PRODUCT DATA

ODEON Room Acoustics Modelling Software — Types 7835, 7836 and 7837

THE ART OF ACOUSTIC ROOM MODELLING

Brüel & Kjær is the sole worldwide distributor of ODEON, a reliable, easy-to-use, modelling software tool for indoor acoustics, developed at the Technical University of Denmark

ODEON is PC software for simulating the interior acoustics of buildings where, from the geometry and properties of surfaces, acoustics can be calculated, illustrated and listened to. ODEON's prediction algorithms (image-source method combined with ray tracing) allow reliable predictions in modest calculation times. ODEON is ideal for the prediction of acoustics in large rooms such as concert halls, opera halls, auditoria, foyers, underground stations, airport terminals, and industrial workrooms. For noise prediction of large machinery in industrial environments, a special ray-tracing algorithm has been developed allowing the modelling of surface and line sources. ODEON is a proven tool for predicting the acoustics of new buildings, as well as for evaluating and recommending improvements in existing ones.

7835, 7836, 7837

Brüel & Kjær

USES

- Prediction of the room acoustics of planned buildings
- Optimisation of the acoustical design of rooms in planned buildings
- Prediction of effect of building changes on room acoustical properties
- Improvement of room acoustics of existing buildings

FEATURES

- Fast modelling using parametric room editor or import from CAD systems
- Verification of model
- Flexible choice of sources, receivers and materials
- Modest calculation time
- Visual results – reflectograms, 3D reflection paths, 3D maps
- High-quality auralization
- Effective project management
- Easy copy and export of results for project reports or presentations

About ODEON

The Origin of ODEON

Fig. 1
Odeon of Herodes Atticus, Athens

The classic, greek odeon evolved from the development of the large, open-air theatre into a more intimate, roofed-over venue for music performance (a place to sing 'odes') and, as such, was the first known instance of the construction of concert halls. The first (1991) version of ODEON was aimed at the prediction of auditorium acoustics. Since then, ODEON has been continually developed and refined, and is now available in three state-of-the-art editions: **Industrial**, **Auditorium**, and **Combined**[1]. All editions run on Microsoft® Windows® 98/NT®/2000/XP.

Calculation Method – Algorithms and Applications

ODEON is based on prediction algorithms (image-source method and ray tracing) allowing reliable predictions in modest calculation times. It is ideal for the prediction of large-room acoustics such as in concert halls, opera houses, foyers, underground stations, airport terminals, industrial workrooms and various auditoria. For noise predic-

1. Specific features for each of the three ODEON editions are listed in the Ordering Information

tion of large machinery in industrial environments, a special ray-tracing algorithm has been developed allowing the modelling of surface and line sources.

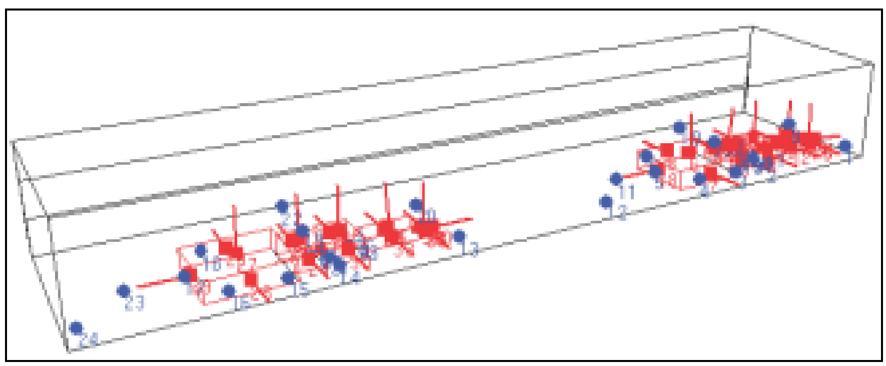
Constructing Your Model

Fig. 2
From image to model – the surface geometry and properties of the real or proposed building are input to your model

Modelling the Room

Room geometries can be imported in DXF format. As another option, room geometries can quickly be modelledor remodelled in a parametric language.

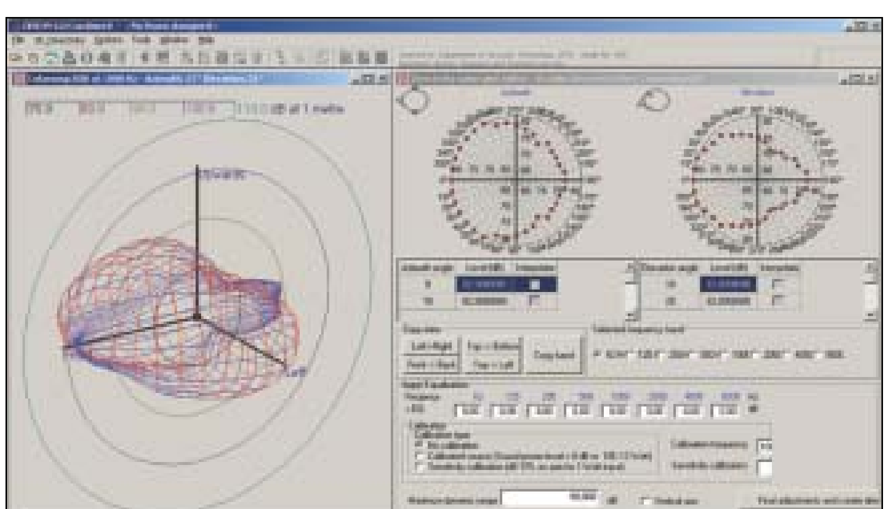
Fig. 3
The ODEON model requires only details that are essential for acoustics calculation. Appropriate sound sources and receivers are assigned and located in the model



Defining Sources

Point sources can be defined by directivity pattern, gain, equalisation and delay, allowing the definition of natural sound sources as well as loudspeaker systems. The Industrial and Combined editions also allow the definition of line and surface sources that are particularly useful for calculations in industrial environments. Positions, orientations, etc., are automatically reflected in 3D displays.

