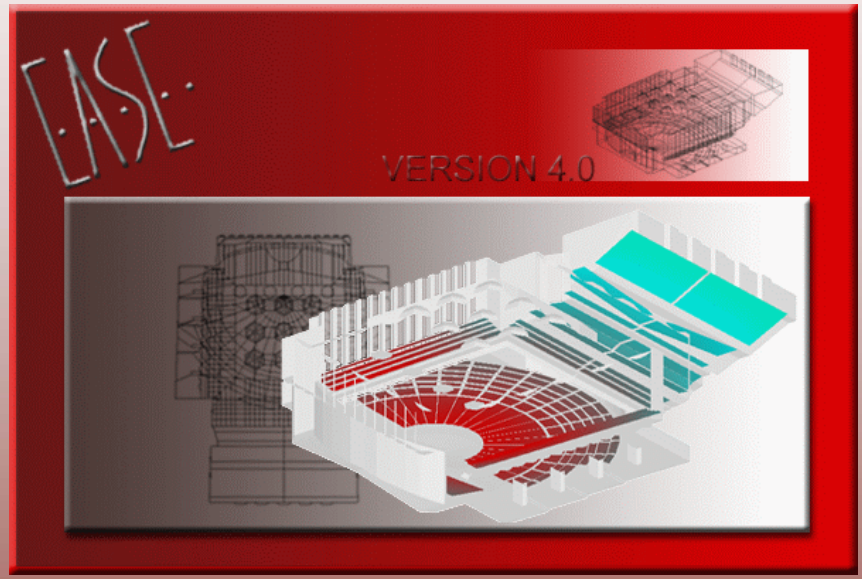
AURA - Analysis Utility for Room Acoustics

Merging EASE for sound reinforcement systems and CAESAR for room acoustics



Wolfgang Ahnert, S. Feistel, Bruce C. Olson (ADA),
Oliver Schmitz, and Michael Vorländer (ITA)

Acoustical Society of America – Fort Lauderdale, Florida – December 2001

Overview

- Introduction
- Look at EASE 4.0
- New room acoustical simulation in EASE
  - Algorithms
  - Results
  - Limitations
- Examples
- Auralization
- Conclusions

Application of computers in sound system design

- until 1965
  mainly in selected cases in research centers by means of huge computers
- 1965 -1980
  Using computer chips of integrated-circuits decreases the price of pocket computers;
  since 1970 programable pocket computers offer first algorithms for acoustics
  i.e. program CASSA from Philips for calculator HP41CX, calculation routines in bar code

Application of computers in sound system design

1983, **CADP1,** graphic CAD for MS-DOS based program by JBL, Version 1.0

1984, **CADP1,** graphic CAD for MS-DOS based program by JBL, Version 2.0

1986, **BOSE-Modeler,** first full graphic CAD MacIntosh-based program
Version 1, 1986 by K. Jacob, T. Birkle/Bose/USA

1986, **CADP1,** upgrade of program for VGA resolutions. First use of color for displaying variations in coverage. by Bruce C. Olson, last version 4.53

1987, **Acousta-CADD**, first full graphic CAD MS-DOS based program
Version 1 by A. Muchimaru Altec Lansing/USA

1988, **Nexo-CADD**, full graphic CAD MS-DOS based program
Version 1, 1988, by Nexo/France, not available anymore

1990, ***EASE***, full graphic CAD MS-DOS based program with pop up menus
Version 1, 1990, by ADA, Germany

1991, **CADP2,** full-graphic CAD Windows 3.1 based program, also running under Windows 95, by JBL/USA, Version 1, last version 1.25

1992, **Acousta-CADD,** Version 2

1993, **BOSE-Modeler,** Version 4 and updates

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Application of computers in sound system design

1993, ***EASE*** *V*ersion 2 and updates

1996, **Acousta-CADD**

Production terminated

1996, ***ULYSSES,*** by IFB/Germany (P. Hallstein)

Version 1, now windows version 2.41

1997, **CADP2**

Further development stopped

1999, ***EASE for Windows,*** by W.Ahnert, R.Feistel, S.Feistel

Version 3.0 for Windows 95/NT/ME/2000

2001, ***EASE for Windows,*** by W.Ahnert, R.Feistel, S.Feistel

Version 4.0 with room acoustic module ***AURA***

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Room Acoustics Programs

1988, CATT-Acoustic, by Dalenbäck/Sweden

Version 1, now version 7.3

1991, ODEON, by Naylor & Rindel/Denmark

Version 1, now version 4.2

1994, RAMSETE, Farina/Italy,

Version 1, now version 2.xx

1998-2001, ***CAESAR***, by

Vorländer - Schmitz/Aachen, Germany

Version 0.12, 2001 version 0.20

2001, ***EASE***, by Ahnert - Feistel/Berlin, Germany

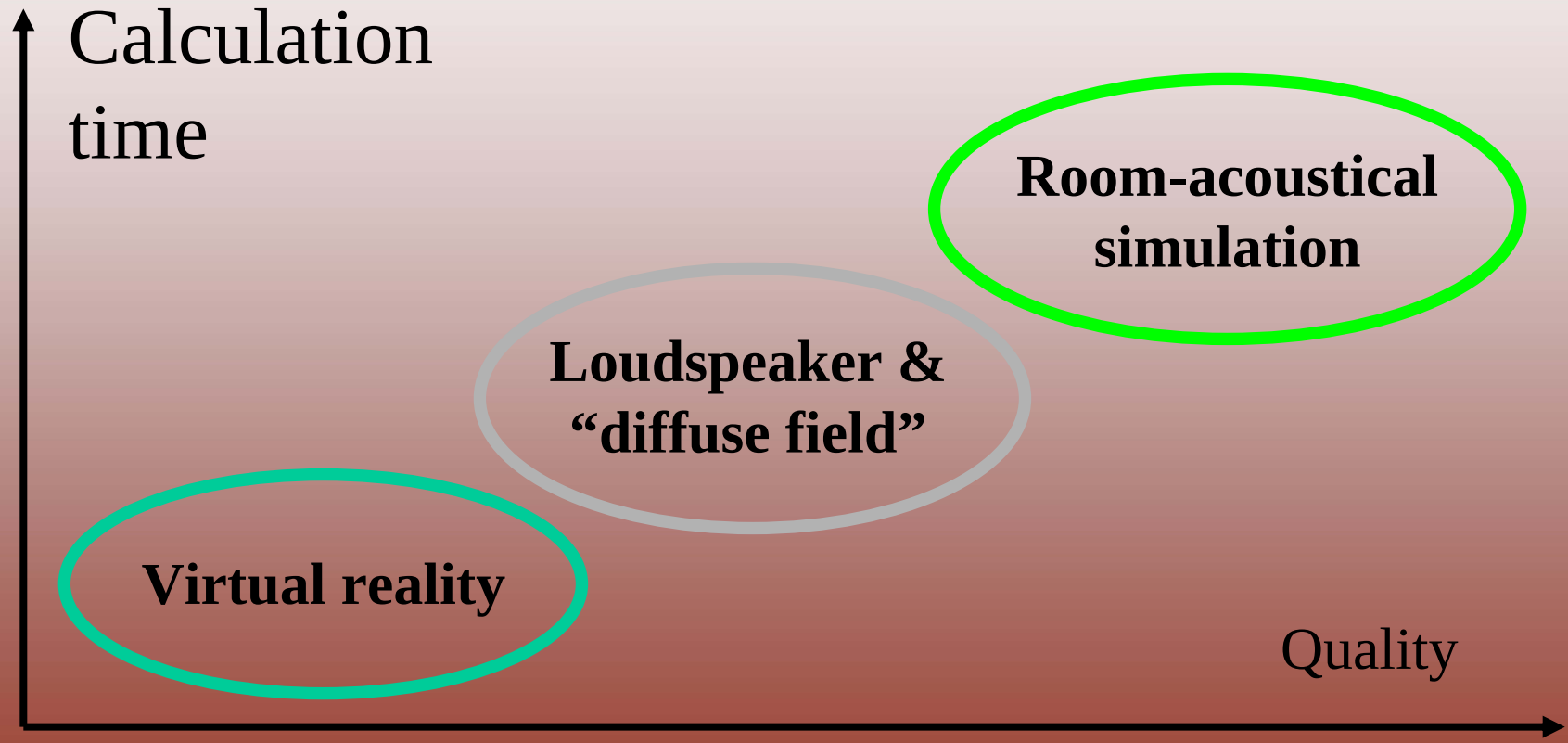
Version 4.0 – Includes **AURA**, Analysis Utility for Room Acoustics

ADA

Past
and future ...

State of the art

Room acoustical simulation



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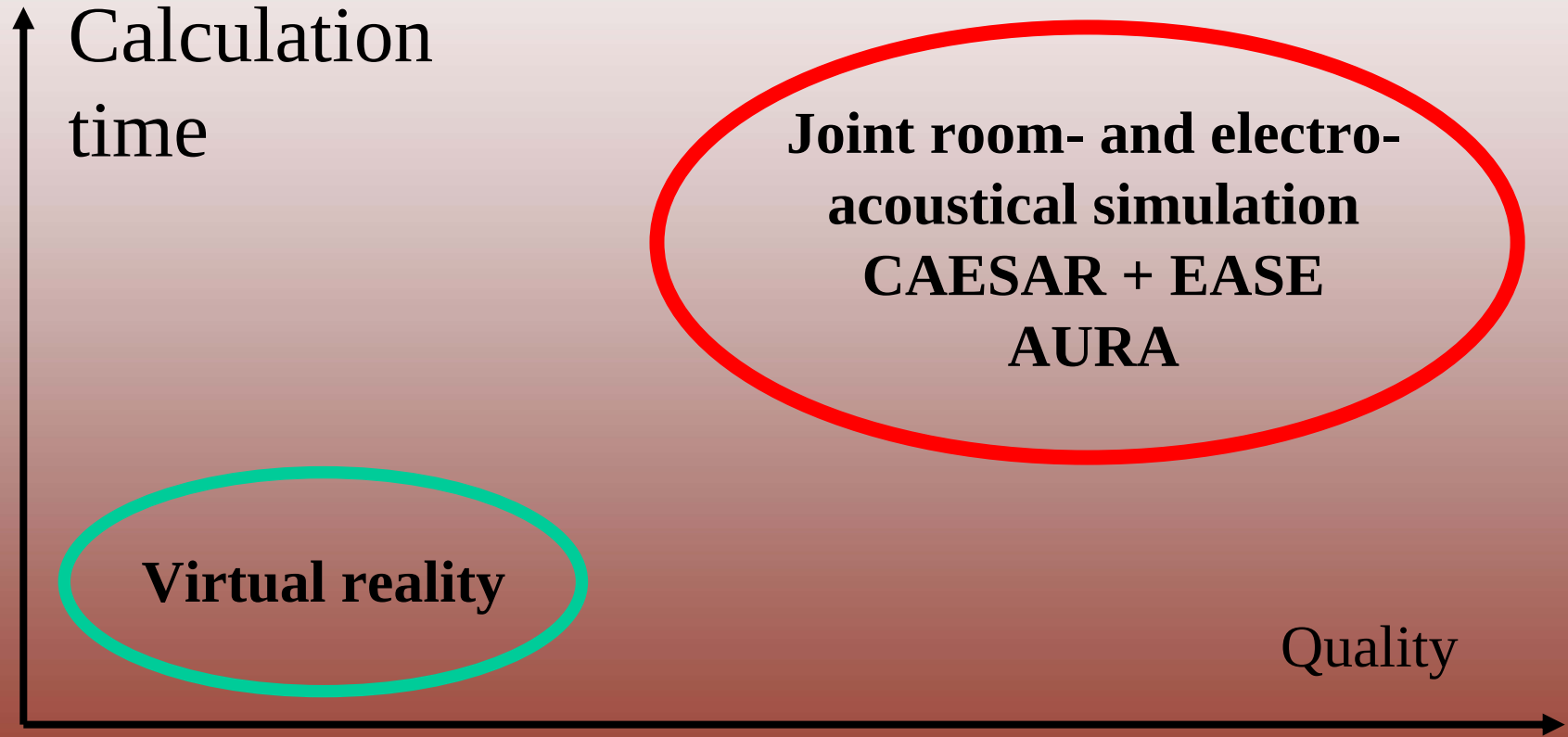
Past and
future ...

State of the art

Room acoustical simulation



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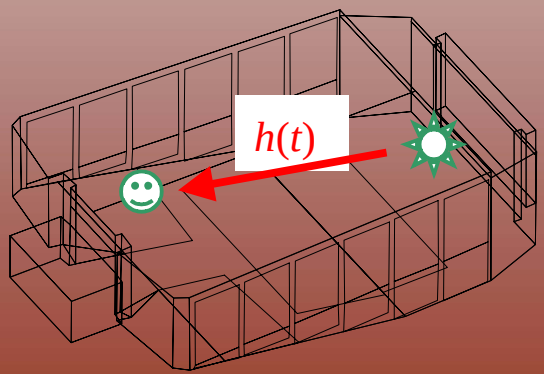
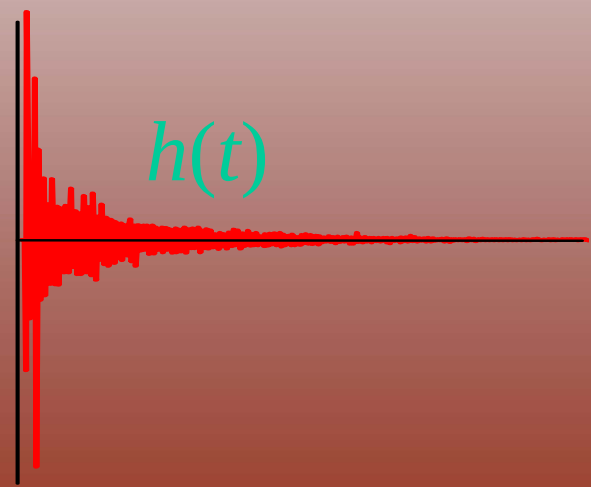
Room acoustics

basics, assumptions

- Sound propagation in rooms is described by impulse responses (source-to-receiver)
- The room is considered as LTI system. Impulse responses contain all acoustic information
- Impulse responses can be processed to obtain single number quantities (***T***, ***C***, ***LF***, ...)





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EASE + CAESAR

Synergy

EASE - ADA

- Electro acoustics
- Speaker database
- Directivity DLL
- 3D-visualization
- Real-time auralization
- Professional support

CAESAR - ITA

- 15 years experience
- Proven in two round robin tests
- Room acoustical parameters
  - ray tracing
- Auralization
  - hybrid simulation combining ray tracing and mirror images
- Scattering !

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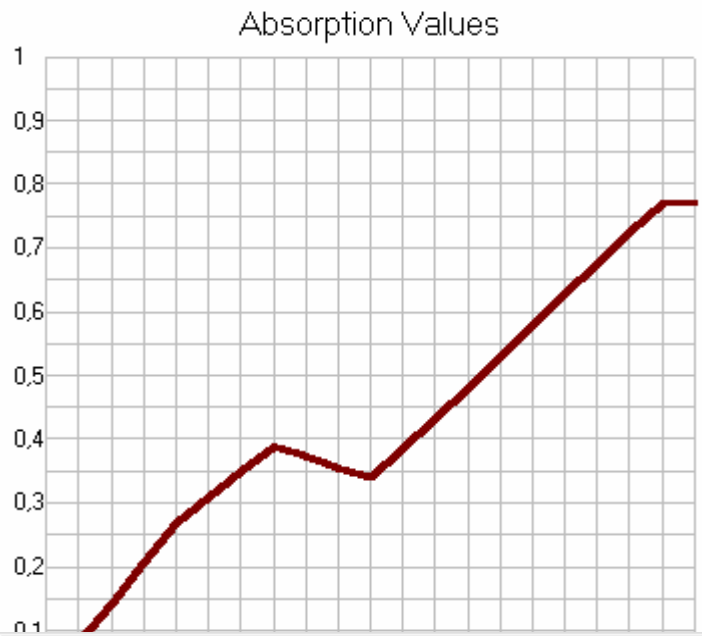
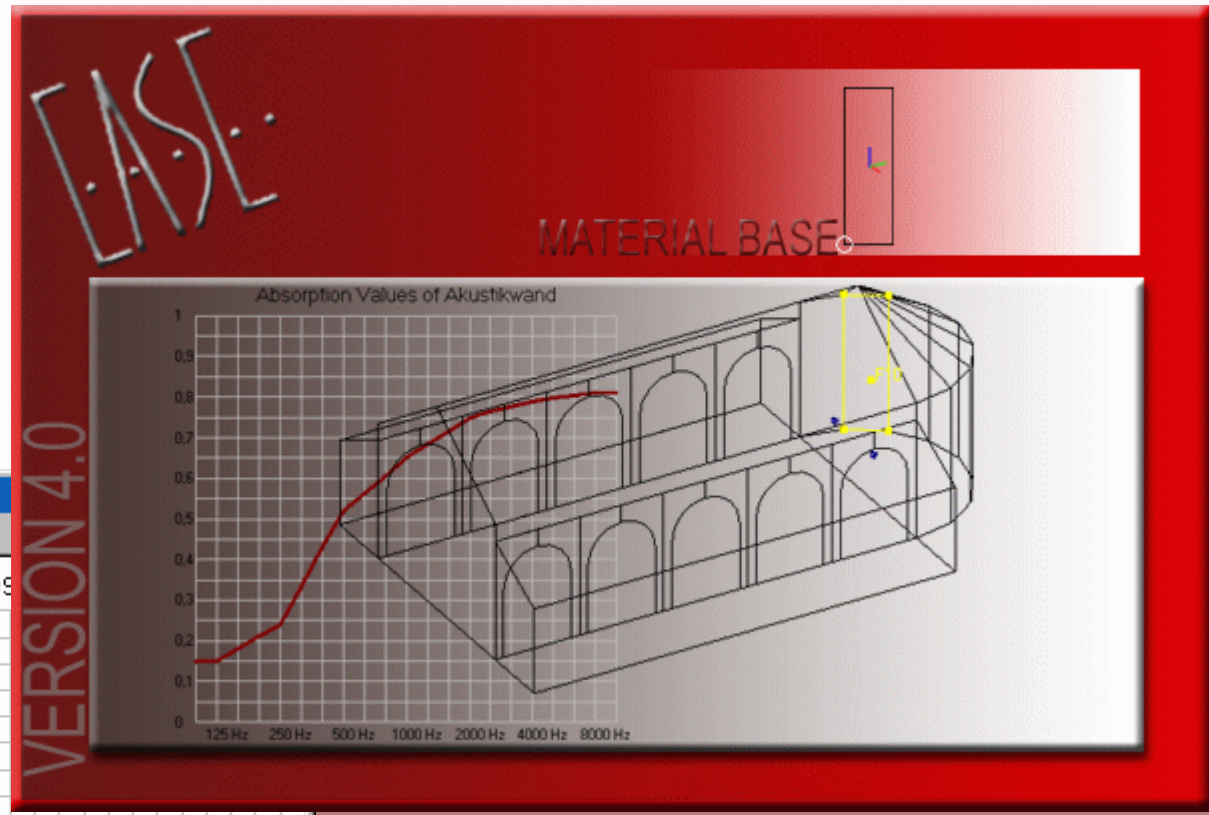
Material data base



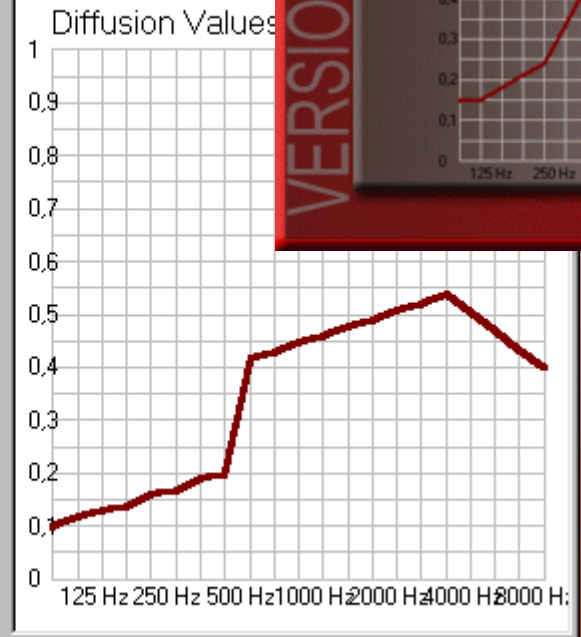


Wall Material Base

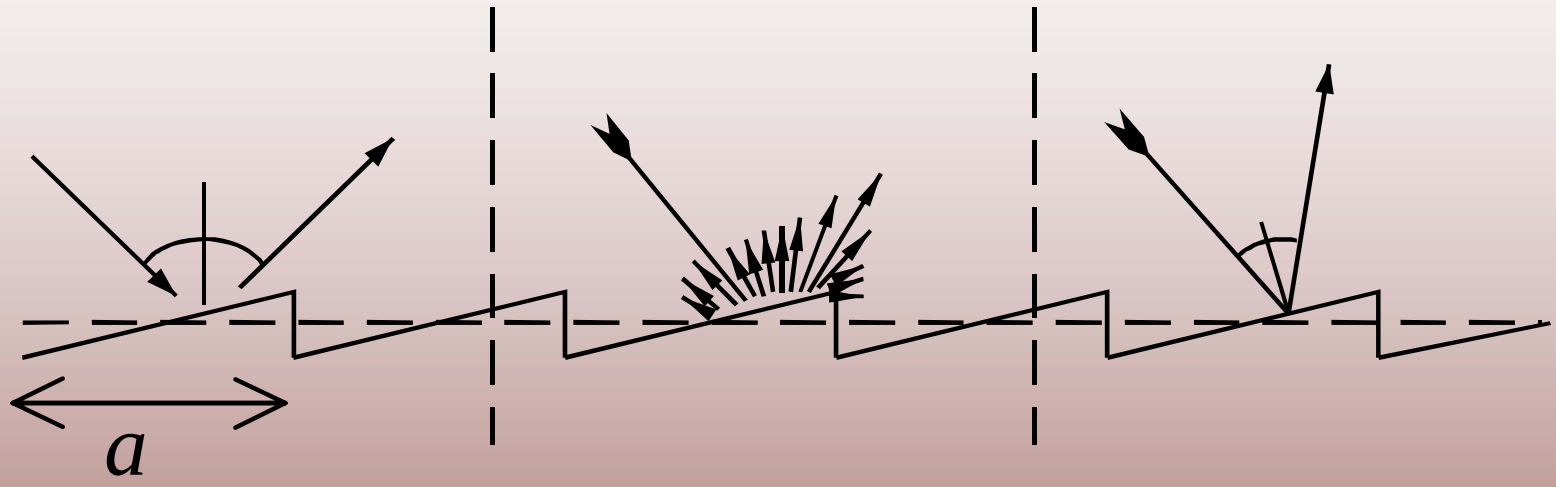
File Edit View Window Help

Wall Material | **Coefficients**

Frequency	Absorption	Diffusion
100 Hz	0.24	0.10
125 Hz	0.24	0.12
160 Hz	0.39	0.13
200 Hz	0.55	0.14
250 Hz	0.70	0.16
315 Hz	0.80	0.17
400 Hz	0.90	0.19
500 Hz	1.00	0.20
630 Hz	0.97	0.42
800 Hz	0.95	0.43
1000 Hz	0.92	0.45
1250 Hz	0.95	0.46
1600 Hz	0.97	0.48
2000 Hz	1.00	0.49
2500 Hz	0.97	0.51
3150 Hz	0.95	0.52
4000 Hz	0.92	0.54
5000 Hz	0.93	0.50

