An overview of CATT-Acoustic™ v7.2

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CATT

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- **32-bit Windows MDI application with seven main modules:**

 Prediction

 Directivity

 Surface properties

 Multiple source addition

 Auralization/Post-processing

 Sequence (batch) processing

 Plot-file viewing/WAV-file playing

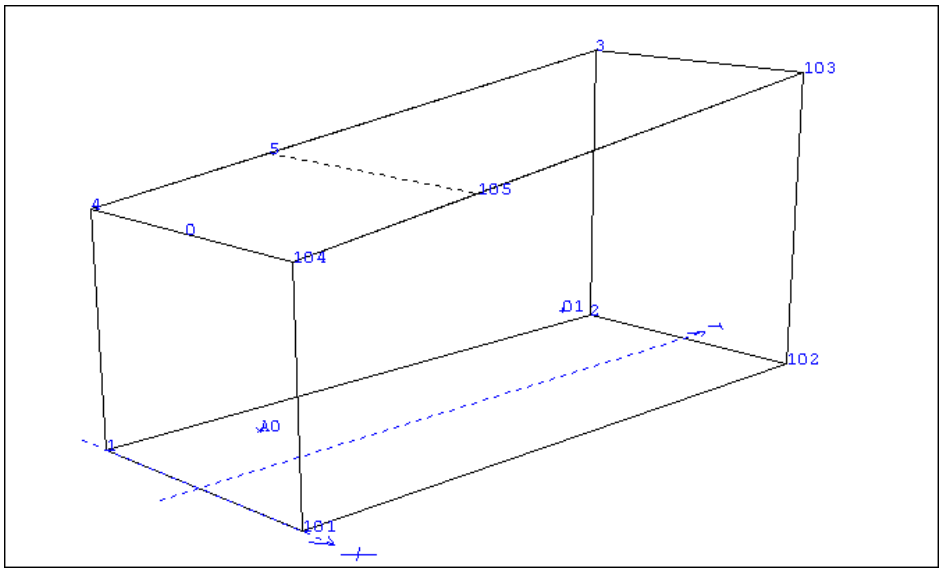
- **Stand-alone modules:**
  - *CATT 3D-viewer* based on *OpenGL*
  - *CATT PLT-viewer*
  - customized editor
- **Documentation:**
  - comprehensive manual
  - context sensitive help
- **v7.2 is the fifth significant version for *Windows* and the software is constantly evolving:**
  - the first 16-bit *Windows* version June 1996
  - the first 32-bit *Windows* version Feb 1998

Prediction module

- **The hall geometry is modeled using a structured hierarchic text format or via *AutoCAD*:**
  - **`INCLUDE`** statements enables a hierarchical structure with hall parts defined in separate files
  - expressions/math functions (e.g. `sin()`, `cos()`)
  - local and global symbolic numerical constants, e.g.
    `GLOBAL` `height = stage_height+10`
  - symbolic string constants, e.g.
    `LOCAL` `wup = "wall of unknown plaster"`
  - tracing and break statements (**SAY**, **RETURN**, **BREAK**)
  - if-then statements for geometry variants (**`IF`** `balcony` **`THEN`**)

- comments
- tools for surface corner locking and object rotation, translation and copying etc. (`lock()`, `cut()`, `x()`, `y()`, `z()`, **`OBJECT`**, **`ROTATE`**, **`TRANSLATE`**, **`COPY`**)
- mirroring of symmetrical (or nearly symmetrical) models (**`MIRROR`**)
- enables very accurate, consistent and maintainable models
- an *AutoCAD* interface written in *AutoLISP* is included that creates files in the *CATT* GEO-format directly (models created in the *CATT* format can also be exported to *AutoCAD* via the interface using an intermediate file format)

- sample geometry-file




```
LOCAL  h  =  8  ;hall height
LOCAL  w  = 10  ;hall width
GLOBAL d  = 24  ;hall depth
```

constant declarations

```
ABS audience = <40 50 60 70 80 80> L <30 40 50 60 70 80>
ABS wood     = <15 13 10  9  8  7> L <30 30 30 30 30 30>
ABS heavyabs = absoflex ;defined in abs. library
```

aborption and diffusion factors 125Hz to 4kHz [%]

MIRROR 100 10 creates mirror corners (100 added) and planes (10 added)

CORNERS

```
 0     0  0                 h
 1  -w/2  0                 0
 2  x(1)  d                 0
 3  x(1)  d                 h+3
 4  x(1)  0                 h
 5  x(1)  0.3*(y(1)+y(2)) lock(0 3 4)
```