Fig. 4
Example of a point source definition with a special directivity pattern – a loudspeaker column that improves the speech intelligibility in a church



Materials

Materials are defined by the absorption coefficients from 63 to 8000 Hz and a scattering coefficient. A transparency coefficient can also be used. Materials are selected from an extendable library of materials. The surface list is linked to a display showing the selected surface in 3D.

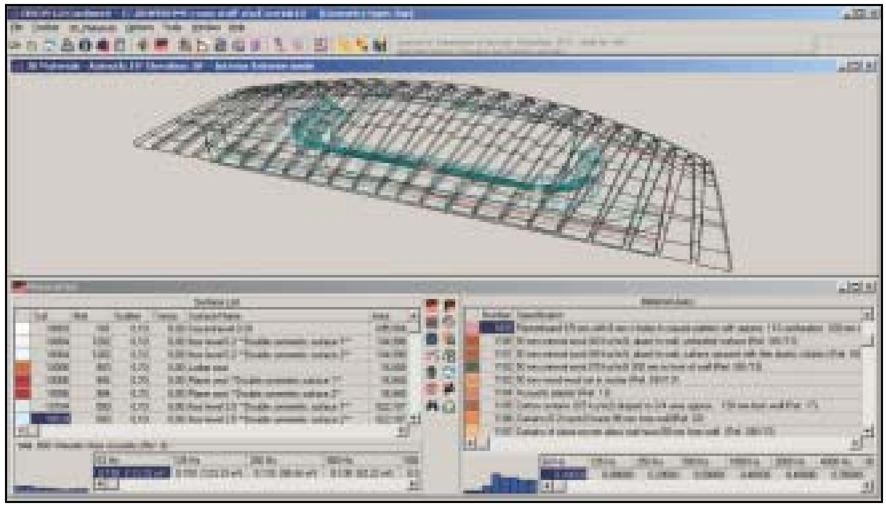


Fig. 5
Surfaces are listed in the left-hand column. Selecting a surface in the list will highlight it in the 3D display. To assign a material to a surface, click on the material (right-hand column) and on the ***Assign*** *button*

Checking your Model

To ensure that calculation results are reliable, it is essential that geometries are consistent. ODEON includes a number of tools for geometry verification, e.g., the 3D Geometry Debugger with a check for duplicate or overlapping surfaces. The ray-tracing display can also be used in the verification of room geometry.

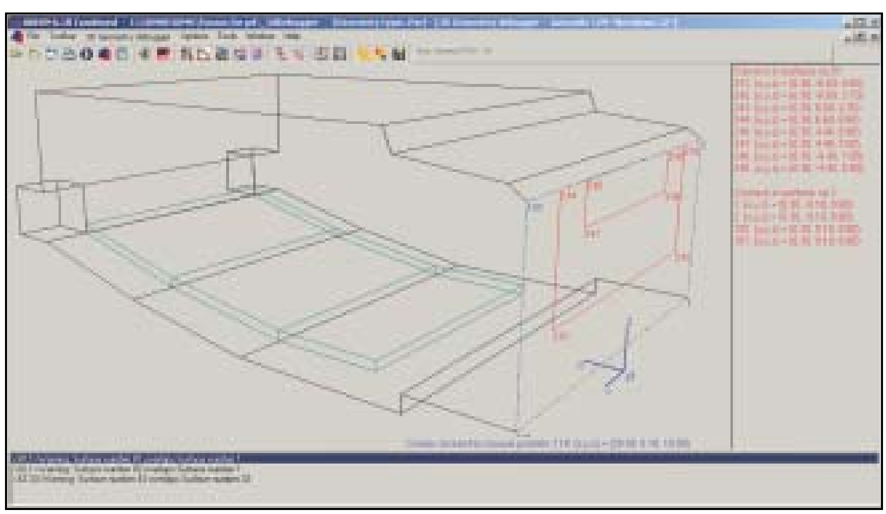


Fig. 6
The 3D Geometry Debugger points out errors in the model such as overlapping, duplicate or warped surfaces. This makes it safe and easy to locate and correct possible errors in the model description

3D Colour Display

The 3D openGL display shows geometry, materials and source positions. This display is useful when checking the validity of room geometries or source and receiver locations. The surface colours are mapped on to the acoustic reflectance of the surface materials – particularly useful when checking that materials are assigned correctly in complicated models and also useful for presentation purposes.

