Reprint from Professional System:

Test of Ulysses

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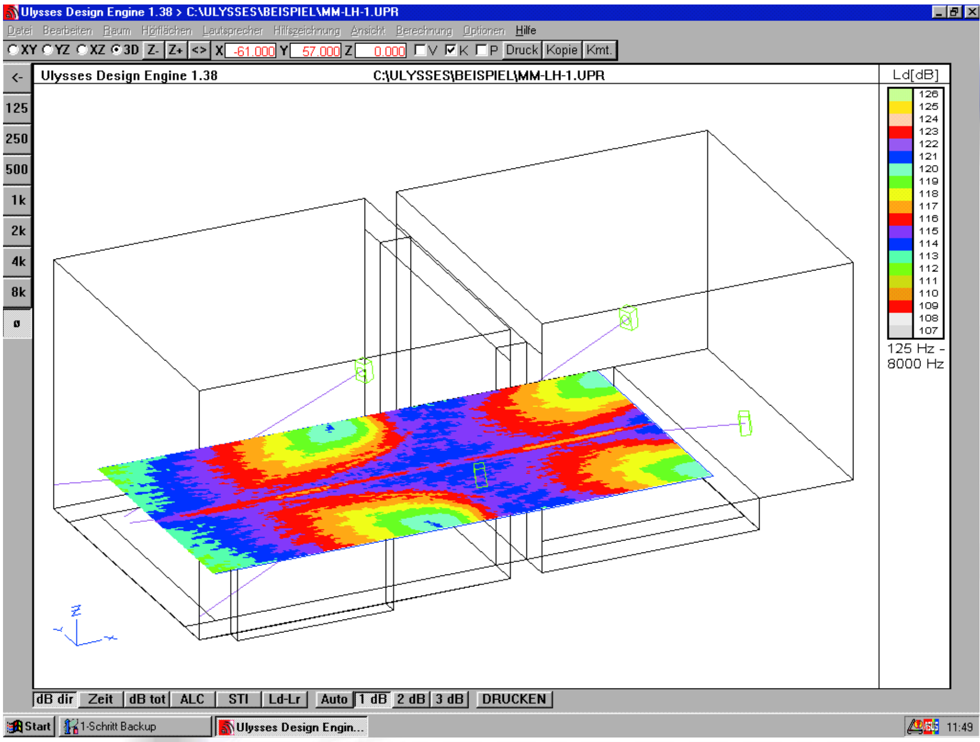


Acoustic simulation

ULYSSES

IFBsoft Germany are the distributors of Ulysses, a software that simulates electro-acoustics. It is aimed at sound contractors to provide an efficient tool for the prediction of sound reinforcement design.

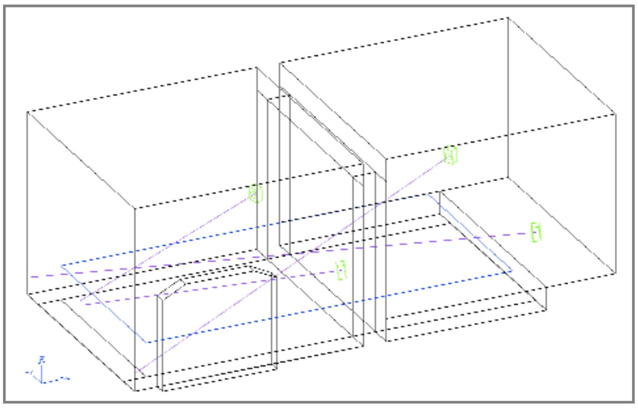
Today almost all public rooms and buildings are equipped with sound systems of varying types and sizes to reproduce music and speech. Typical applications are convention and conference halls, stadiums, train stations and churches. The emphasis is mostly on speech reproduction which demands high quality performance, i.e. intelligibility. In recent years legislation has provided some guidelines for the efficiency of such systems to ensure that public announcements can be made in critical situations. The requirements for music reproduction are just as interesting and problematical. For background music, e.g. in a department store, the primary aspects are unobtrusive installation and even dispersion across large areas. Such systems are not only used to reproduce program material but also pleasant sound carpets. A good example is the field of acoustic design where pleasant acoustic environments are created by providing appropriate background sounds. When applying for a credit in an architecturally open customer area of a bank customers may have the awkward feeling of being overheard at the neighboring table. In such cases unobtrusive background sounds may subconsciously create the impression of acoustic isolation and put the customer at ease. This example is not as far fetched and exotic as it may seem. Today, the acoustics of rooms, buildings and public areas are ever increasingly designed for a purpose.

For that reason it is quite obvious that sound architects and contractors wished for a tool to closely predict the results of a sound system installation. Today CAD software is also increasingly used for the design of mobile systems, e.g. for outdoor events.

