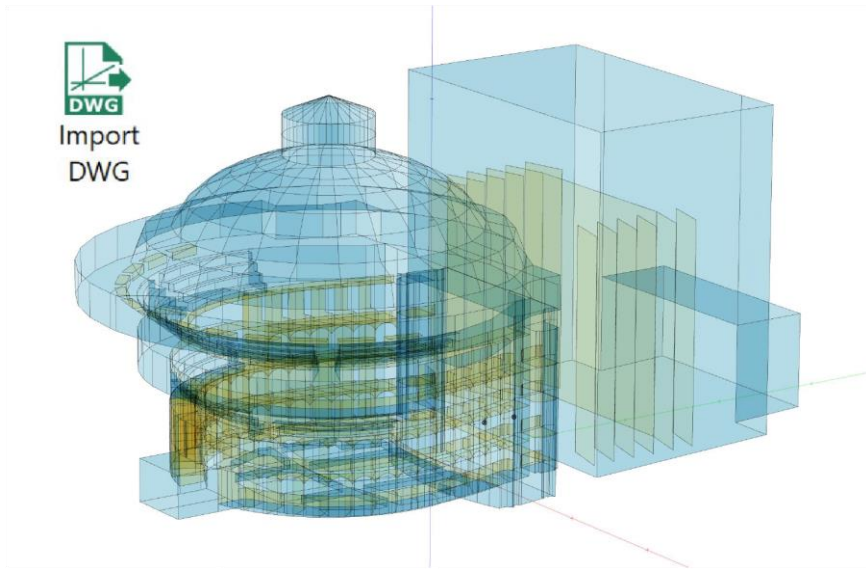
Direct Entry

- Using the built-in, light-weight 3D editor
- Based on drawings



Import of DWG Files

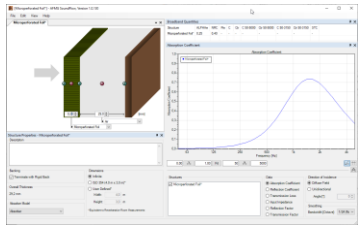
- Using external CAD tools, such as AutoCAD, SketchUp or Vectorworks

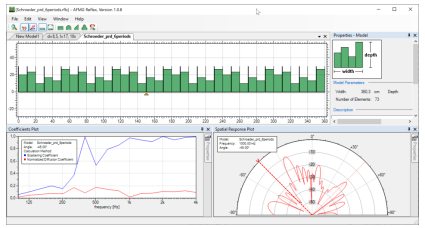


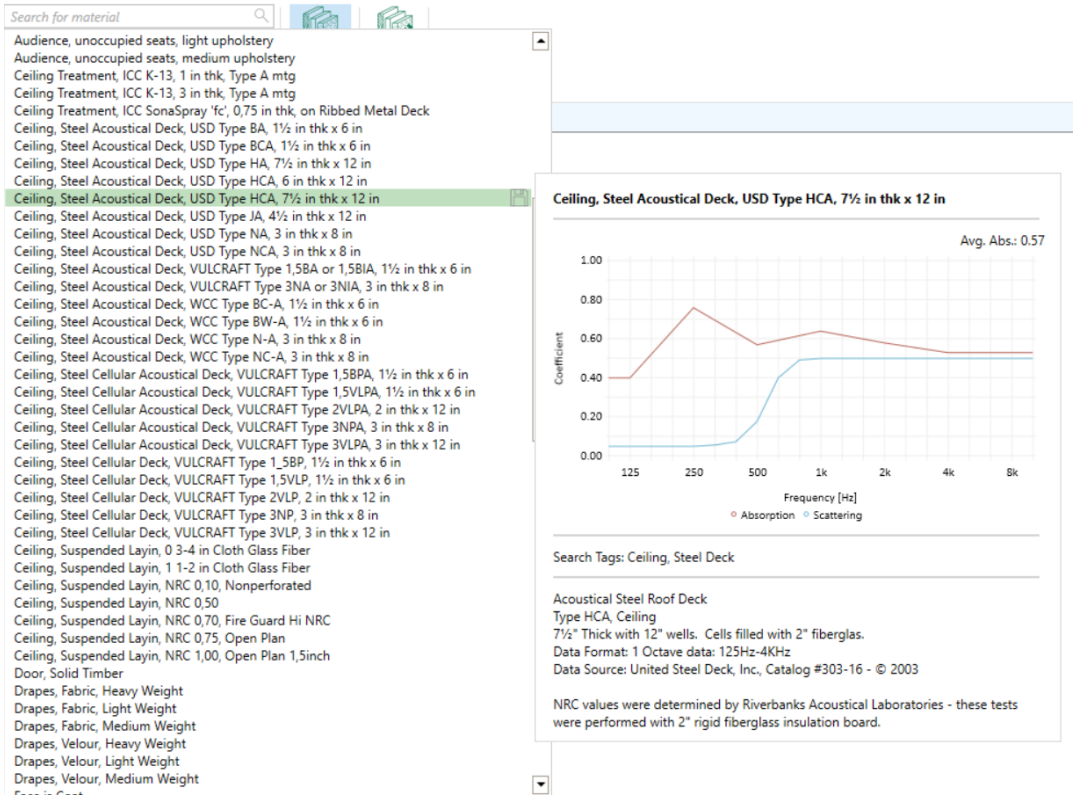
Assignment of Materials

Large Database of Materials for Ceilings, Walls and Floors

- Material name and description
- Reference
- Absorption coefficients
- Scattering coefficients
- Material editor
- Calculation possible using the tools AFMG SoundFlow, AFMG Reflex