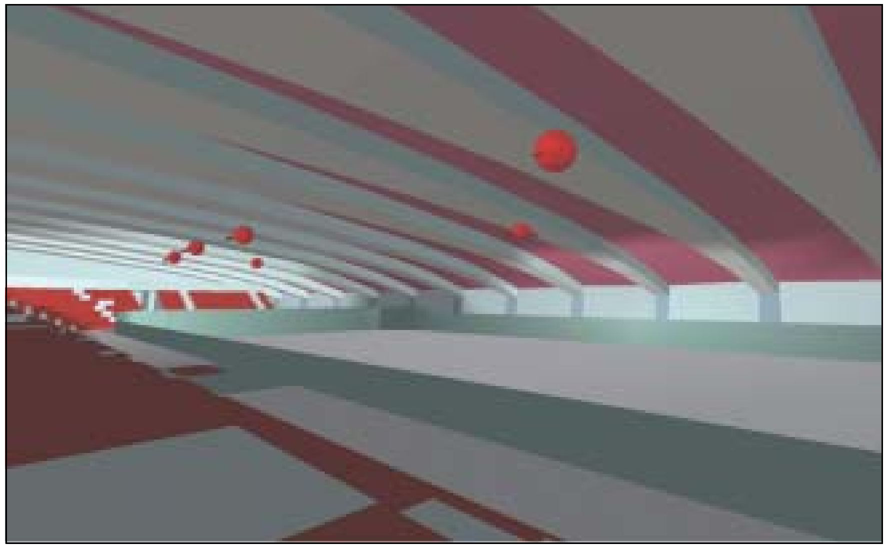


Fig. 7
The 3D display is useful for checking the validity of the model. It can be viewed from all aspects, both inside and outside, using rotation, move and zoom features

Project Management

Thorough project management is an important ODEON feature. ODEON always ensures that results stored with a project are consistent with the specified geometry, materials, sources, etc. A project stored in the program archive contains all the information needed for full documentation. A project, and all its associated data, can be saved into a compressed file for easy backup or e-mail transfer.

Results

Calculation

Most calculation parameters are set automatically but, for special cases, the user may want to change some parameters, e.g., temperature and relative humidity.

Decay Curves

Two global-decay methods are available – the **Quick Estimate** based on statistical formulae, and the more precise **Global Estimate** based on ray tracing, thus taking room shape, source position, and the position of absorbing materials into account. The global-decay methods can be used for checking the overall decay time and absorption in the model. The Global Estimate corresponds to the reverberation decay averaged over an infinite number of points in the model and thus represents an ideal in traditional reverberation time measurements.

Fig. 8
Quick Estimate gives an overview of the model's reverberation time and absorption, and suggests the changes in absorption needed to obtain a certain reverberation time

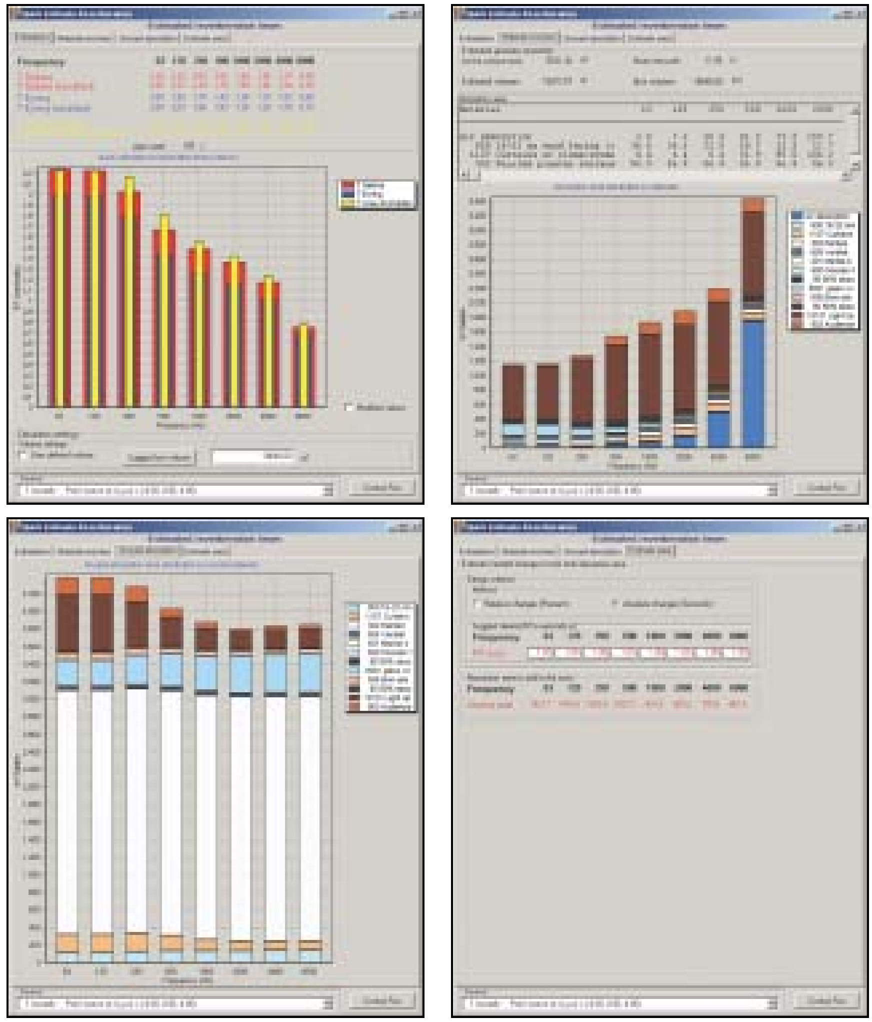
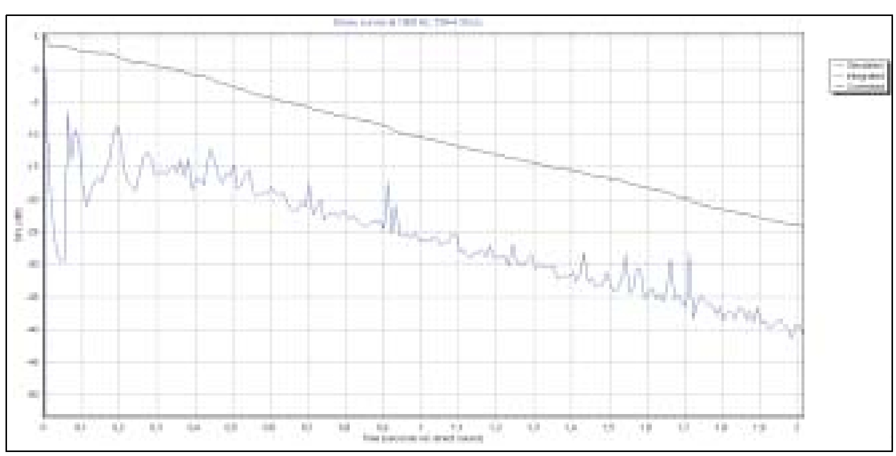