University facilities and R&D departments have been developing acoustic CAD software for many years. Due to increasingly powerful PCs these high capacity programs can now be run on affordable hardware. They provide results in graphic form, and some include the auralisation of the simulated room. For this they calculate impulse response and directivity. After that any program material may be listened to on DSP systems in real time. Impulse response calculation is rather demanding and results in longer computing times. It requires precise room data and the acoustic specifications of the room materials.

The auralisation Ulysses provides is without real time processing, although it can be calculated quickly on a PC and then listened to via an audio interface. More on that later.

The next step into virtual reality includes moving sound sources and listeners and even listener head movement in real time. This is becoming increasingly important in today's new media and communication technologies. Currently these simulating methods still require powerful external hardware besides the actual PC. Therefore their use is limited to research laboratories, although the speedy development of the computer market might make them soon available to PC users.



ill. 1: Model of a room with loudspeakers

ROOM SIMULATION THEORY

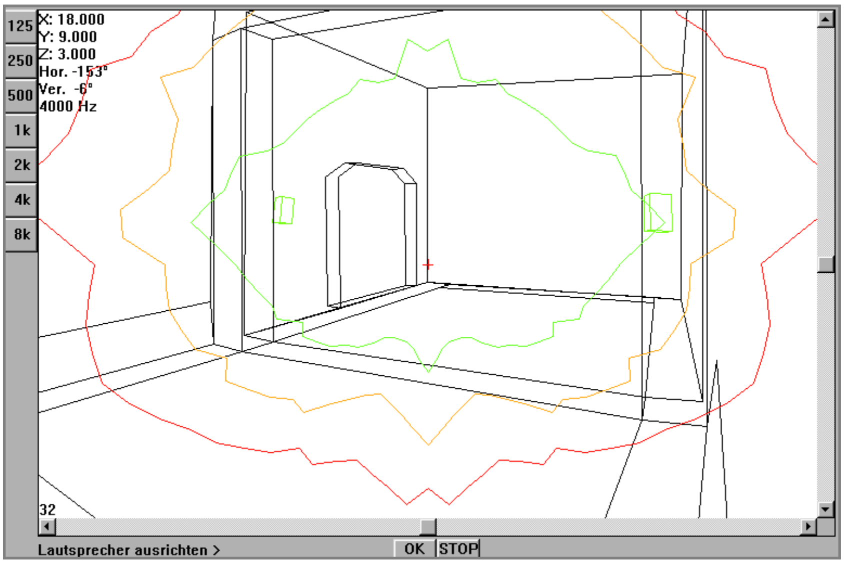
Sound dispersion can only be described exactly by the wave theory approach under consideration of all peripheral conditions. These are caused by room boundaries, e.g. a maximum SPL on a reflecting wall. An analytical or even just a numerical solution of the wave equation is only practicable under simple circumstances, e.g. for a cube. It is applied with the finite element method in research to analyse diffraction effects at low frequencies.

For frequencies with a short wavelength relative to room dimensions the simpler models of geometrical acoustics are most effective to calculate a sound field. These calculate sound dispersion from mirror sources or ray tracing only, and mirror position and ray direction is analysed by geometry laws.

For ray tracing a sound source may be seen as the transmitter of sound particles. Their directionally dependent density describes the directivity of the source. The sound particles then arrive at the listener directly or by one or more reflections. When reflected they are more or less absorbed depending on their frequency and boundary material properties. Reflections may be purely geometrical or reverberating. The sound field of a room which is to be calculated is equal to the density of the sound particles. Absorption and air damping are regarded as a frequency dependent diminution of sound particle energy in this model.

THE ULYSSES SIMULATION ENGINE

Ulysses uses a combination of the mirror source imaging and ray tracing methods of geometrical acoustics. All sound sources are mirrored on all boundaries visible from the source position to capture all first order reflections. For second order



ill. 2: Look in the room throught the loudspeaker

reflections these mirror sources are mirrored again on all boundaries visible from their position which increases the number of sources exponentially. For example a room with 36 boundaries (W) and 4 sources (Q) the direct sound is calculated from 4 sources, first order reflections are calculated from 144 and second order reflections are calculated from 5184 sources. This means calculation effort will be immense quickly. The number of calculations of the *n*-th order is derived from the following formula:

$$\mathrm{sum} = Q \times \sum_{m=0}^{m=n} W^m = Q \times \left(1 + W + W^2 + W^3 + \ldots\right)$$

The ray tracing method requires less effort since calculations only increase in linear fashion with each order. A 1° grid source for instance disperses approximately 65.000 rays (S). Their reflections are then traced up to the desired order. The formula for the number of calculations of the *n*-th order is

$$\mathrm{sum} = Q \times W \times S \times n$$

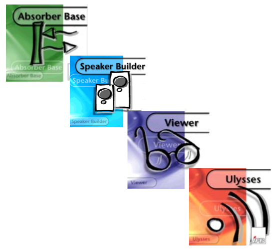
Ray tracing is less exact, however, since the rays are not infinitely dense and possibly do not reach all boundaries. For that reason Ulysses incorporates both methods and calculates the essential first reflections by the mirror source method which is 100% exact. Subsequent reflections are calculated by ray tracing beginning with the order that requires less effort than mirror sourcing. This order *n* is calculated by the formula

$$Q \times W \times S \times n \leq Q \times \sum_{m=0}^{m=n} W^m$$

Orders lower than *n* apply mirror sourcing.