corner-number x y z

MIRROR creates 101 as w/2 0 0

x(1) returns the x-value of corner 1

lock(0 3 4) automatically handles the sloped ceiling

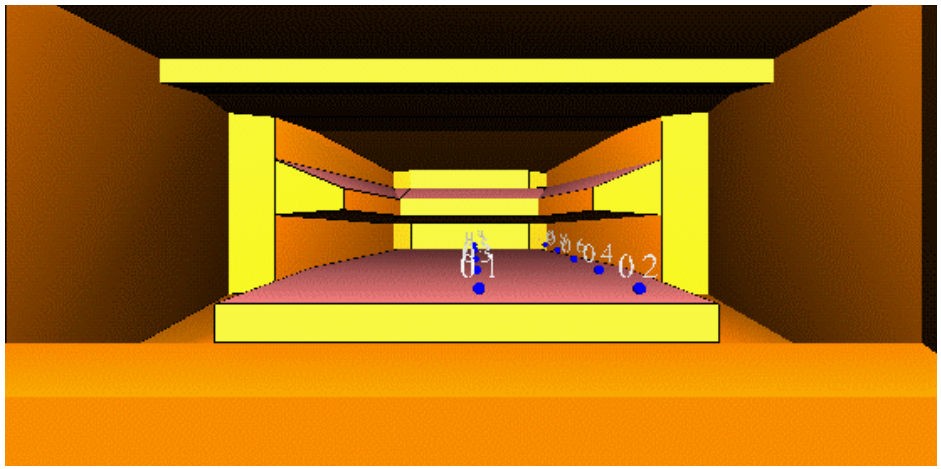
PLANES

```
[1 floor / 2 1 101 102 / audience ]

[2 ceiling / 4 5 3 103 105 104 /
   (hard / 4 5 105 104 / wood)
   (soft / 5 3 103 105 / heavyabs) ]

[3 stage wall / 1 4 104 101 / wood ]

[4 rear wall / 2 102 103 3 / wood ]

[5 side wall / 1 2 3 4 / wood ]
```

the sloped ceiling is divided in two parts with different properties

MIRROR will create the right side wall as plane 5+10=15

- comprehensive geometry check/debug options
- export to *AutoCAD*
- export to the *OpenGL*-based *CATT 3D-viewer*
- export to *VRML* 2.0:
  - the *Virtual Reality Modeling Language* enables interactive 3D models
  - with auralized sound (click a 3D button and the binaural sound associated with the view is played).
  - *VRML*-files (.wrl) can be linked to web pages by using a *VRML* Browser plug-in or add-on to WWW browsers.

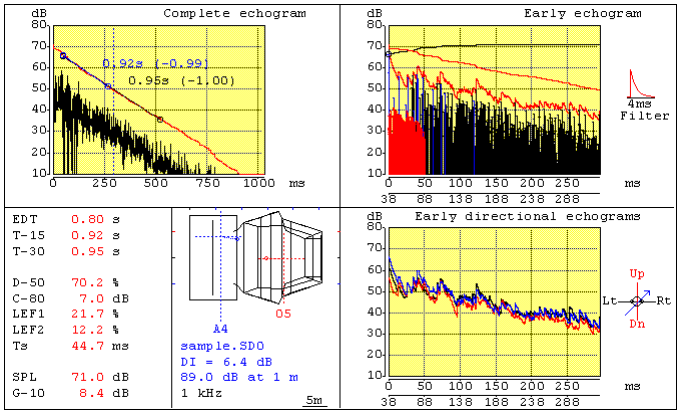


- **Prediction methods:**
  - several methods are available:
    - the unique RTC (Randomized Tail-corrected Cone-tracing)
    - ray-tracing
    - ISM (Image Source Model)
  - up to 260 sound sources
  - up to 100 receivers
  - frequency range 125 Hz to 4000 Hz octave-bands (extrapolation is made to enable full frequency range auralization)
  - frequency dependent diffusion

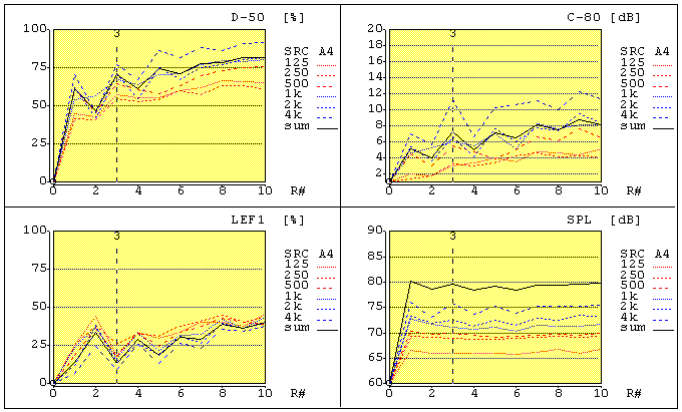
- optional automatic surface size- and frequency-dependent edge diffusion

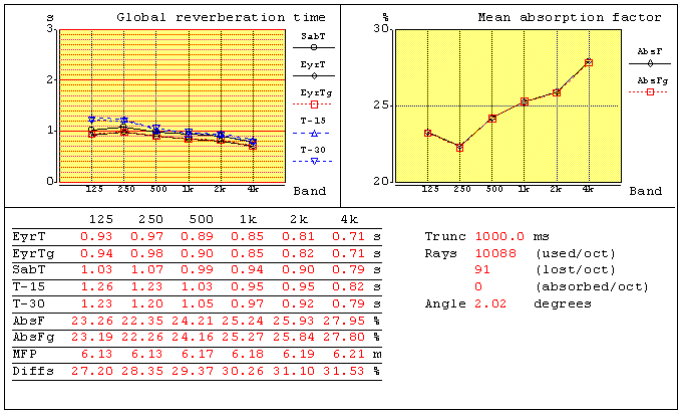
♦ **The RTC is used for full detailed prediction:**

- the RTC is a very general prediction method and is the result of 9 years of development and experience from the ISM, Ray-tracing and Cone-tracing. It could be called the *mother of all hybrids* since it uses elements from all three methods
- auto features that suggest a sufficient number of cones and cone truncation time
- full-length echograms
- detailed early part echograms
- directional early part echograms (X, Y, Z)
- "sound roses" in time intervals (> v7.2k)



- selectable echogram smoothing with filter type and time constant selectable for each octave-band
- calculation of measures: D-50/C-50, C-80, Ts, LEF, LFC, G-10, SPL, RASTI, STI, EDT, T-15, T-30, Sabine RT, Eyring RT
- octave-band Transmission Index curves
- wall hit statistics
- mean free path statistics
- mean absorption statistics
- average RT graphs and other statistical data
- *Excel* export