Fig. 9
Reverberation decay at a point in the seating area of a theatre in a converted gas-production building. Strong fluctuations can be seen at the beginning of the decay



For each receiver point in the model, the squared impulse response is calculated and shown as a decay curve and an integrated decay curve. These results can be directly compared to those measured at the same points in the real room.

Ray Tracing

Two ray-tracing displays are provided. The first shows single-point ray tracing, i.e., rays radiated from the source during calculation of point responses, which is useful for the verification of room geometry and source positions. The other shows two-point ray tracing, i.e., the early reflection paths from a point source to a receiver, and is linked to the reflectogram (see Fig. 12) to locate the path of particular reflections.

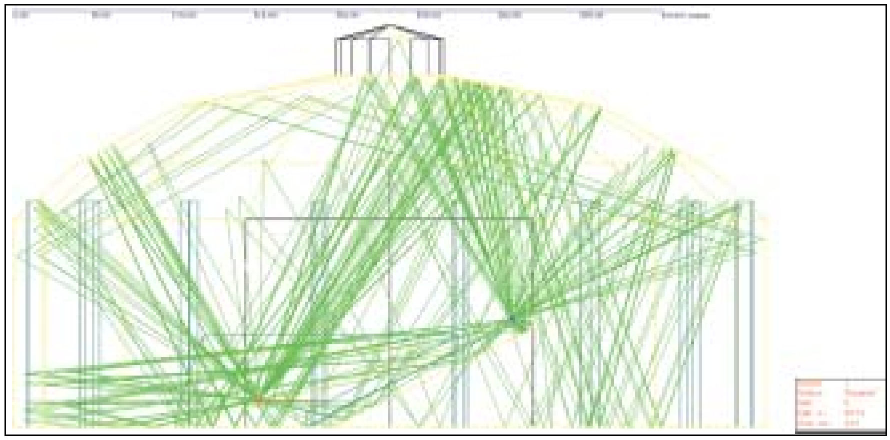


Fig. 10
Ray tracing shows the path of each ray and is useful for checking room geometry. The tracing shown is from the building in Fig. 9, showing the focusing effect of the dome