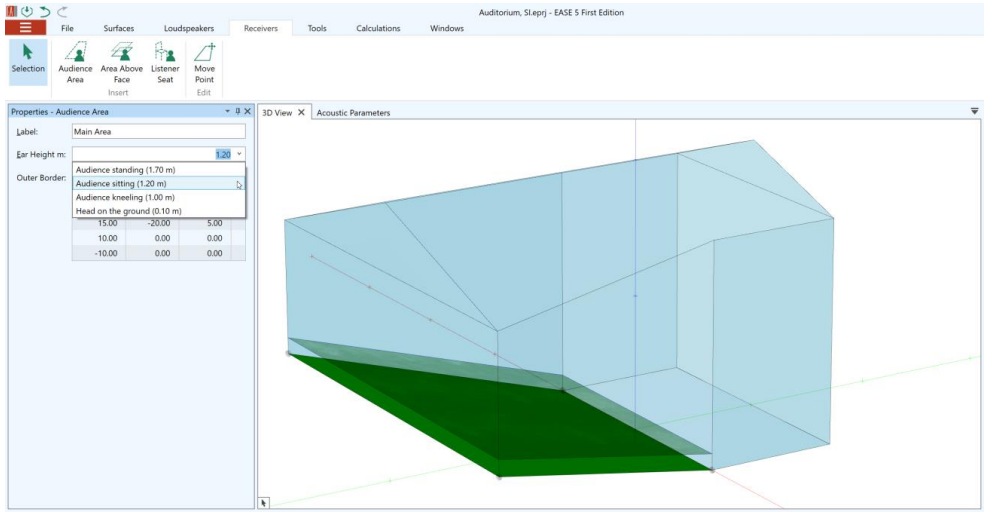




Audience Areas and Listener Seats

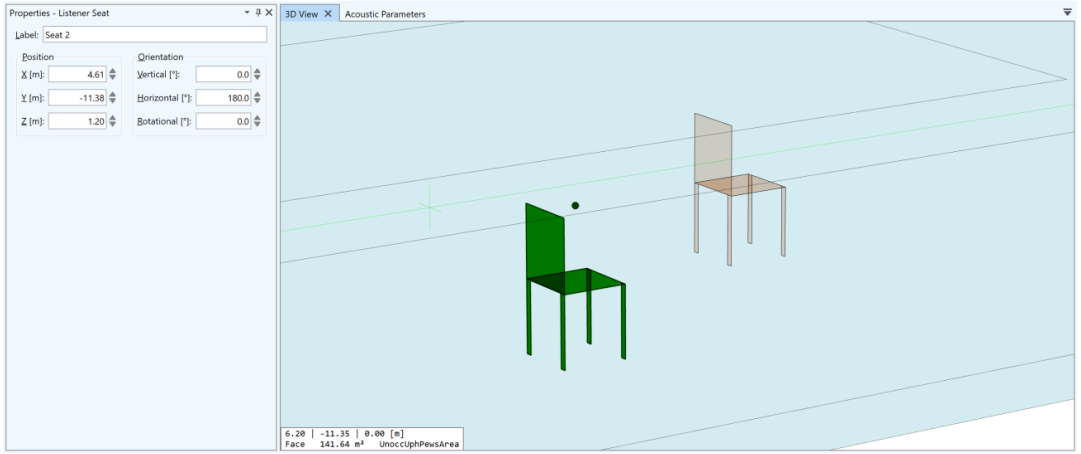
Audience Areas

- Virtual planes for mappings and other calculations



Listener Seats

- Representative listening or measurement positions for mapping and auralisation

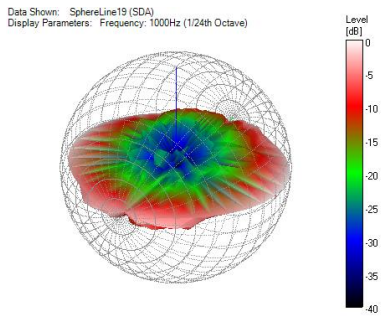


Loudspeakers

Large, comprehensive database, of about 2500 data sets by 140 brands, incl. musical instruments

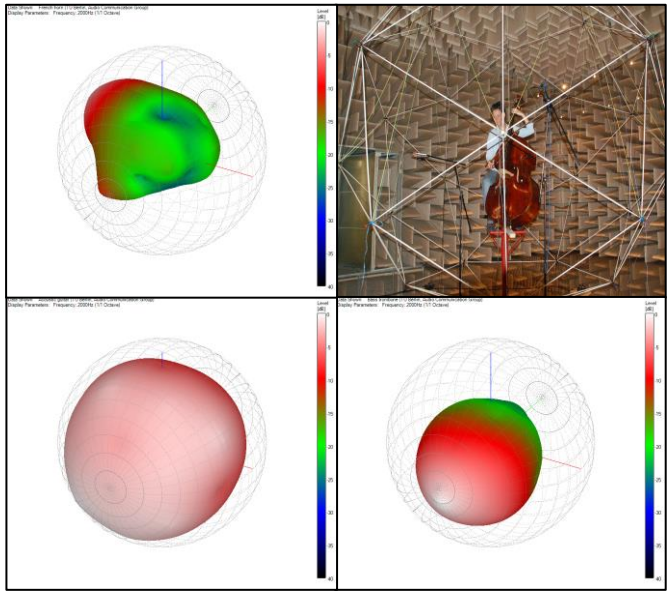
GLL Data Format

- Mechanical, electrical and acoustical properties of a sound source
- High-resolution data for directivity and sensitivity for calculation accuracy up to 1 dB