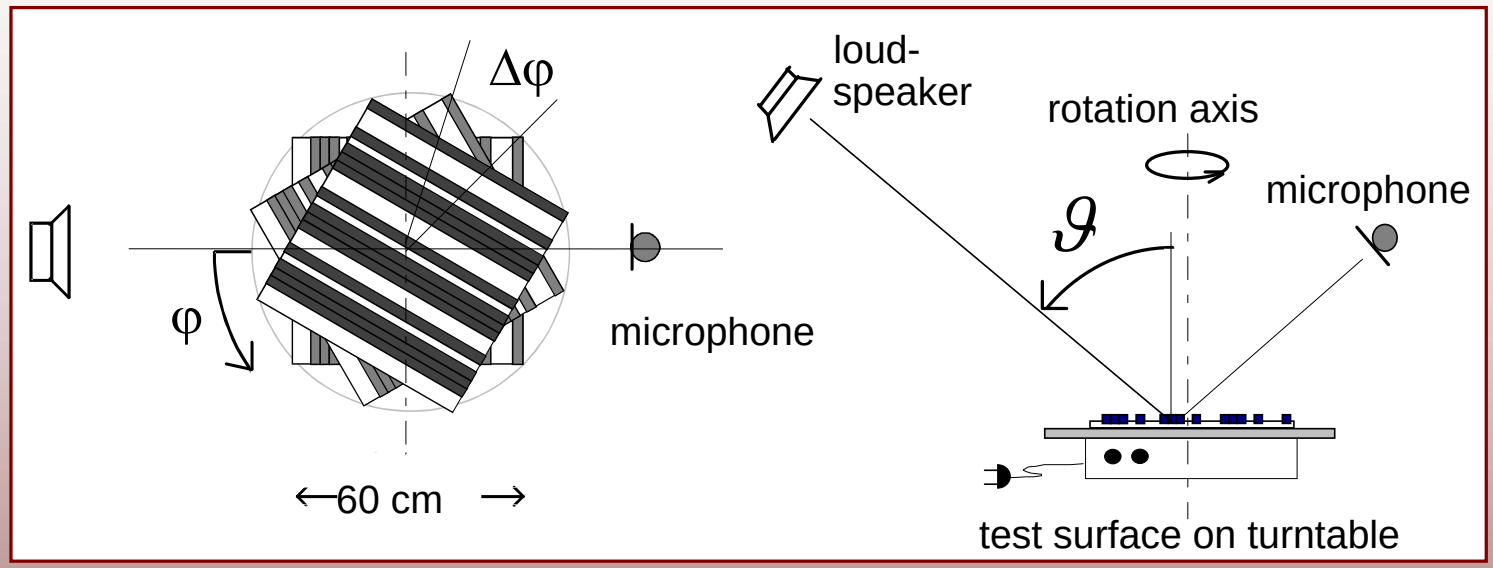


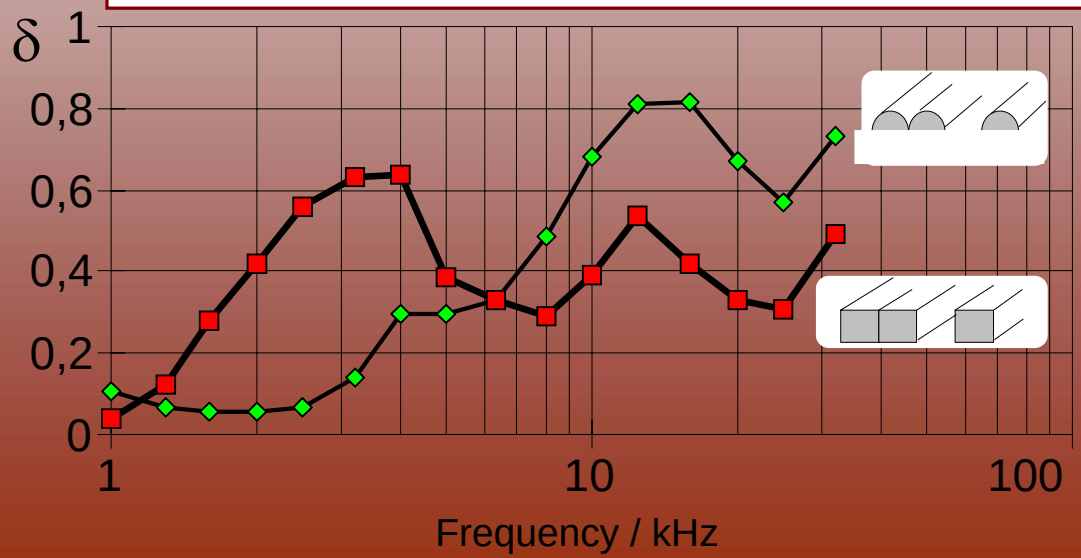
Rough or corrugated surfaces



$f \ll c/2a$ $f \approx c/2a$ $f \gg c/2a$

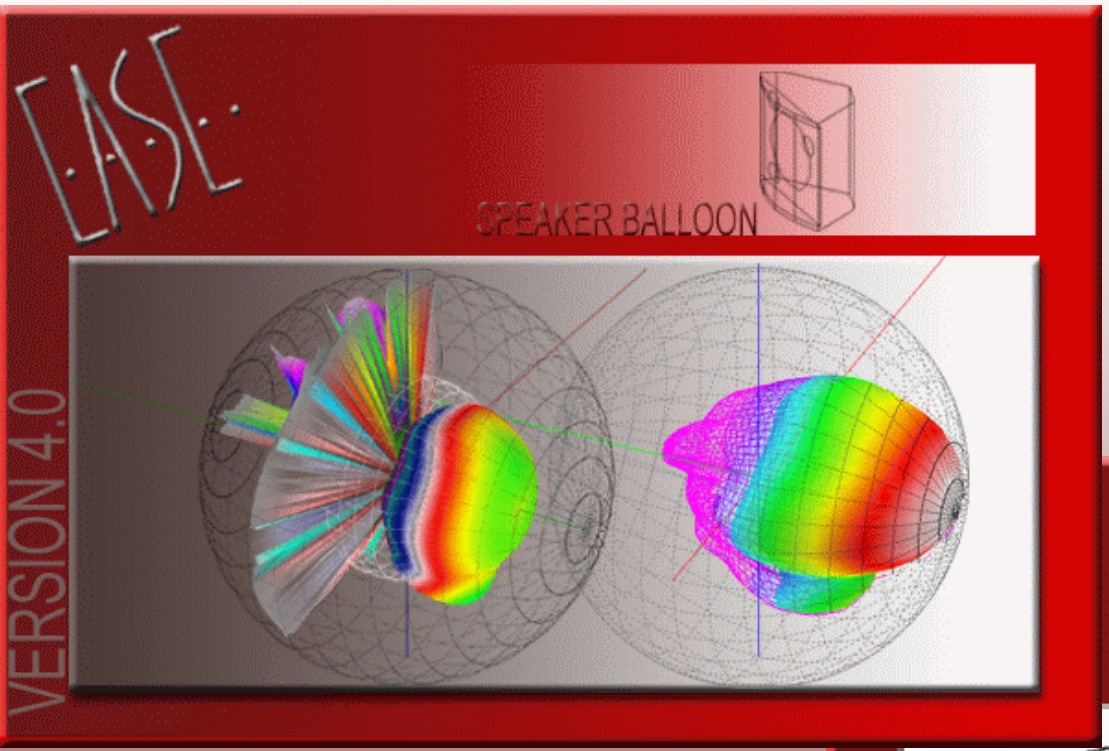
Random-incidence scattering coefficient

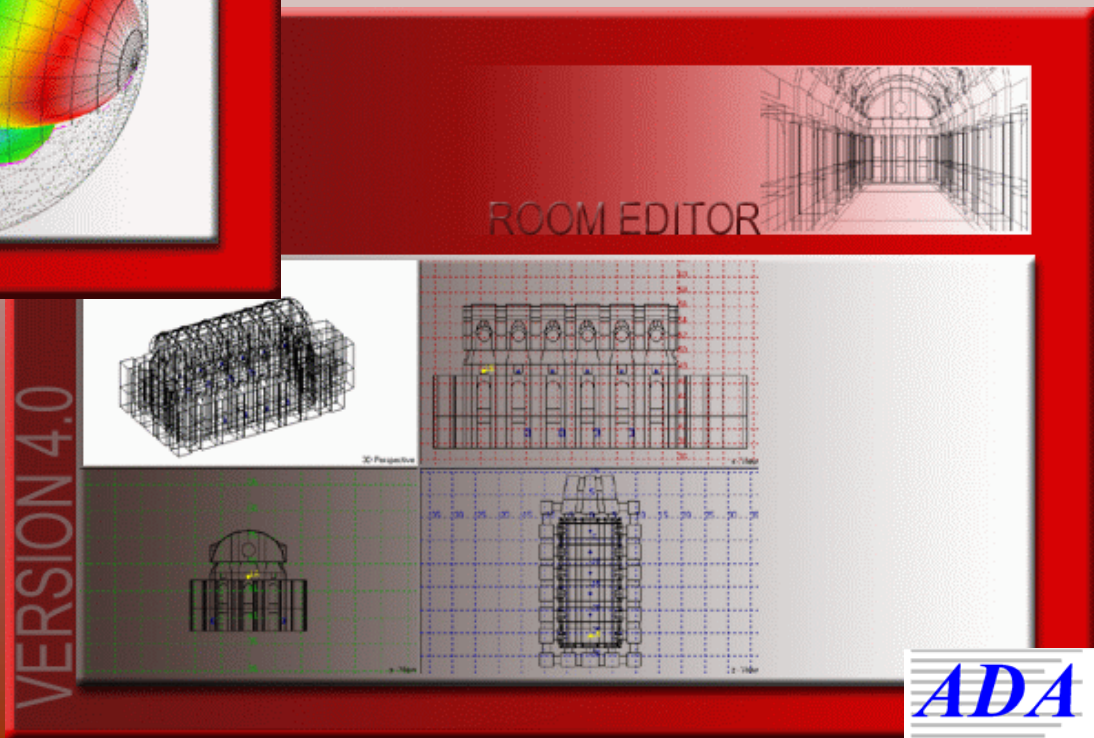




$$\delta = 1 - \frac{\left|\underline{R}_{specular}\right|^2}{1-\alpha}$$

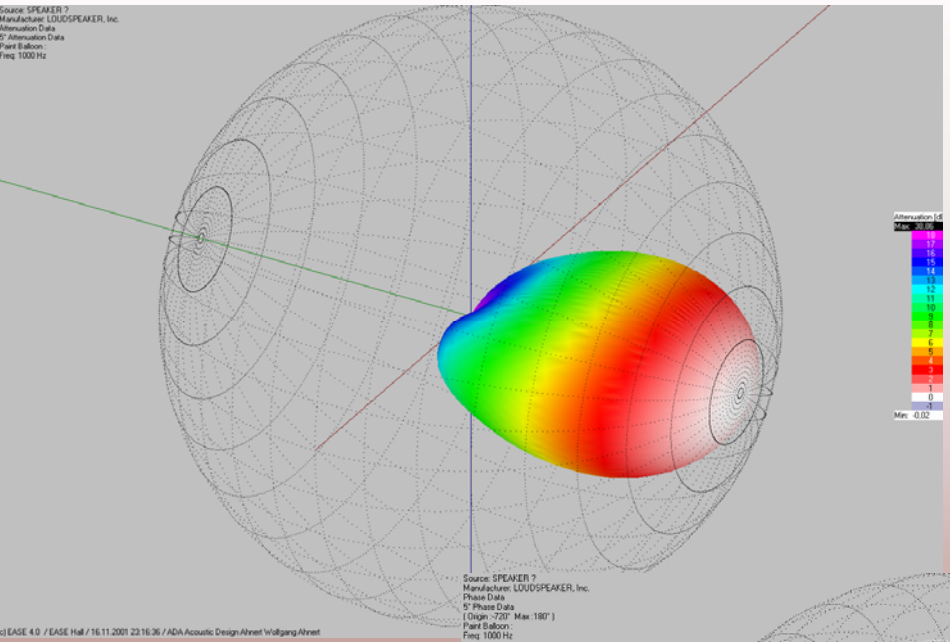
Source and room editor

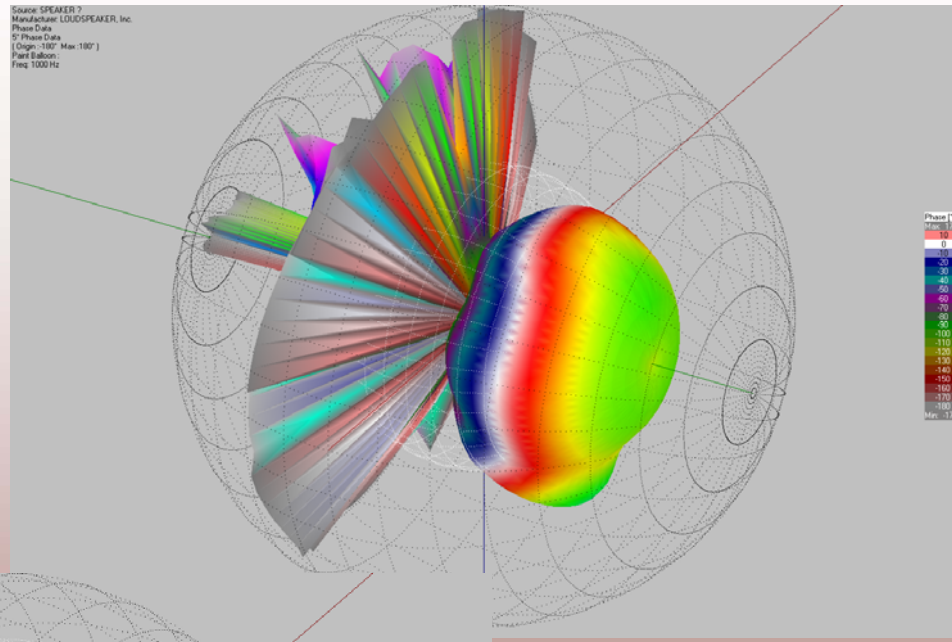


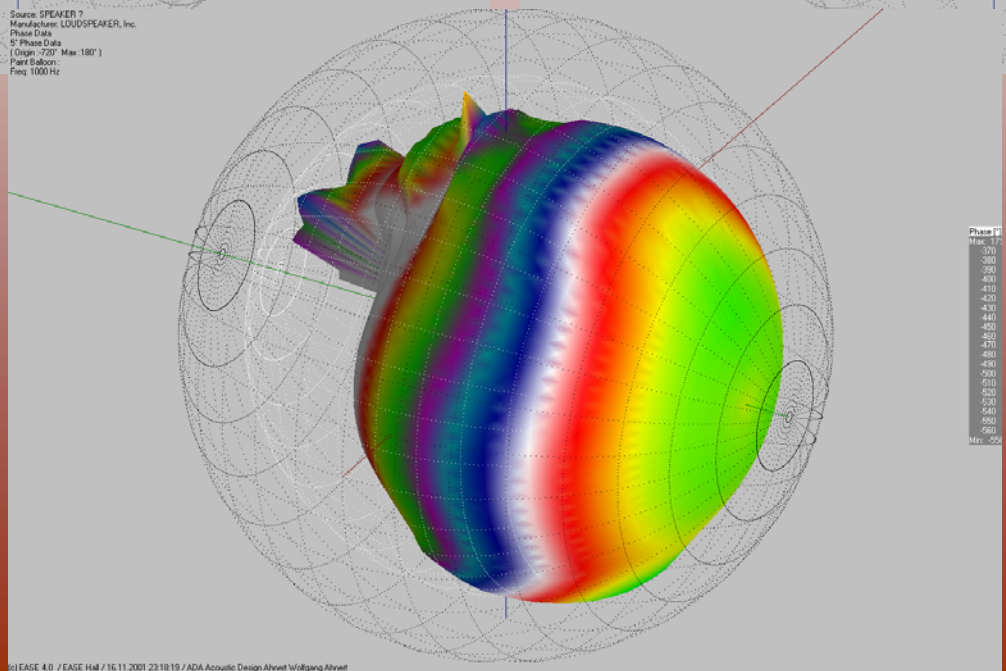


ADA

Magnitude and Phase balloon

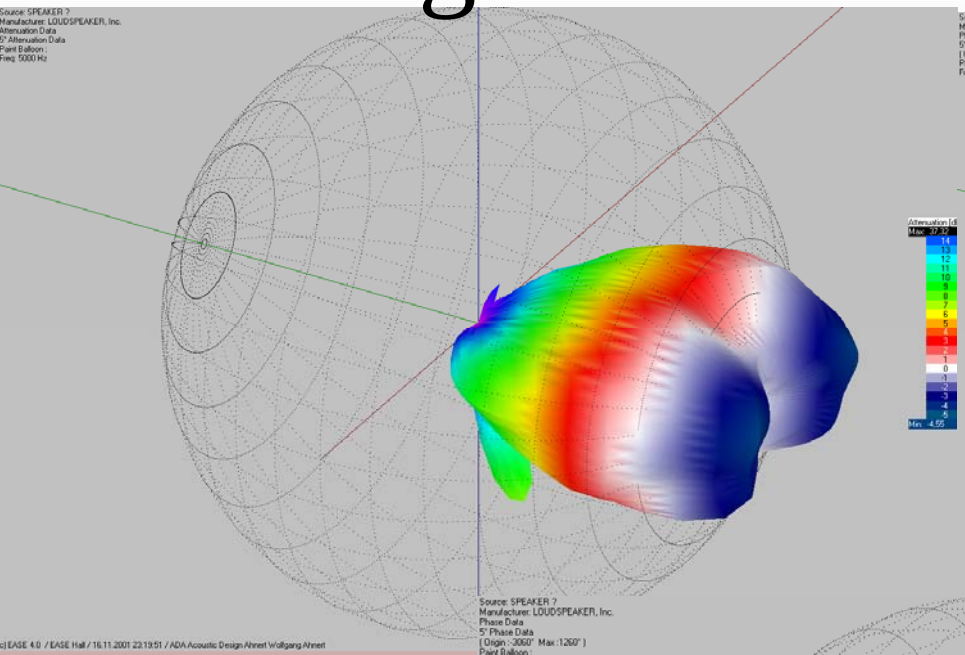


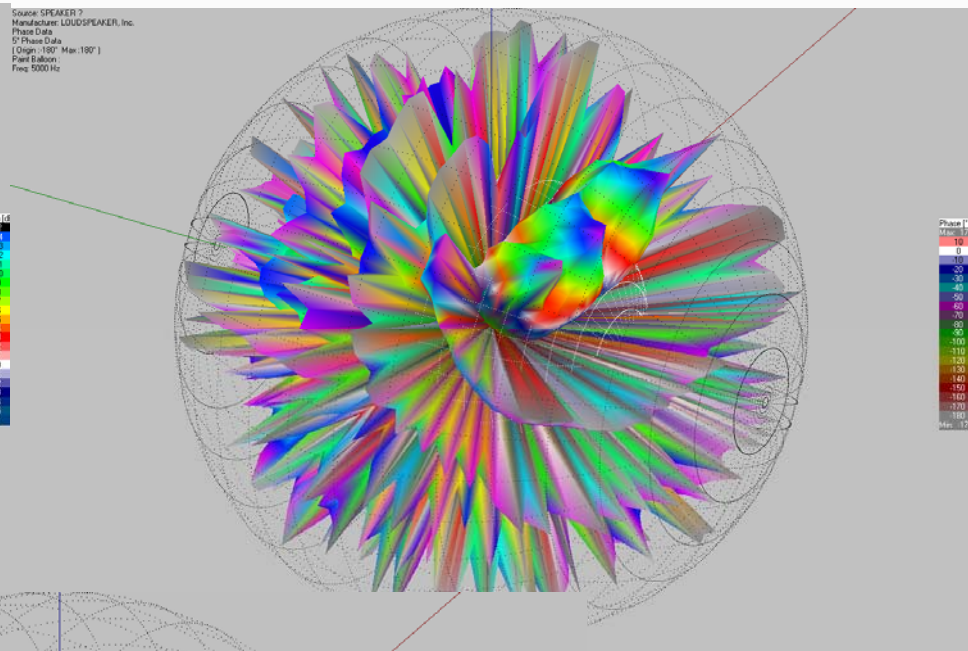