Room Acoustic Parameters

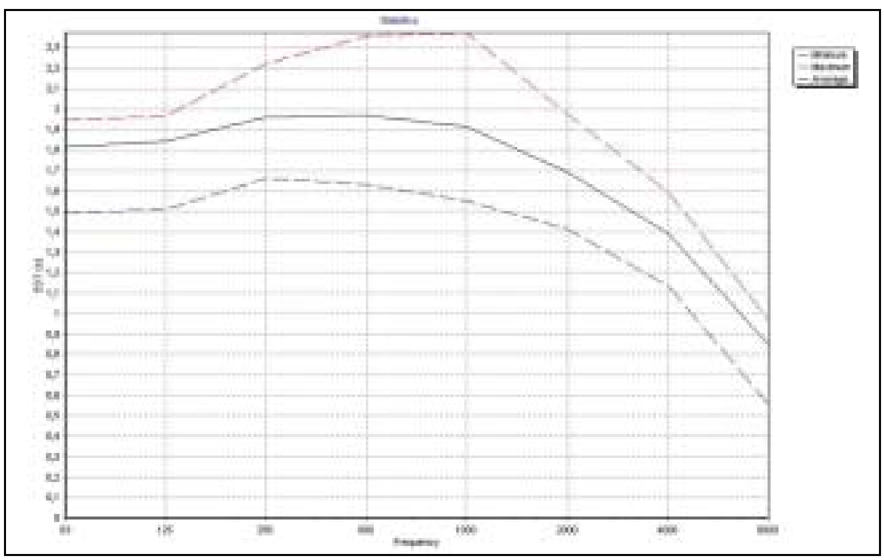


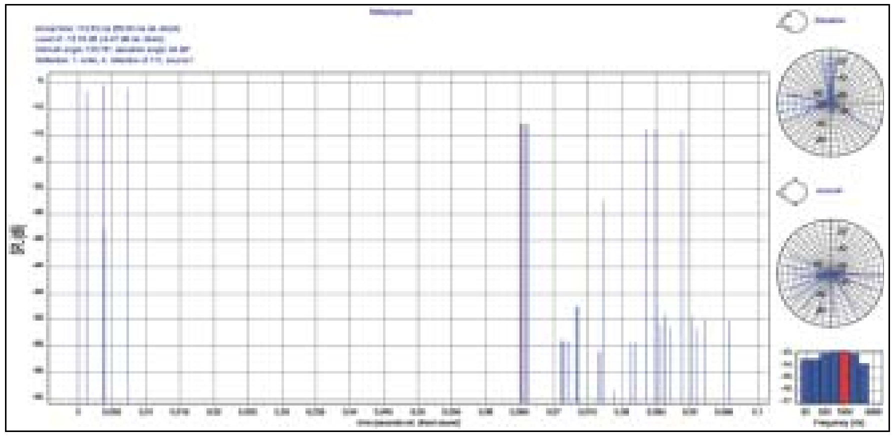
Fig. 11
The maximum, minimum and average of a room acoustical parameter calculated at several receiver points

For each receiver point, a number of acoustical parameters are calculated from the integrated decay curve.

Reflectogram

The reflectogram shows the arrival time and level of all reflections, referred to the direct sound. It helps identify useful, as well as unwanted, reflections.

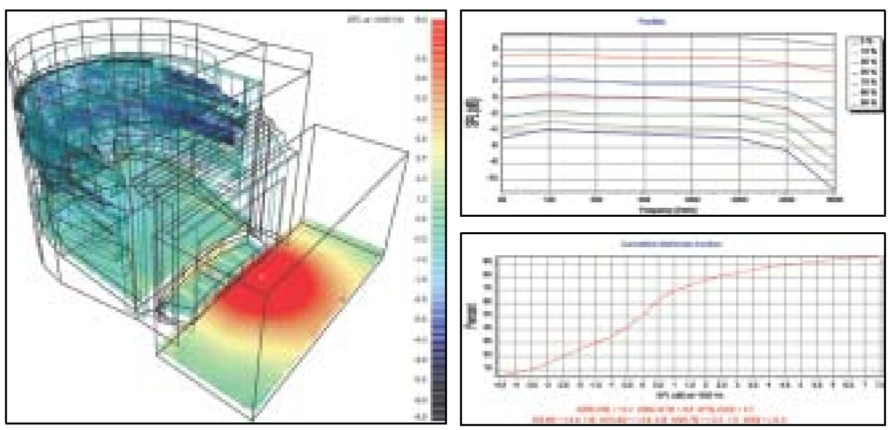
Fig. 12 Reflections within the dome of the same theatre (see Fig. 10). The clustering of reflections points to an echo problem. Ray tracing helps identify echo-causing room surfaces



Maps

Maps of calculated parameters can be calculated for any number of selected receiver surfaces. Such parameters include, e.g., sound-pressure level, energy parameters or intelligibility (Speech Transmission Index). The resolution of the map (grid resolution) is selected to give sufficient detail within an acceptable length of calculation time.

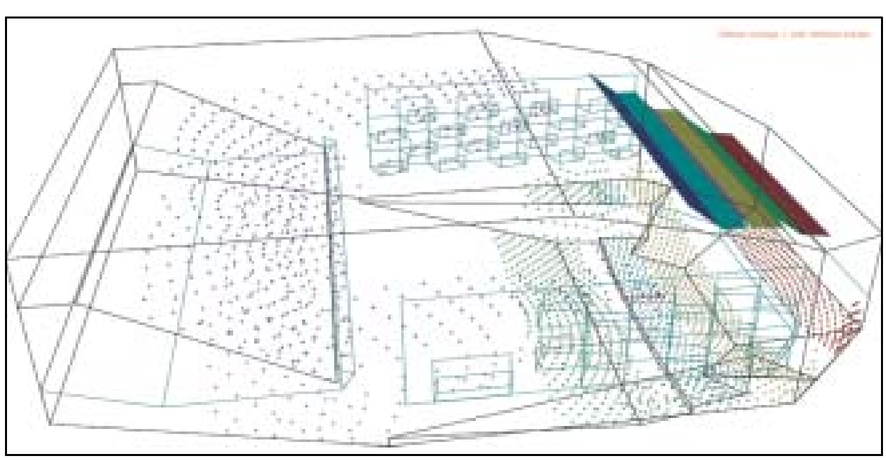
Fig. 13 *Calculated SPL mapping. The graphs on the right show the corresponding 'cumulative distribution graph' and 'fractiles' for the SPL grid. Opera House project for Ankara Congress and Cltural Centre (Architect: Özgür Ecevit, Acoustics: Jordan Akustik, Denmark)*



Reflector Coverage

Reflectors are often used to direct reflections into areas that need sound reinforcement. The reflector coverage display allows fast evaluation of the receiver area covered by a number of reflectors for a selected source position.