INTRODUCTION TO THE SOFTWARE

The Ulysses software package consists of four individual Windows-based programs and offers the usual functions known from other software. The high processing speed, especially the graphics processing, and the low RAM requirements are most convenient. The actual program and the auxiliary files are so compact they fit on a single floppy disk. Installation is easy and actually untypical. A zip file must be unpacked in the desired directory – that's all. IFB offers a demo version free of charge which includes all functions, but data cannot be saved. When buying the software the demo version is cleared by a PC-specific code and turned into the full version for unrestricted use. As mentioned before Ulysses consists of four individual programs



- Absorber Base
- Speaker Builder
- Viewer
- Design Engine.

The Design Engine is the main program which performs all calculating functions. It is used for room editing, loudspeaker positioning and shows the calculation results. The Design Engine requires loudspeaker and absorber data bases which can be created and processed with the auxiliary programs Speaker Builder and Absorber Base. For actual work only the Design Engine is required. The Speaker Builder and Absorber Base provide a data survey for the standard user. A special version of the Speaker Builder is available to loudspeaker manufacturers to create protected data bases that cannot be altered during later use. Finally there is the Ulysses Viewer. It is free of charge and may be passed on without restrictions. It provides customers, architects and sound contractors with the opportunity to view, copy and print project data calculated by Ulysses including all results, room drawings and loudspeaker placement.

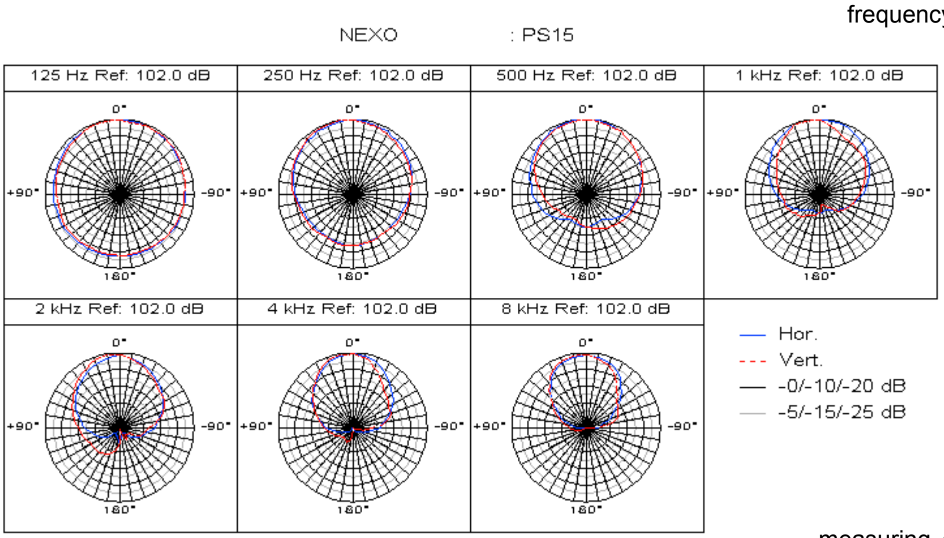
ABSORBER BASE

Floor, ceiling and wall materials, interior decoration, drapes, movie screens, seating, even the audience are acoustically defined by their varying degrees of frequency dependent absorption. There are two important causes for the absorption of sound: friction loss by air movement within porous materials, and resonance of resonant materials. Porous absorbers are increasingly efficient at high frequencies, while resonance absorbers are only efficient at their resonant frequency. A large audience in an auditorium is highly absorptive. The amount of absorption may increase from about 50% at low frequencies of 125Hz to nearly 100% above 500Hz. At higher frequencies and longer signal delays aerodynamic damping which depends on temperature and humidity is also noticeable.

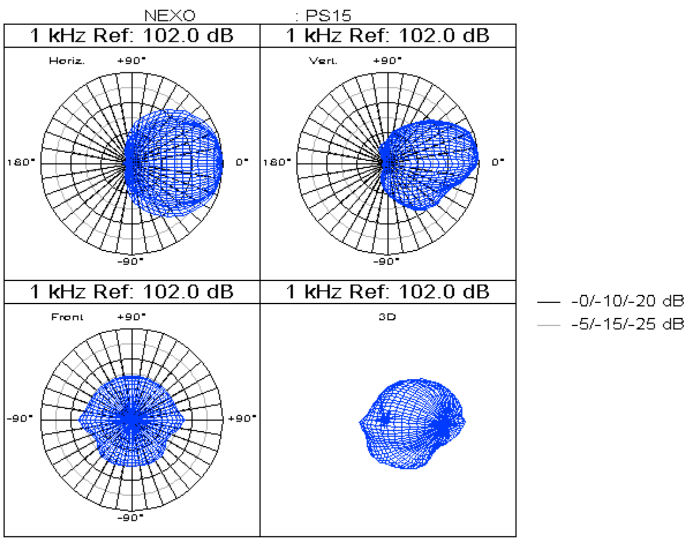
The Ulysses package includes an absorber data base. It contains the specifications of common materials, and their absorptive qualities are listed in octave steps from 125Hz to 8KHz. All materials and their properties can never be listed together since there are simply too many. Extensive catalogs and damping material manufacturers like G+H provide specifications especially for acoustic designers who can store them in the Ulysses Absorber Base. However, problems may originate if surfaces have been altered by painting or materials are unknown. In such cases the material must be measured on the job or analysed in a laboratory.