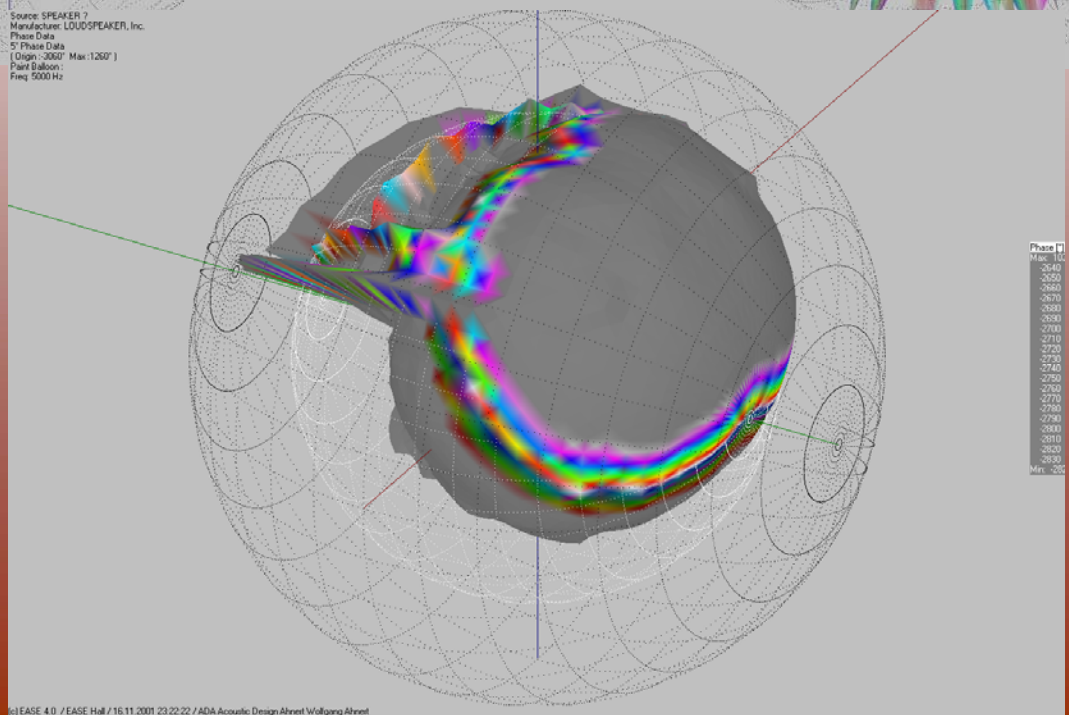
1000 Hz

Magnitude and Phase balloon

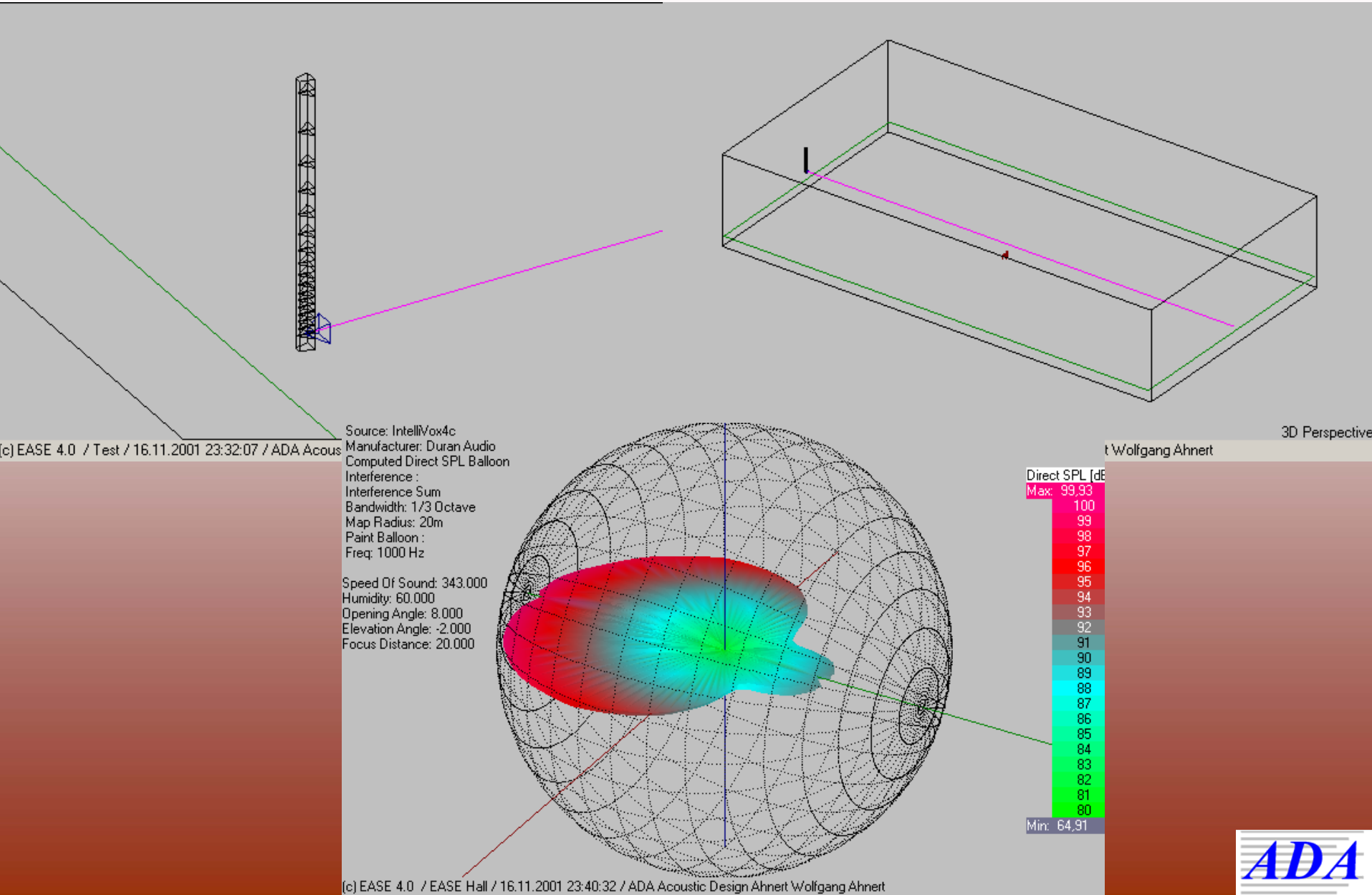




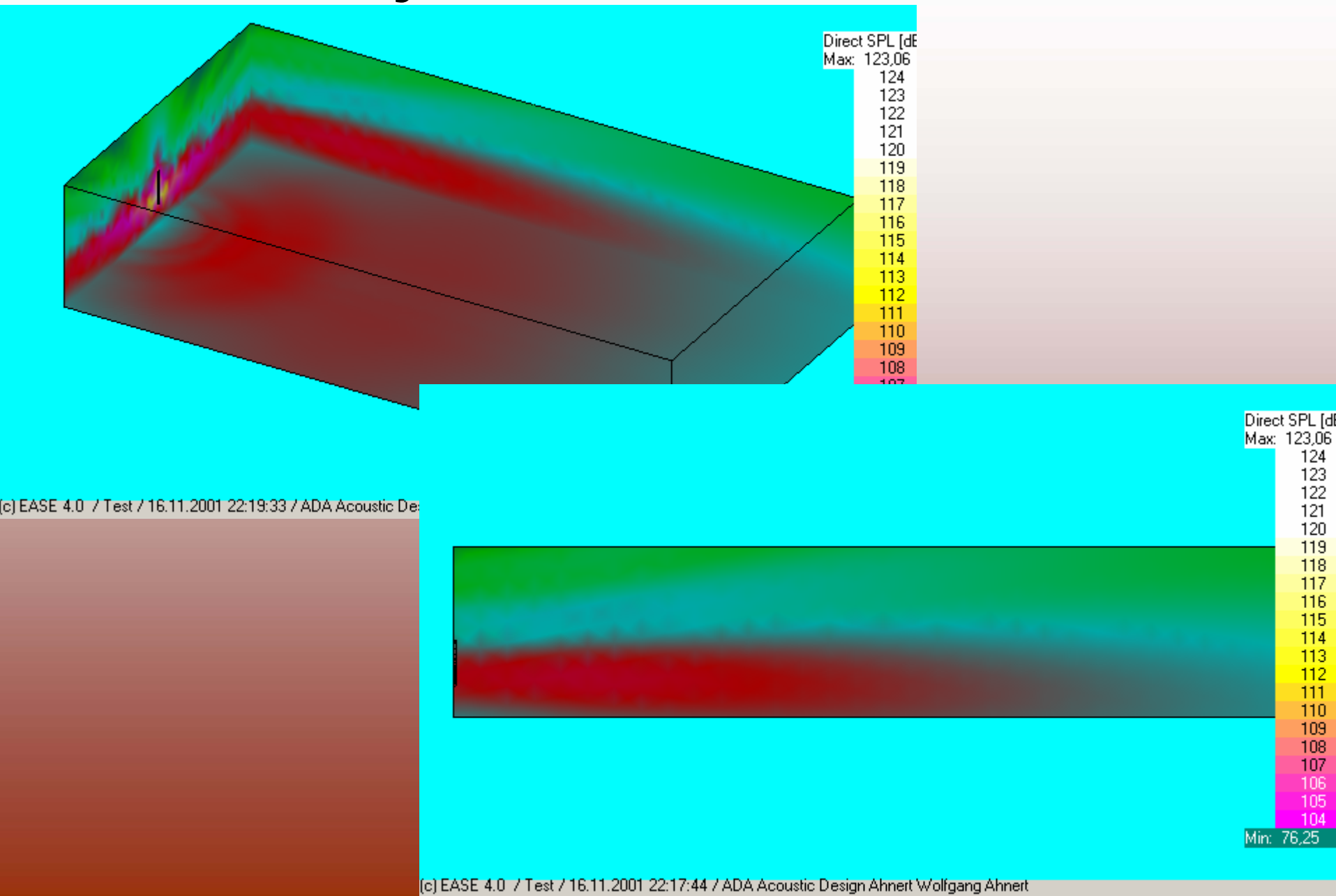
5000 Hz



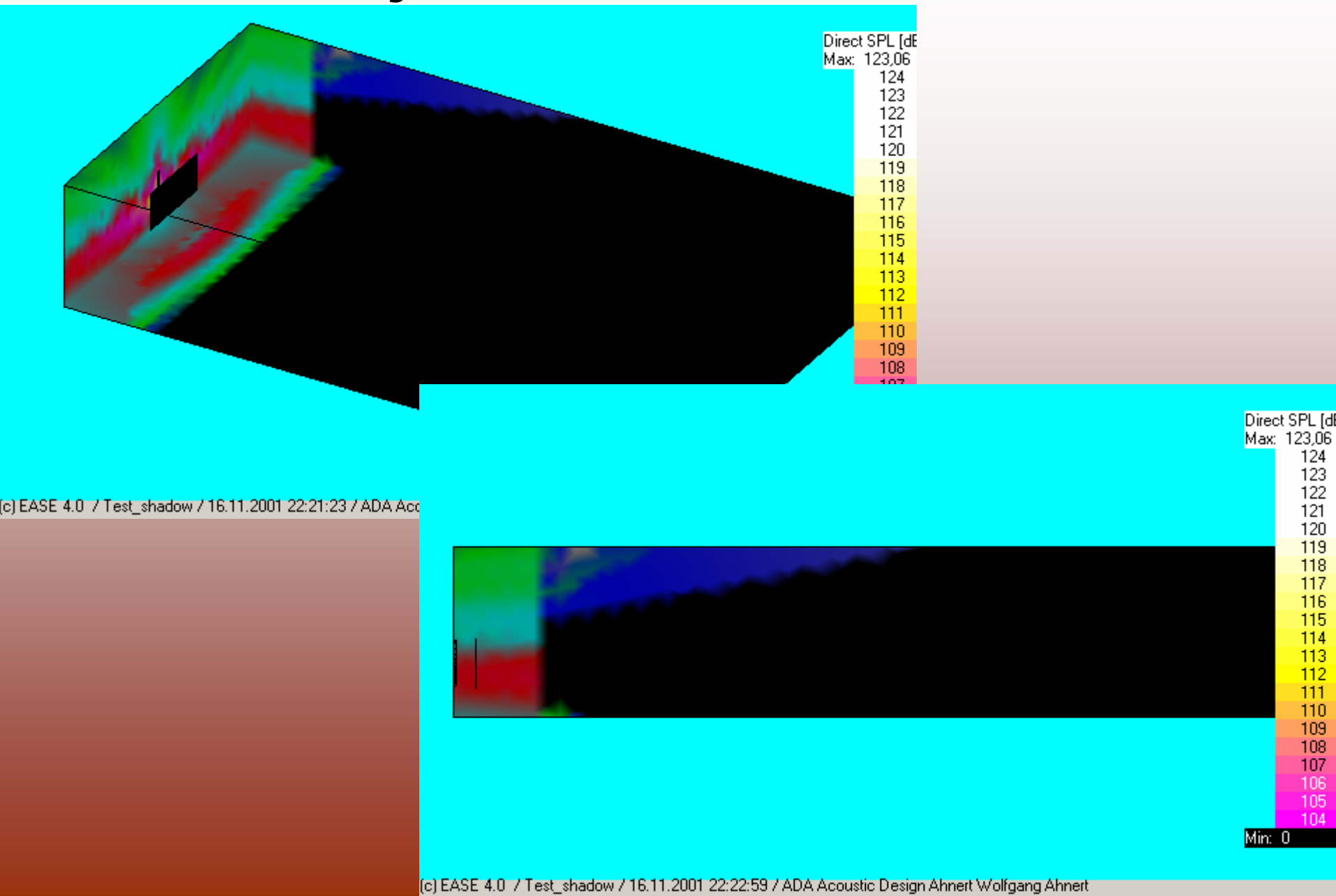
Line Array Simulation

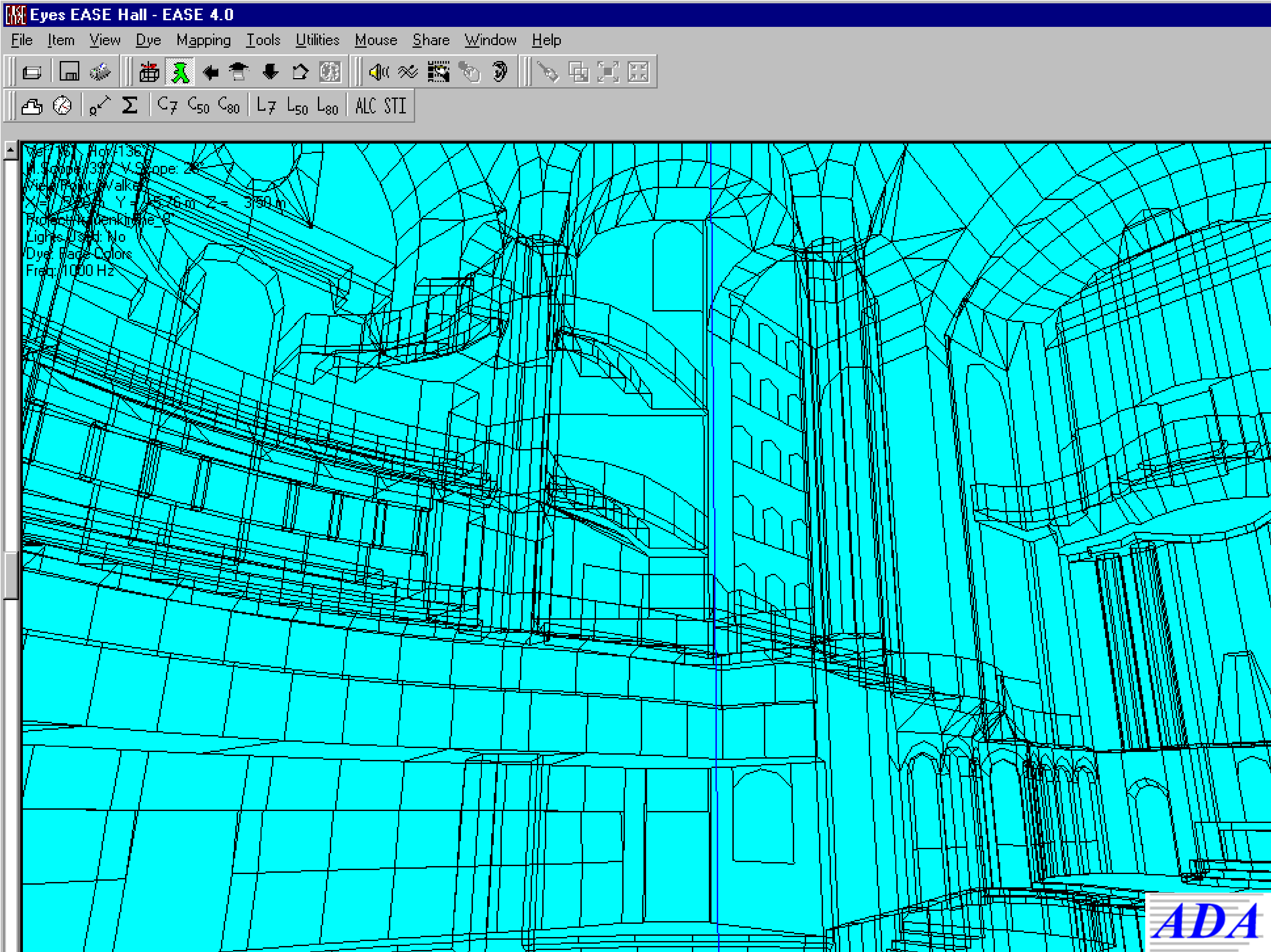


Line Array Simulation – Direct SPL

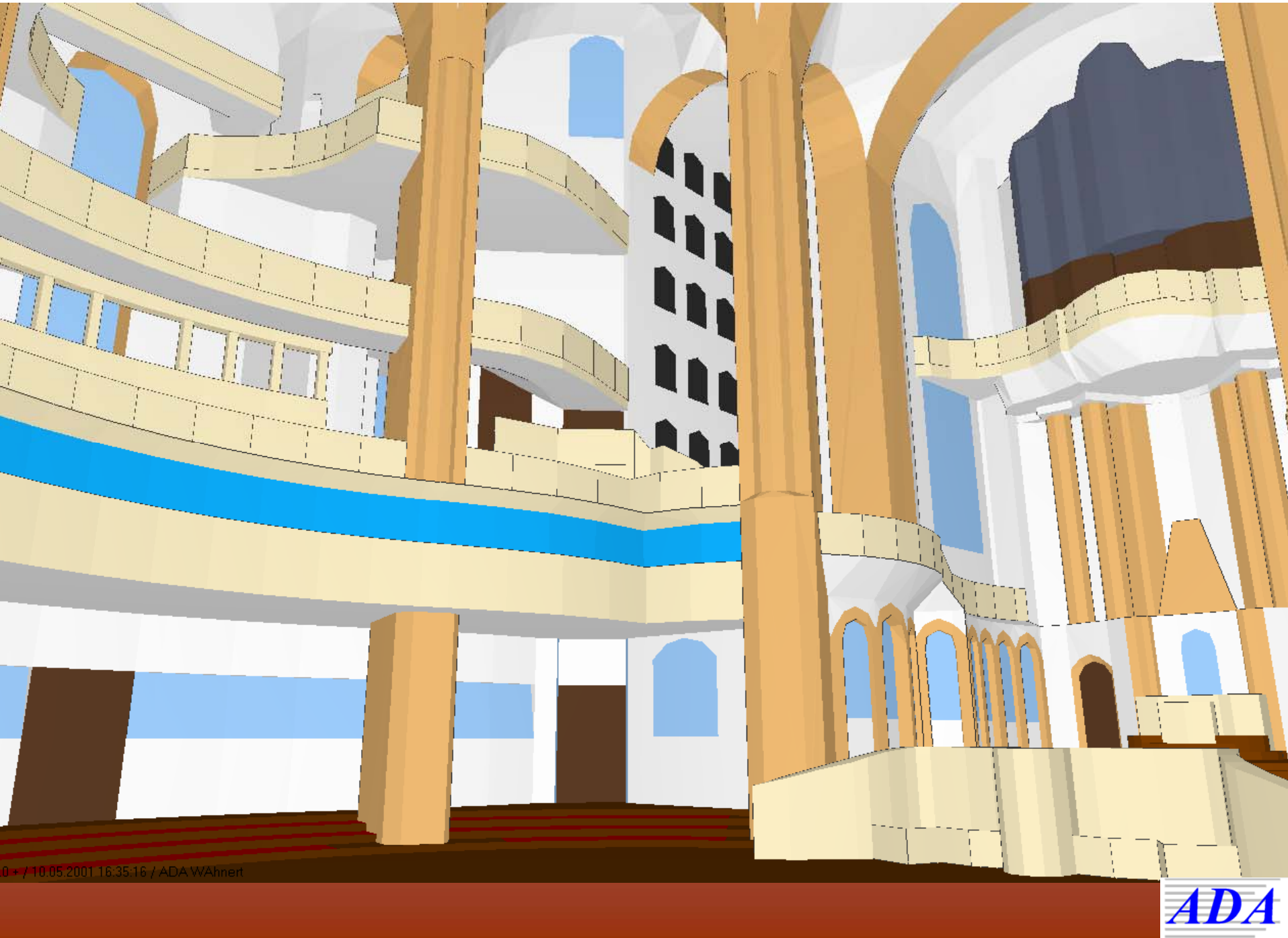


Line Array Simulation – With Baffle



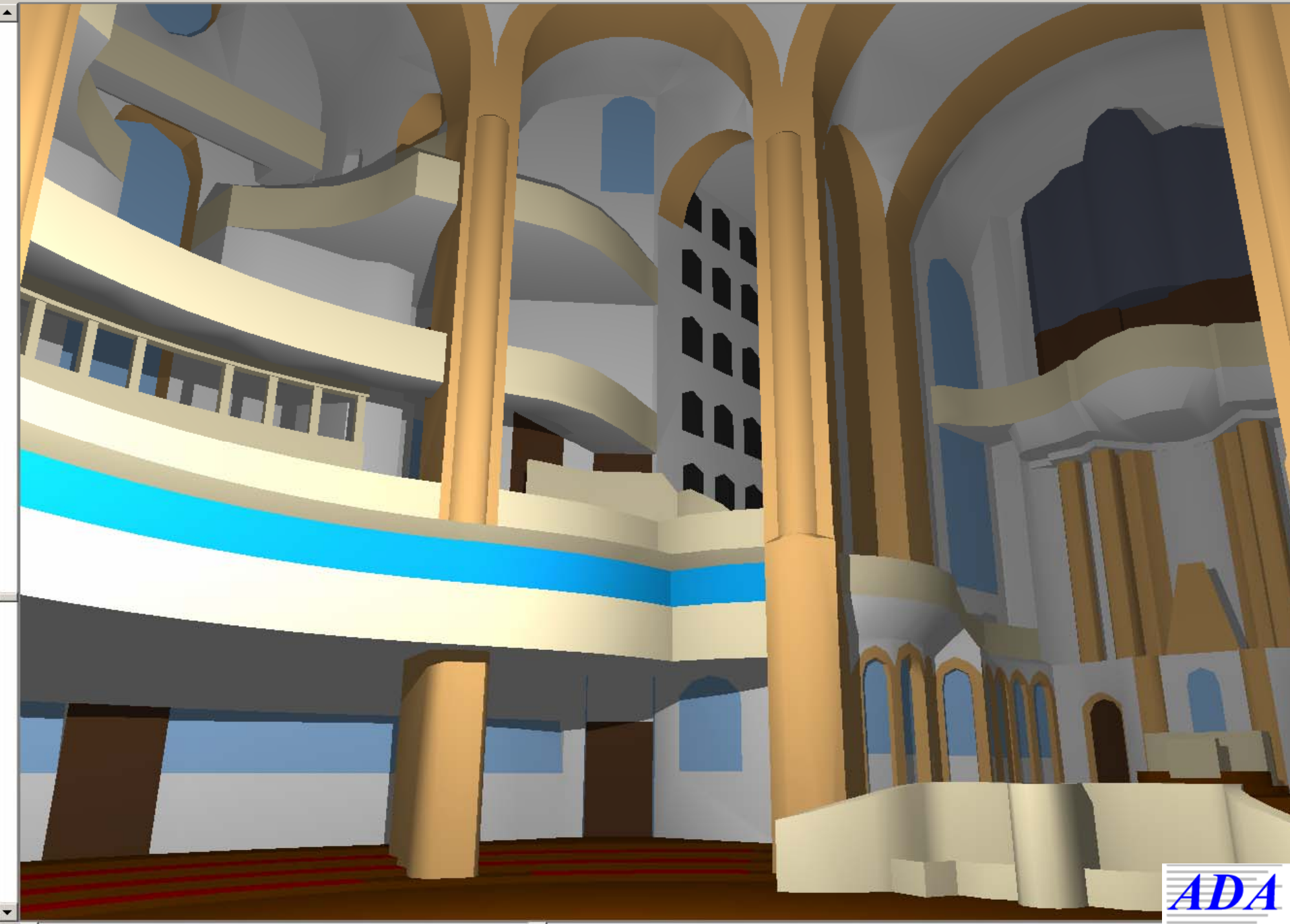


Eyes EASE Hall - EASE 4.0
File Item View Dye Mapping Tools Utilities Mouse Share Window Help
ALC STI
Lights Used: No
Dye: Face Colors
Freq: 1000 Hz
ADA