Fig. 14 *The Royal Festival Hall in London – for each reflector, the reflection pattern shows how well it directs sound to the intended audience area*



Auralization

Fig. 15
In auralization, you can 'replay' sound in the model and hear how the design affects music, speech or other acoustic signals. Since the ultimate goal is to improve perceived sound quality, this is a very powerful tool for the designer

The input signal for auralization is a digital recording (.wav file) or any signal played on the recording input of the soundcard. In ODEON, this recording is then processed using the calculated Binaural Room Impulse Response (BRIR). The auralization is based on binaural technology to allow three-dimensional presentation of the predicted acoustics over headphones. All calculations, including the ray tracing, received reflections at a receiver point, binaural filtering and convolution, are carried out by ODEON in a one-step process which does not require pre- or post-processing. The BRIRs include *full filtering* of each reflection in nine octave bands (the 16 kHz band being extrapolated) and applying a set of HRTFs (Head Related Transfer Functions) for each reflection. A BRIR for auralization is typically based on more than 100 000 reflections. The resulting sound is saved as another standard .wav file or played in real-time over the soundcard if the soundcard supports this.

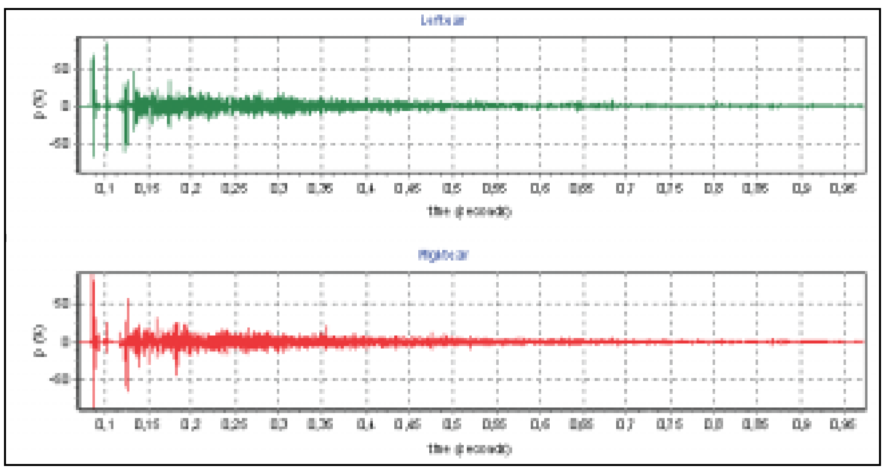


Fig. 16
BRIR (Binaural Room Impulse Response) calculated at a receiver position

Printing and Export

Results, graphic displays and calculation properties can be printed in high quality from within ODEON. Graphics can be exchanged via the Windows® clipboard or via files in multiple formats. Calculated results can be exported to a text file.

Case: Multi-purpose Hall

The Queen's Hall

Fig. 17
The Queen's Hall, Copenhagen, acoustically designed with the aid of ODEON

ODEON was used for the design of the Queen's Hall in the recent expansion of the Royal Library in Copenhagen. Known locally as the 'Black Diamond' and inaugurated in 1999, the hall is mainly designed for chamber music but will also be used for rhythmic music, meetings and lectures. The Queen's Hall holds up to 600 people and its reverberation time can be adjusted from 1.1 s up to 1.8 s, while side-wall mounted acoustic diffusers prevent flutter echo. Simulations during the design phase, using ODEON, had shown that this would be necessary – see the calculated decay curves (Fig. 19).