Natural Sources

- Measurement of 21 musical instruments by TU Berlin & RTWH Aachen

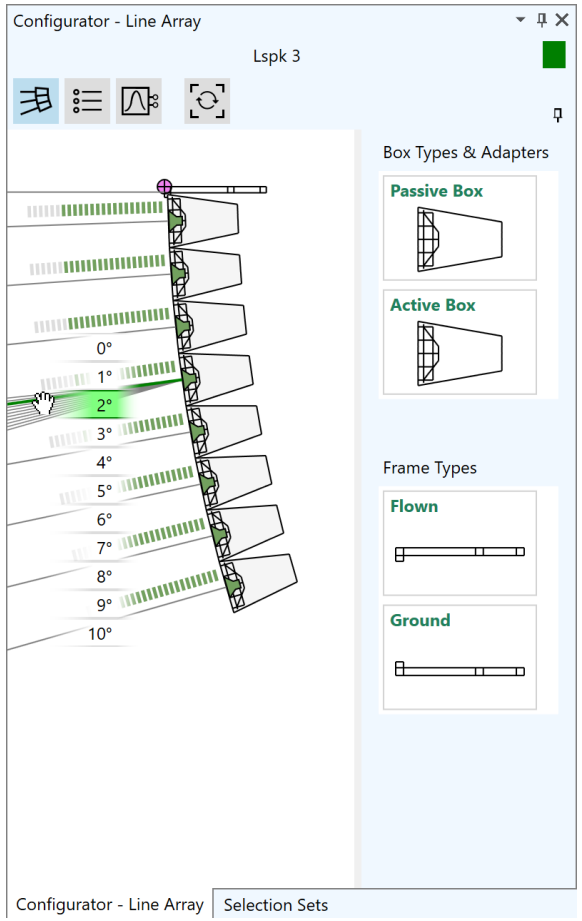


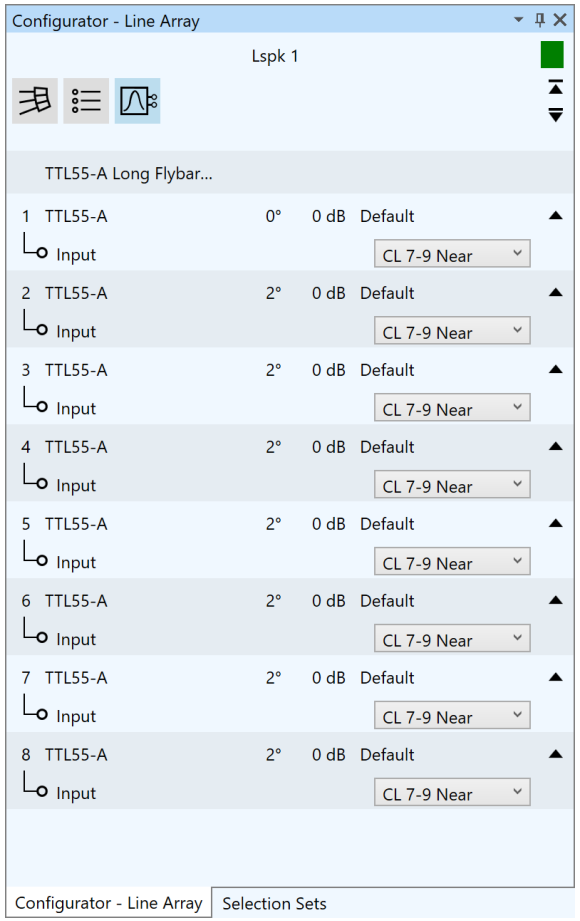
Types of Loudspeakers

- Loudspeakers, line arrays , steered columns, panels

Loudspeakers

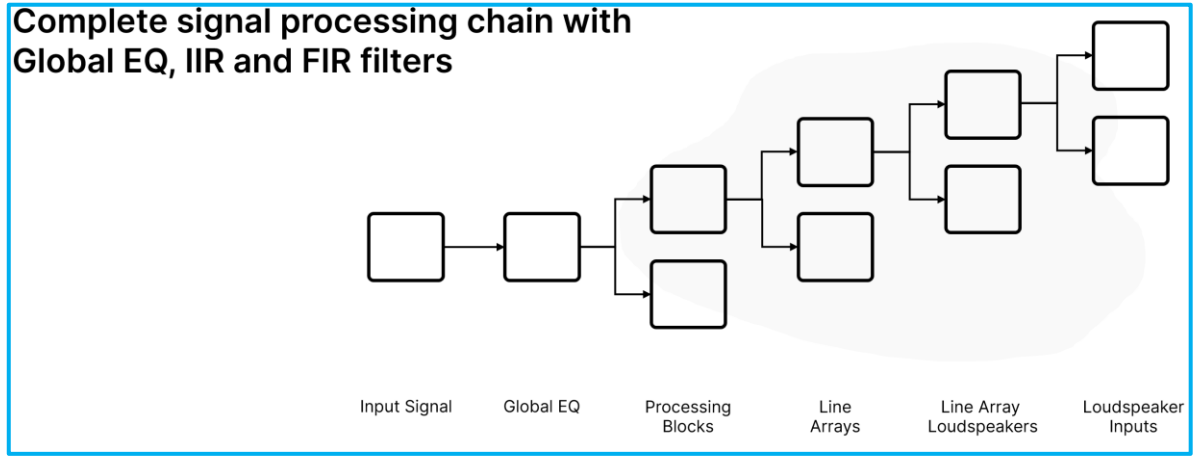
- Configuration of a line array

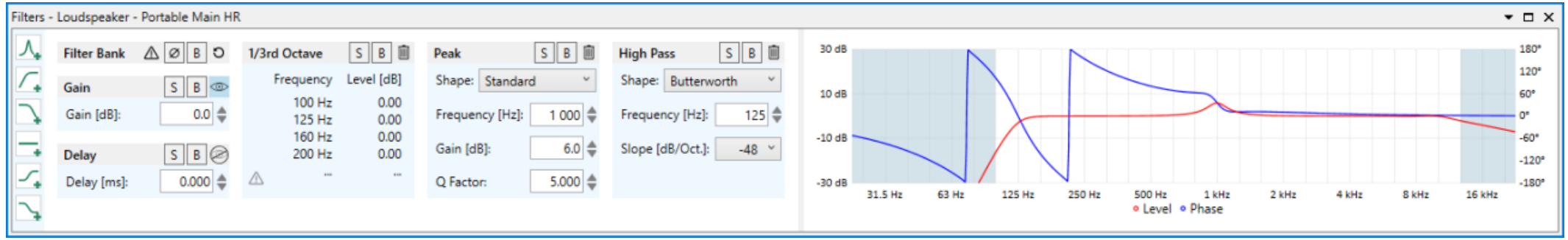




Loudspeakers

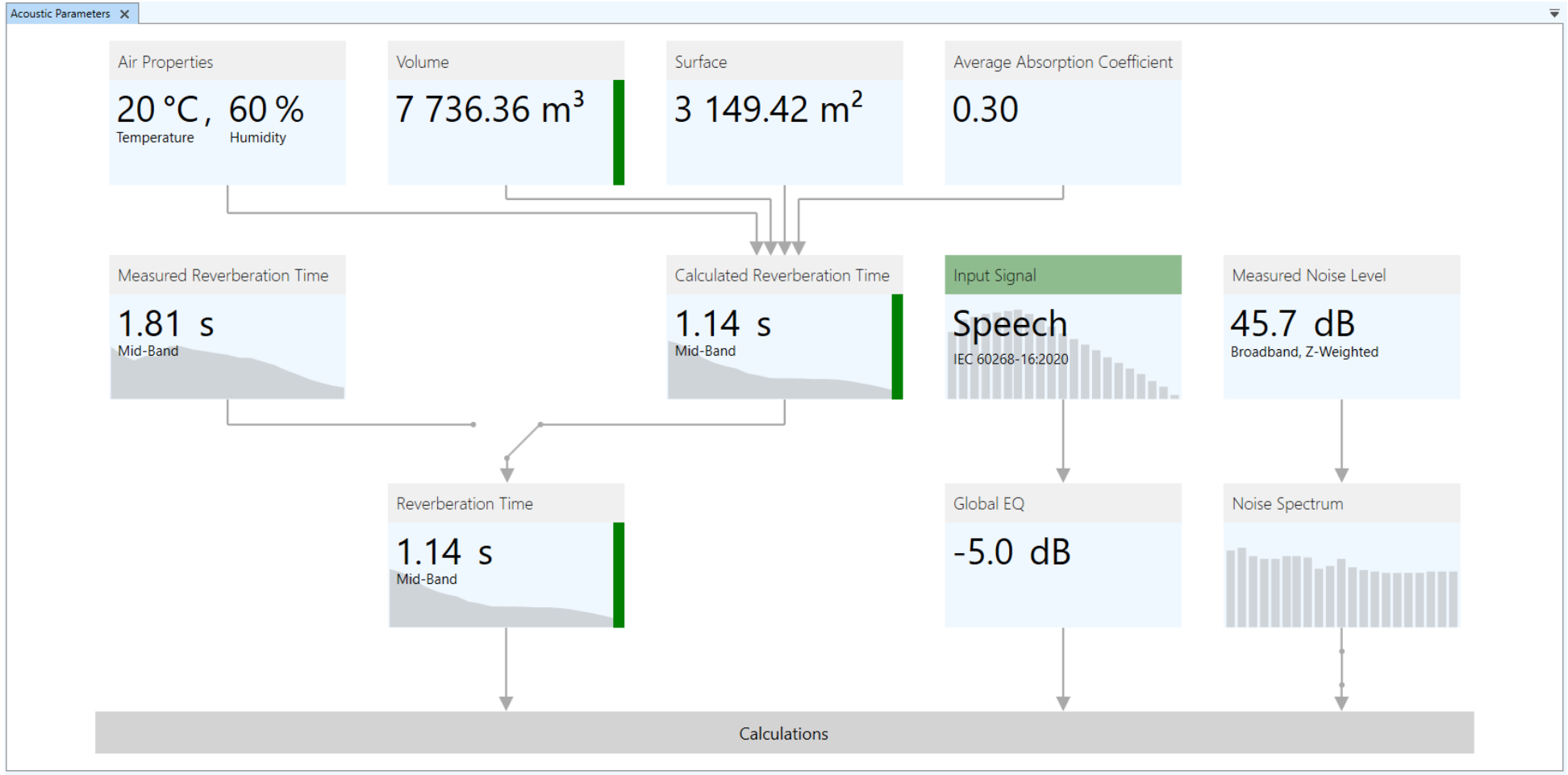
- Signal processing - EASE internal filter stage available for individual loudspeakers, line arrays, processing blocks, global EQ