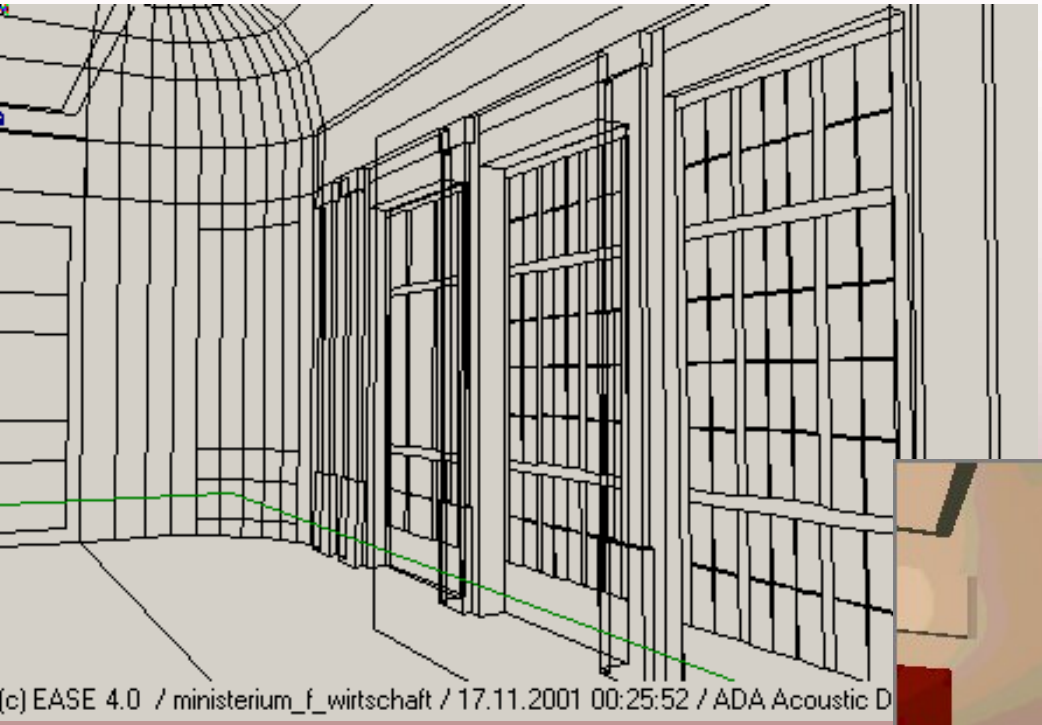

0 + / 10.05.2001 16:35:16 / ADA WAhnert

EASE Vision

File Item View Calculation Help

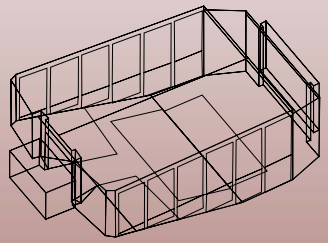


Texture Mapping in EASE



Room acoustical computer simulation

CAD model +
material data

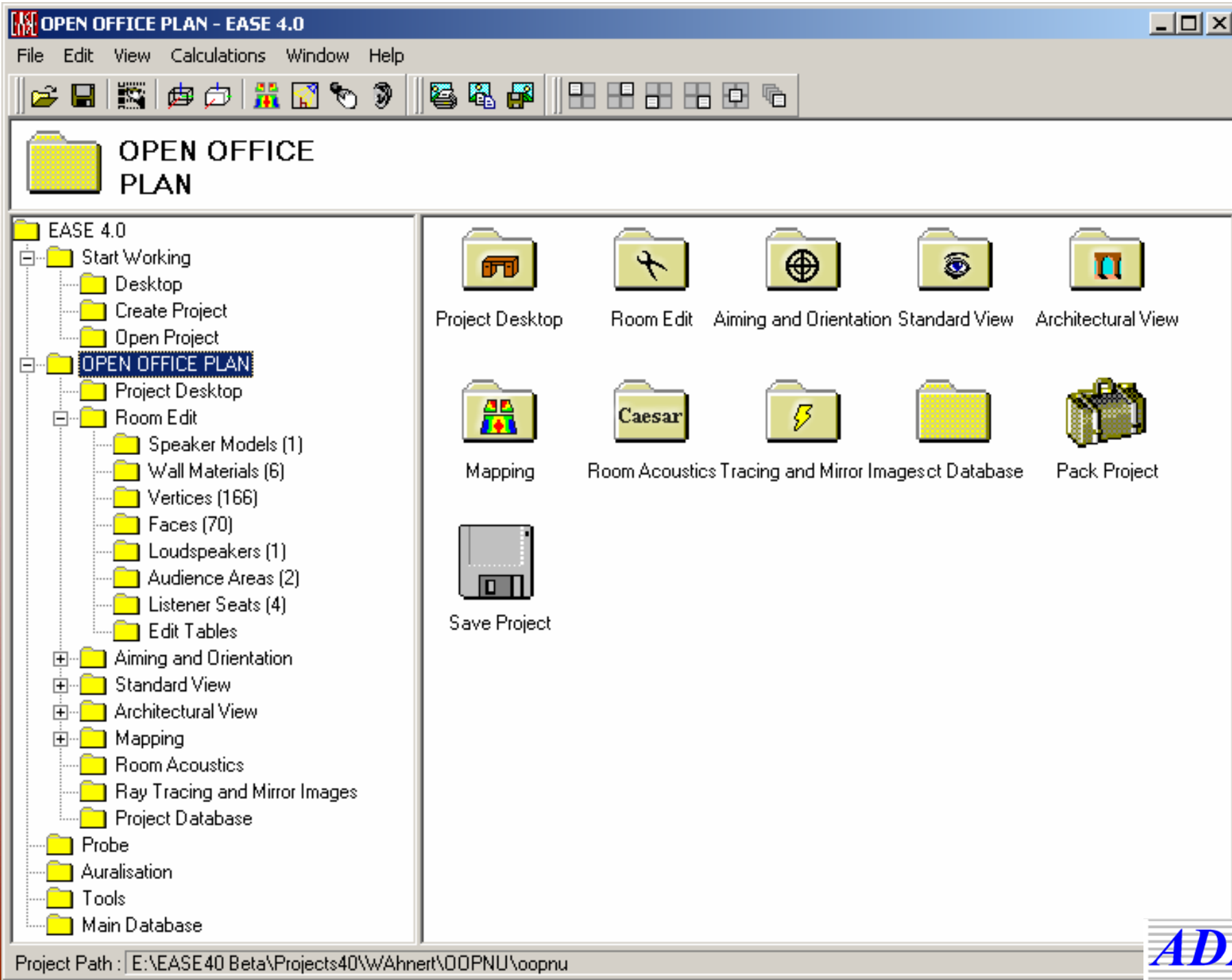


Simulation algorithm

Objective single number quantities

Real-time convolution

ADA


OPEN OFFICE PLAN - EASE 4.0
File Edit View Calculations Window Help
OPEN OFFICE PLAN
EASE 4.0
Start Working
Desktop
Create Project
Open Project
OPEN OFFICE PLAN
Project Desktop
Room Edit
Speaker Models (1)
Wall Materials (6)
Vertices (166)
Faces (70)
Loudspeakers (1)
Audience Areas (2)
Listener Seats (4)
Edit Tables
Aiming and Orientation
Standard View
Architectural View
Mapping
Room Acoustics
Ray Tracing and Mirror Images
Project Database
Probe
Auralisation
Tools
Main Database
Project Desktop
Room Edit
Aiming and Orientation
Standard View
Architectural View
Mapping
Caesar
Room Acoustics
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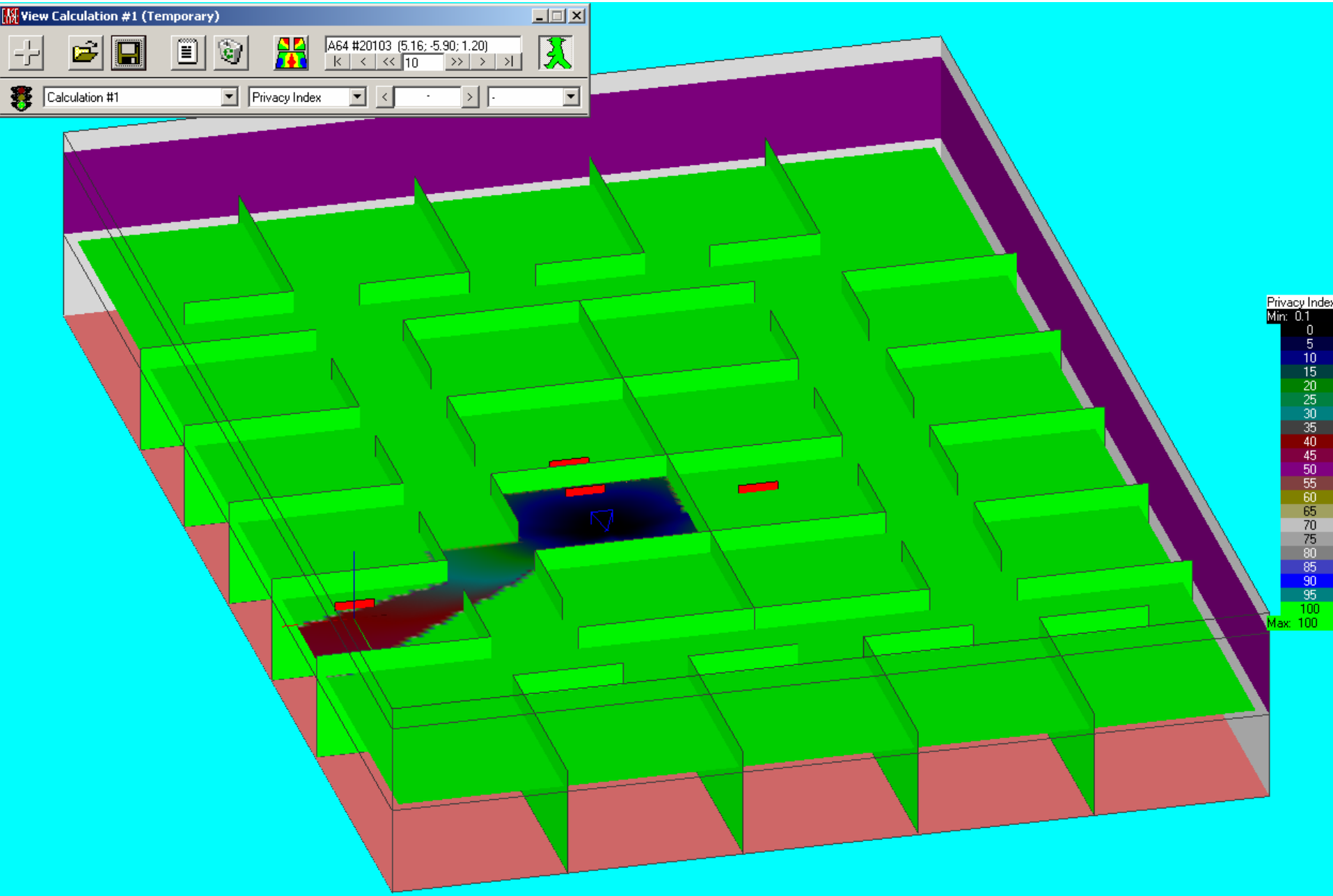
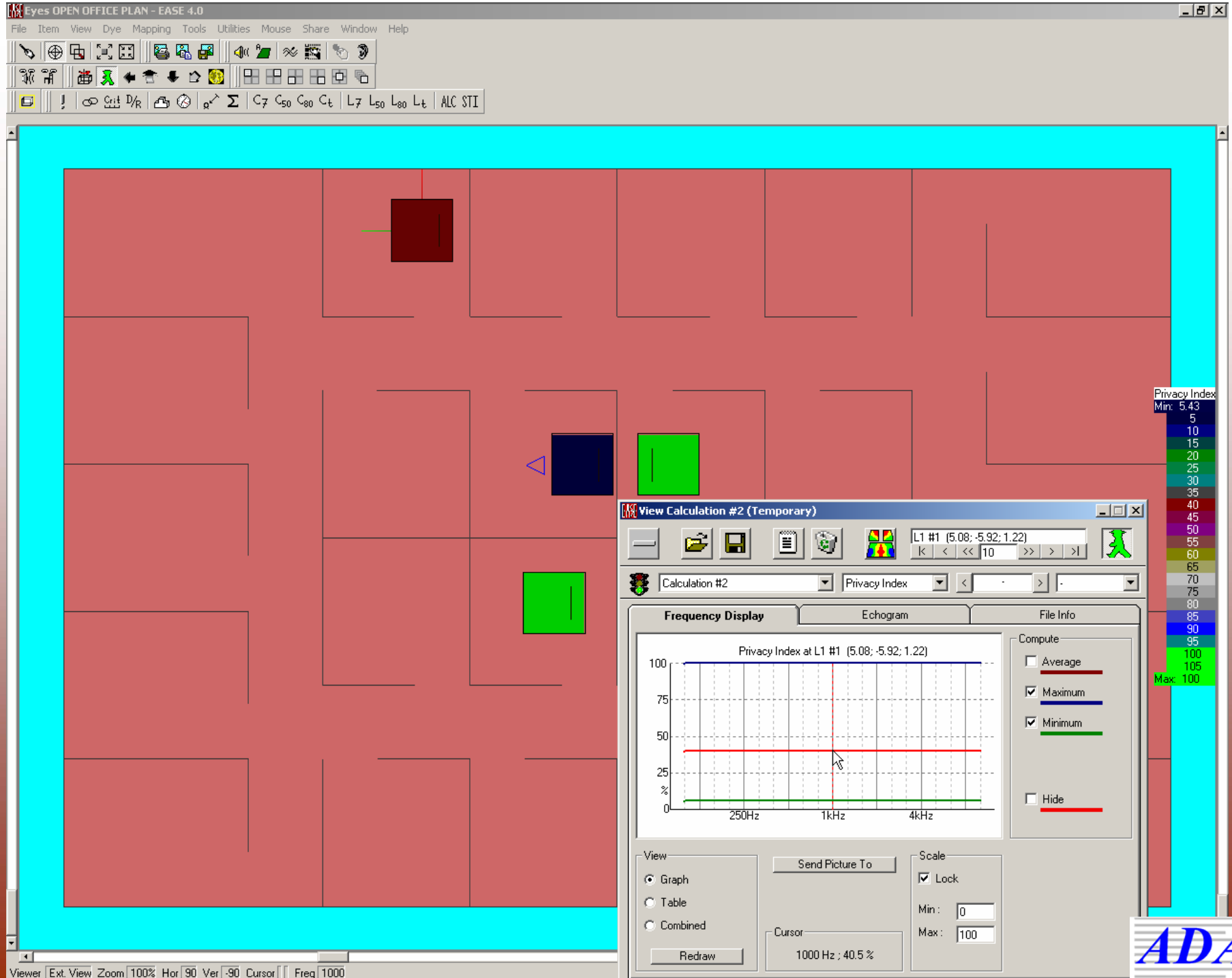
ct Database
Pack Project
Save Project
Project Path : E:\EASE40 Beta\Projects40\WAhnert\OOPNU\oopnu
ADA


View Calculation #1 (Temporary)
A64 #20103 (5.16; -5.90; 1.20)
10
Calculation #1
Privacy Index
Privacy Index
Min: 0.1
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Max: 100


Eyes OPEN OFFICE PLAN - EASE 4.0
File Item View Dye Mapping Tools Utilities Mouse Share Window Help
Privacy Index
Min: 5.43
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
Max: 100
View Calculation #2 (Temporary)
L1 #1 (5.08; -5.92; 1.22)
Calculation #2
Privacy Index
Frequency Display
Echogram
File Info
Privacy Index at L1 #1 (5.08; -5.92; 1.22)
100
75
50
25
%
0
250Hz
1kHz
4kHz
Compute
Average
Maximum
Minimum
Hide
View
Graph
Table
Combined
Redraw
Send Picture To
Cursor
1000 Hz ; 40.5 %
Scale
Lock
Min : 0
Max : 100
Viewer Ext. View Zoom 100% Hor 90 Ver -90 Cursor Freq 1000
ADA

Calculation #1 (Single Map)
File: E:\EASE40 Beta\Projects40\WAhnert\OOPNU\Mapping\Privacy Index - Audience.emp

Direct & Statistical Field Mapping, 12/6/2001 1:24:29 AM
Shadow : On
Interference :
Interference Sum
(Speaker Phase used)
Bandwidth : 1/3 Octave
Noise : On

Freq[Hz]	Noise[dB]	RT[s]
1000	31.00	0.24

Seats: 0
Area Data Points: 22250
Face Data Points: 0

Maps available:
Privacy Index

Loudspeaker = PERS
Position[m] x = 1.2 y =-7.64 z = 1.23
Direction[°] h = 0 v = 0 r = 0
Speaker = MANN_NORMA
Delay[ms] = 0

Freq[Hz]	Level[dB]	Phase[deg]
100	49.00	0.00
125	49.00	0.00
160	51.00	0.00
200	53.00	0.00
250	55.00	0.00
315	56.00	0.00
400	57.00	0.00
500	58.00	0.00
630	55.67	0.00
800	53.33	0.00
1000	51.00	0.00
1250	49.67	0.00
1600	48.33	0.00
2000	47.00	0.00
2500	45.67	0.00
3150	44.33	0.00
4000	43.00	0.00
5000	41.33	0.00
6300	39.67	0.00
8000	38.00	0.00
10000	38.00	0.00

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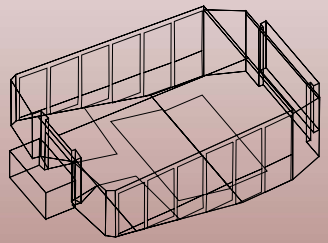
Room acoustical computer simulation

CAD model +
material data



Simulation algorithm

Objective single number quantities

Real-time convolution

ADA

Impulse response calculations

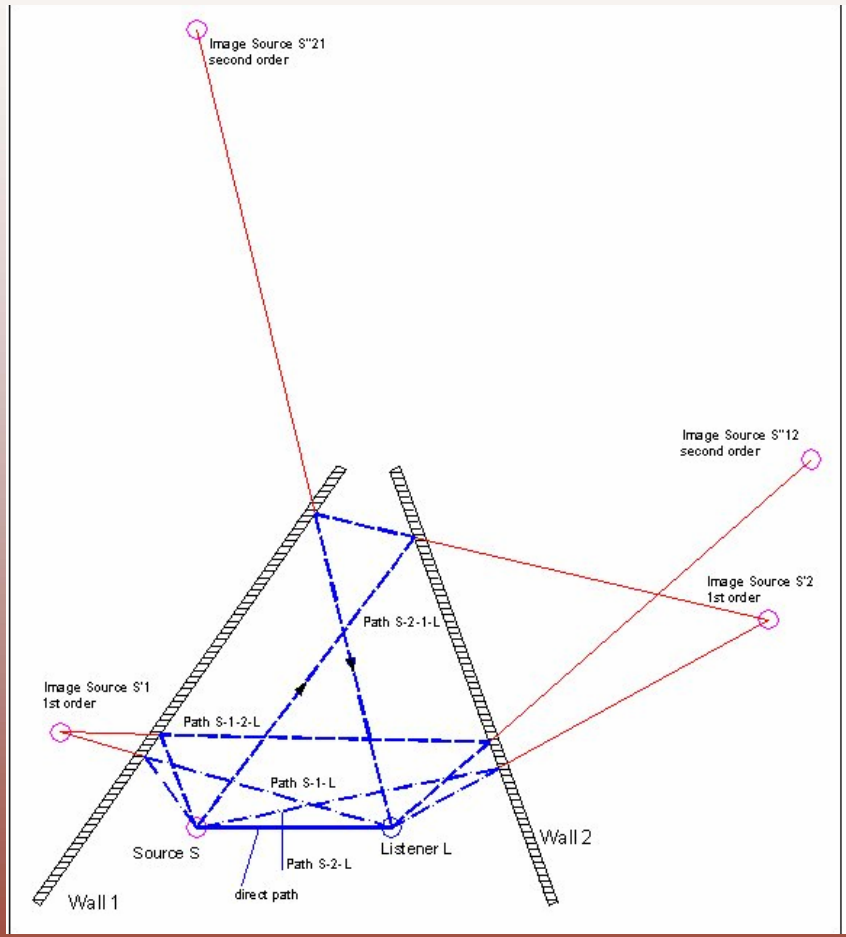
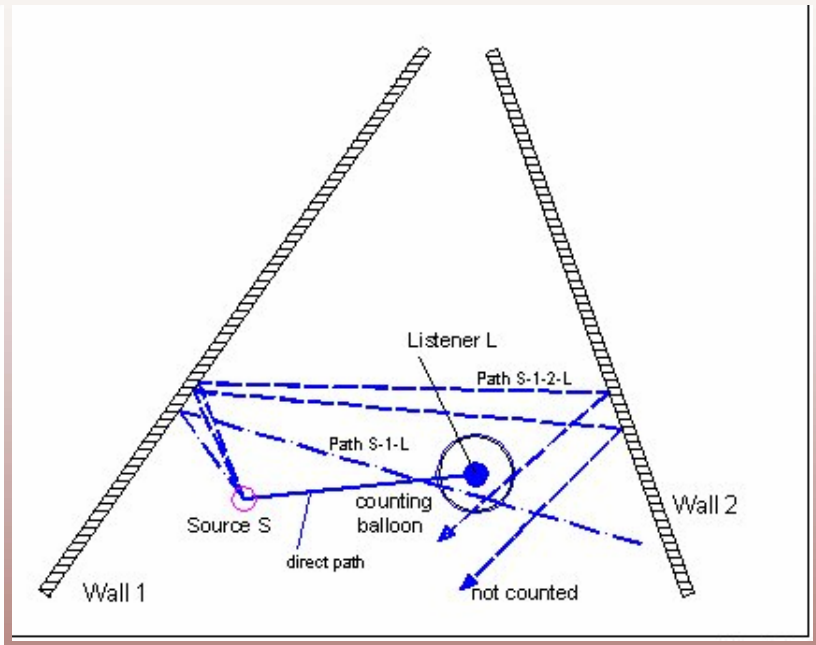
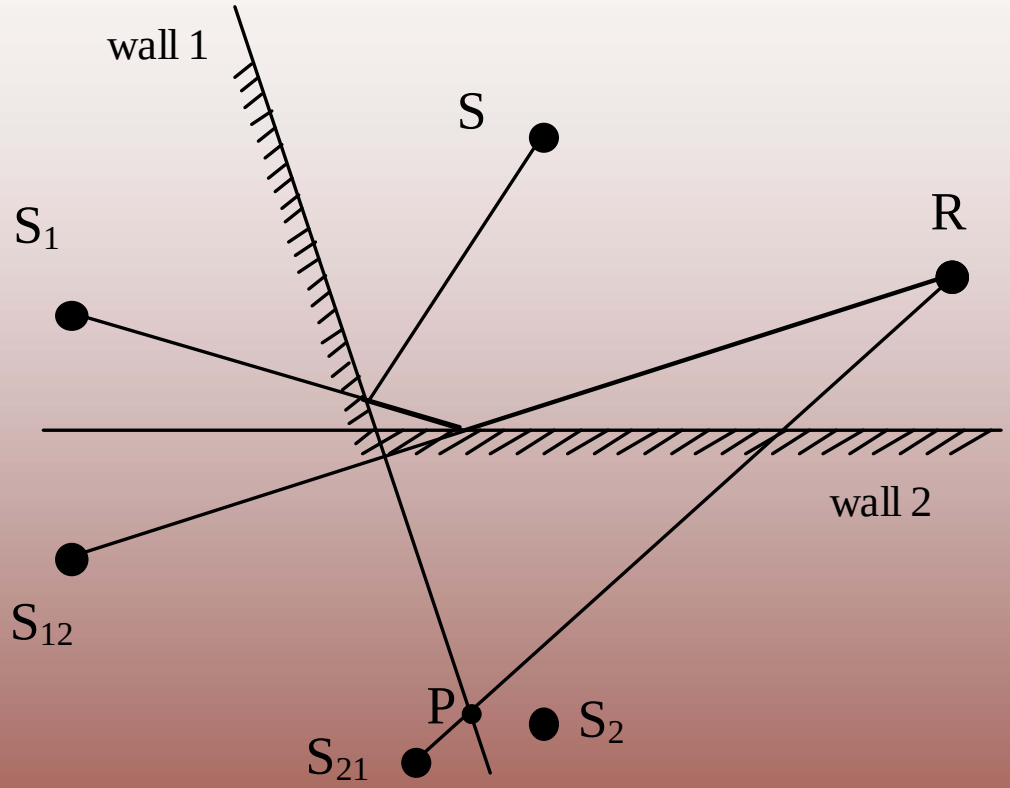


Image Model method



Ray Tracing with counting balloon

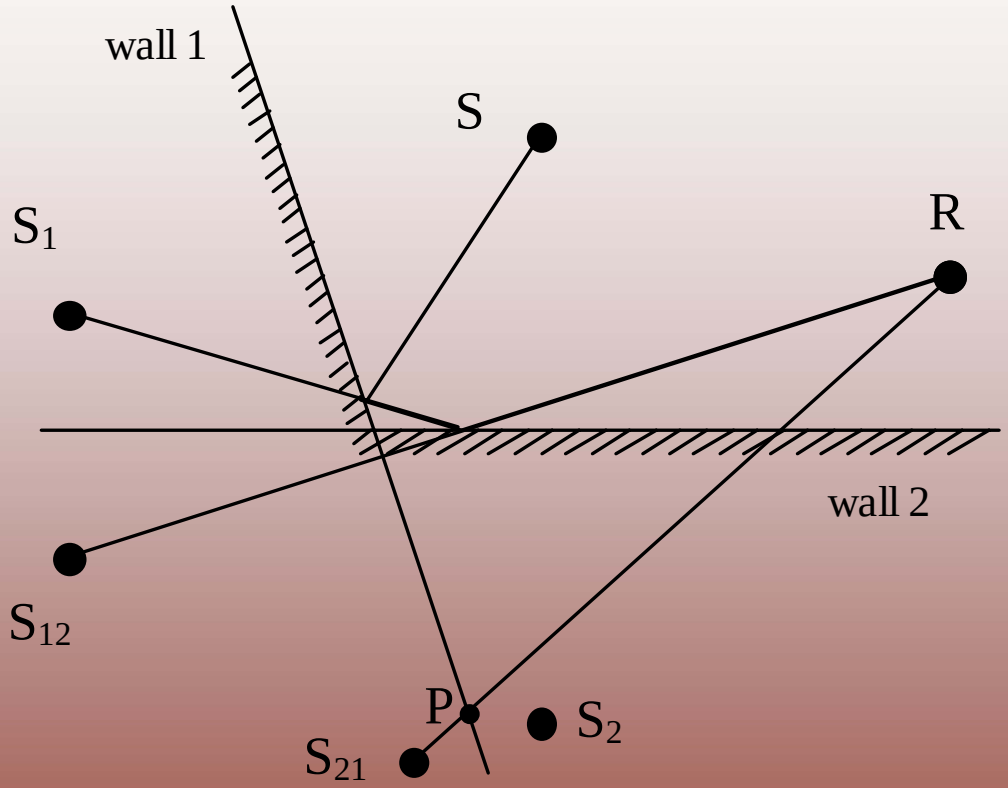
Image sources

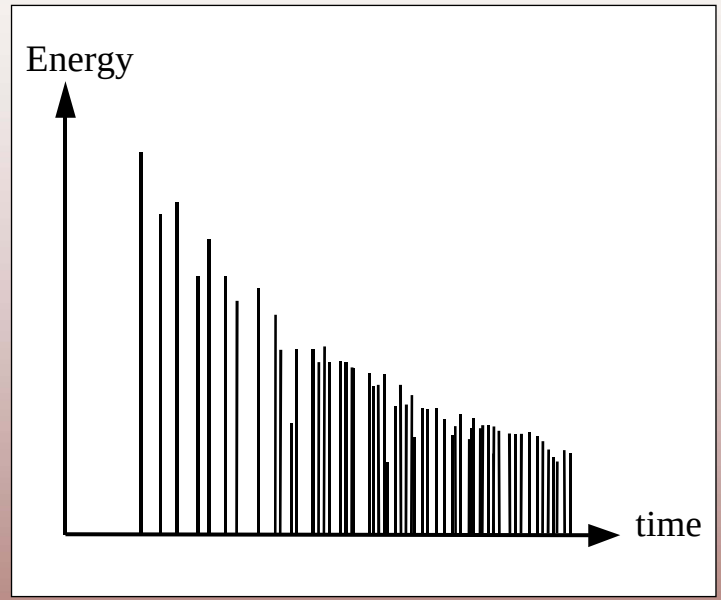


- Geometrical construction
- Audibility test
- Very expensive for high reflection orders

$$S \rightarrow S_{n_1} \rightarrow S_{n_1 n_2} \rightarrow \ldots \rightarrow S_{n_1 n_2 \ldots n_{i-1}} \rightarrow S_{n_1 n_2 \ldots n_i}$$

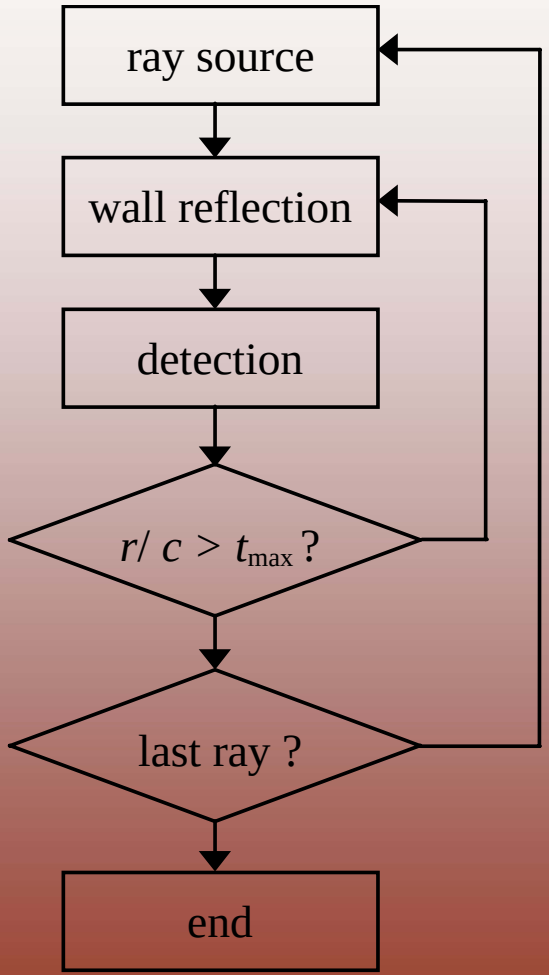
Image sources



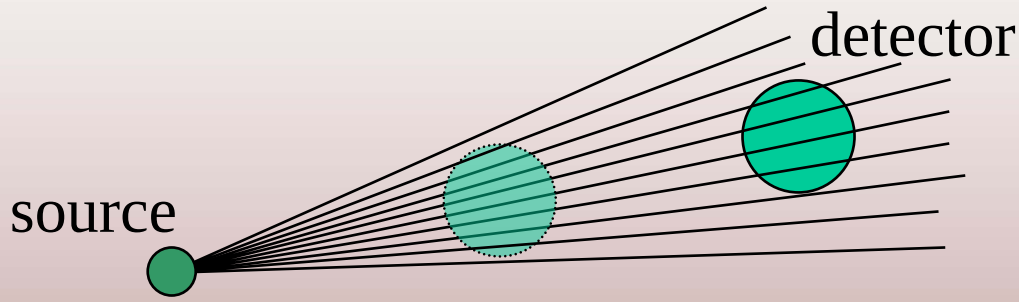


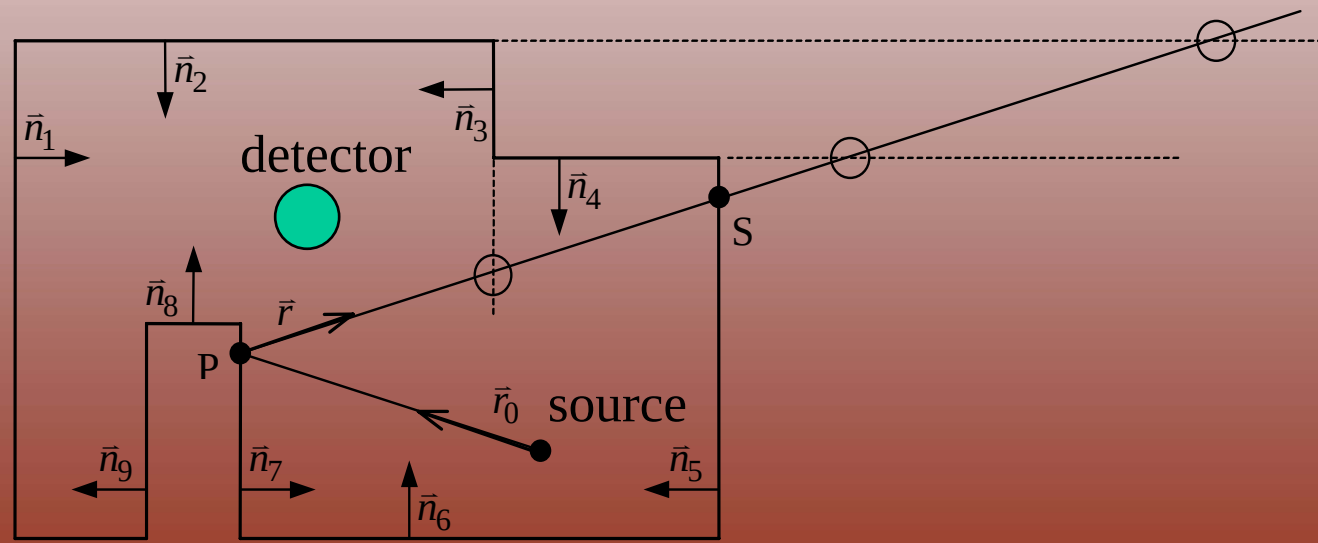
$$S \rightarrow S_{n_1} \rightarrow S_{n_1 n_2} \rightarrow \ldots \rightarrow S_{n_1 n_2 \ldots n_{i-1}} \rightarrow S_{n_1 n_2 \ldots n_i}$$