Fig. 18
ODEON model of the Queen's Hall shows flutter echo reflection paths

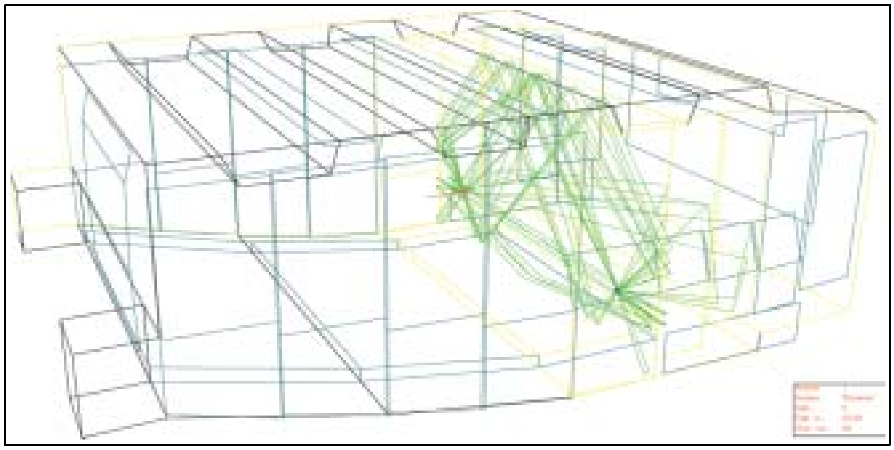


Fig. 19
Flutter echo as seen in the ODEON simulated decay curve

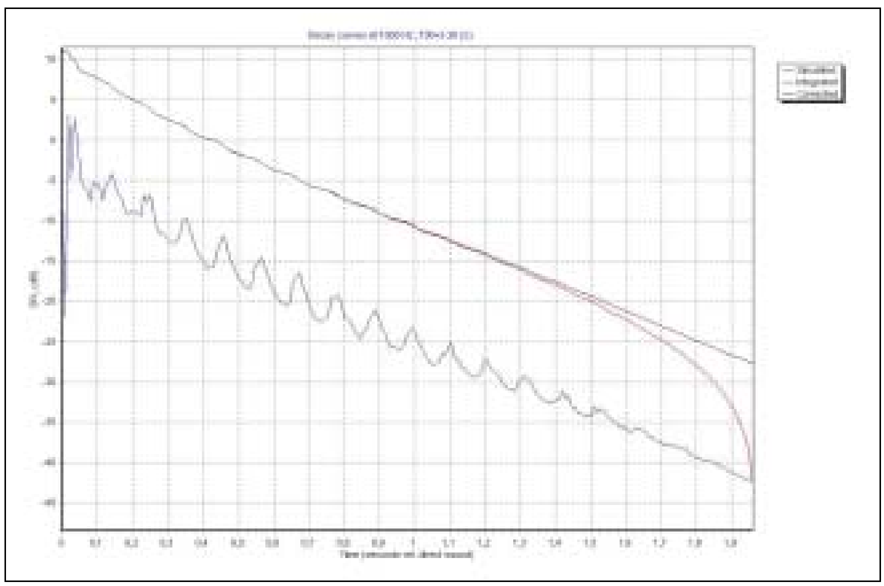
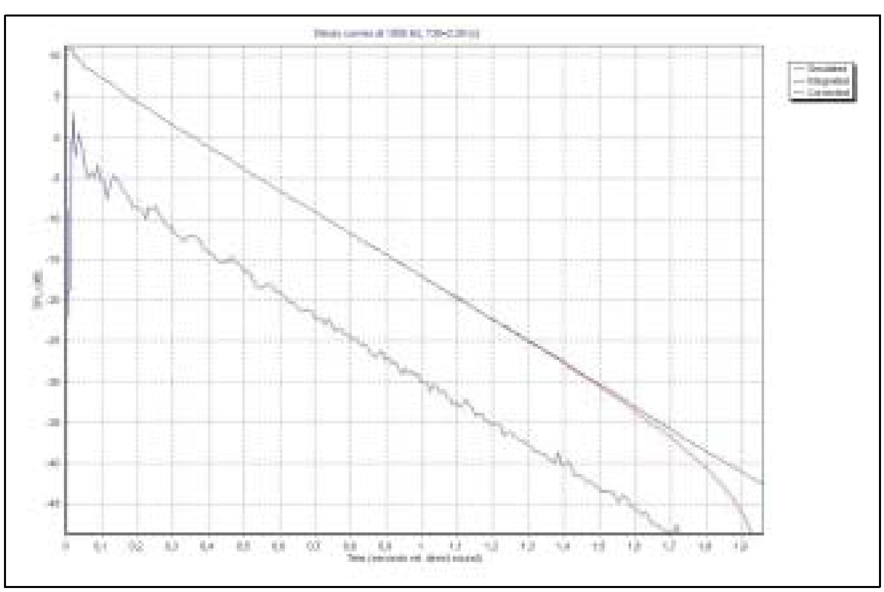


Fig. 20
Decay curve of ODEON model documenting the effect of diffusors



Case: Power Station

Prediction of Noise in Industrial Environments

Elsamproject, the Danish Power Project Agency, has verified ODEON's prediction accuracy. In a turbine hall at a power plant (also illustrated in Fig. 2 and Fig. 3), the A-weighted sound-pressure level was measured at twelve receiving points and compared to the levels estimated by ODEON. The room and its machinery were modelled by 54 surfaces. The sound sources were modelled by 30 surface sources (the surfaces of the two turbines) and four point sources (ball bearings). Relevant data for radiated sound power were measured with the intensity method. Test results show very high correlation between measured and estimated results, the average deviation being less than 1 dB.

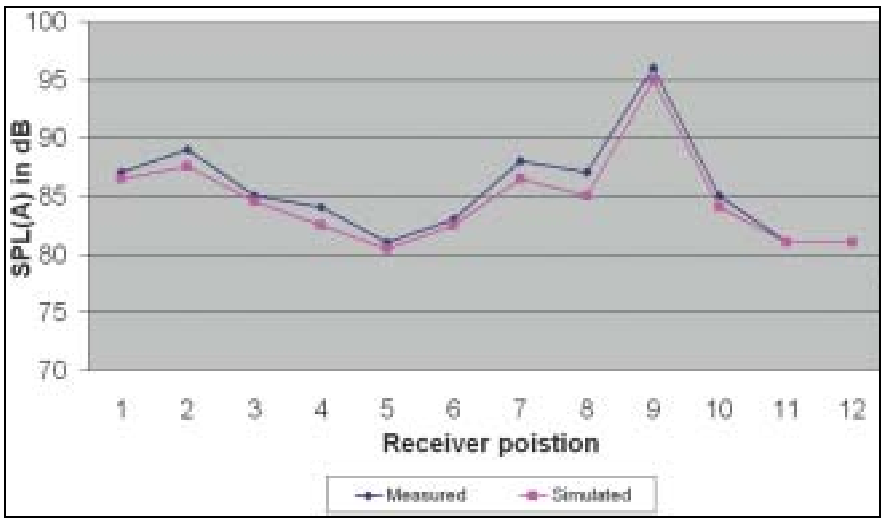


Fig. 21
Comparison of measured and simulated sound-pressure levels (please refer to Fig. 2 and Fig. 3), showing very high correlation

Specifications – Types 7835, 7836 and 7837

OPERATION
The software is a true 32-bit Windows® program, operated using buttons and/or menus and shortcut keys