Ulysses Speaker Datasheet							
Manufacturer	NEXO						
Type	PS15						
Data source	Data converted from EASE						
dto.							
Input format	Half sphere,10° resolution						
Frequency [Hz]	125	250	500	1000	2000	4000	8000
Max. Power(AES)[W]	1200	1200	1200	1200	1200	1200	1200
SPL @1W @1m [dB]	101.8	101.8	102.0	101.8	101.0	101.4	101.0
Nominal impedance[Ohms]	8	8	8	8	8	8	8
Directivity factor Q	2.1	3.2	4.5	8.7	9.7	12.0	14.1
Directivity index [dB]	3.2	5.1	6.5	9.4	9.9	10.8	11.5
Efficiency [%]	9.5	6.2	4.4	2.3	2.1	1.7	1.4
Comment							

ill. 3: Datasheet of a loudspeaker



ill. 4: Horizontal and vertical polar diagrams



ill. 5: Directivity shown in 3D balloons

SPEAKER BUILDER

The other important Ulysses data base contains loudspeaker data. Ulysses currently lists all data in octave bands from 125Hz to 8KHz including sensitivity in dB @ 1W/1m, power handling in W, nominal impedance in Ohms, directivity factor, directivity in dB, efficiency in % and dispersion characteristics (ill. 3). The Speaker Builder calculates efficiency and the directivity factor automatically after measuring. Dispersion is shown in 5° steps within an equidistant spherical grid around the loudspeaker. The Speaker Builder saves only sound pressure levels at 1W/1m for all positions. For future versions the inclusion of the frequency dependent phase response is planned. Higher spatial resolution and 1/3 octave bands are also in discussion.

In practice the current format already involves the measuring of 2.738 single frequency bands which must be smoothed per octave and saved. If loudspeaker construction is symmetrical to its vertical axis or the horizontal axis as well (like a coaxial speaker) measuring can be limited to a semi or quarter sphere. The remaining values result from mirroring at the symmetry planes. Measuring requires a complicated mechanical construction to rotate the loudspeaker around two axes. Some loudspeaker manufacturers have especially constructed large mechanical setups which record the measuring series fully or semi automated in procedures of sometimes several hours. The Speaker Builder does not let the user create his own files or change existing ones which makes sense if the manufacturer guarantees correct measurings. But it provides an opportunity to survey the dispersion characteristcs of various systems using the included data base. These are shown in classic polar diagrams (ill. 4) or very nice 3D balloons (ill. 5).

The user can gather loudspeaker data from the included files or in some cases directly from the manufacturer. New data records can be downloaded free of charge from the IFB home page http://www.ifbcon.de

CLUSTER CALCULATION

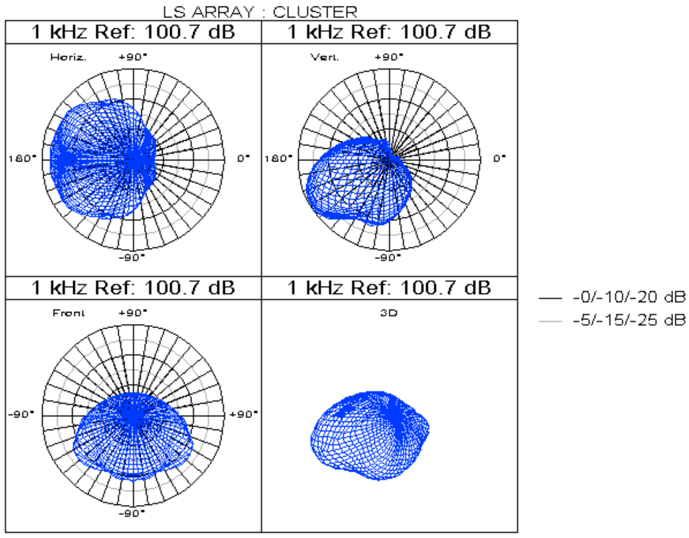
Since loudspeakers very often are used in clusters Ulysses includes the option of cluster calculation. The result may then be saved like a loudspeaker file and shown as polar diagram or balloon (ill. 6). Ulysses determines the geometrical center of the cluster and then calculates the complex SPL total for each octave band from 125Hz to 8KHz within a 5° grid with a 100 m radius. Calculation includes both amplitude and phase response. Calculating the levels of each octave from the 1/3 octave bands and subsequent smoothing is a clever method and a good compromise between a purely energetic and a complex frequency selective calculation which correlates very well with the actual listening impression.