Ray tracing



distance law: ray density

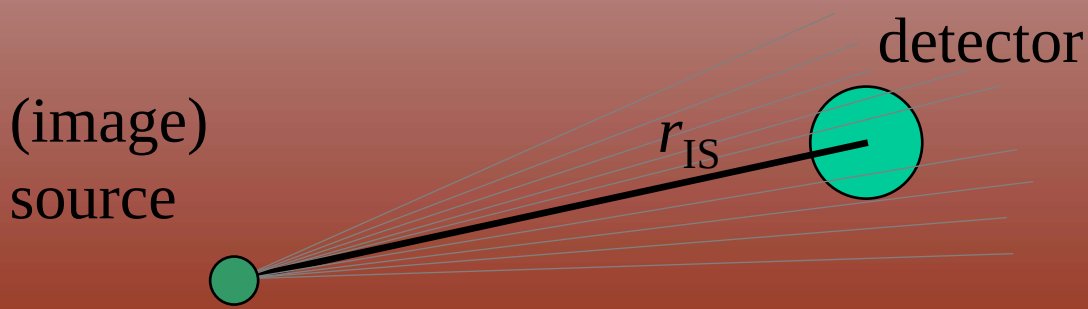




Hybrid models

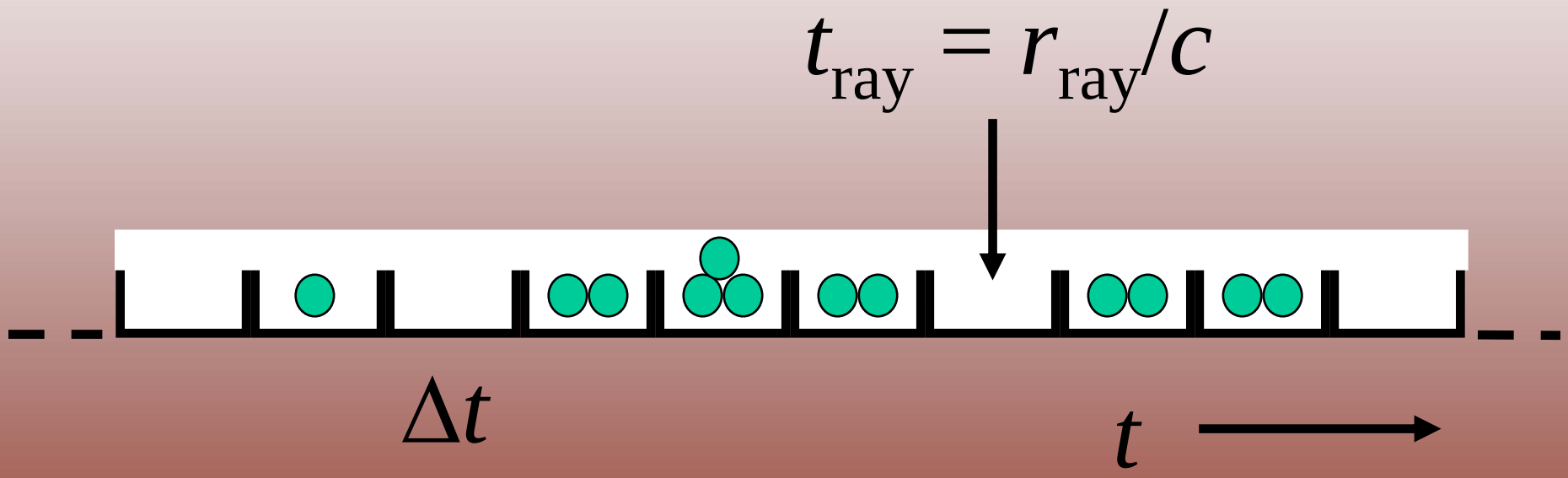
- “Forward audibility test of image sources”
- Rays (cones, ...) hitting a receiver can be addressed to audible image sources
- Dialects: Tracing of cones, triangular beams, pyramids, ..
- Higher Order possible but some mirror images are missed
- Parameter : spatial resolution $\Rightarrow$ calculation time

distance law: analytically $t = r_{IS}/c$, $E \sim 1/r_{IS}^2$

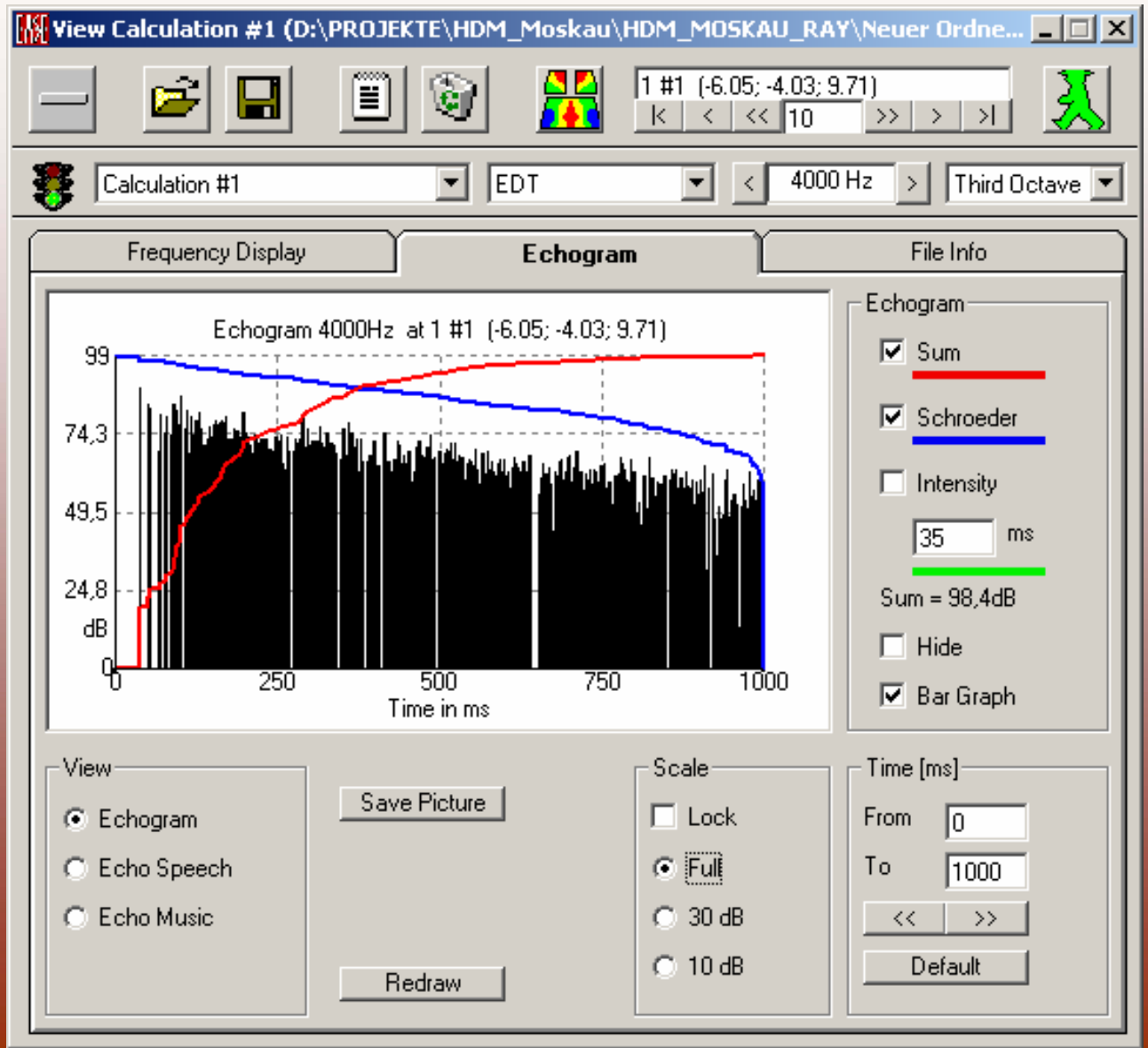


Echogram

- Recording of counts and energy in time histograms

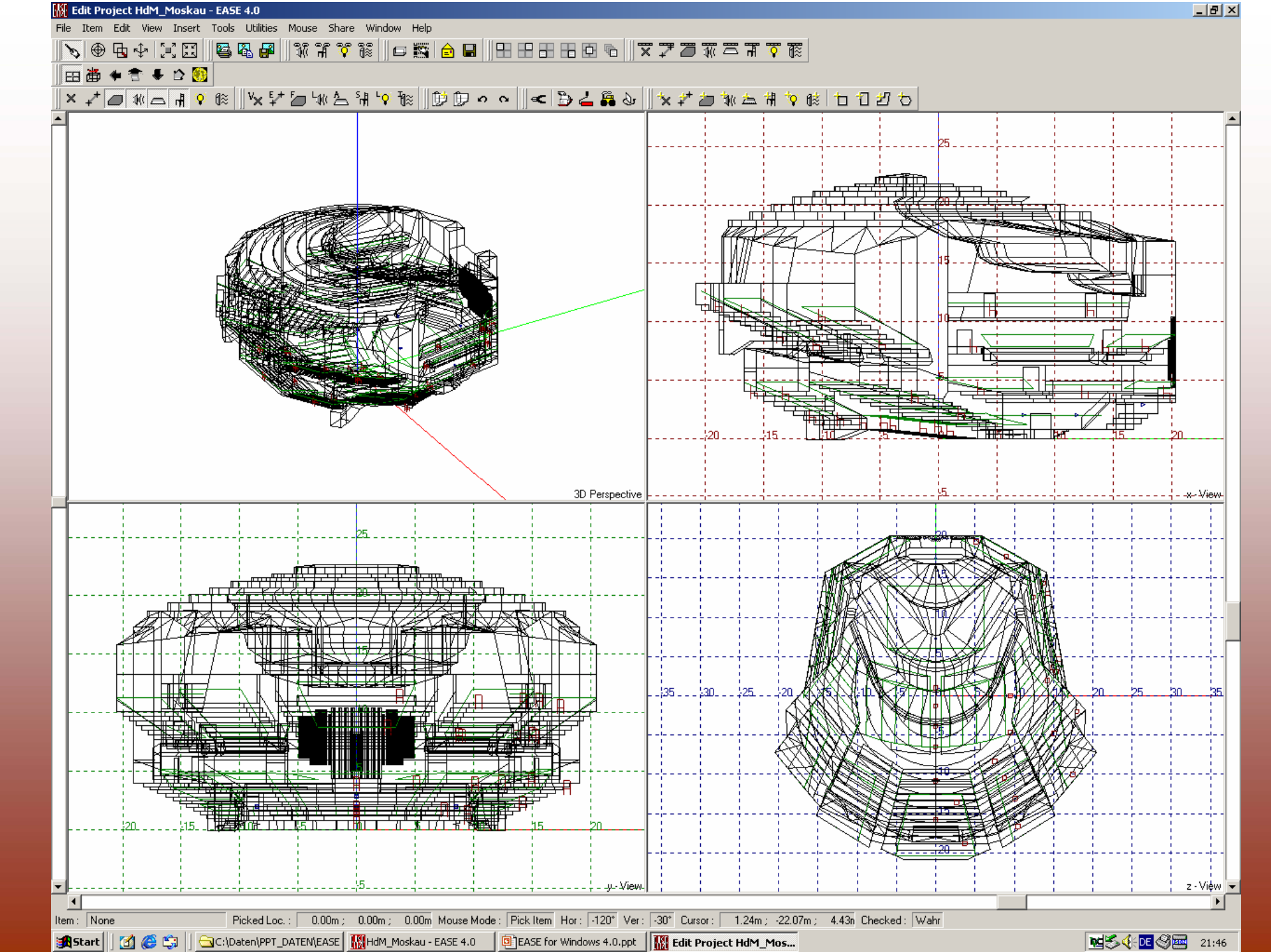


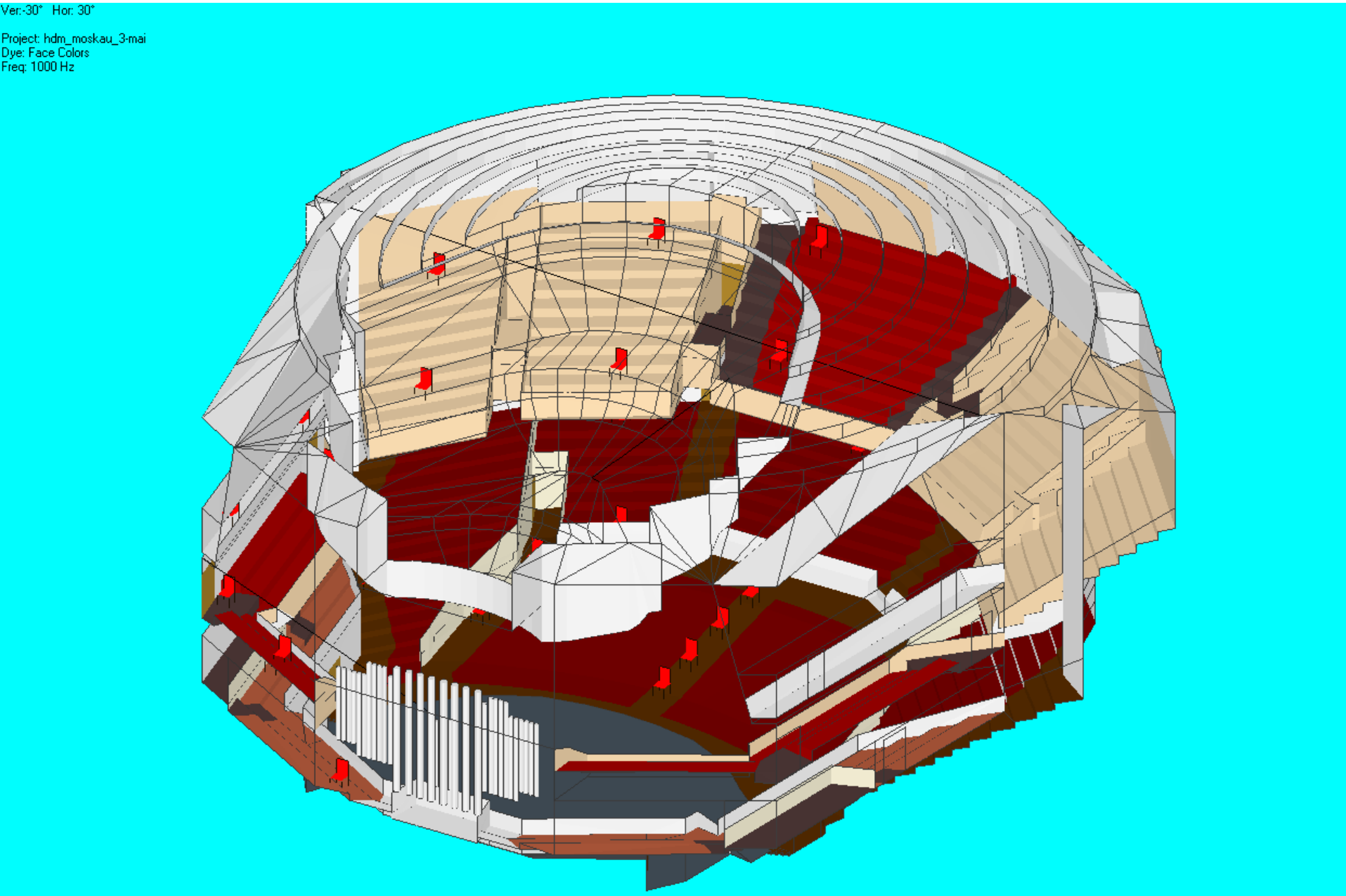
Energy time curve



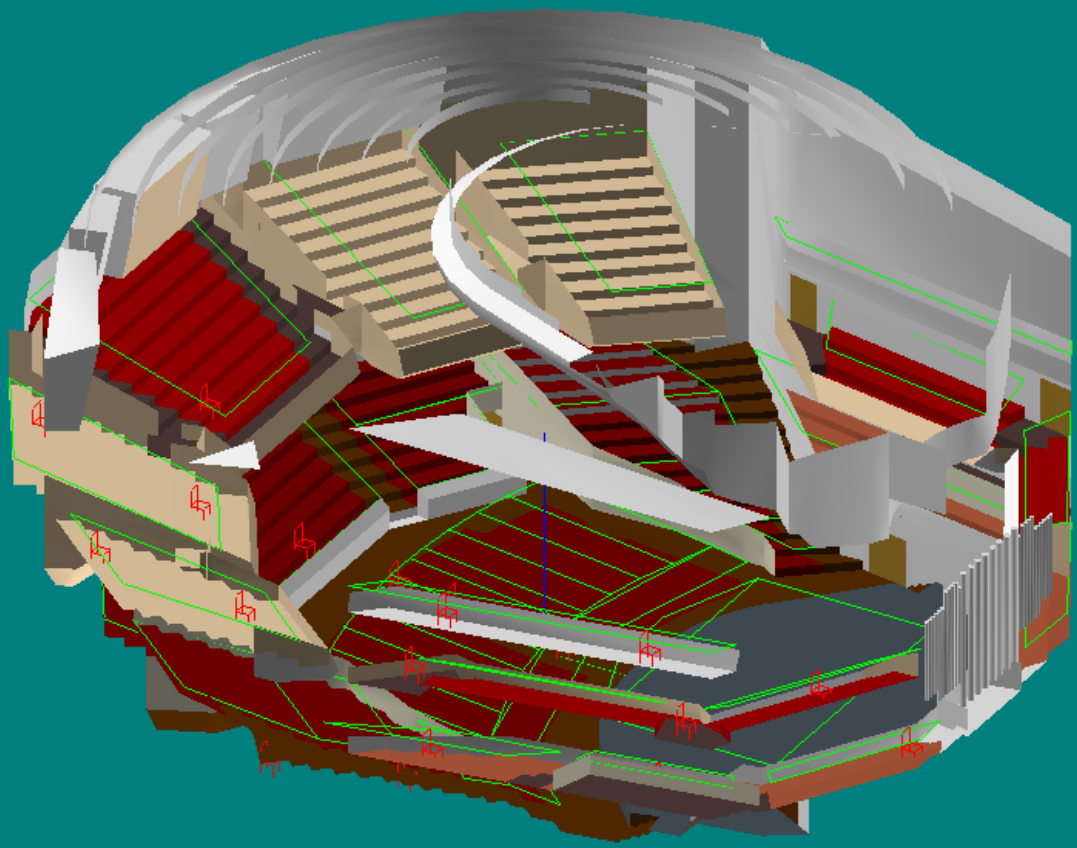
- EDT, T10, T20, T30
- C80, C50
- LF, LFC
- TS, Echo
- AlCons, STI, RaSTI
- Level etc.

ADA

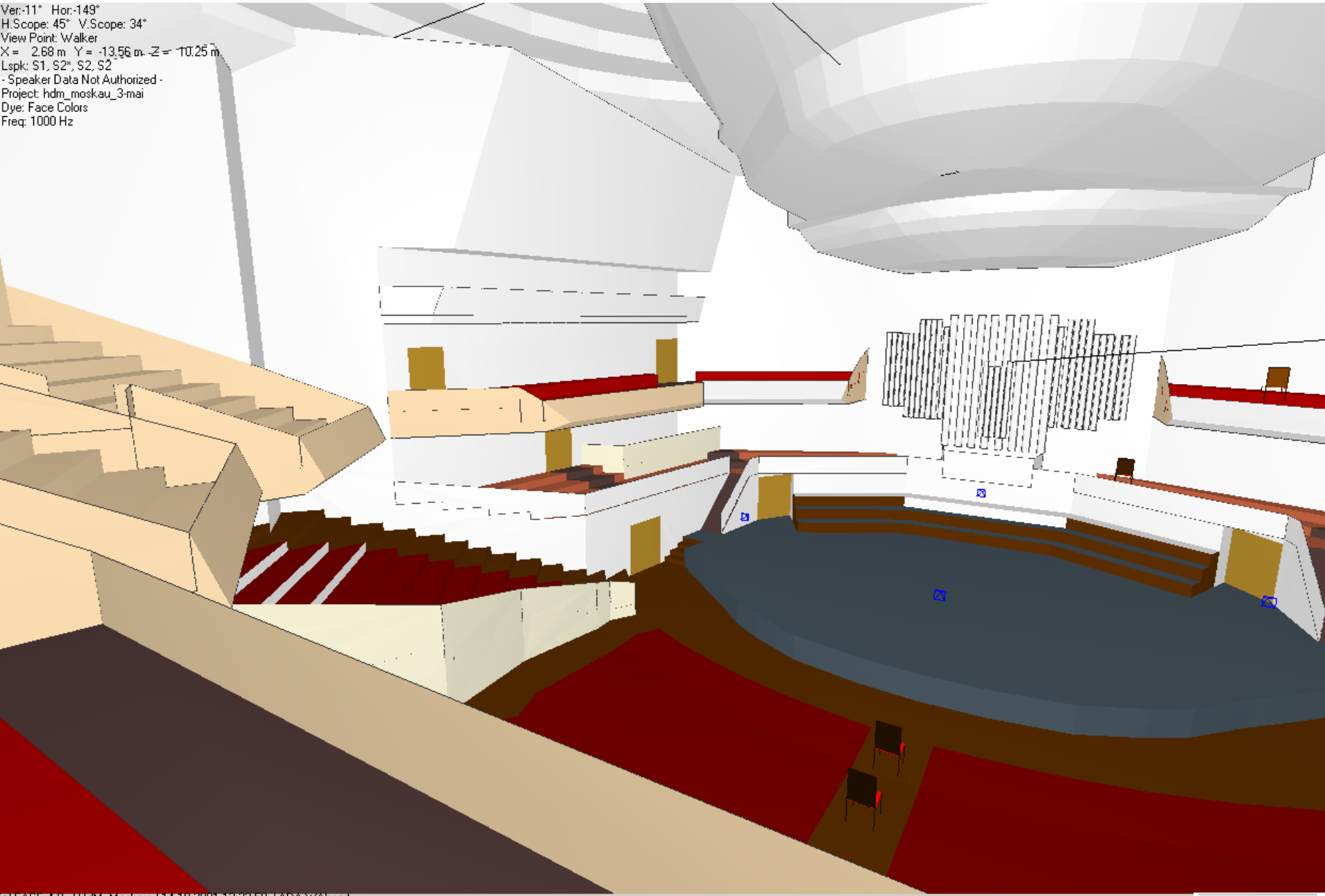

Edit Project HdM_Moskau - EASE 4.0
File Item Edit View Insert Tools Utilities Mouse Share Window Help
3D Perspective
x- View
y- View
z - View
Item : None
Picked Loc. : 0.00m ; 0.00m ; 0.00m
Mouse Mode : Pick Item
Hor : -120°
Ver : -30°
Cursor : 1.24m ; -22.07m ; 4.43n
Checked : Wahr
Start
C:\Daten\PPT_DATEN\EASE
HdM_Moskau - EASE 4.0
EASE for Windows 4.0.ppt
Edit Project HdM_Mos...
21:46