HELP
Context-sensitive help is avaliable throughout the program

CALCULATION METHOD
Hybrid combining ray tracing with image-source modelling
Early Reflections: Image-source model and ray tracing
Late Reflections: Ray-tracing method simulating diffuse reflections

FREQUENCY RANGE
8 octave bands from 63 Hz to 8 kHz
(Lin) and A-weighted levels are calculated from octave levels

MODEL TOOLS
Editor: Text editor supporting parametric modelling
Import Facility: Import of DXF (Drawing Exchange Format) files from CAD software like AutoCAD
Verification: 3D display, 3D ray tracing, 3D view, automatic check for warped and overlapping surfaces

MODEL ITEMS
Model Size: Maximum dimension 2000 × 2000 × 2000 m
Points: Max. 500 per surface
Surfaces: Up to a max. of 50000
Corners: Up to a max. of 100000
Sources: Point, Line or Surface sources, up to a max. total of 99
Receiver Points: Virtually no limit to the number of points
Materials: Extendable materials library, specifying absorption, Scatter and Transparency coefficient. Built-in material editor

RESULTS *(Properties in Italics: Auditorium and Combined Editions only)*
Ray Tracing: Dynamic display of rays during calculation
Quick Estimate: Fast estimation of reverberation time based on diffuse-field assumptions (Sabine, Eyring, and Arau-Puchades formulae)
Global Estimate: Estimate of reverberation time taking room shape and position of absorbing materials into account
Single Point Response: *Detailed results and auralization options for a selected receiver*
Multi-point Response: Acoustical parameters for a specified number of receivers
Grid Response: Map of room acoustical parameters
Reflector Coverage: *3D display of first reflection hits for selected surfaces*

Specifications – Types 7835, 7836 and 7837 (continued)

ROOM ACOUSTIC PARAMETERS *(Properties in Italics: Auditorium and Combined Editions only)*
- Sound Pressure Level, SPL
- A-weighted Sound Pressure Level, SPL(A)
- Rate of Spatial Decay, DL_2
- Reverberation Time, T_{30}
- Early Decay Time, EDT
- Speech Transmission Index, STI
- Centre Time, Ts
- Level rel. 10 m free-field, G
- *Clarity, C_{80}*
- *Deutlichkeit, D_{50}*
- *Early Lateral Energy Fraction, LF_{80}*
- *Early Support, ST_{early}*
- *Late Support, ST_{late}*
- *Total Support , ST_{total}*
- *A-weighted, Late Lateral Sound Pressure Level, LLSPL(A)*

AURALIZATION
Input: Anechoic or semi-anechoic sound file in .wav format. Stereo and multi-channel recordings can be handled
Mixer: Multiple sources and multiple signals can be included in one simulation
Processing: Convolution of sound file with BRIR (Binaural Room Impulse Responses). BRIRs are simulated using full filtering of each reflection in nine-octave bands and applying a set of HRTFs (Head Related Transfer Functions) for each reflection
Output: Binaural (2-channel) .wav file optimised for headphone playback – open-type headphones recommended

Sound Card Minimum Requirements: Stereo, 16 bits, 44100 Hz sampling
For Loss-free Input from DAT Recorder: Digital input and output

PRINTOUT AND EXPORT
Graphs and tables can be exported via clipboard in several formats (.wmf, .emf., .bmp., .gif., .jpg), or printed. Results, including parameters, reflection data, curves, etc., can be exported in ASCII (text) format for further processing in other programs

PROJECT MANAGEMENT
Job Control: Job List specifies source(s), receiver(s) and calculation type for each simulation
Max. Number of Jobs within a Project: 20
Changes: Consistency is maintained between results and setup of room and calculation parameters. Inconsistent results are deleted (after warning)
Saving Projects: Built-in utilities for copying, deleting and archiving projects including all associated data. Can save a project into a single compressed file for backup or e-mail

COMPUTER SYSTEM
Operating Systems: Windows® 98, NT®, 2000 and XP
RAM: Minimum 32 MB, recommended 128 MB
Free Disk Space: Minimum 100 MB, recommended 1 GB
CPU: Minimum 500 MHz Pentium® recommended
Auxiliary Hardware: CD-ROM drive, SVGA graphics display/adaptor, mouse or other pointing device
Sound Card: 2 channels, 44.1 kHz

Ordering Information

Including the difference in features between the editions.

Industrial Edition Type 7835
Intended for environmental acoustics where SPL, SPL(A), T_{30} and STI are the important results. The Industrial edition allows modeling of point sources, line sources and surface sources, making it possible to model large and complex sound sources. Single Point Response, Reflector Coverage and some auditoria parameters (see specifications) are not included.

Auditorium Edition Type 7836
Intended for calculation of large sets of room acoustical parameters. A number of graphical tools are built in including a reflectogram, a 3D reflection paths' display, and reverberation-curve displays. The Auditorium edition provides built-in auralisation features. Unlike the Industrial edition, the Auditorium edition is not capable of modelling line and surface sources.

Combined Edition Type 7837
Combined features of Auditorium and Industrial Edition

Services Available
7835/6/7-MS1: 1-year support and upgrade agreement
7835/6/7-X-100: Upgrade from Odeon versions 4.0 and later
7835/6/7-X-200: Upgrade from Odeon versions 3.x and earlier

Brüel & Kjær reserves the right to change specifications and accessories without notice.

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