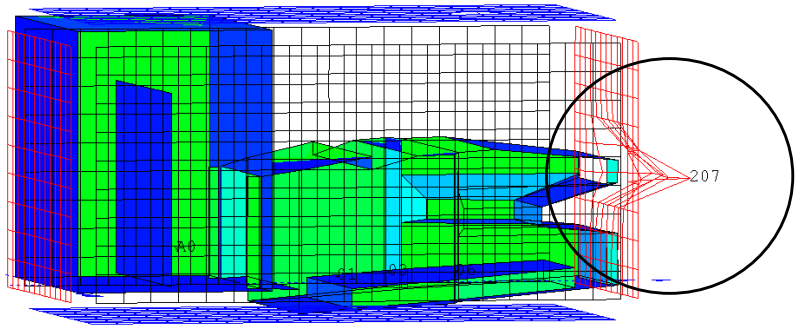




	125	250	500	1k	2k	4k	
EyrT	0.93	0.97	0.89	0.85	0.81	0.71	s
EyrTg	0.94	0.98	0.90	0.85	0.82	0.71	s
SabT	1.03	1.07	0.99	0.94	0.90	0.79	s
T-15	1.26	1.23	1.03	0.95	0.95	0.82	s
T-30	1.23	1.20	1.05	0.97	0.92	0.79	s
AbsF	23.26	22.35	24.21	25.24	25.93	27.95	%
AbsFg	23.19	22.26	24.16	25.27	25.84	27.80	%
MFP	6.13	6.13	6.17	6.18	6.19	6.21	m
Diffs	27.20	28.35	29.37	30.26	31.10	31.53	%

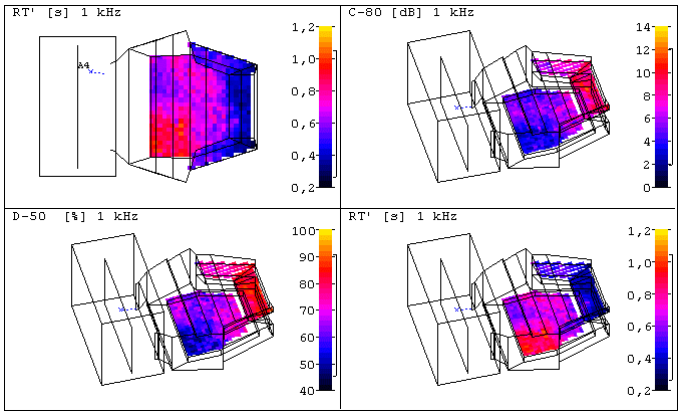
Trunc 1000.0 ms
Rays 10088 (used/oct)
91 (lost/oct)
0 (absorbed/oct)
Angle 2.02 degrees

- optionally includes interference effects between direct sounds from multiple sources (post-processing in the Multiple sources module)
- ray leak display and leak occurance as a func judging leak severity)



♦ **Ray-Tracing is used for audience area 2D/3D**

- auto features that suggest a sufficient numbe truncation time
- mapping of direct sound with and without source coverage angles
- mapping of early coverage: SPL and LEF in four time intervals (e.g. 0-20, 20-50, 50-80 and 80-300 ms)
- mapping of measures: D-50/C-50, C-80, Ts, LEF, G-10, SPL, RT, RASTI, STI, source-

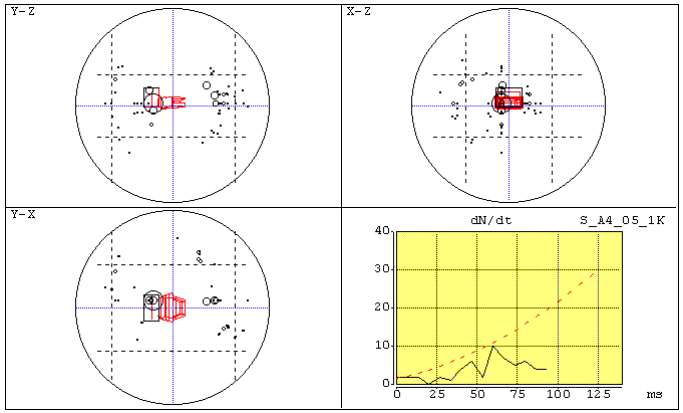


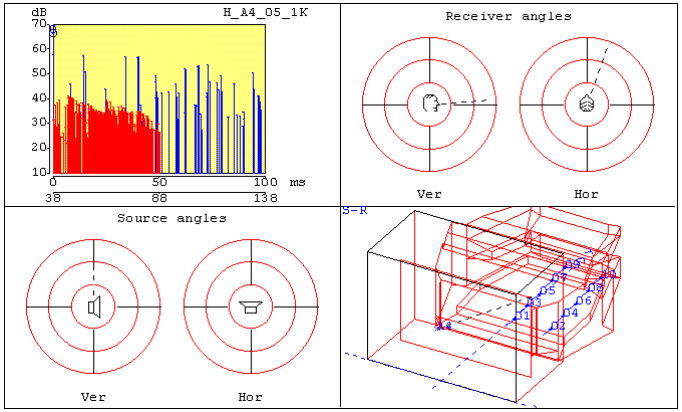
group delays, and closest source-group

- mapping statistics: "33% of all C-80 values are between -2 .. 2 dB"
- optionally includes interference effects between direct sounds