Whille planning the German government's new plenary hall sound system the author has employed Ulysses to calculate the two system clusters which consist of five loudspeaker systems each. Extensive measuring of the installed system did confirm the simulation results. Since the cluster is completely asymmetrical and hard to calculate the cluster calculation algorithm Ulysses uses is most efficient.

PROJECT DEVELOPMENT WITH THE DESIGN ENGINE

The Ulysses Design Engine is the heart of the software package which performs all calculations, auralisation and room data input as well. Speaker Builder, Absorber Base and Viewer can be seen as additional tools for loudspeaker and material selection and customer presentation.

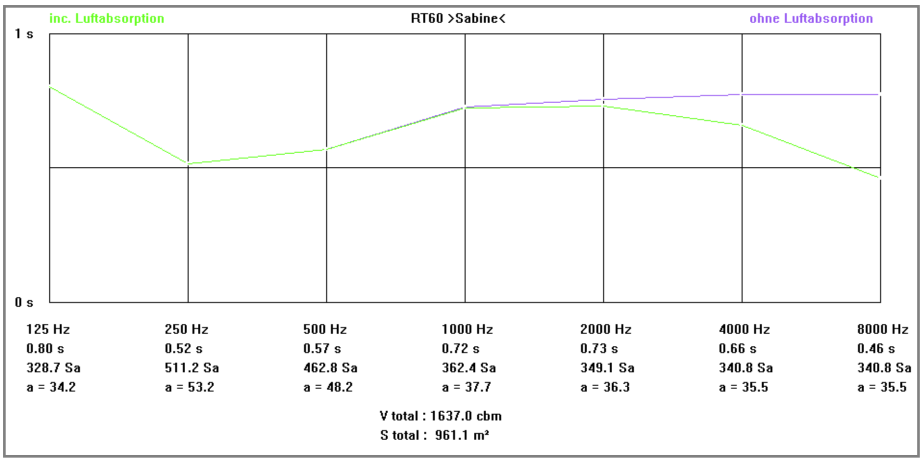
The following functions and calculations all refer to the Design Engine. Reverberation time is acoustically important and can be calculated from room data and the charts which contain the amount of wall absorption according to Sabine, Eyring or Fitzroy. These simple calculations result in a frequency dependent reverberation time curve which can be shown with or without air absorption (see ill. 7 for instance). Octave band reverberation times can also be entered manually after measuring existing rooms.



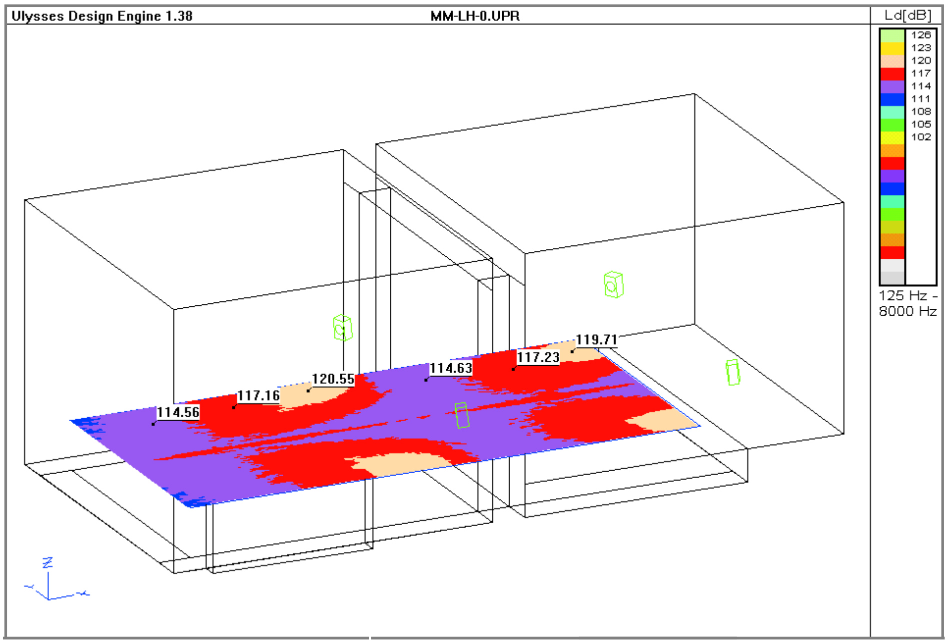
ill. 6: Balloon from a cluster calculation of two loudspeakers

The most important feature of Ulysses is probably the sound field calculation of individual room areas defined as listening areas. These areas can be determined anywhere in a room, and both the direct sound (ill. 8) and the ratio of direct sound and reverberant sound (ill. 9) may be calculated. For direct sound field calculation only the loudspeaker directivity characteristics, the inverse square root law and the amount of air damping are required.