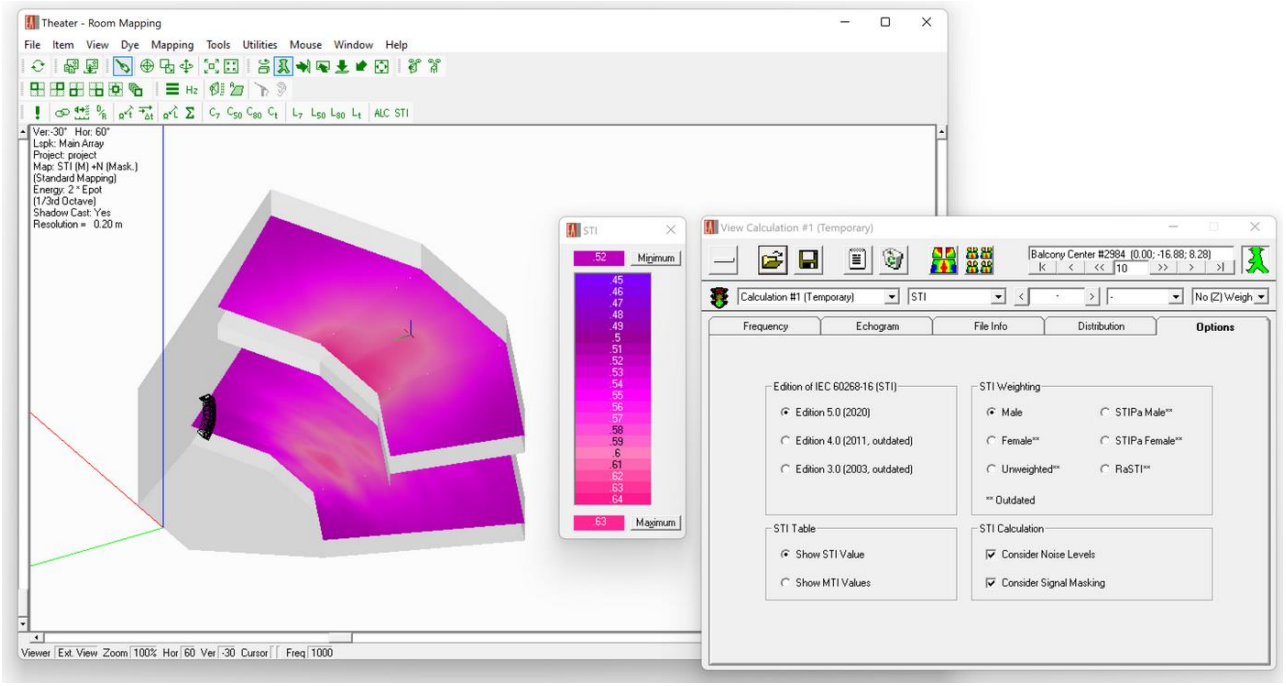
Calculation Functions

Acoustic Parameters of the Room



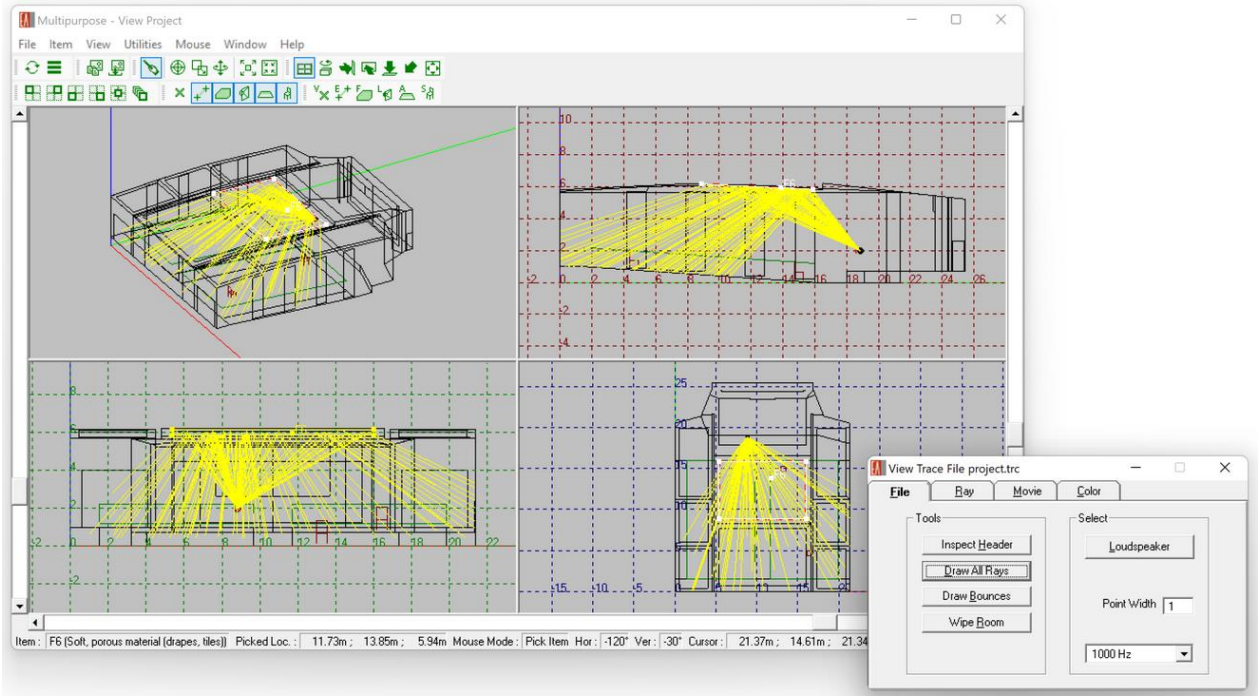
Statistical Calculations

- Standard Mapping: Simulation based on diffuse-field assumption
- Reverberation time according to Eyring or by entering measured values
- Various result quantities, such as according to ISO 3382 and IEC 60268-16
  - Levels DSPL, TSPL
  - Speech intelligibility STI
  - Definition, clarity: D, C50, C80