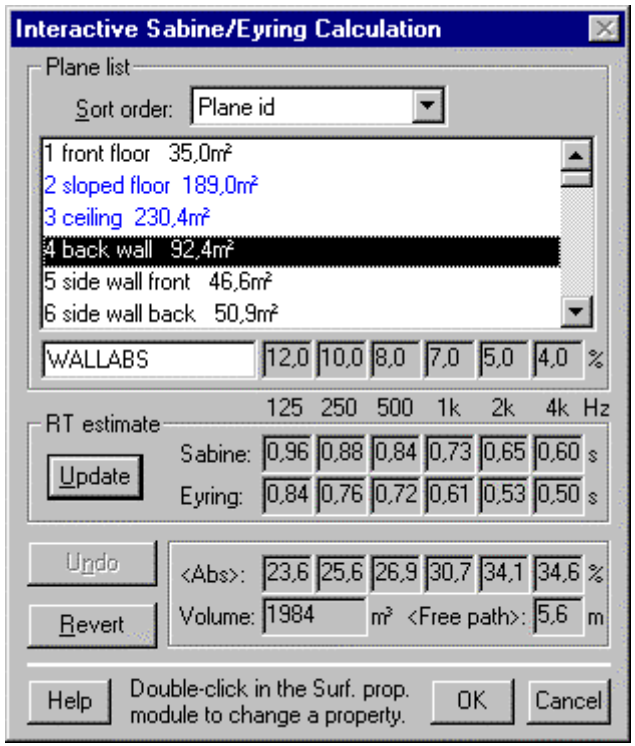
♦ **The ISM is used for qualitative early reflection analysis:**

- detailed early echograms
- image source 3D space
- interactive reflection trace





- **Interactive Sabine/Eyring RT calculation:**
  - included is a very powerful and easy to use spreadsheet-like function:
    - Sabine and Eyring RT estimates can be done while changing absorption
    - for some halls (due to a "mixing" shape or suitable diffusion/absorption distribution) the Sabine and Eyring RT estimates come very close to actual T-30 values estimated from line regression on the decay curves. For such halls "what if?" RT games can quite safely be based on classical RT estimates.
    - Undo and Revert options
    - Absorption use statistics (how much of each material is used)

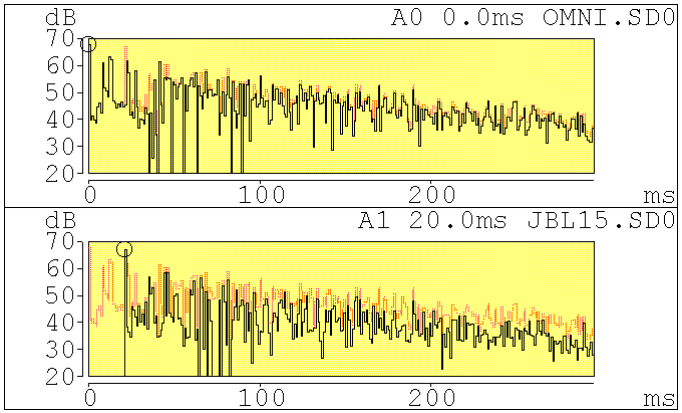


- the surface list can be sorted according to various criteria:
  - absorption (125&250, 500&1k, 2k&4k or 125-4k Hz)
  - absorption area (125&250, 500&1k, 2k&4k or 125-4k Hz)
  - plane (Id, Name or Area)

- **1995 prediction round-robin results (PTB auditorium at 1kHz):**
  - *CATT-Acoustic* (v5,DOS) was very successful in a round-robin with 16 participants (Vorländer, Proc. 15th ICA Trondheim 1995)
  - *CATT-Acoustic* was one of only three programs that were judged to give reliable and useful results. Of these three 5 of the 8 predicted measures were best evaluated by *CATT-Acoustic*
  - The RTC utilized by v7 gives overall better results being of a more general nature
- **1998 round-robin results (Elmia Concert Hall 125Hz-4kHz):**
  - pre-release v7 participated with similarly good results
  - more complex test, not as easy to give clear results
- **Many succesful v7 comparisons have been made since 1998**

♦ Multiple Source Addition Module

- addition of results from the Prediction module
- very fast recalculation after changes in source directivity, aim, delay and eq and head-direction
- optionally creates new results for the Binaural post-processing module
- individual echograms displayed together with the total echogram



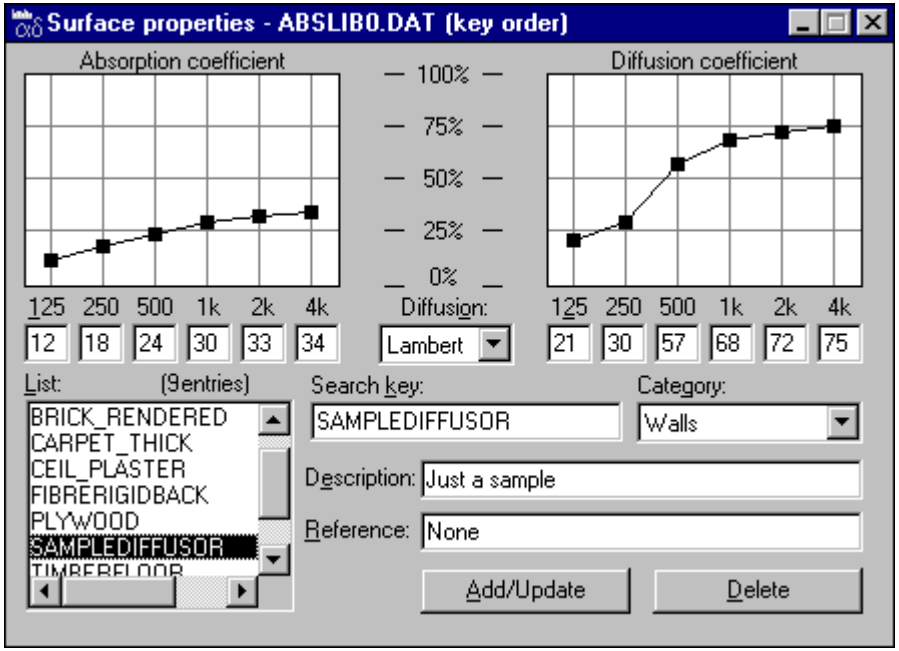
- optionally includes interference effects between direct sounds
- *Excel* export