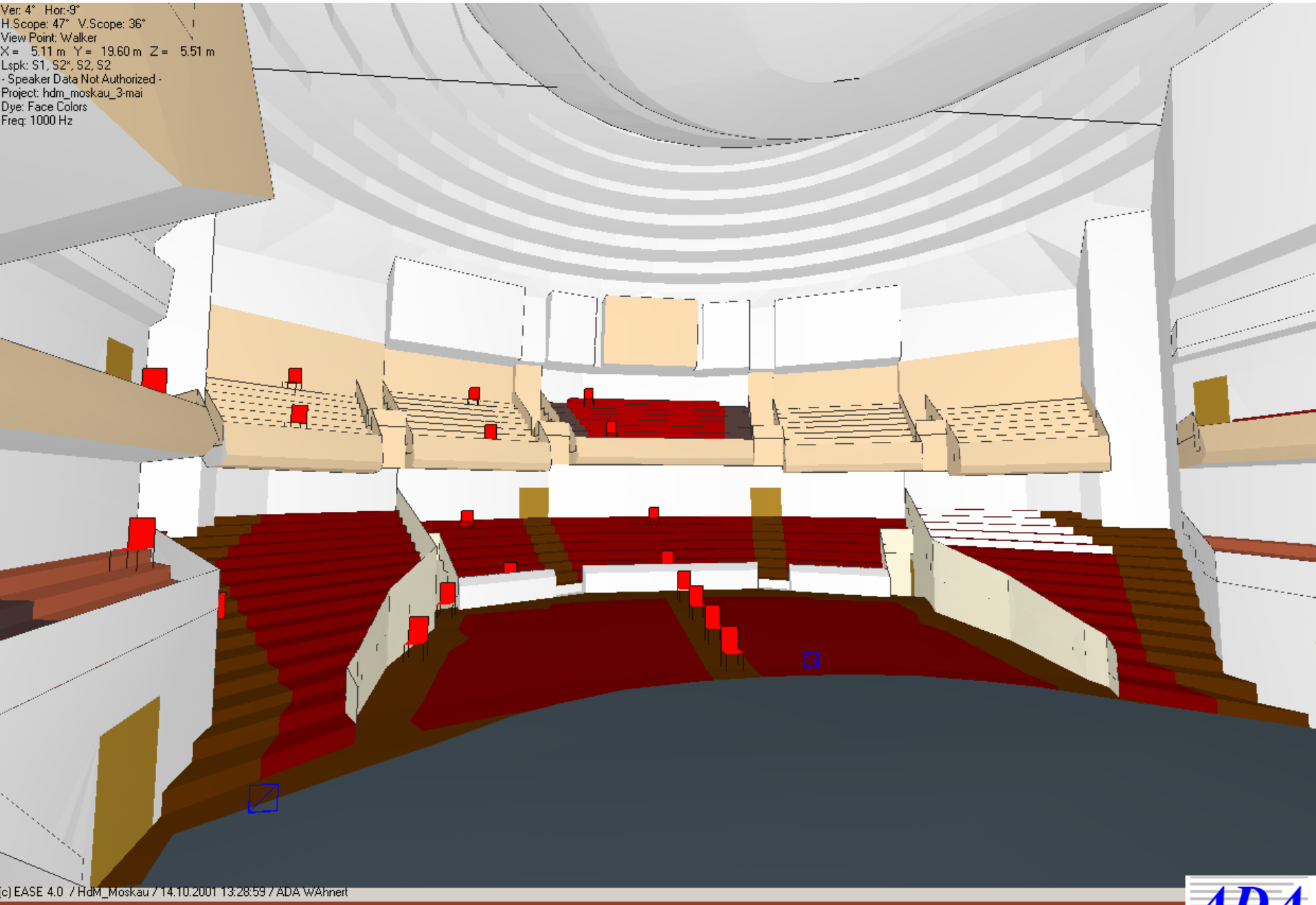

Ver:-30° Hor: 30°
Project: hdm_moskau_3-mai
Dye: Face Colors
Freq: 1000 Hz

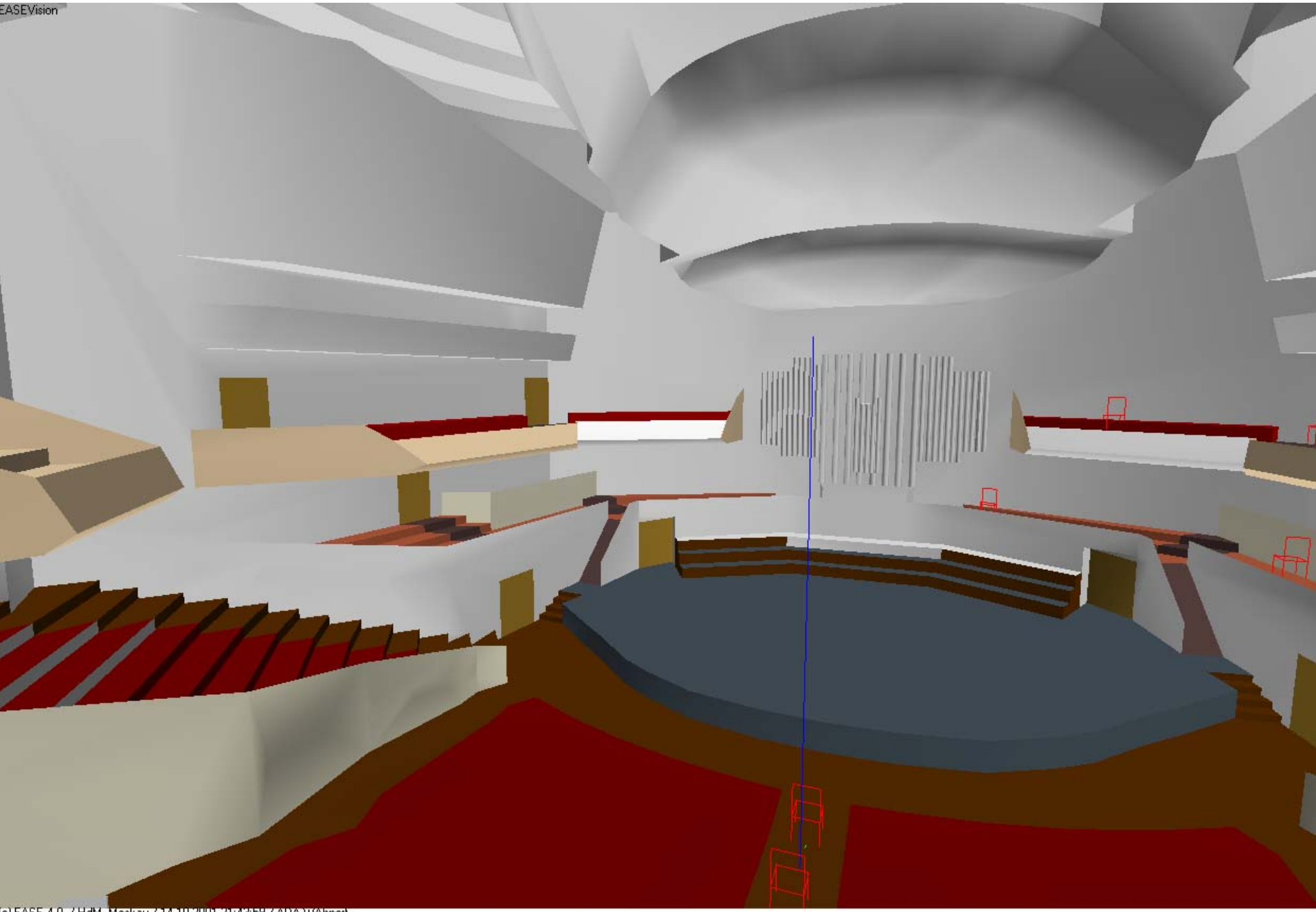
EASEVision

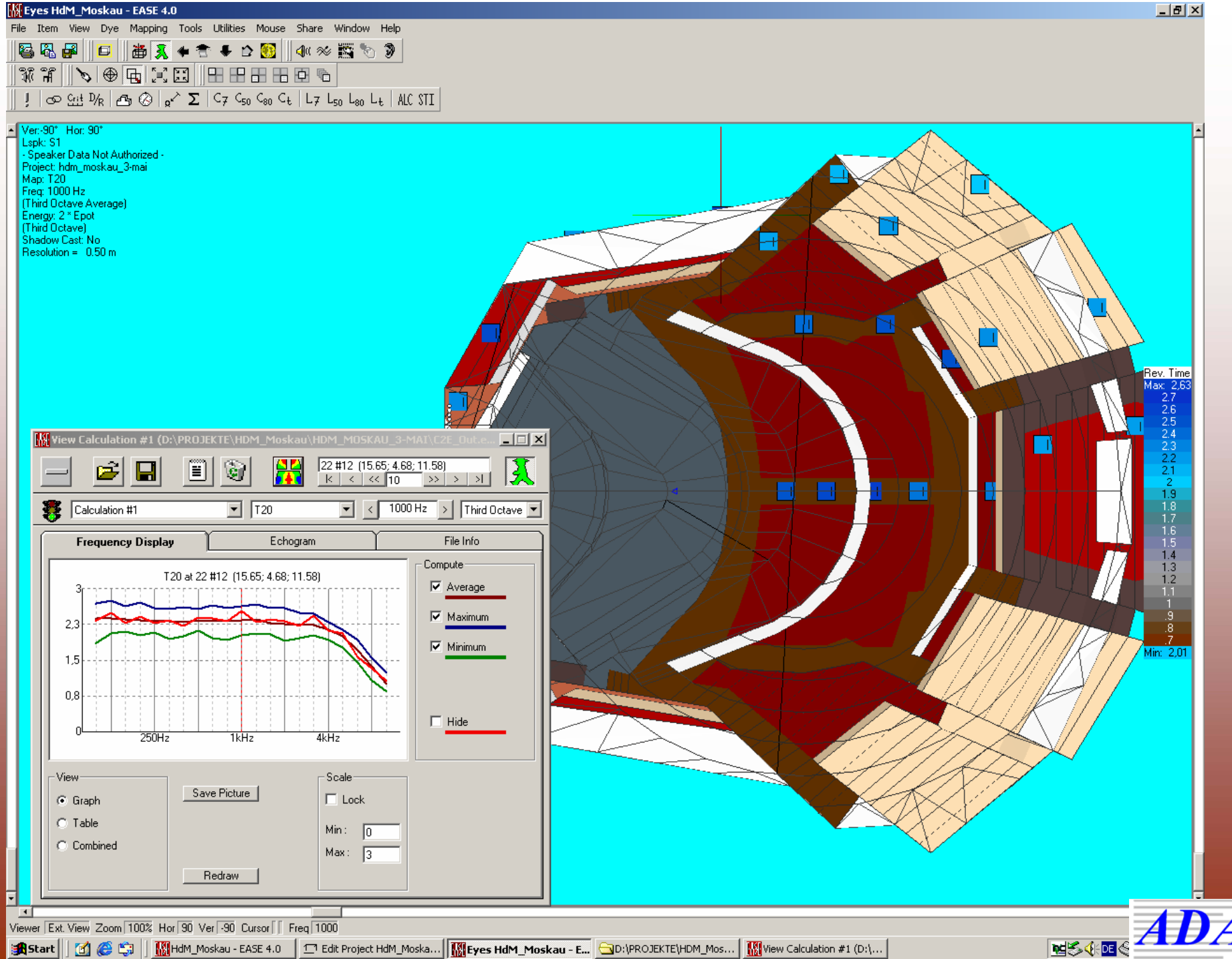


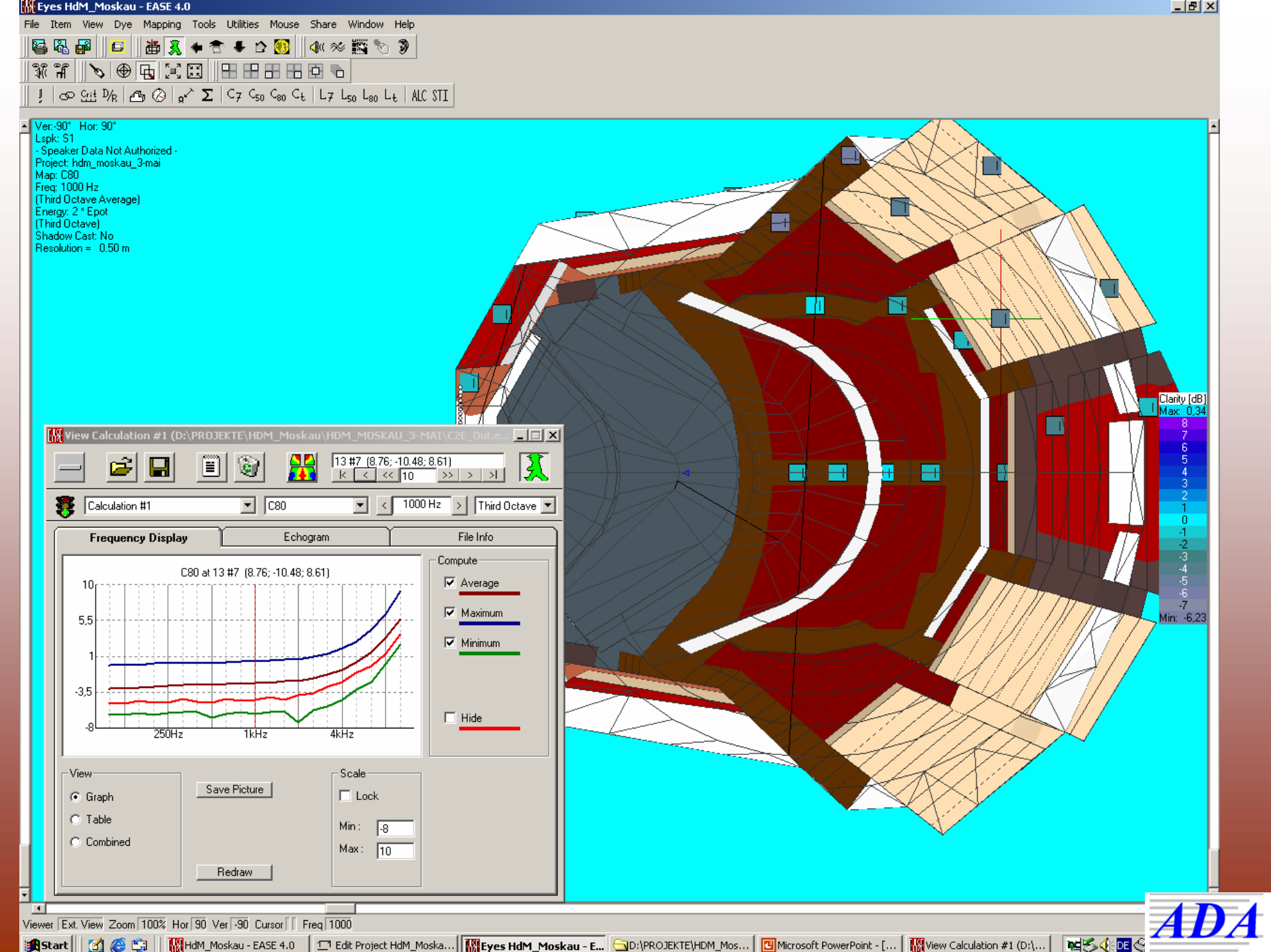
(c) EASE 4.0 / HdM_Moskau / 14.10.2001 21:41:50 / ADA WAhnert

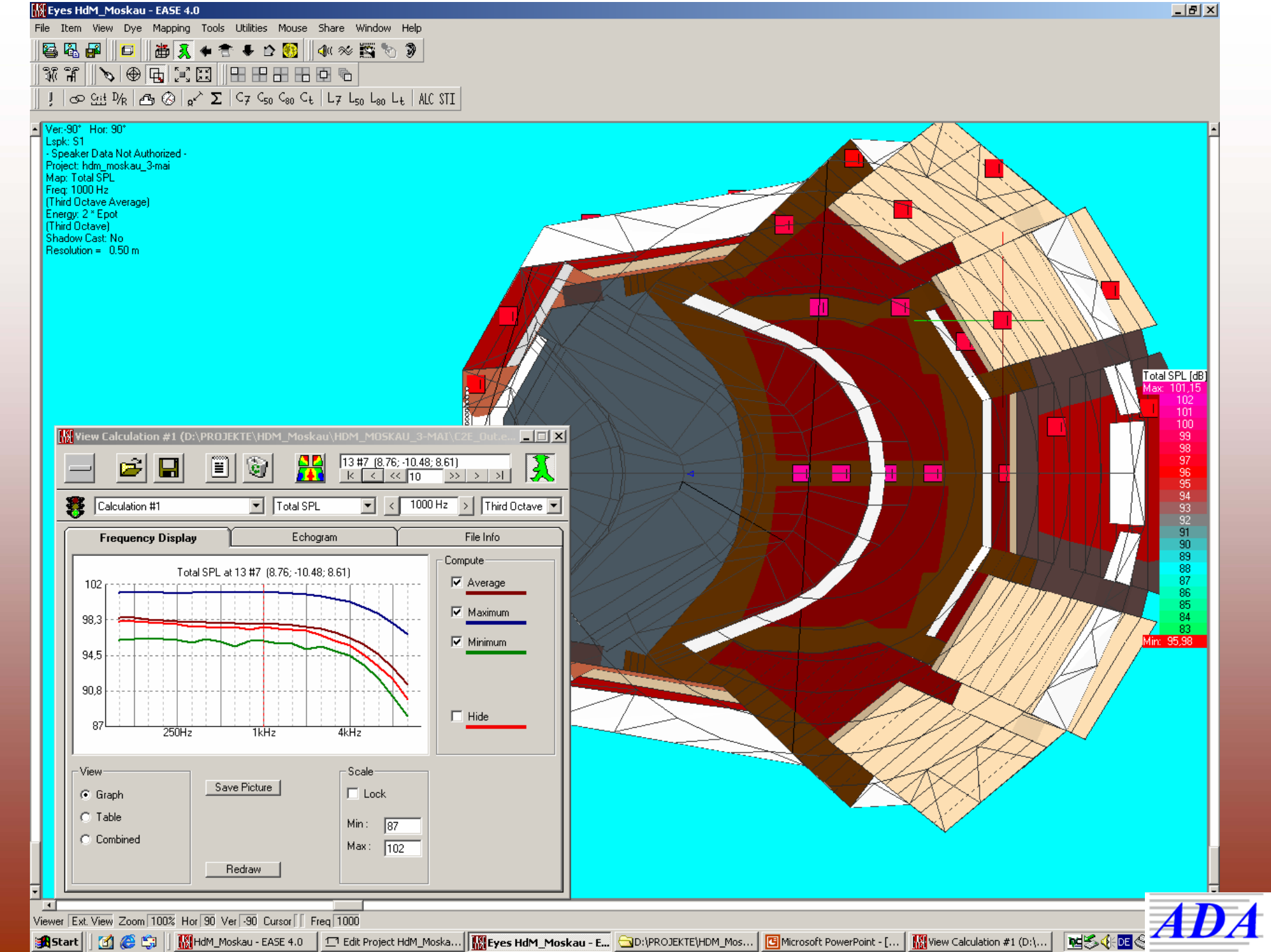

Ver:-11° Hor:-149°
H.Scope: 45° V.Scope: 34°
View Point: Walker
X = 2.68 m Y = -13.56 m Z = -10.25 m
Lspk: S1, S2*, S2, S2
- Speaker Data Not Authorized -
Project: hdm_moskau_3-mai
Dye: Face Colors
Freq: 1000 Hz
(c) EASE 4.0 / HdM_Moskau / 14.10.2001 13:22:59 / ADA WAhnert

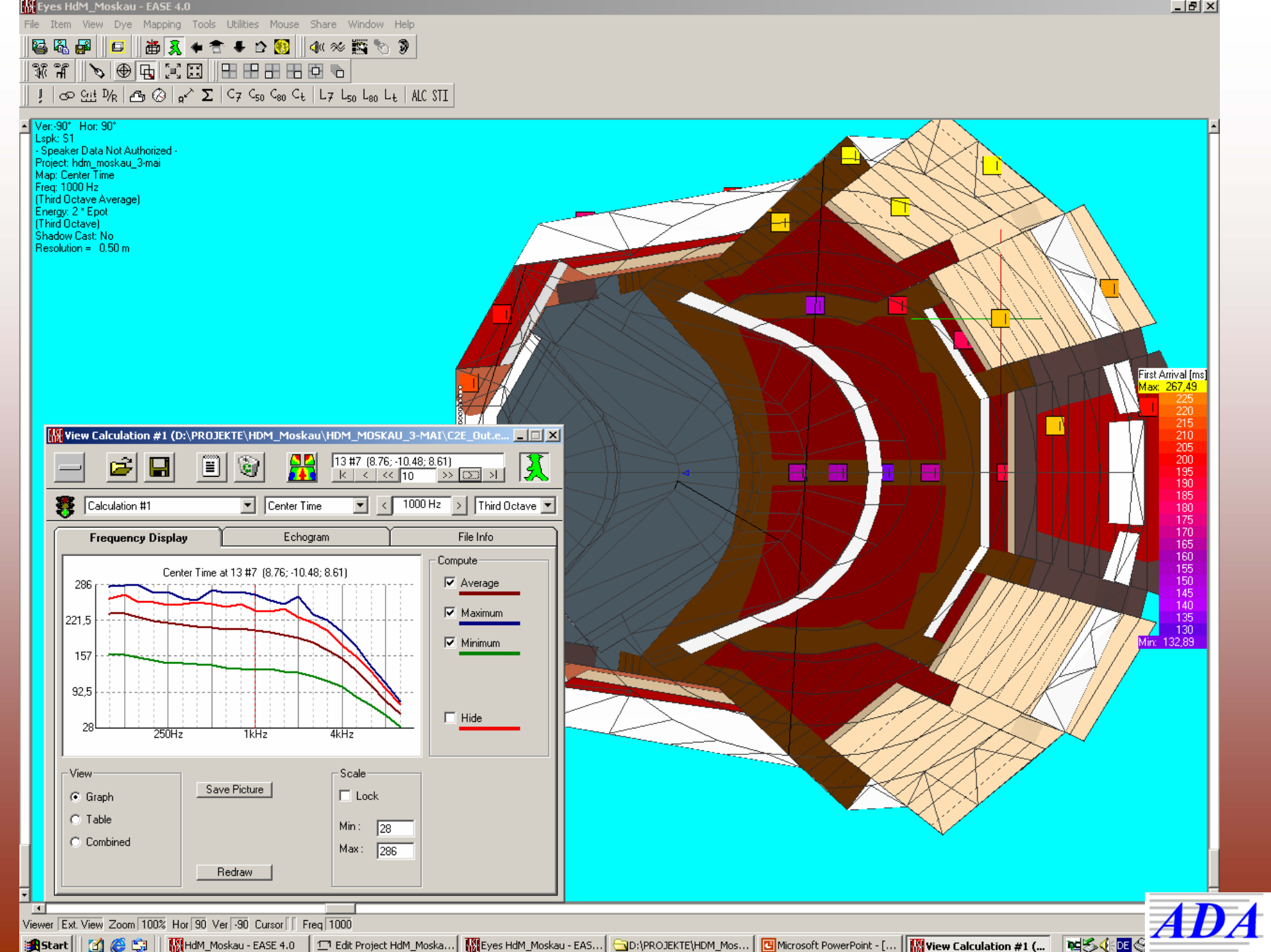

Ver: 4° Hor:-9°
H.Scope: 47° V.Scope: 36°
View Point: Walker
X = 5.11 m Y = 19.60 m Z = 5.51 m
Lspk: S1, S2*, S2, S2
- Speaker Data Not Authorized -
Project: hdm_moskau_3-mai
Dye: Face Colors
Freq: 1000 Hz
(c) EASE 4.0 / HdM_Moskau / 14.10.2001 13:28:59 / ADA WAhnert

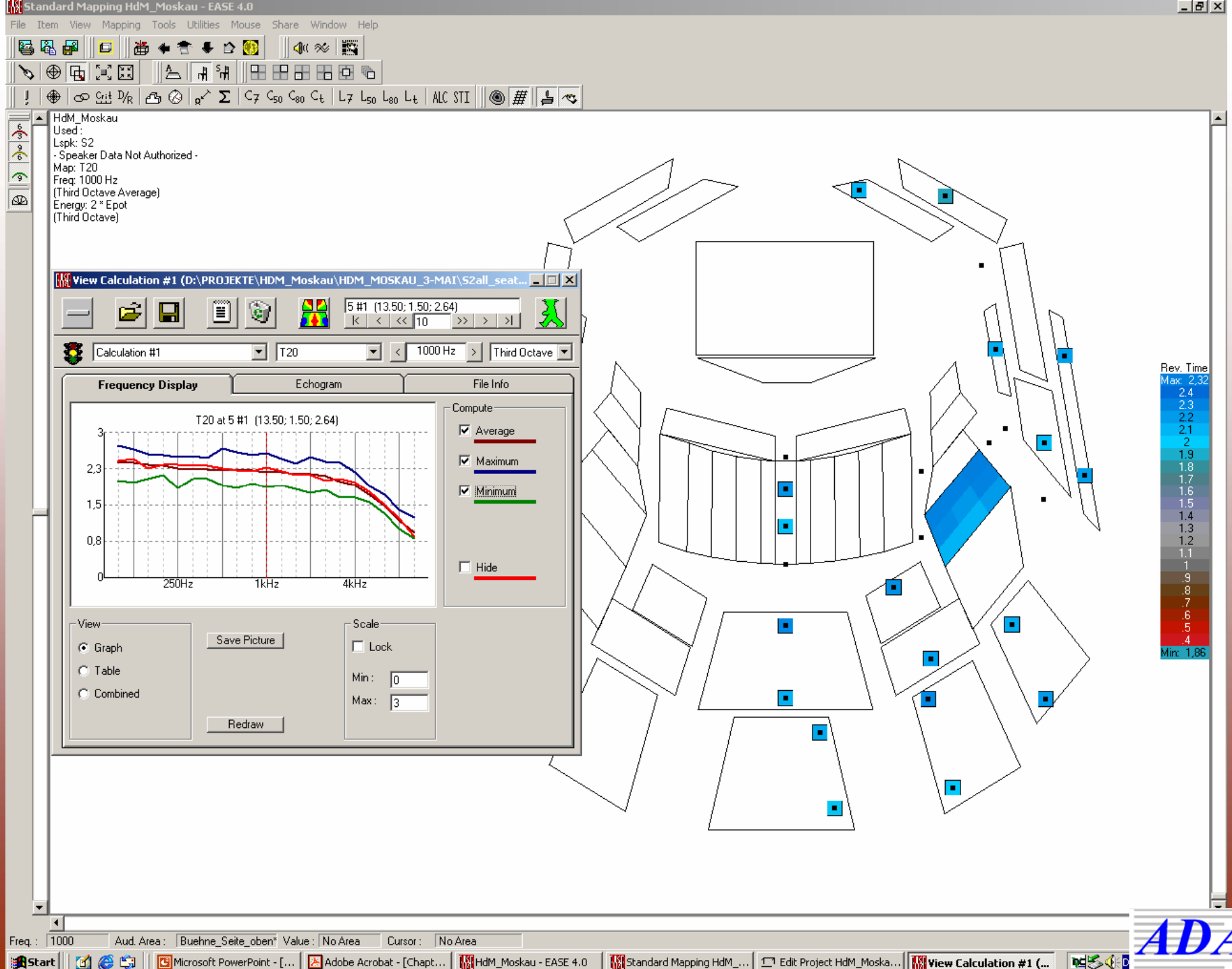

EASEVision
(c) EASE 4.0 / HdM_Moskau / 14.10.2001 21:43:59 / ADA WAhnert

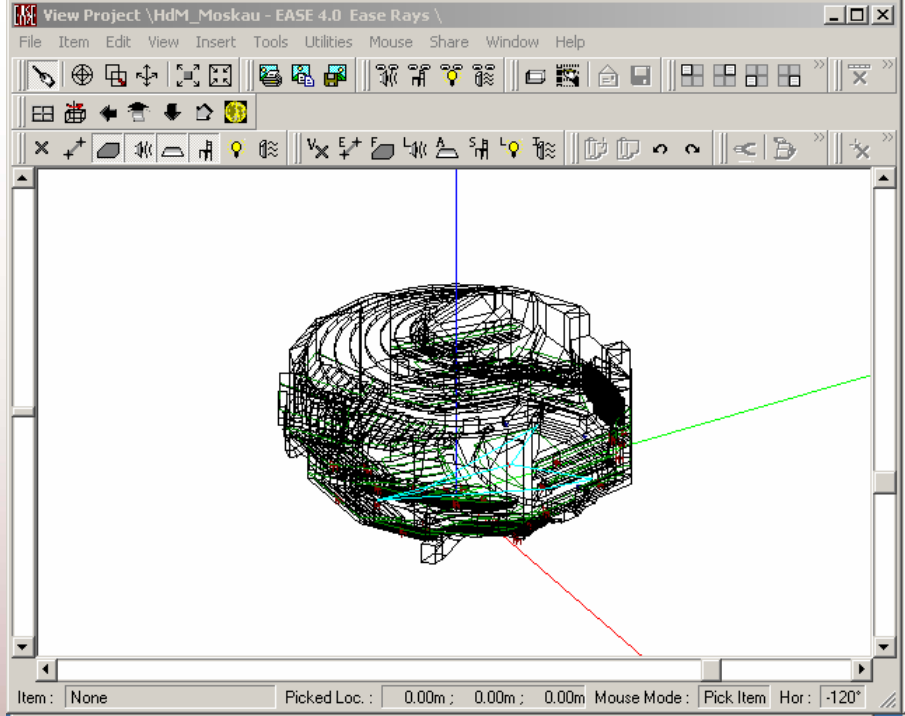

Eyes HdM_Moskau - EASE 4.0
File Item View Dye Mapping Tools Utilities Mouse Share Window Help
Ver:-90° Hor: 90°
Lspk: S1
- Speaker Data Not Authorized -
Project: hdm_moskau_3-mai
Map: T20
Freq: 1000 Hz
(Third Octave Average)
Energy: 2 * Epot
(Third Octave)
Shadow Cast: No
Resolution = 0.50 m
Rev. Time
Max: 2,63
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
.9
.8
.7
Min: 2,01
View Calculation #1 (D:\PROJEKTE\HDM_Moskau\HDM_MOSKAU_3-MAI\C2E_Out.e...
22 #12 (15.65; 4.68; 11.58)
Calculation #1
T20
1000 Hz
Third Octave
Frequency Display
Echogram
File Info
T20 at 22 #12 (15.65; 4.68; 11.58)
3
2,3
1,5
0,8
0
250Hz
1kHz
4kHz
Compute
Average
Maximum
Minimum
Hide
View
Graph
Table
Combined
Save Picture
Redraw
Scale
Lock
Min : 0
Max : 3
Viewer Ext. View Zoom 100% Hor 90 Ver -90 Cursor Freq 1000
Start
HdM_Moskau - EASE 4.0
Edit Project HdM_Moska...
Eyes HdM_Moskau - E...
D:\PROJEKTE\HDM_Mos...
View Calculation #1 (D:\...