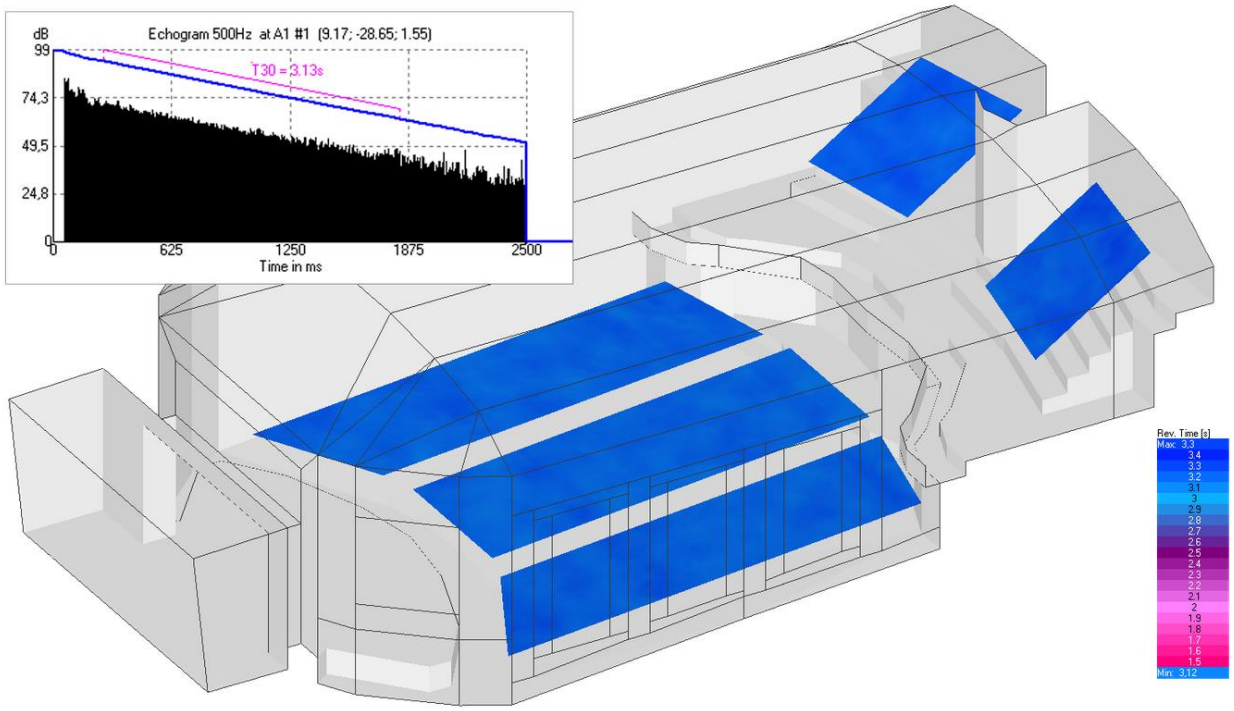
Reflection Analysis

- Raytracing module:
  - Geometrical raytracing (specular reflections), primarily early part
  - Analysis of audible reflections, focusing effects and flutter echoes
- Mirror image method or Monte-Carlo based raytracing
  - Reflectogram: Level, arrival time, direction of individual reflections



Sound Particles Method

- AURA module: Calculation of full-length impulse response
- Raytracing based on specular reflections and scattering algorithm
- Result quantities according to ISO 3382 and IEC 60268-16 with high accuracy
  - T20, T30
  - STI
  - D, C80
  - …



Result Quantities of Calculation Methods

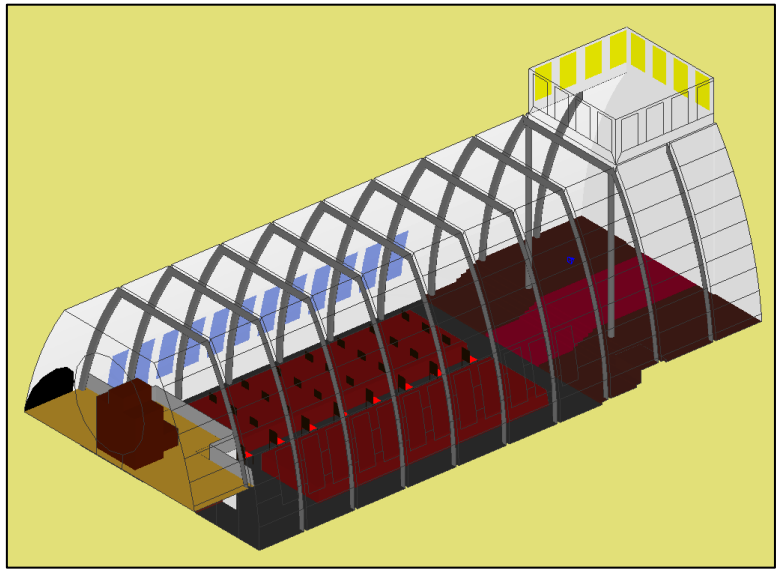
- Room acoustics:
  - Reverberation time (RT): EDT, T10, T20, T30
  - Speech intelligibility: STI according to current IEC 60268-16
  - Critical Distance (reverberation radius)
  - Definition and Clarity: D, C50, C80
  - LF, LFC, G, Center Time

- Electro-acoustics
  - Direct + Total SPL
  - D/R Ratio
  - Sound Pressure Levels: L7, L50, L80, L-Split
  - Privacy Index, Articulation Index
  - S/N Ratio
  - Arrival Time, ITD Gap
  - Etc.