Surface Properties Module

- named properties including frequency dependent diffusion factors
- properties can also be entered directly into geo-files
- enables high-level constructs such as:

```
ABS wood = <12 10 8 7 6 5>

ABS wallabs = wood
```

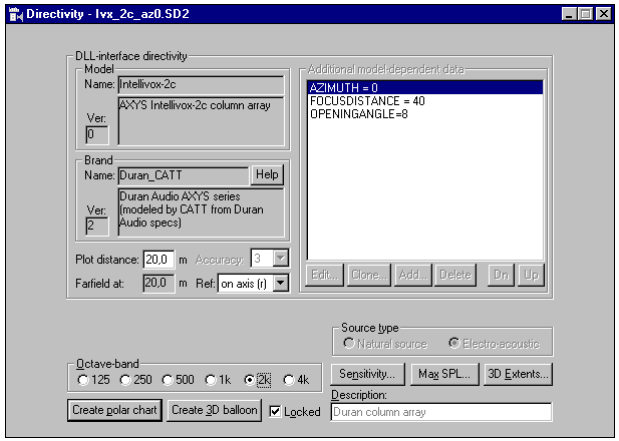
- multiple libraries (library selected in Preferences)



- frequency range 125 Hz to 4 kHz in octave-bands (8 and 16kHz extrapolation for auralization)
- sorting according to: key, category, reference, LF-, MF-, HF-absorption, overall absorption or overall diffusion
- text import/export
- with the Interactive Sabine RT Prediction option, double-clicking a property immediatelly recalculates the resulting Sabine RT

Directivity Module

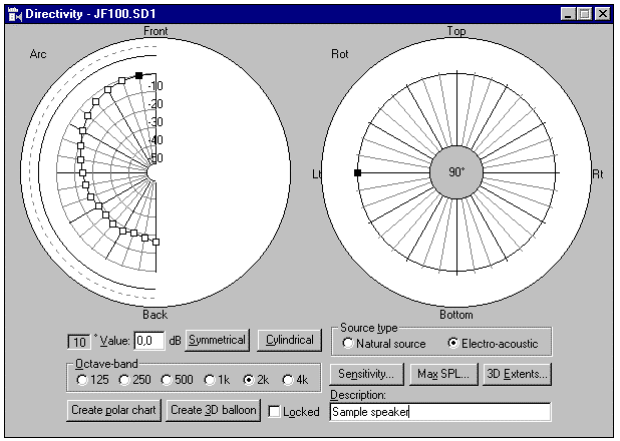
- **type "SD2" based on a general 32-bit DLL Directivity Interface (DDI).**
  - offers array modeling (very high resolution distance dependent directivity), a general handling of directivity and a potentially much higher degree of accuracy than the 10-degree "industry standard"
  - can handle extended near-fields.
  - DDI is prepared for the newly discussed high-resolution AES standard but lets a manufacturer offer high-resolution data even before a new file-format is agreed on.

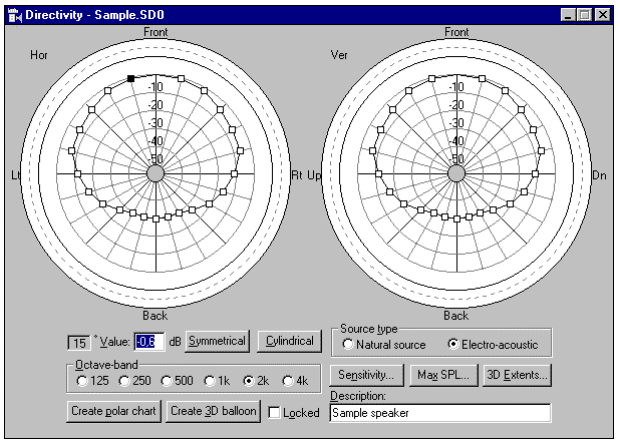


- offers data hiding and hiding of intellectual property (e.g. for DSP-controlled arrays or other special designs).
- parameter control of e.g. beam steering, beamwidth and focus (manufacturer/model dependent)
- DDI white paper in available
- Current DDI-modules are:
  - *Duran Audio's AXYS Intellivox* series DSP-controlled columns arrays (including all beam-steering options)
  - *L-Acoustics V-Dosc/dV-Dosc* (final stages of verification)
  - a generic module that can do array modeling including the near-field. Each transducer is described by its 3D location, SD0 or SD1 directivity pattern, 3D aim, octave-band or FIR-filter weights, and delay. Used e.g. for *Duran Audio's Target* system