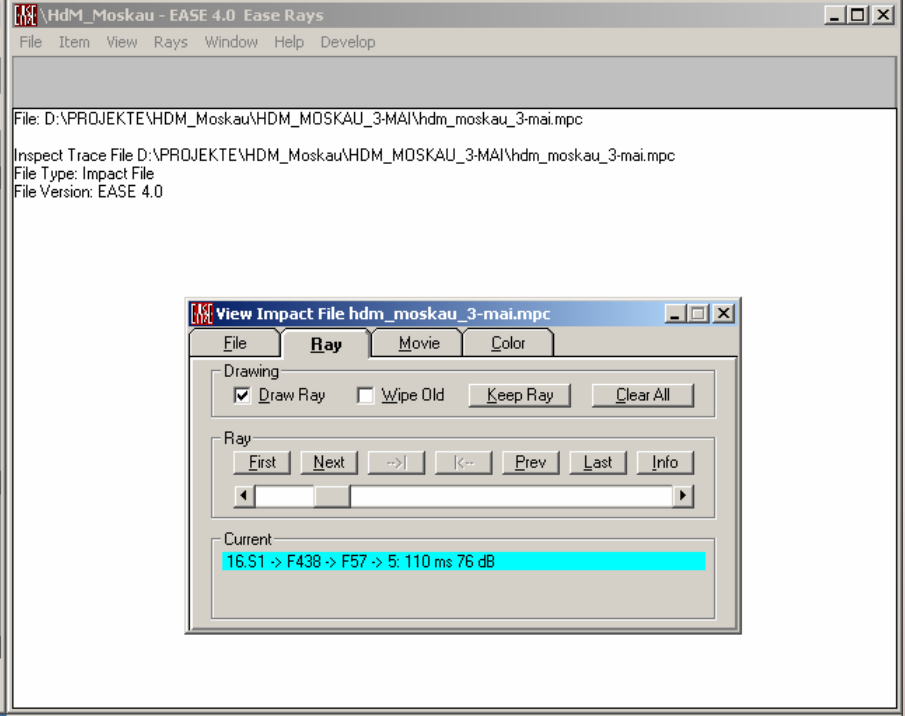

Eyes HdM_Moskau - EASE 4.0
File Item View Dye Mapping Tools Utilities Mouse Share Window Help
Ver:-90° Hor: 90°
Lspk: S1
- Speaker Data Not Authorized -
Project: hdm_moskau_3-mai
Map: C80
Freq: 1000 Hz
(Third Octave Average)
Energy: 2 * Epot
(Third Octave)
Shadow Cast: No
Resolution = 0.50 m
Clarity [dB]
Max: 0,34
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
Min: -6,23
View Calculation #1 (D:\PROJEKTE\HDM_Moskau\HDM_MOSKAU_3-MAI\C2E_Out.e...
13 #7 (8.76; -10.48; 8.61)
Calculation #1
C80
1000 Hz
Third Octave
Frequency Display
Echogram
File Info
C80 at 13 #7 (8.76; -10.48; 8.61)
10
5,5
1
-3,5
-8
250Hz
1kHz
4kHz
Compute
Average
Maximum
Minimum
Hide
View
Graph
Table
Combined
Save Picture
Redraw
Scale
Lock
Min : -8
Max : 10
Viewer Ext. View Zoom 100% Hor 90 Ver -90 Cursor Freq 1000
Start
HdM_Moskau - EASE 4.0
Edit Project HdM_Moska...
Eyes HdM_Moskau - E...
D:\PROJEKTE\HDM_Mos...
Microsoft PowerPoint - [...
View Calculation #1 (D:\...
ADA

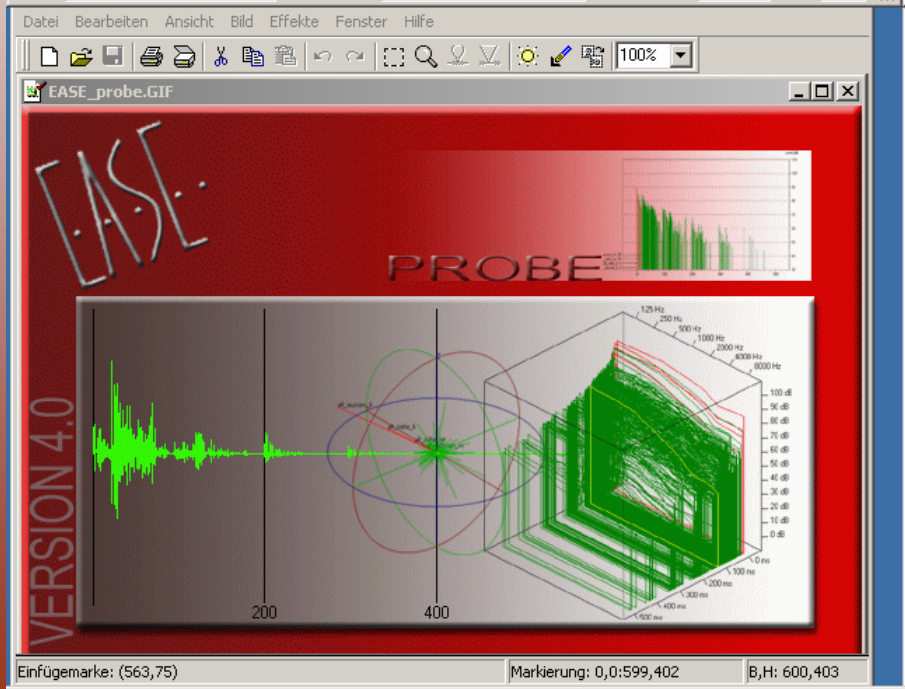

Eyes HdM_Moskau - EASE 4.0
File Item View Dye Mapping Tools Utilities Mouse Share Window Help
Ver:-90° Hor: 90°
Lspk: S1
- Speaker Data Not Authorized -
Project: hdm_moskau_3-mai
Map: Total SPL
Freq: 1000 Hz
(Third Octave Average)
Energy: 2 * Epot
(Third Octave)
Shadow Cast: No
Resolution = 0.50 m
Total SPL [dB]
Max: 101,15
102
101
100
99
98
97
96
95
94
93
92
91
90
89
88
87
86
85
84
83
Min: 95,98
View Calculation #1 (D:\PROJEKTE\HDM_Moskau\HDM_MOSKAU_3-MAI\C2E_Out.e...
13 #7 (8.76; -10.48; 8.61)
Calculation #1
Total SPL
1000 Hz
Third Octave
Frequency Display
Echogram
File Info
Total SPL at 13 #7 (8.76; -10.48; 8.61)
102
98,3
94,5
90,8
87
250Hz
1kHz
4kHz
Compute
Average
Maximum
Minimum
Hide
View
Graph
Table
Combined
Save Picture
Redraw
Scale
Lock
Min : 87
Max : 102
Viewer Ext. View Zoom 100% Hor 90 Ver -90 Cursor Freq 1000
Start
HdM_Moskau - EASE 4.0
Edit Project HdM_Moska...
Eyes HdM_Moskau - E...
D:\PROJEKTE\HDM_Mos...
Microsoft PowerPoint - [...
View Calculation #1 (D:\...
ADA

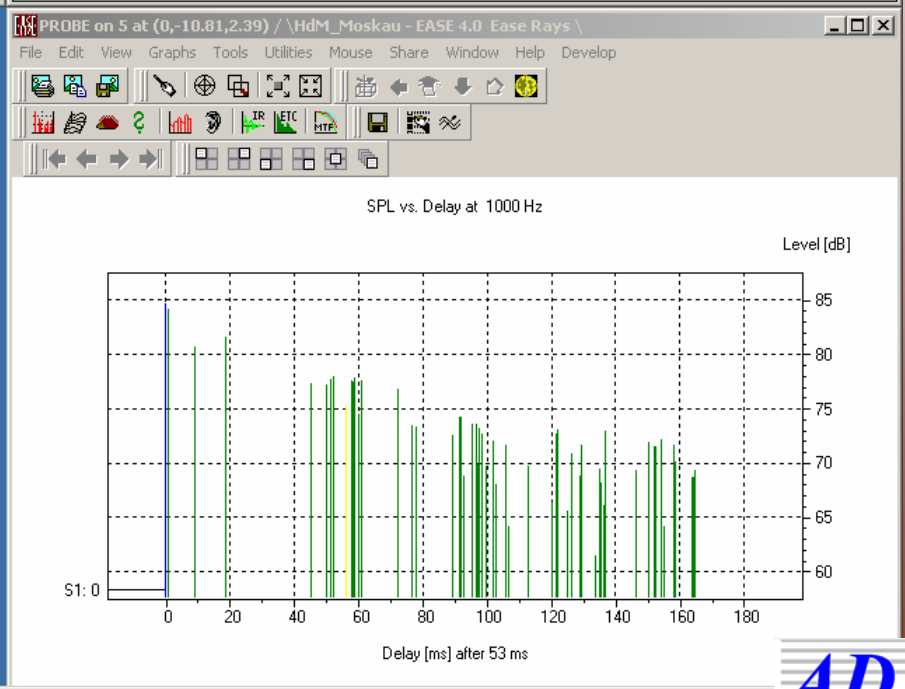

Eyes HdM_Moskau - EASE 4.0
File Item View Dye Mapping Tools Utilities Mouse Share Window Help
Ver:-90° Hor: 90°
Lspk: S1
- Speaker Data Not Authorized -
Project: hdm_moskau_3-mai
Map: Center Time
Freq: 1000 Hz
(Third Octave Average)
Energy: 2 * Epot
(Third Octave)
Shadow Cast: No
Resolution = 0.50 m
First Arrival [ms]
Max: 267,49
225
220
215
210
205
200
195
190
185
180
175
170
165
160
155
150
145
140
135
130
Min: 132,89
View Calculation #1 (D:\PROJEKTE\HDM_Moskau\HDM_MOSKAU_3-MAI\C2E_Out.e...
13 #7 (8.76; -10.48; 8.61)
Calculation #1
Center Time
1000 Hz
Third Octave
Frequency Display
Echogram
File Info
Center Time at 13 #7 (8.76; -10.48; 8.61)
286
221,5
157
92,5
28
250Hz
1kHz
4kHz
Compute
Average
Maximum
Minimum
Hide
View
Graph
Table
Combined
Save Picture
Redraw
Scale
Lock
Min : 28
Max : 286
Viewer Ext. View Zoom 100% Hor 90 Ver -90 Cursor Freq 1000
Start
HdM_Moskau - EASE 4.0
Edit Project HdM_Moska...
Eyes HdM_Moskau - EAS...
D:\PROJEKTE\HDM_Mos...
Microsoft PowerPoint - [...
View Calculation #1 (...
ADA


Standard Mapping HdM_Moskau - EASE 4.0
File Item View Mapping Tools Utilities Mouse Share Window Help
HdM_Moskau
Used :
Lspk: S2
- Speaker Data Not Authorized -
Map: T20
Freq: 1000 Hz
(Third Octave Average)
Energy: 2 * Epot
(Third Octave)
View Calculation #1 (D:\PROJEKTE\HDM_Moskau\HDM_MOSKAU_3-MAI\S2all_seat...
5 #1 (13.50; 1.50; 2.64)
Calculation #1
T20
1000 Hz
Third Octave
Frequency Display
Echogram
File Info
T20 at 5 #1 (13.50; 1.50; 2.64)
3
2,3
1,5
0,8
0
250Hz
1kHz
4kHz
Compute
Average
Maximum
Minimum
Hide
View
Graph
Table
Combined
Save Picture
Redraw
Scale
Lock
Min : 0
Max : 3
Rev. Time
Max: 2,32
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
.9
.8
.7
.6
.5
.4
Min: 1,86
Freq. : 1000
Aud. Area : Buehne_Seite_oben
Value : No Area
Cursor : No Area
Start
Microsoft PowerPoint - [...
Adobe Acrobat - [Chapt...
HdM_Moskau - EASE 4.0
Standard Mapping HdM_...
Edit Project HdM_Moska...
View Calculation #1 (...
ADA

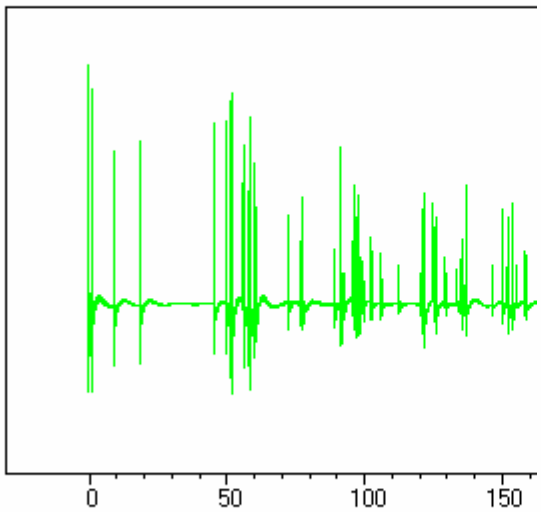

View Project \HdM_Moskau - EASE 4.0 Ease Rays \
File Item Edit View Insert Tools Utilities Mouse Share Window Help
Item : None
Picked Loc. : 0.00m ; 0.00m ; 0.00m
Mouse Mode : Pick Item
Hor : -120°


\HdM_Moskau - EASE 4.0 Ease Rays
File Item View Rays Window Help Develop
File: D:\PROJEKTE\HDM_Moskau\HDM_MOSKAU_3-MAI\hdm_moskau_3-mai.mpc
Inspect Trace File D:\PROJEKTE\HDM_Moskau\HDM_MOSKAU_3-MAI\hdm_moskau_3-mai.mpc
File Type: Impact File
File Version: EASE 4.0
View Impact File hdm_moskau_3-mai.mpc
File Ray Movie Color
Drawing
Draw Ray
Wipe Old
Keep Ray
Clear All
Ray
First Next Prev Last Info
Current
16.S1 -> F438 -> F57 -> 5: 110 ms 76 dB


Datei Bearbeiten Ansicht Bild Effekte Fenster Hilfe
EASE_probe.GIF
EASE
PROBE
VERSION 4.0
200
400
Einfügemarke: (563,75)
Markierung: 0,0:599,402
B,H: 600,403


PROBE on 5 at (0,-10.81,2.39) / \HdM_Moskau - EASE 4.0 Ease Rays \
File Edit View Graphs Tools Utilities Mouse Share Window Help Develop
SPL vs. Delay at 1000 Hz
Level [dB]
S1: 0
Delay [ms] after 53 ms

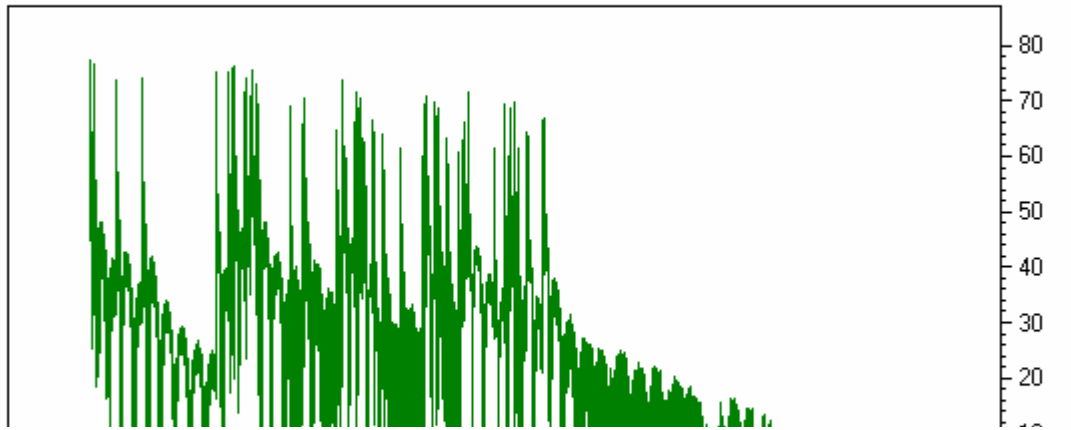
Impulse Resp



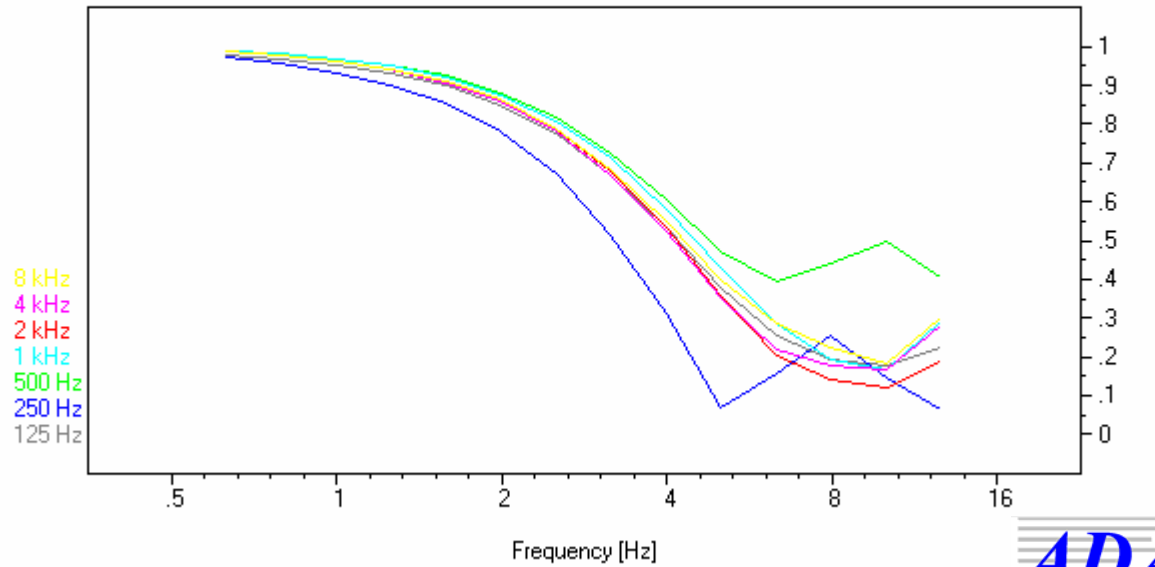
Delay [m

(c) EASE 4.0 / 14.10.2001 19:53:49 / ADA WAhnert

Energy Time Curve

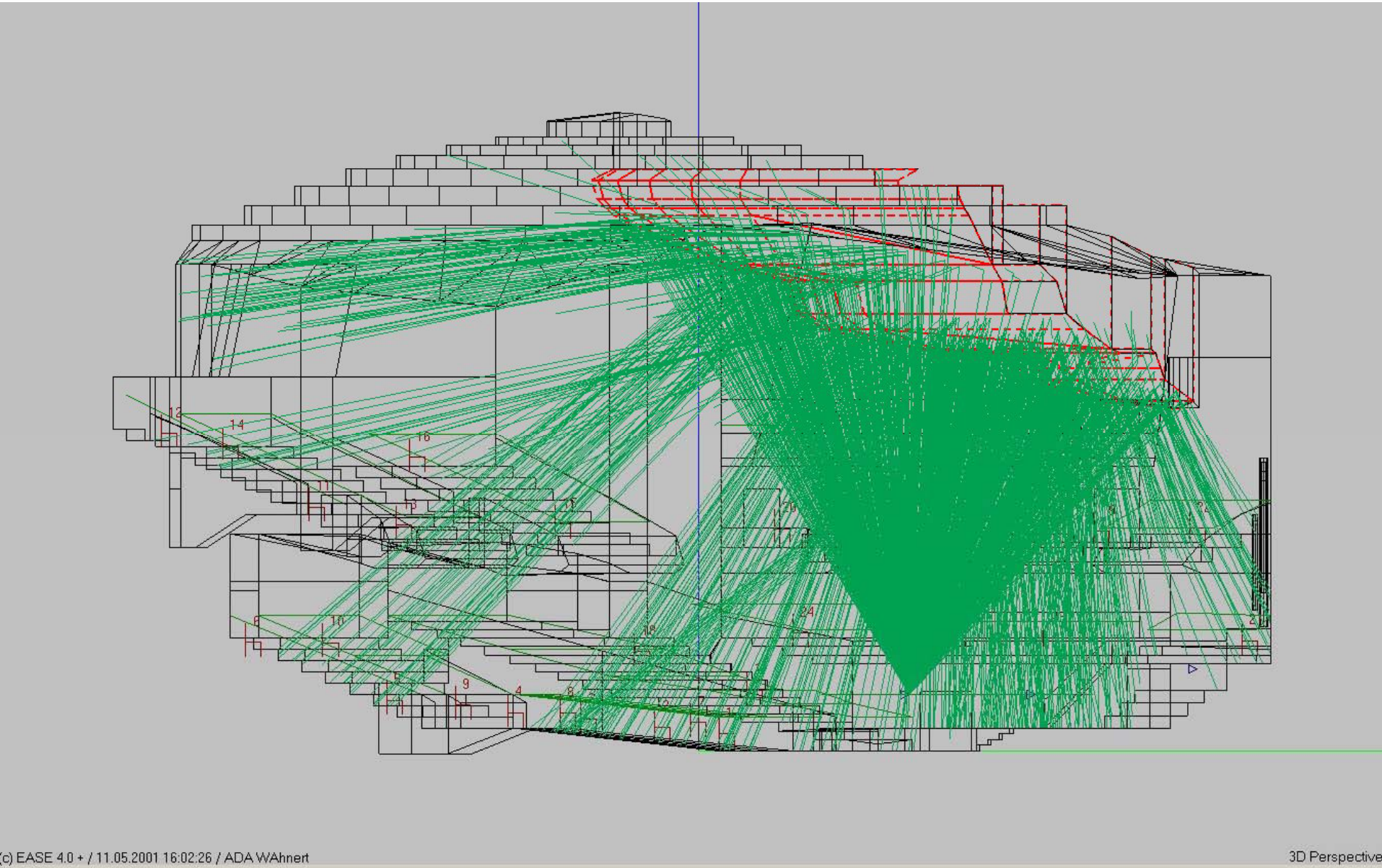


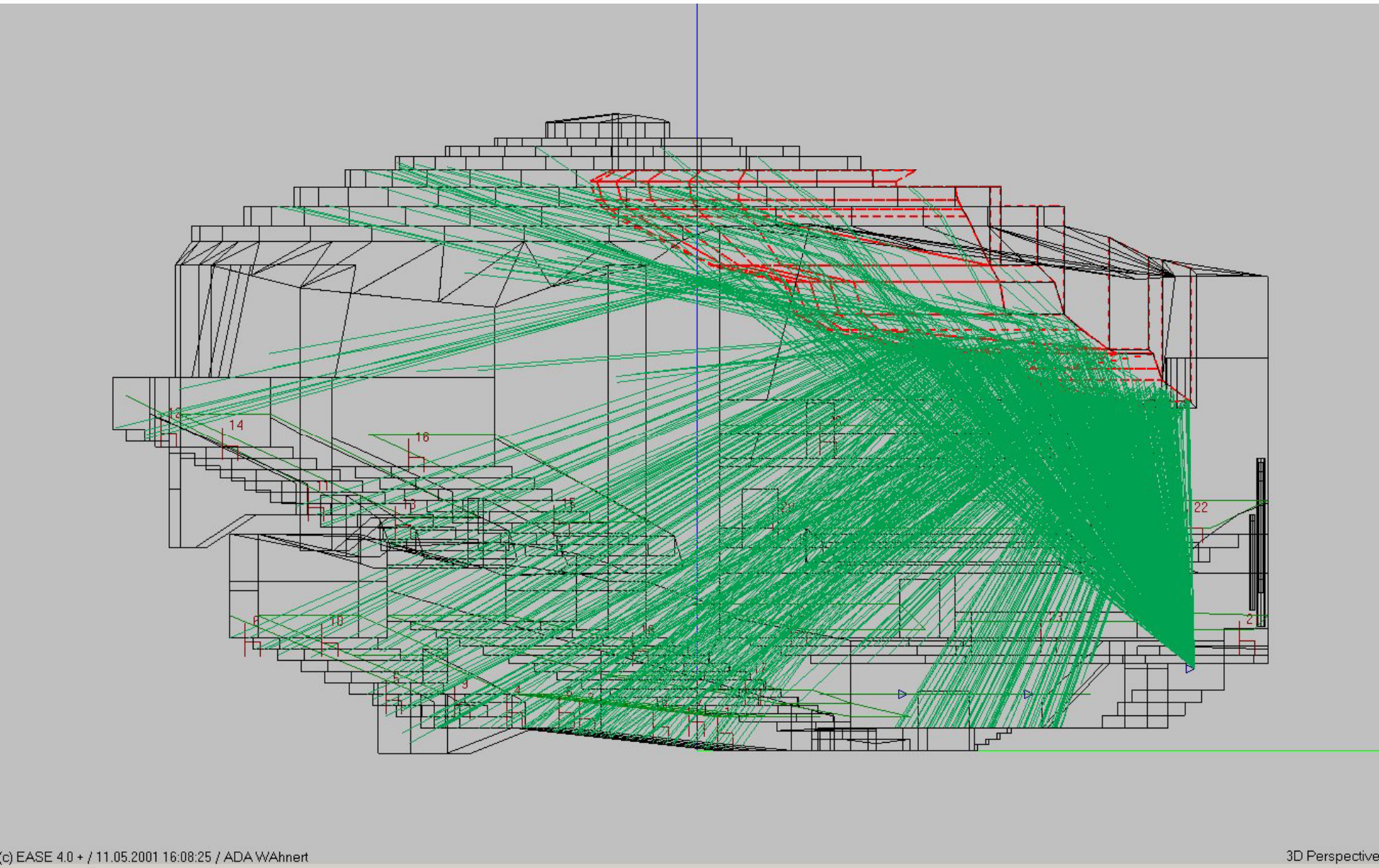
Modulation Transfer Function: STI = 0.630