Application Examples

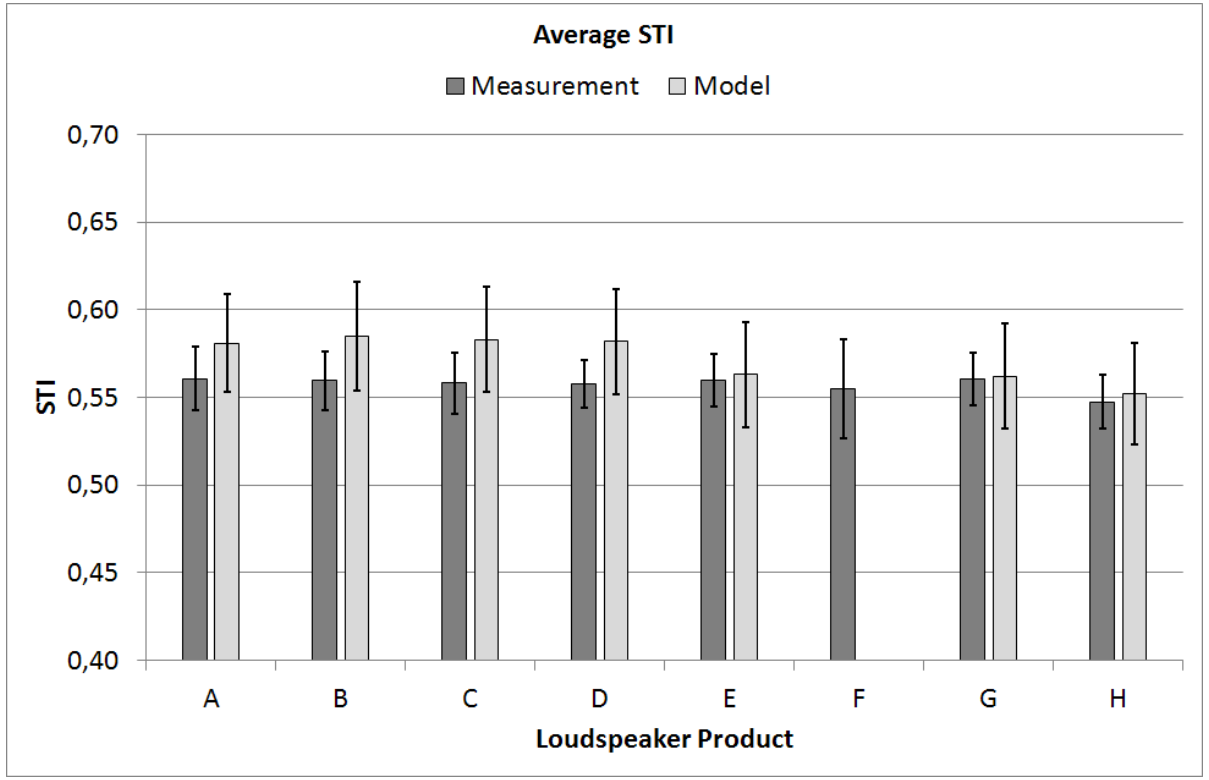
Application Examples

- Comparison of digitally steered columns:
  - Church „Sankt Mariä Heimsuchung“, Herzogenrath-Kohlscheid, Germany
  - Ca. 4.500 m³, reverberation time of ca. 2,5 - 3 s
  - Comparison of measurements with EASE AURA simulation at 32 positions
  - High-resolution loudspeaker data in GLL or DLL format



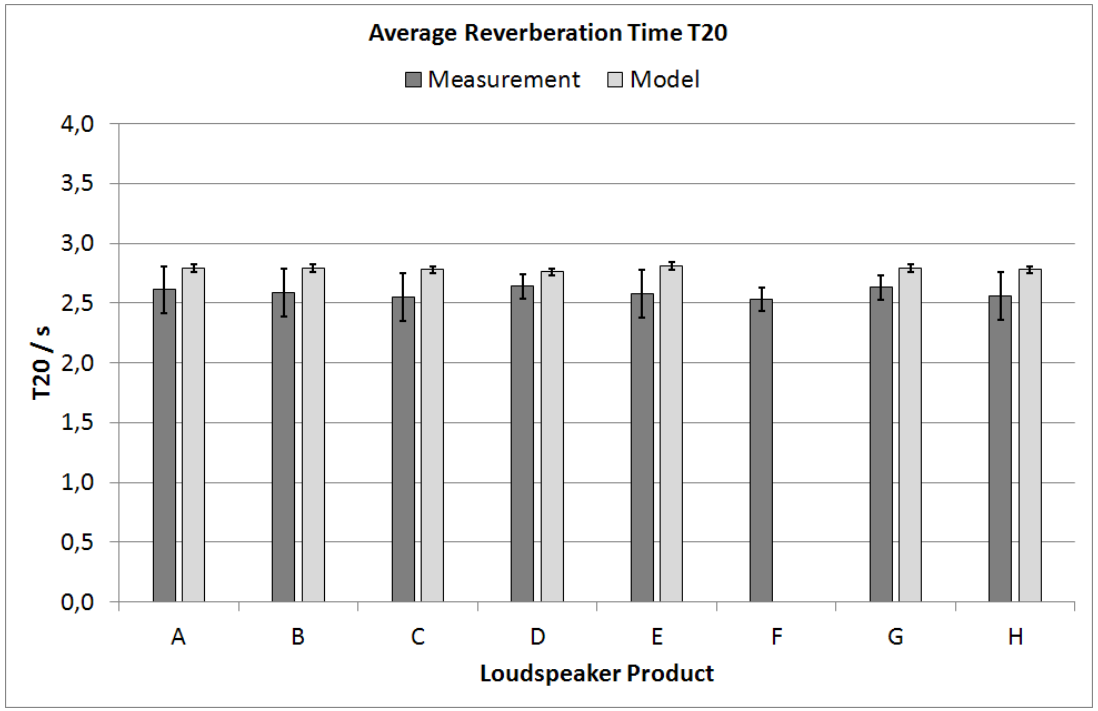
Comparison of Digitally Steered Columns

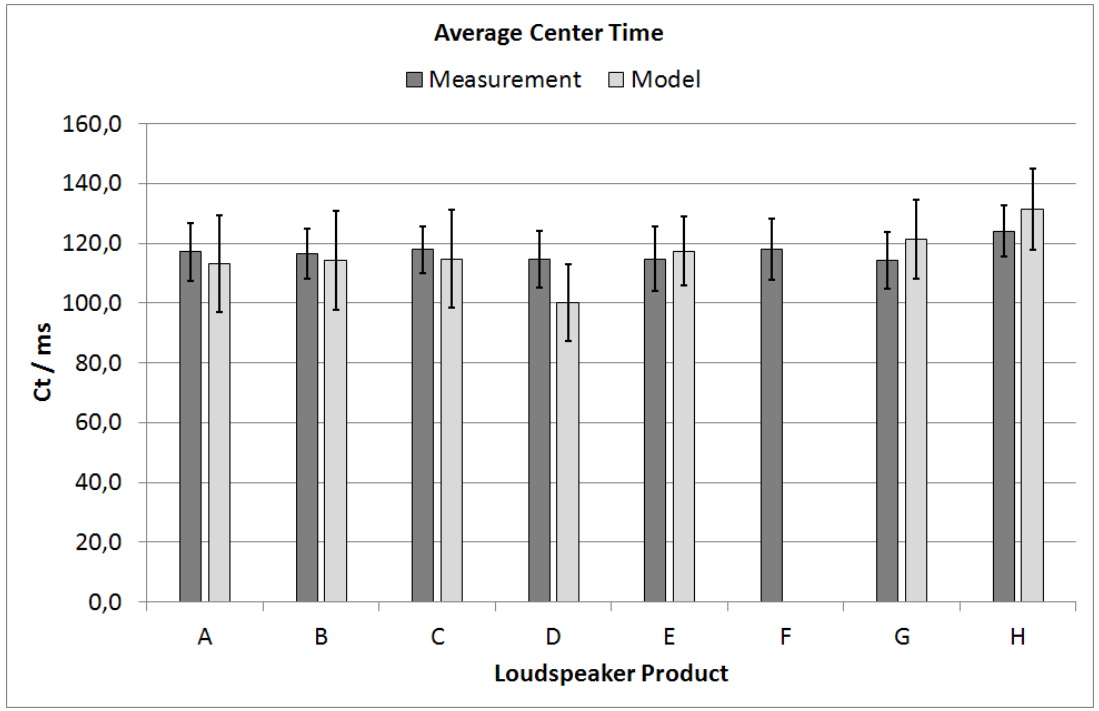
- Speech Intelligibility STI
  - Measurement and simulation match within uncertainty
  - Only small differences across different products