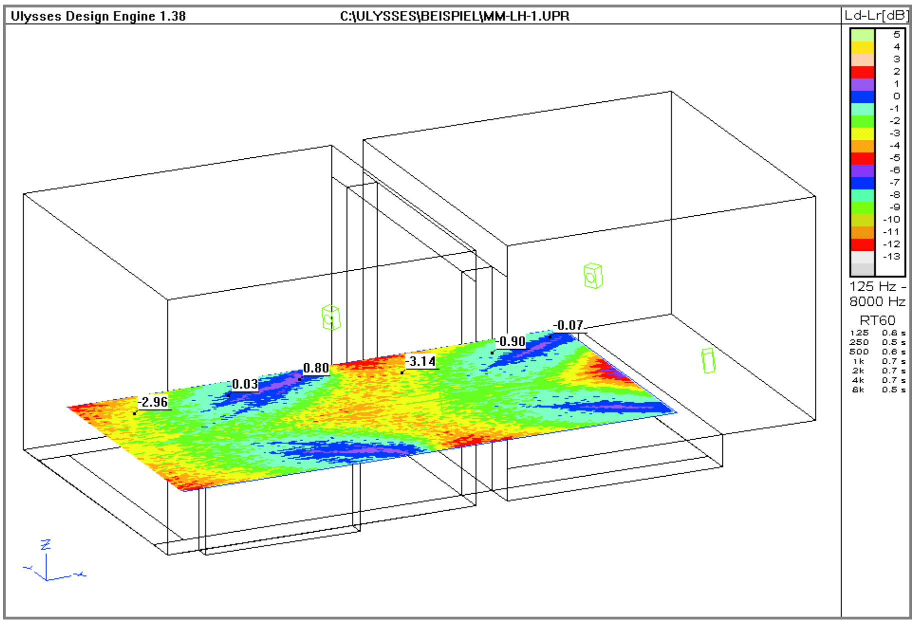
To calculate the reflected sound Ulysses distinguishes between two methods. One is the very fast method of statistic acoustics which calculates the reverberant field from the radiated energy total, the absorptive areas and room volume. In reality results are only correct if all sources are omnidirectional and the absorptive areas are evenly distrubuted. Since this is usually hardly ever the case calculation results are more or less faulty. This method must be viewed with skepticism because it disregards speaker directivity onto a highly absorptive listening area in a reverberant room, but this is not the program's fault, of course. The statistic method is appropriate, however, for level calculation of a distributed system for instance.Here it basically regards each speaker as omnidirectional source which radiates energy that is calculated from efficiency and power feed. This energy equals that of the actual loudspeaker, but radiation is depending on loudspeaker directivity.



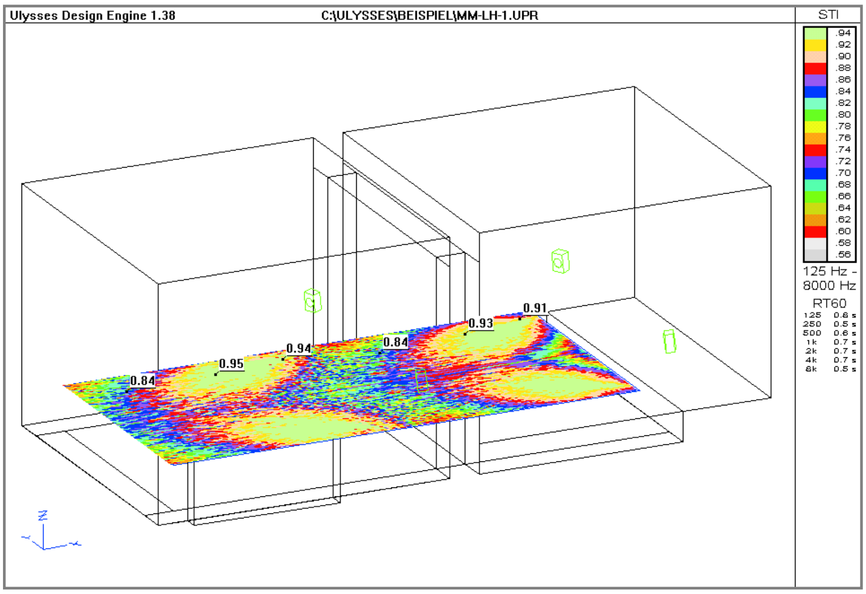
ill. 7: Reverberation time curve shown with or without air absorption



ill. 8: Direkt sound



ill. 9: Ratio of direct sound and reverberant sound



ill. 10: STI values at the audience area

The second method of reverberant field calculation is ray tracing as described above which calculates reflections up to a determined order. It completely integrates loudspeaker directivity as listed in the speaker data base into the calculation. Ray tracing is substantially more exact, unfortunately it is more time-consuming and measuring may take up to several hours. Also, it does not provide a result for the total listening area but only an ETC for a certain listening point.