(c) EASE 4.0 / 14.10.2001 19:54:47 / ADA WAhnert

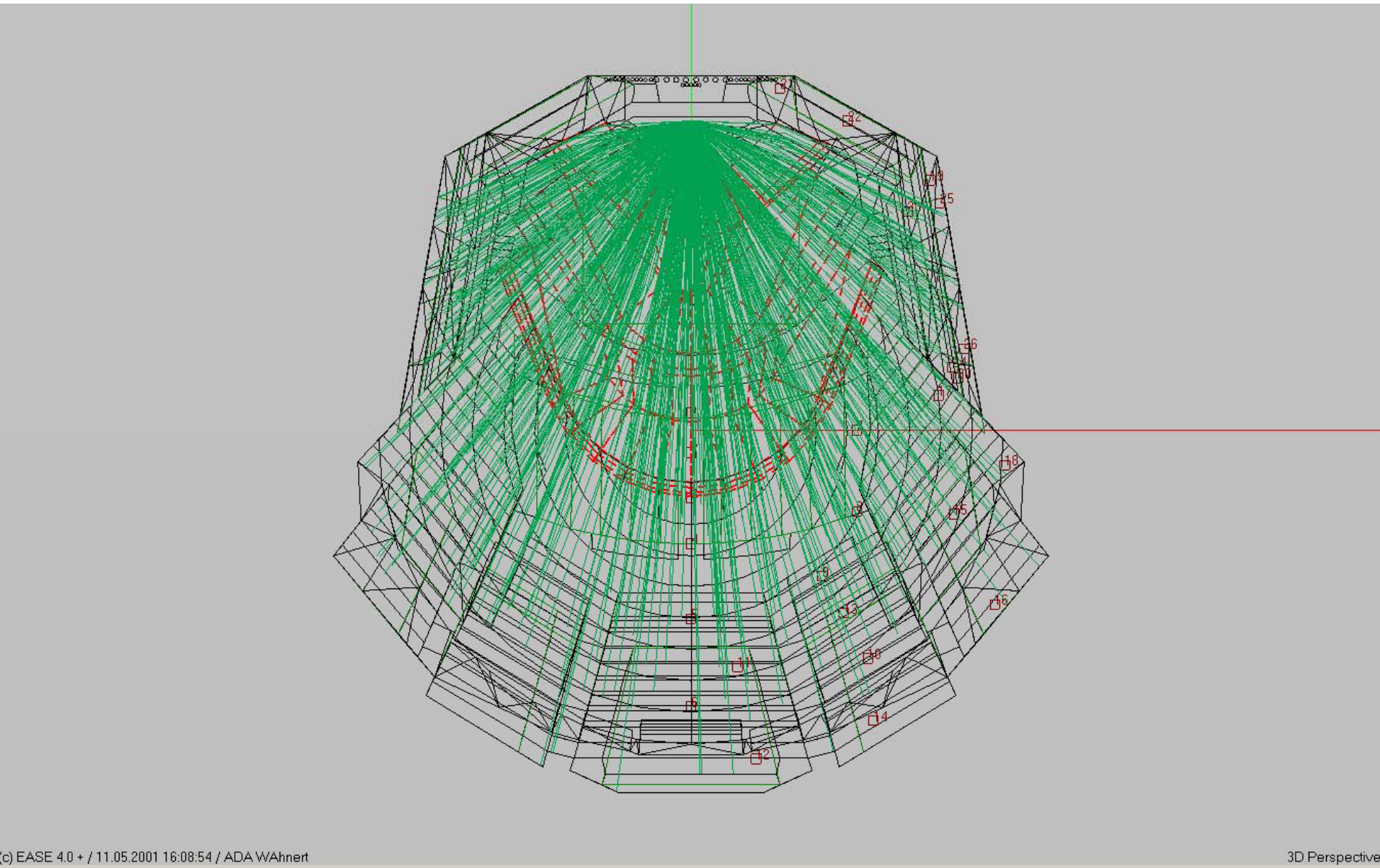
ADA

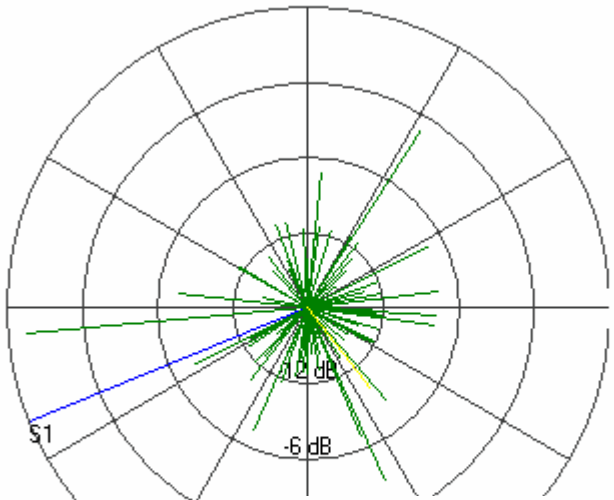

(c) EASE 4.0 + / 11.05.2001 16:02:26 / ADA WAhnert
3D Perspective

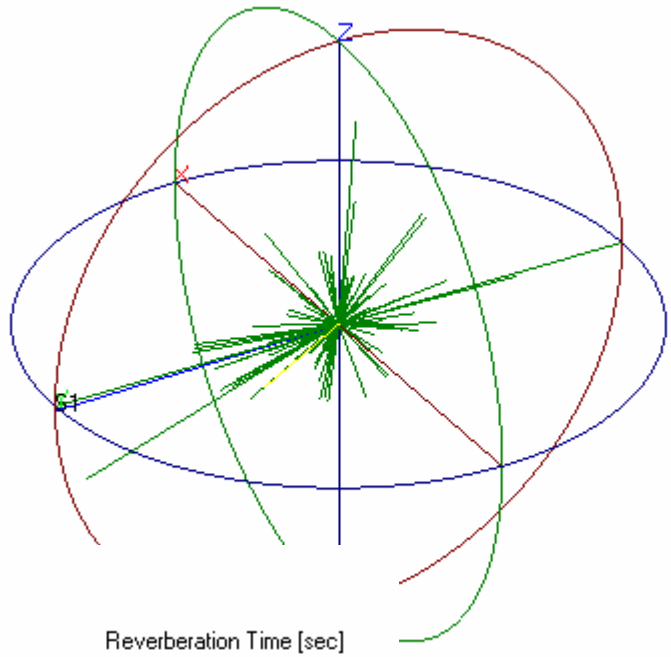


(c) EASE 4.0 + / 11.05.2001 16:08:25 / ADA WAhnert

3D Perspective


(c) EASE 4.0 + / 11.05.2001 16:08:54 / ADA WAhnert
3D Perspective

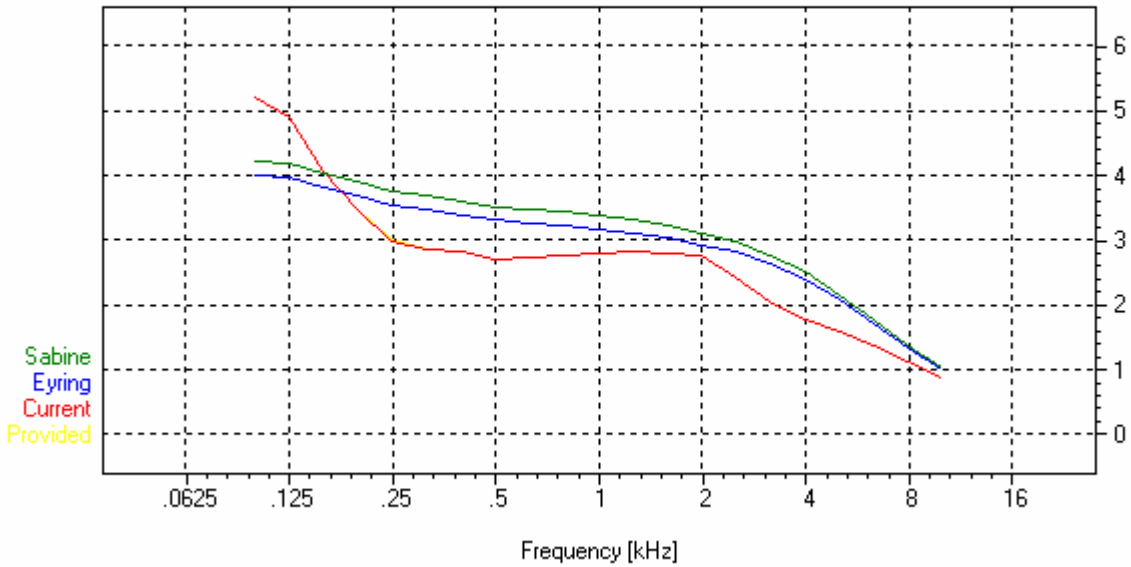




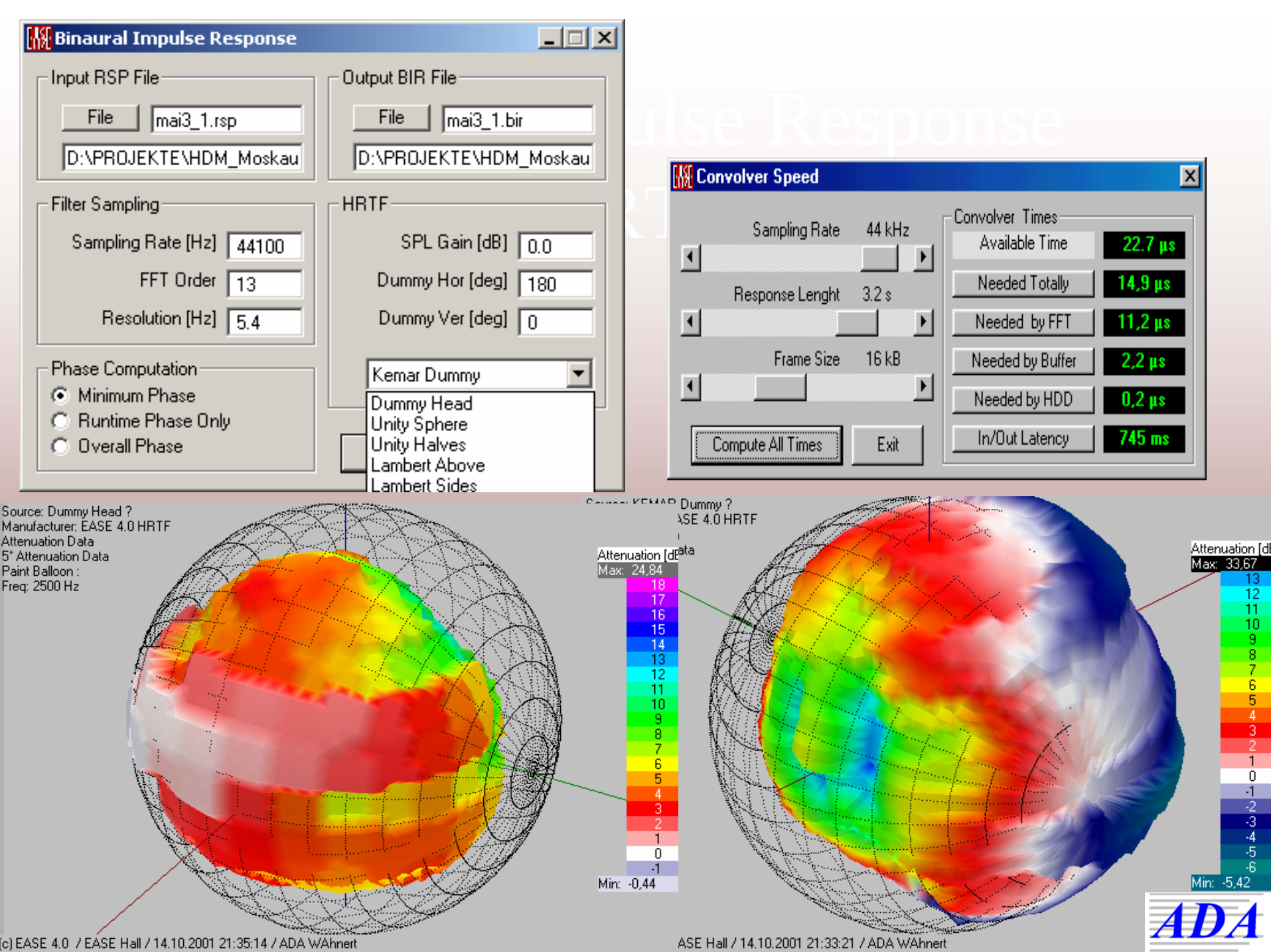
Room Reverberation Local Decay Fit

Reverberation Time [sec]

9:55:47 / ADA WAhnert



ADA


Binaural Impulse Response
Input RSP File
File
mai3_1.rsp
D:\PROJEKTE\HDM_Moskau
Output BIR File
File
mai3_1.bir
D:\PROJEKTE\HDM_Moskau
Filter Sampling
Sampling Rate [Hz] 44100
FFT Order 13
Resolution [Hz] 5.4
HRTF
SPL Gain [dB] 0.0
Dummy Hor [deg] 180
Dummy Ver [deg] 0
Kemar Dummy
Dummy Head
Unity Sphere
Unity Halves
Lambert Above
Lambert Sides
Phase Computation
Minimum Phase
Runtime Phase Only
Overall Phase
Convolver Speed
Sampling Rate 44 kHz
Response Lenght 3.2 s
Frame Size 16 kB
Compute All Times
Exit
Convolver Times
Available Time 22.7 µs
Needed Totally 14,9 µs
Needed by FFT 11,2 µs
Needed by Buffer 2,2 µs
Needed by HDD 0,2 µs
In/Out Latency 745 ms
Source: Dummy Head ?
Manufacturer: EASE 4.0 HRTF
Attenuation Data
5° Attenuation Data
Paint Balloon :
Freq: 2500 Hz
Attenuation [dB
Max: 24,84
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
Min: -0,44
(c) EASE 4.0 / EASE Hall / 14.10.2001 21:35:14 / ADA WAhnert
Dummy ?
ASE 4.0 HRTF
Attenuation [dB
Max: 33,67
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
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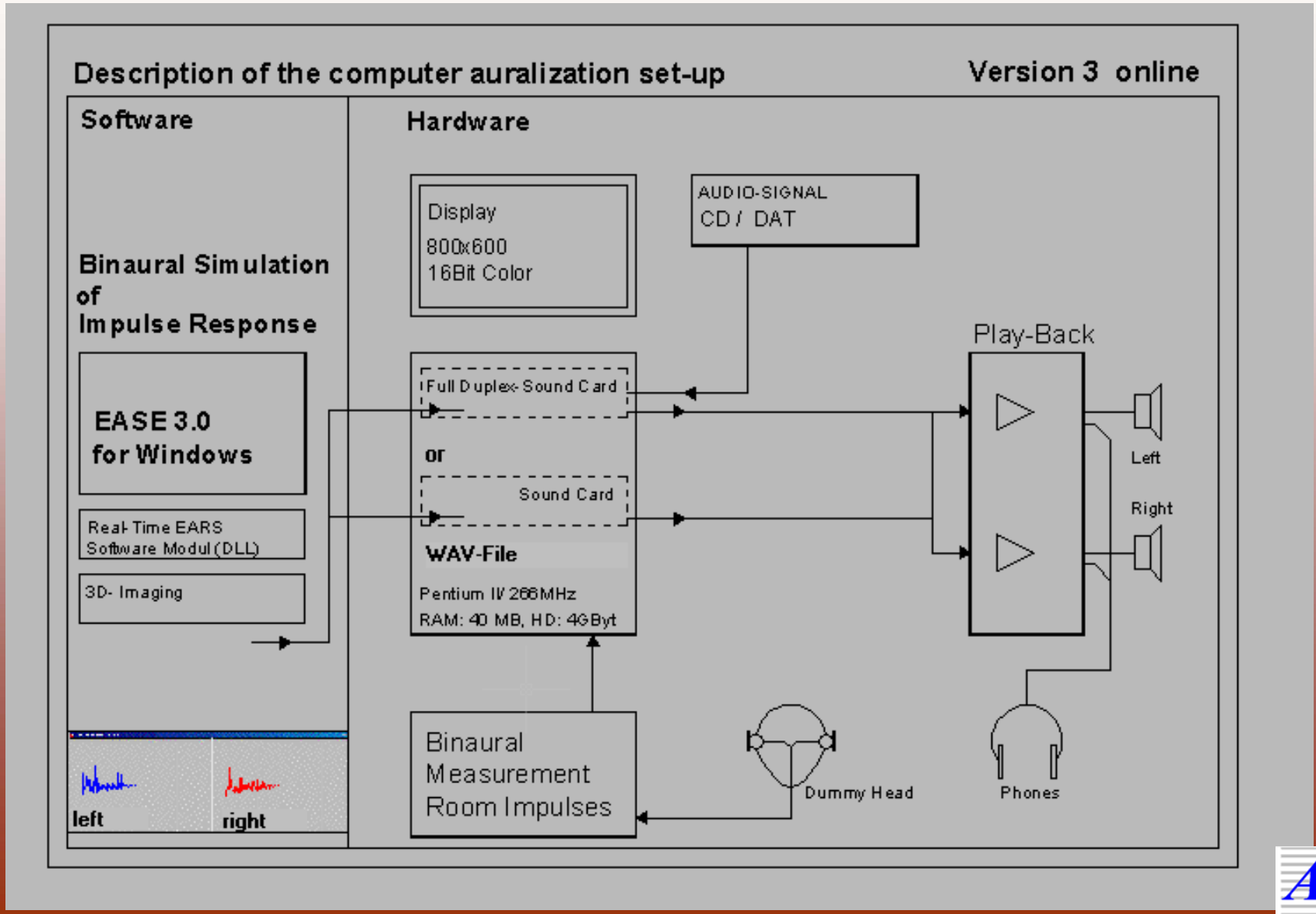
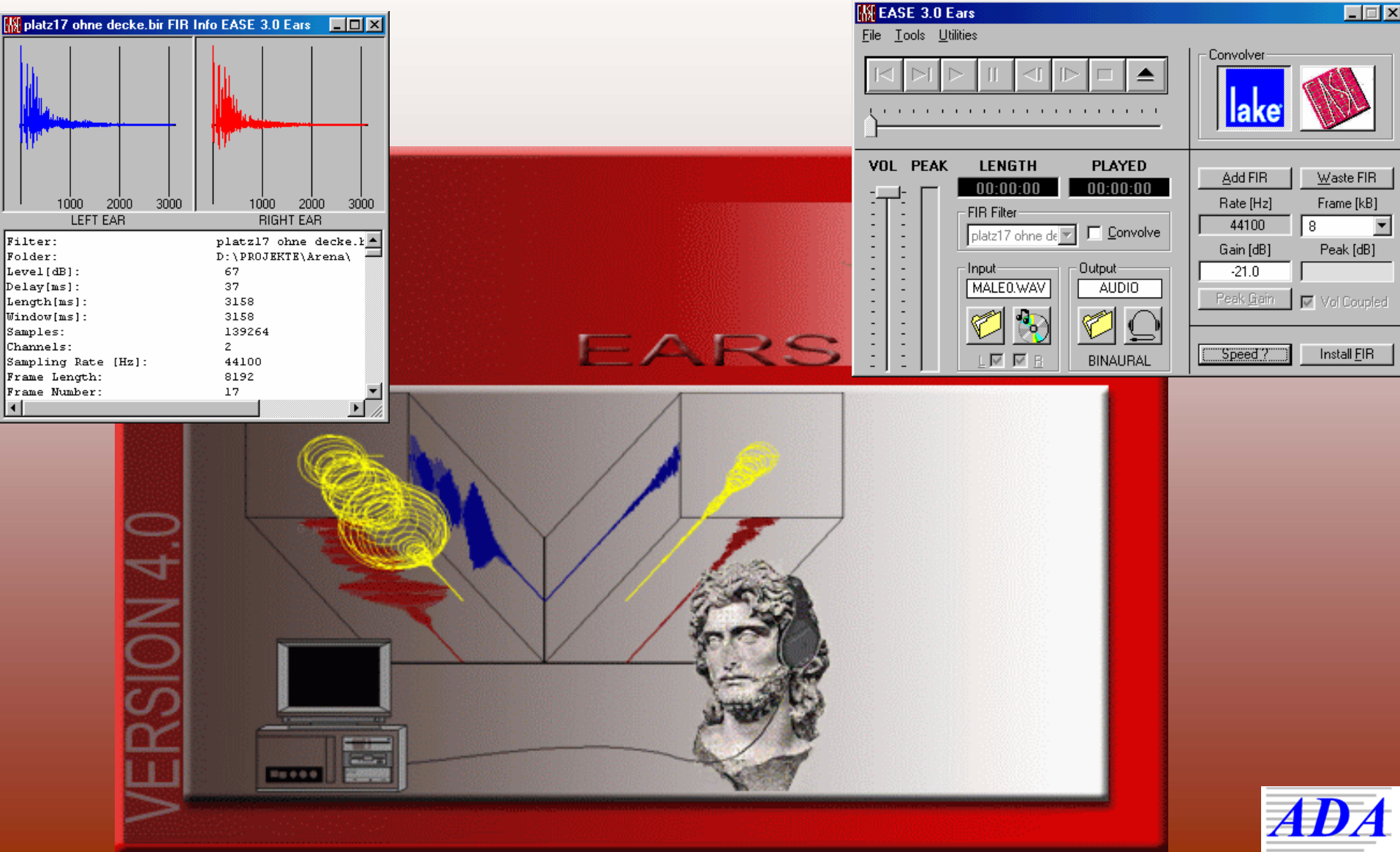
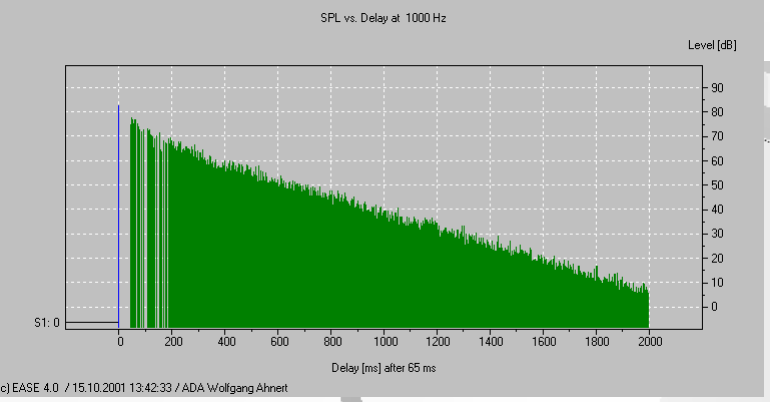
ADA

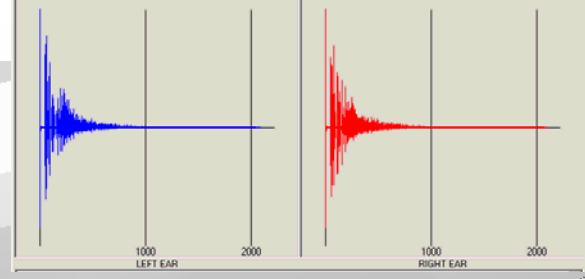
Auralization – Real-Time



Auralization – Real-Time







Voice

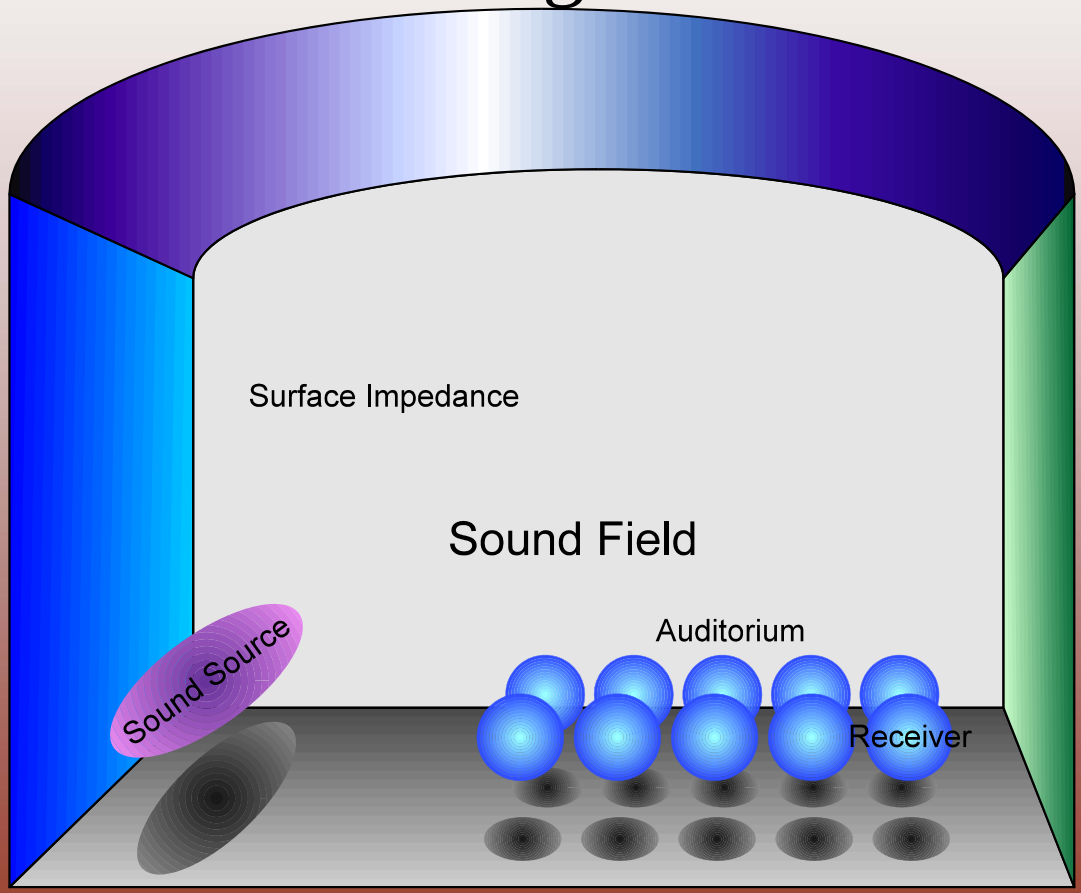
Orchestra

Voice

Orchestra

Limitations of computer models

Factors causing uncertainties



- sound field modeling
  - acoustically correct model of the room?
  - conflicting demands!
  - diffraction? focusing?
- material data
  - complex surface impedance?
  - scattering coefficient?
  - seats and audience?
- source data
  - multiple sources?
  - directivity of sound sources?

Advantages of EASE 4.0 computer models

- General items
  - Time of calculation
  - Import and export to and from other CAD programs
  - Virtual acoustic
  - Combination of statistical and wave model calculations
- Overall simulation
  - Use for light simulations
  - Sight line considerations
  - Infrared and high frequency radiation
  - Living room application
  - General use of textures and tapestry

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