Comparison of Digitally Steered Columns

- Average reverberation time T20
- Center time





Octave band of 1 kHz

Comparison of Digitally Steered Columns

Summary

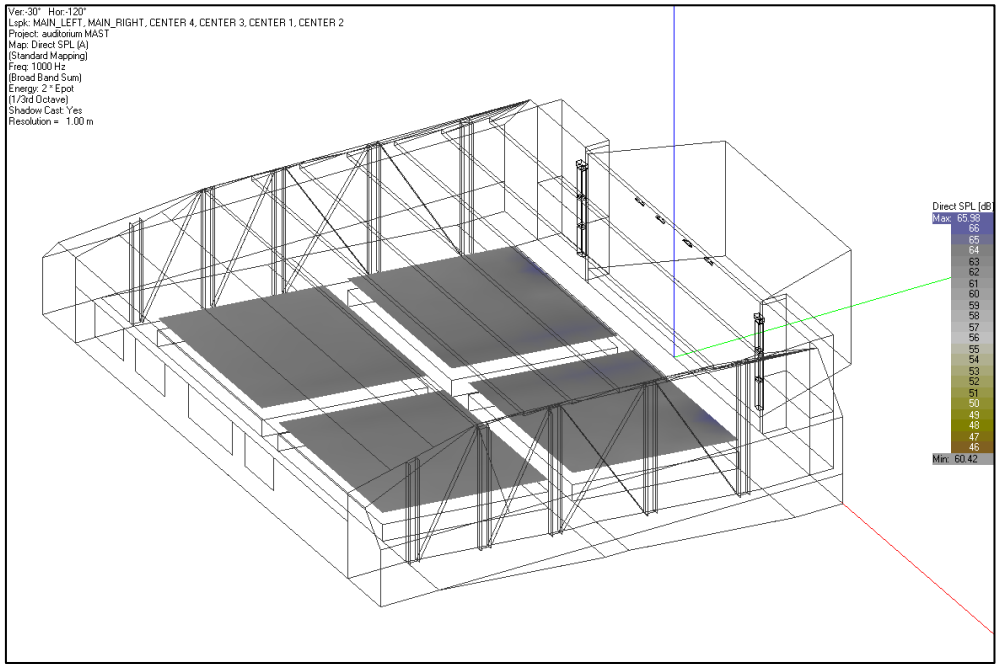
- Eight different column speakers in typical reverberant church
- Measurement and simulation results match well

=> Digitally steered columns can be modeled accurately with EASE

=> Differences between products are small, perhaps more visible in more complex installations

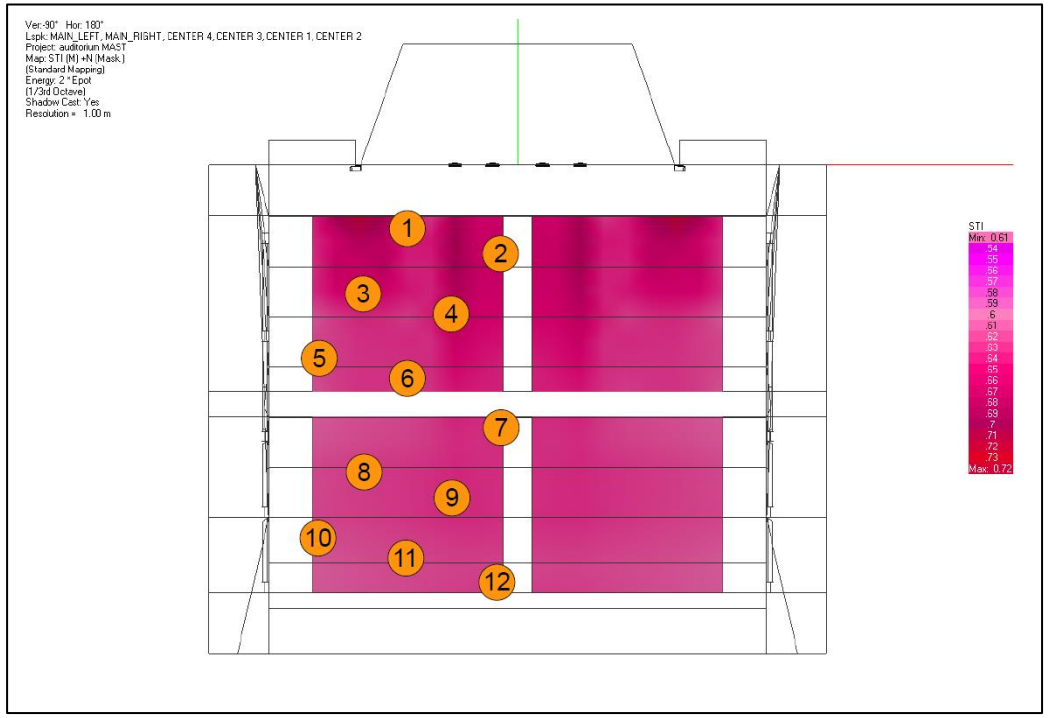
Application Examples

- Speech intelligibility in an auditorium
  - Task: Optimizing the STI
  - Ca. 2.500 m³, reverberation time of 1.2 s
  - Line arrays with beam shaping by AFMG FIRmaker
  - Reflective ceiling, seating covered by leather
  - Noise level at ca. 37,5 dB (A)



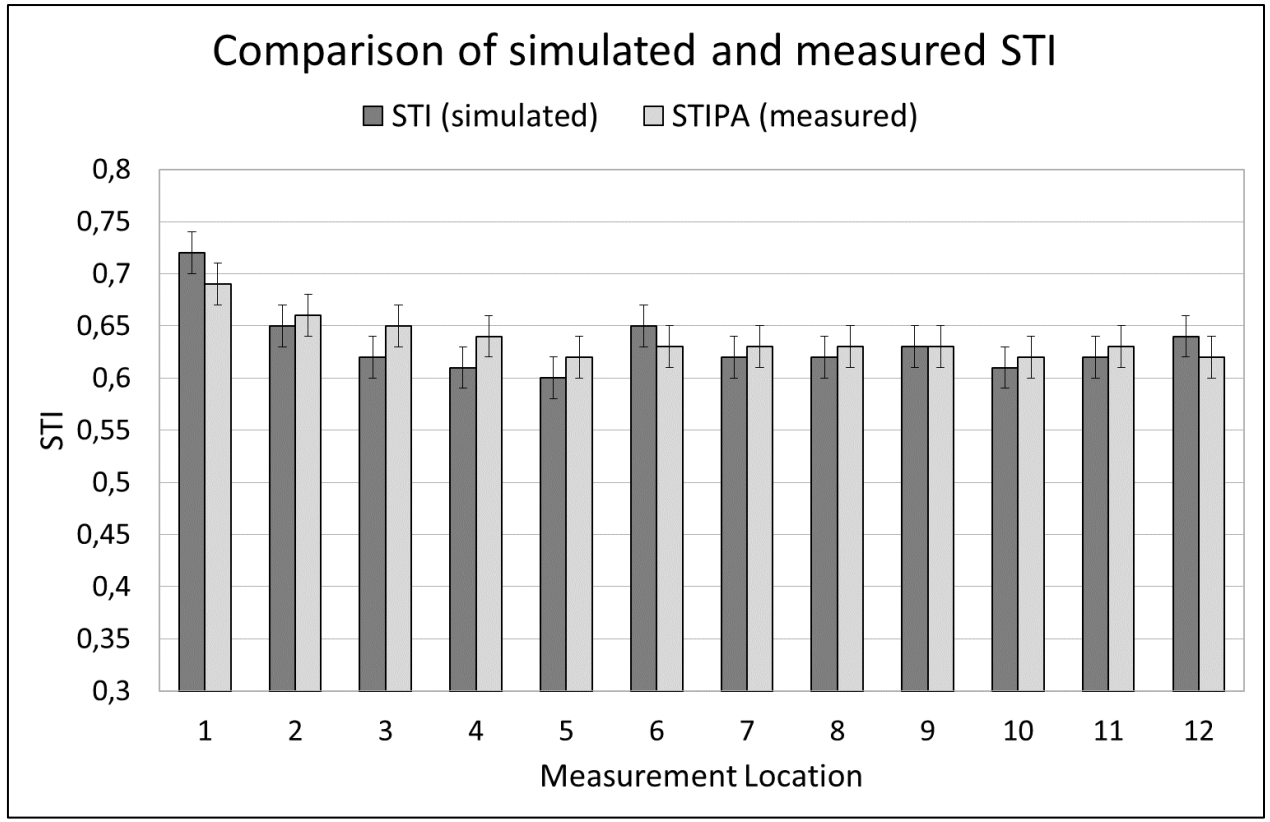
Speech Intelligibility in an Auditorium

- Modeling in EASE:
  - High-resolution loudspeaker data in GLL format
  - Comparison with measurements at 12 positions