For this position the ray tracing algorithm calculates level and delay of the arriving sound. The ETC shows the arrival of the direct sound and the intensity of subsequent reflections across a time axis (ill. 11). This is especially useful to determine possible echos which are shown as strong late reflections. To establish the cause of a certain reflection a Reflectogram may be used to show the course of ray tracing within the room. (ill. 12)

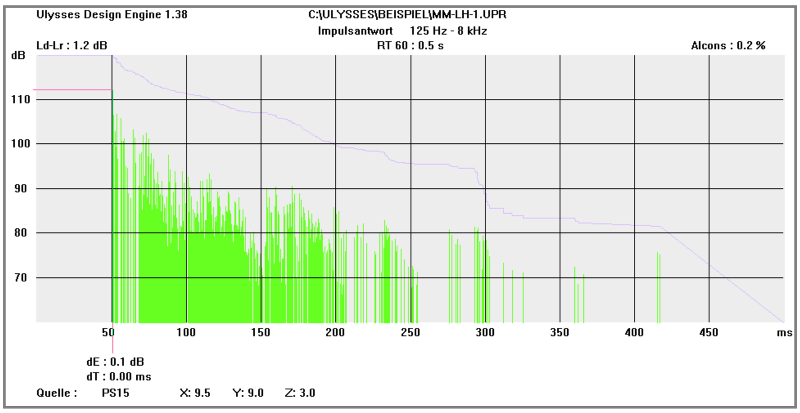
For auralisation an impulse response may be generated from the ETC for the convolution with a music or speech sequence.

LISTENING TO SIMULATED ROOMS

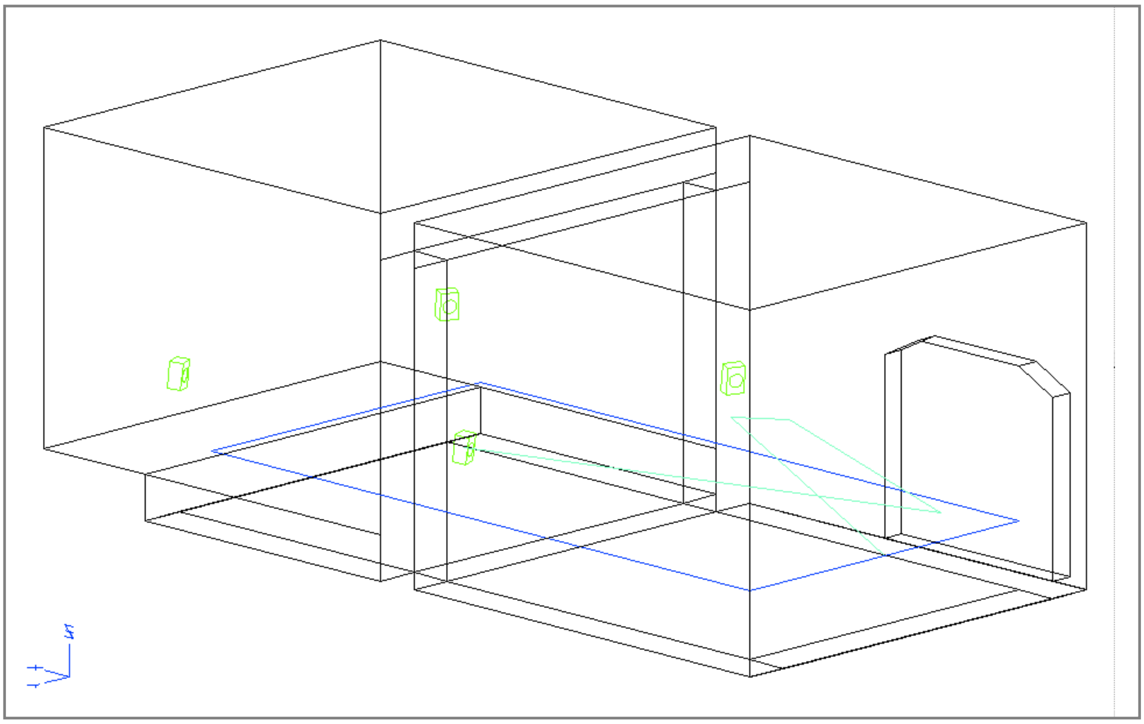
For virtual playback and listening to the simulated room a16-bit 44.1kHz or 22.05kHz WAV file signal is necessary. For speech 22.05 should usually be sufficient which cuts computing time by half. Reverberation-free signals are especially suitable so only the reverb of the simulated room is audible. For convolution with the simulated impulse response the computing time is x times (x = number of reflections divided by 16) the wave file length when using a 200MHz Pentium MMX computer. After calculation both the source file and the file calculated for the simulated room can be played back directly by the Ulysses Design Engine. A correctly installed quality soundcard is required, of course.