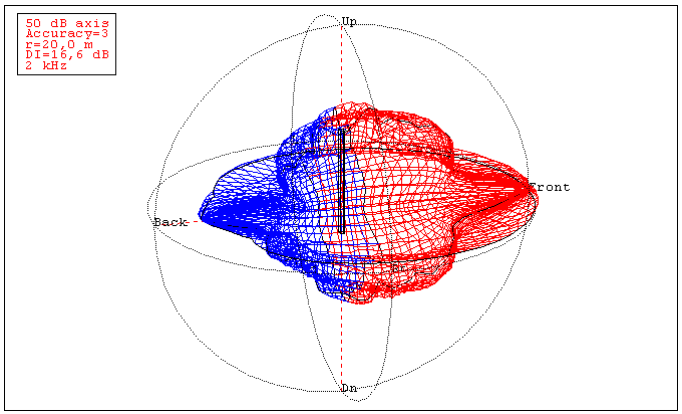
- 3D-balloon interpolation (can speed up full array calculations 10-100 times while retaining the nearfield handling at the expense of 10º resolution, to be used for faster initial aiming).

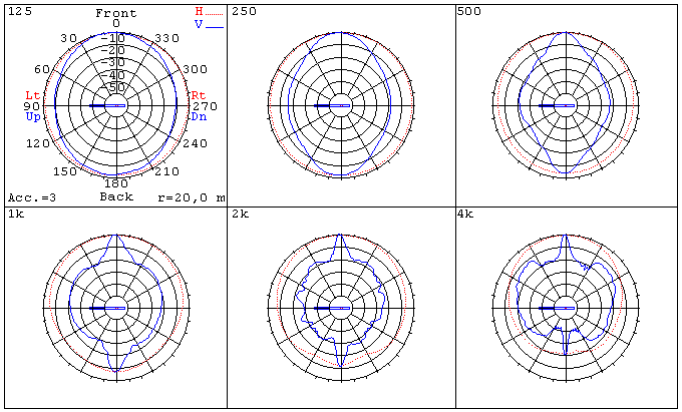
- **type "SD1" based on interpolation from measured 10º full space data. This kind of data is the current "industry standard" and can be requested from most loudspeaker manufacturers**
- **type "SD0" based on interpolation from 15º horizontal and vertical polar diagrams**
- **text import/export of SD0/SD1, text export from SD2 to SD0 or SD1**
- **graphical editing of SD0/SD1 (no spreadsheets)**
- **collections of directivities based on e.g. brand, type or favorites.**





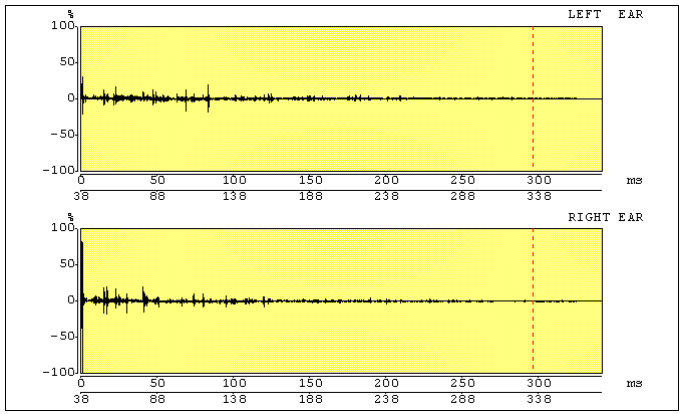
- **3D extents shown for all types**
- **optional data locking to prevent accidental change of directivities**
- **3D-balloons sampled at 7.5º for SD0 and at 5º for SD1 and SD2. For SD0 and SD1 interpolation is performed while for SD2 any available resolution will be used.**
- **polar graphs**
  - for SD0 and SD1 at the measurement points of 15º and 10º respectivelly
  - for SD2 at 2º so that narrow beams can be well displayed, no angular resolution limit at actual prediction

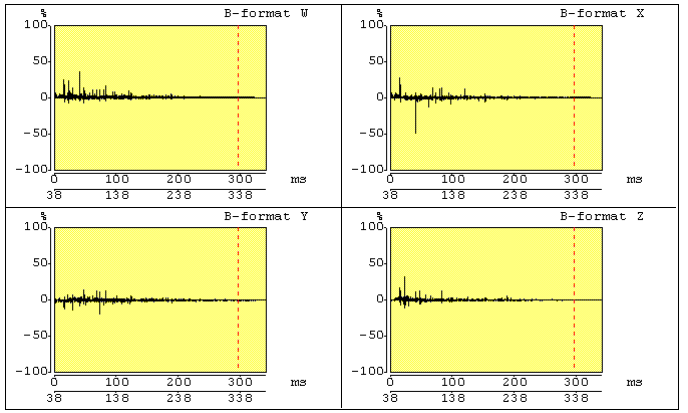




Auralization/Post-processing Module

- post-processing is based on results from the Prediction or the Multiple Source Addition modules
- general auralization method that is the result of 8 years of development and experience of auralization and, just like the prediction method, it employs several different techniques. For special cases also an ISM-based method can be used
- 16, 22.05, 32, 44.1 or 48 kHz operation
- full bandwidth auralization by using extrapolation of 8k and 16kHz