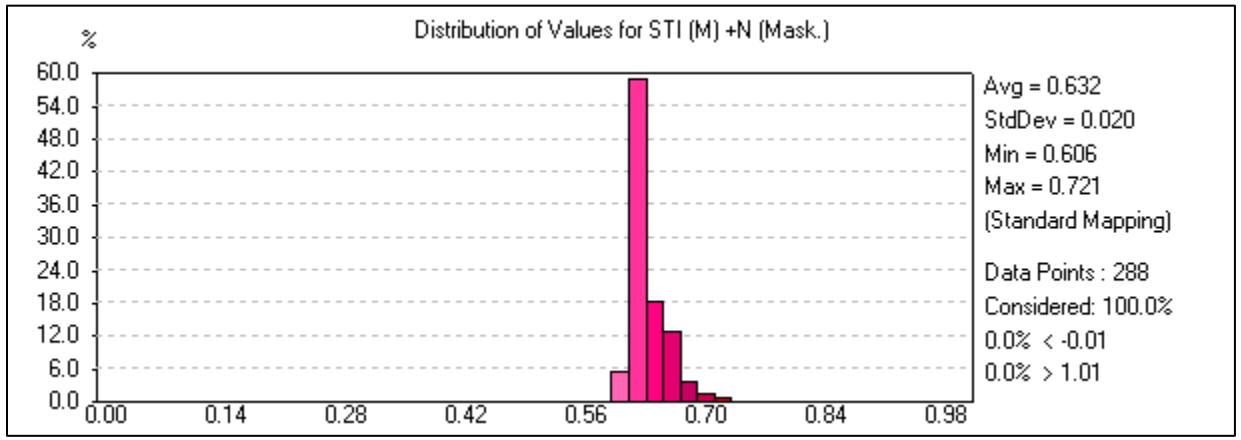
Speech Intelligibility in an Auditorium

- Speech intelligibility STI
  - Measurement and simulation results match within uncertainty
  - Subjective optimization of signal level on site corresponds to simulation results



Speech Intelligibility in an Auditorium

- Distribution statistics for simulated STI
  - High uniformity due to FIRmaker coverage optimization
  - Optimization of signal level vs signal masking and noise level



Speech Intelligibility in an Auditorium

Summary

- Improvement of STI in EASE 5:
  - Coverage optimization with FIRmaker
  - Adjustment of signal level using STI Optimizer function
- Confirmation via measurements

=> Simulation allows accurate calculation and maximization of speech intelligibility

Summary and Outlook

- Summary
  - Overview model entry
  - Calculation methods
  - Application examples

- More information
  - Questions? Please get in touch!
  - Website: www.afmg.eu
  - Free trial version of EASE 5
  - AFMG video channel at www.youtube.com/@AFMG.Simulation.Measurement
  - References / publications

Links & References

Published Articles and Books

(1) S. Feistel, D. Ponteggia, "Optimizing Speech Intelligibility in Practical Applications using State-of-the-Art Acoustic Simulation Tools “, to be presented at the International Acoustics & Sound Reinforcement Conference of the Audio Engineering Society (2024 Jan)

(2) S. Feistel, D. Ackermann, S. Weinzierl, "Using high-resolution directivity data of musical instruments for acoustic simulation and auralization", 155th Convention of the Audio Engineering Society (2023 Oct)

(3) W. Ahnert, S. Feistel, "Fortschritte im Projektdesign auf Basis von akustischen Simulationen", Tagung der Deutschen Gesellschaft für Akustik (2023 Mar)

(4) S. Feistel, "Modeling the Radiation of Modern Sound Reinforcement Systems in High Resolution", (Logos Verlag, Berlin, 2014)

(5) S. Feistel, A. Goertz, "Digitally Steered Columns: Comparison of Different Products by Measurement and Simulation", 135th Convention of the Audio Engineering Society (2013 Oct)

(6) S. Feistel, M. Sempf, K. Köhler, H. Schmalle, "Adapting Loudspeaker Array Radiation to the Venue Using Numerical Optimization of FIR Filters", 135th Convention of the Audio Engineering Society (2013 Oct)

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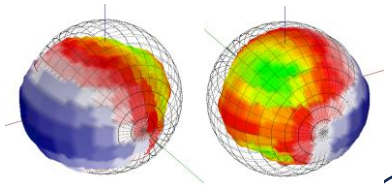
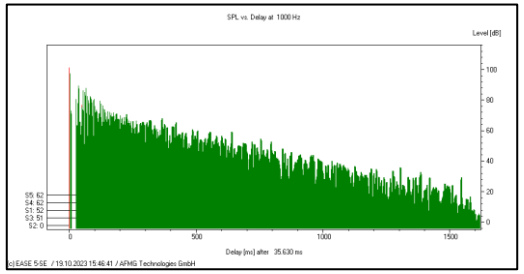
Auralisation

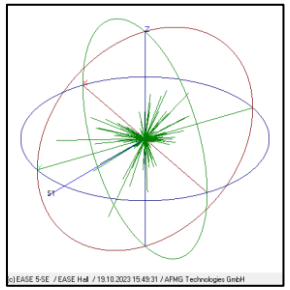
HRTF



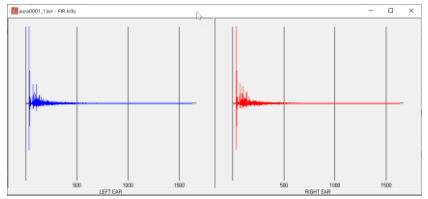
Live source
Anechoic recording

Reflectogram





BIR filters



Binaural reproduction

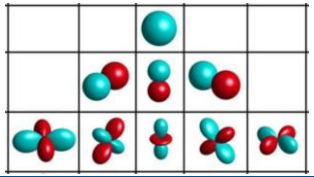
Improved by headtracking

B-format filters

- Aural_R.wav
- Aural_S.wav
- Aural_T.wav
- Aural_U.wav
- Aural_V.wav
- Aural_W.wav
- Aural_X.wav
- Aural_Y.wav
- Aural_Z.wav

Ambisonics reproduction

SH



Scattering Data for Materials

Scattering in EASE:

- Global setting, e.g. 20% or S-curve
- Material: measurement, estimate