The signal reproduced from the source file by the loudspeakers is now audible at the determined listening position in the simulated room. The listener is regarded as a monaural receiver with omnidirectional characteristics.

Ulysses does not apply the more complex binaural simulation with two directional receivers that are the equivalent of human ears. This method requires measuring the receivers in a dense spherical grid like the loudspeakers and their directivity must be determined in frequency dependent groups, i.e. the source from which the sound arrives at the binaural receiver must be evaluated depending on the frequencies. Signal delay and phase response between the two receivers become part of the calculation. This method is necessary for an exact directional simulation since a sound source is detected primarily via interaural delays and directional sound filtering by the ear transfer function.



ill. 11: ETC curve for a position in the back of the room



ill. 12: Course of ray tracing from a reflexion within the room

The current Ulysses version 1.38 also does not add a statistically established reverberation curve to the onset of the impulse response that has been calculated. The next version which is currently tested will include this feature. To reduce calculation effort reverberating rays are not traced any further if their level is below the direct sound level by a predetermined value. This so-called abortion criterion cuts the naturally infinite reverberation short. To create the impression of a fading reverberation this is replicated by a reverb algorithm.

Altogether the Ulysses auralisation is rather simple which the instruction manual emphasizes. The main objective is an acoustic survey that is definitely correct but does not include the impression of directivity and the faint late reflections. In practice however the auralisation was fully sufficient to evaluate the acoustic properties of a room. The sound was very natural and free of coloring. In summary the Ulysses auralisation is an effective compromise between computing time and useful results.

COMPATIBILITY WITH OTHER SOFTWARE

Since simulation software largely depends on loudspeaker and absorber data bases the compatibility with other software must be examined. It is useful if simulated rooms can be interchanged to compare simulation results. In this case the plenary hall was edited with EASE at first to calculate and realise an auralisation.

For the import of the loudspeaker data the UNF format was defined for Ulysses which allows easy conversion of the GDF format used by CADP2 and EASE. However, the Ulysses Speaker Builder also allows the direct import of EASE and AcoustaCadd data bases and UNF or GDF files.

APPLICATIONS

Ulysses is clearly aimed at contractors and planning departments dealing with sound reinforcement for large rooms and anechoic fields. The emphasis is on easy operation, fast graphic routines and short computing times. Once experienced with Ulysses one might even want to optimize sound systems for smaller projects.

Going through the Ulysses menus and the auxiliiary tools one surprisingly realizes there is nothing superfluous and hardly anything to miss. The software should be appropriate for 90% of all sound system design.

Of course there are quite a few features of sound field calculation Ulysses ignores such as dispersion on surface structures, diffraction or audience absorption. However, these subtleties might only be of interest to an acoustic engineer working on extensive and costly projects that require perfect simulation and auralisation. These jobs demand comprehensive programs several times the price of Ulysses, and their operation is much more time consuming. One should therefore clearly distinguish between complex acoustic design, e.g. for a concert hall, which might require months of work, and the design of a sound reinforcement concept where the best possible use of a sound system depending on room acoustics is the main objective. For the latter Ulysses is a most appropriate tool.

INSTRUCTION MANUAL AND TRAINING

Currently the only support that comes with the Ulysses software package is online help. The instructions mostly refer to the actual operation of the program which should be the purpose of online help. Further background information on the calculation processes and a basic introduction are unfortunately not available. A short introduction using a real-life example might be welcome by the beginner, and experienced acoustic engineers might be interested in a detailed explanation of the calculation methods.

Fortunately the main activities of IFB-Soft, distributor of the software and an affiliate of IFB, are training and seminars on sound reinforcement. One and a half day Ulysses User Workshops deal extensively with operating the software, acoustic basics and the interpretation of results. An IFB employee is also available for a one day crash course on the customer’s premises. The cost of the workstation version of the software including a backup is approx. 995 €. In the U.S. Ulysses is distributed by IRP Professional Sound Product. The software package and online help are available in both German or English.

CONCLUSION

Ulysses is a Windows-based software package to simulate rooms and sound systems. Basic operation and all functions are optimized for real-life requirements without unnecessary features which results in short computing times and fast graphics. It takes only a short time to become familiar with the program, so you can soon concentrate on the actual job of designing. Slow processing, complicated entry routines, gigantic amounts of superfluous data and system crashes hardly ever occur (if they occur at all) which might surprise some users of modern software packages. Ulysses did prove its qualities simulating the sound system of the German government’s new plenary hall in Berlin. Both the calculation of the two cluster systems and the simulation of several listening areas within the hall corresponded extremely well with the actual measuring results. This means planning with Ulysses is safe and sound. The purchase price is pleasingly low, and There are more than 60 registered users already, and the purchase price is pleasingly low. However, this should not be the decisive factor but since Ulysses provides exact results very quickly overall project costs can be significantly reduced.

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