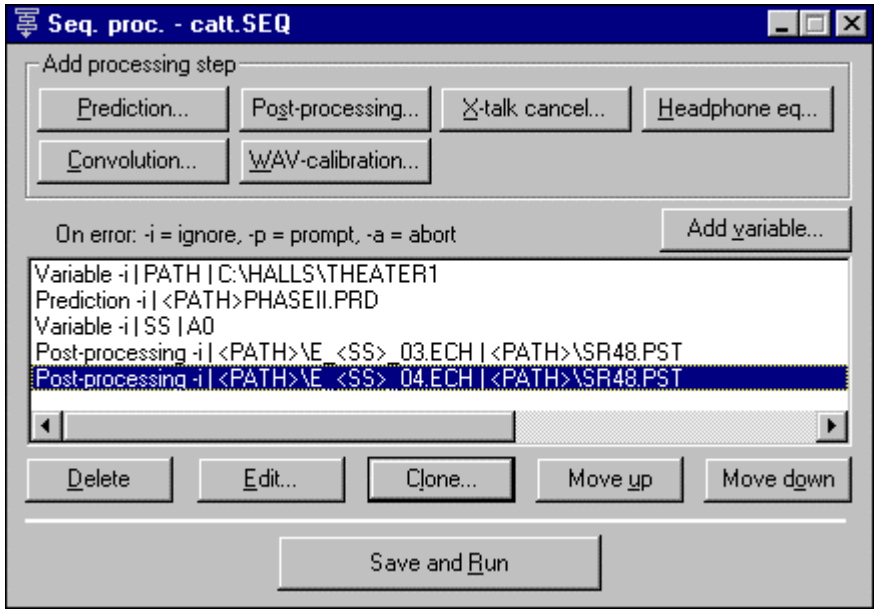
- **binaural, microphone, stereo, or B-format post-processing**
- **IACC (Inter-Aural Correlation Coefficient) calculation for binaural responses**
- **multiple source auralization using the same anechoic source (typically for PA systems) or using different anechoic sources:**
  - stereo speakers, background noise + speech etc.)
  - 5-channel replay/setups/simulations for special-purpose tests (e.g. 5-channel recording techniques)
- **loudspeaker replay of simulated or recorded binaural sound via loudspeakers using cross-talk cancellation filters:**
  - loudpeaker positions are selected
  - optional individual loudspeaker correction
  - many options for creating the cross-talk filters

- **file-conversion utilities (*MATLAB* .MAT, *MLSSA* .TIM, *Windows* .WAV, *Lake* .SIM,...)**
- **general and secure handling of HRTF libraries and headphone equalization filters enables licensing of HRTF libraries and headphone filters from various sources (so far 3 distinct HRTF sets are available and 10-15 headphone filters). Headphone equalization and HRTFs in user Preferences**
- **sample rate conversion tool also to 88.2 and 96 kHz (integer ratios)**
- **impulse response filtering tool (headphone eq, cross-talk cancellation, general FIR eq)**
- **software convolution at real-time speed of anechoic music/speech with synthesized impulse responses**

- **convolution can also be performed in real time and without latency for virtual reality applications using *Lake Technology* hardware where also loudspeaker replay using Ambisonic and dynamic auralization with head-tracking can be selected**
- **anechoic WAV-file info compilation (scalefactor, level in octave-bands, reference etc.)**
- **WAV-file player with single-file, A/B and play-list functions (runs automatically after a convolution)**
- **full version users are automatically also licenced for *The FIReverb Suite™* :**
  - *PureVerb™* - creates natural-sounding FIR reverberation for mono, stereo, AB-stereo, B-fromat and 5-channel
  - *MultiVolver™* - a multi-channel off-line convolver that can process up to 8 ch in x 8 ch out (e.g. 2x5 for stereo to 5-channel upmix).

Sequence (batch) Processing Module

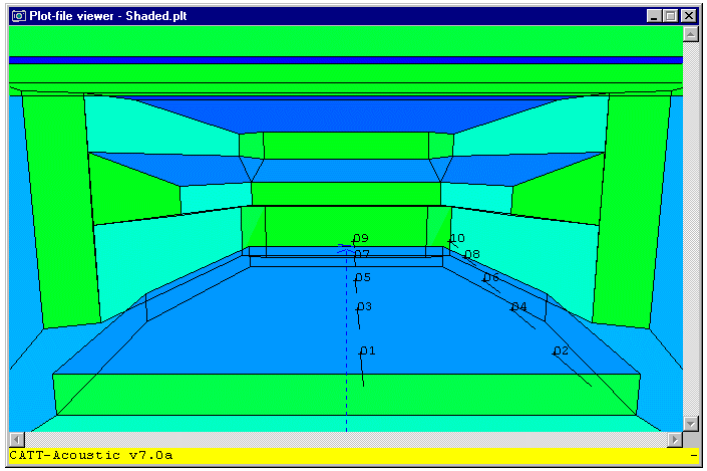
- **all steps from Prediction and Post-processing to Convolution and WAV-file calibration can be made to run automatically enabling "batch" runs.**
- **cross-talk filtering and headphone eq can be performed in batch to give both headphone and loudspeaker replay options from not equalized responses**
- **when the processing chain has been run once, a complete re-run after e.g. a changed ceiling height requires only a re-run of the sequence**

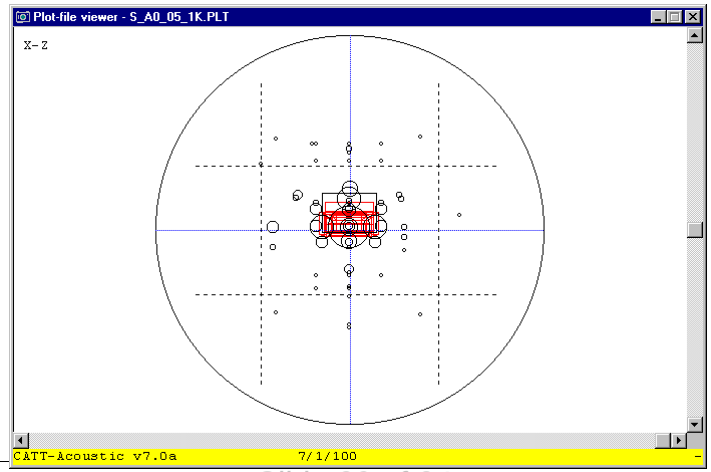


- **sequences can be merged so that from separate prediction, post-processing and convolution sequences, a full sequence can be created**
- **sequences can be started from any step**
- **string variables can be defined that allows for generic sequences that can be re-used by changing a variable (e.g. a file path)**

Plot-file Viewer/WAV-file Player Module

- **the viewer/player shows results from the other modules:**
  - shaded 3D models with selectable palettes
  - color mapping with selectable palettes
  - double-buffered smooth 3D transformations with direct mouse control.
  - 2D graphics
- **all 2D graphics can be zoomed for details and displays values when the mouse is passed over**

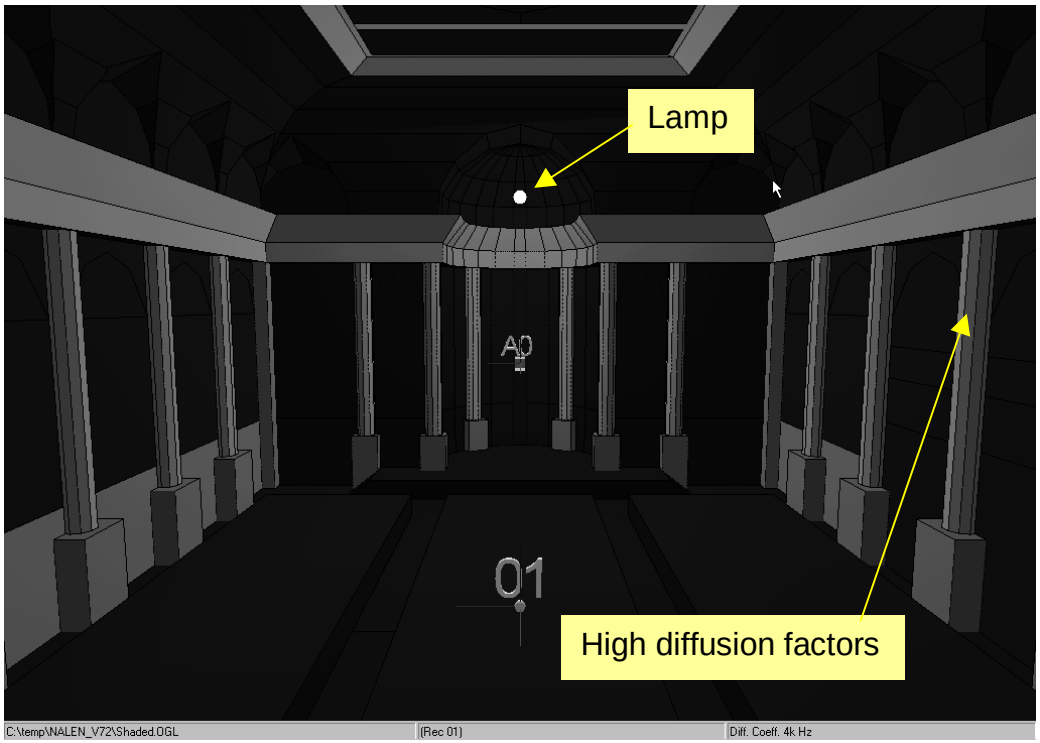




- **graphics can contain animated sub-frames e.g. showing animated reflection traces**
- **the viewer can also be used to present results to customers by assembling an optionally auto-playing list of plot- and WAV-files**
- **exports graphics in *Windows* Meta (.EMF), *Windows* Bitmap (.BMP) and Encapsulated PostScript (.EPS) formats**
- **clipboard Meta-file and Bitmap copy**
- **the stand-alone *CATT PLT-viewer* is included:**
  - can be used for customer presentations not requiring installation of the full *CATT-Acoustic*
  - comes with its own help-file
  - freely distributable

CATT 3D-viewer based on OpenGL

- **the *CATT 3D-viewer*:**
  - is small (< 100 kB!)
  - for customer presentations
  - is freely distributable
- **color surface coding:**
  - absorption factor
  - diffusion factor
  - specularity
  - diffusitivity



- **variable lighting**
- **animated viewpoint transitions**
- **animated walkthroughs**
- **WAV-file playing in walkthrough**
- **viewpoint lists that can be saved and loaded for presentations**
- **on/off selection of all elements:**
  - surfaces/edges
  - source/receiver-items (id, coord system, aim, head direction,...)
  - lamps
  - coordinate system
  - palette used for color coding

- **elements can be individually colored**
- **the viewer requires *OpenGL* 1.1 to be installed on your system (preinstalled on all *Windows* versions except 95 OSR1 but can then be downloaded for free from http://www.opengl.org) and automatically 3D hardware support**

Finally

- ***CATT-Acoustic* comes in four versions**
  - Free Demo : demo prediction, demo auralization. No limitation in building models, full help-file documentation
  - Prediction version : full prediction, demo auralization
  - Full version : full prediction, full auralization, *The FIReverb Suite,* CD with anechoically recorded source material
  - Full version with extra functionality for *Lake Technology* users
- **Non-commercial use discount**
- **Information and graphics used in this presentation (plus many more) can be found at the *CATT* web-site where also the demo can be downloaded:**

www.catt.se