Predicting Acoustical Performance with

CATT-A

by Pat Brown

It has been our custom to provide software over-views to acquaint our readers with some of the engineering tools that serve our industry. While I could simply reprint excerpts from the documentation of the platform being examined, I prefer instead to "start from scratch" and endure the learning curve required to get some actual results from the application. This approach yields much more insight into the subtleties of the application, and hopefully provides a more balanced perspective for our readers. These overviews are also tutorial in nature, as many of the concepts are applicable to similar platforms.

CATT-Acoustic™ is a software application that allows investigations into the acoustical characteristics of an auditorium. Such investigations can be used to predict the sonic performance of a space or to evaluate proposed acoustical changes. Acoustical predictions are also a necessary part of sound reinforcement system design, since the performance of a sound system is not independent of the characteristics of the space into which it is placed. This article is to acquaint the reader with some of the capabilities of CATT-Acoustic.

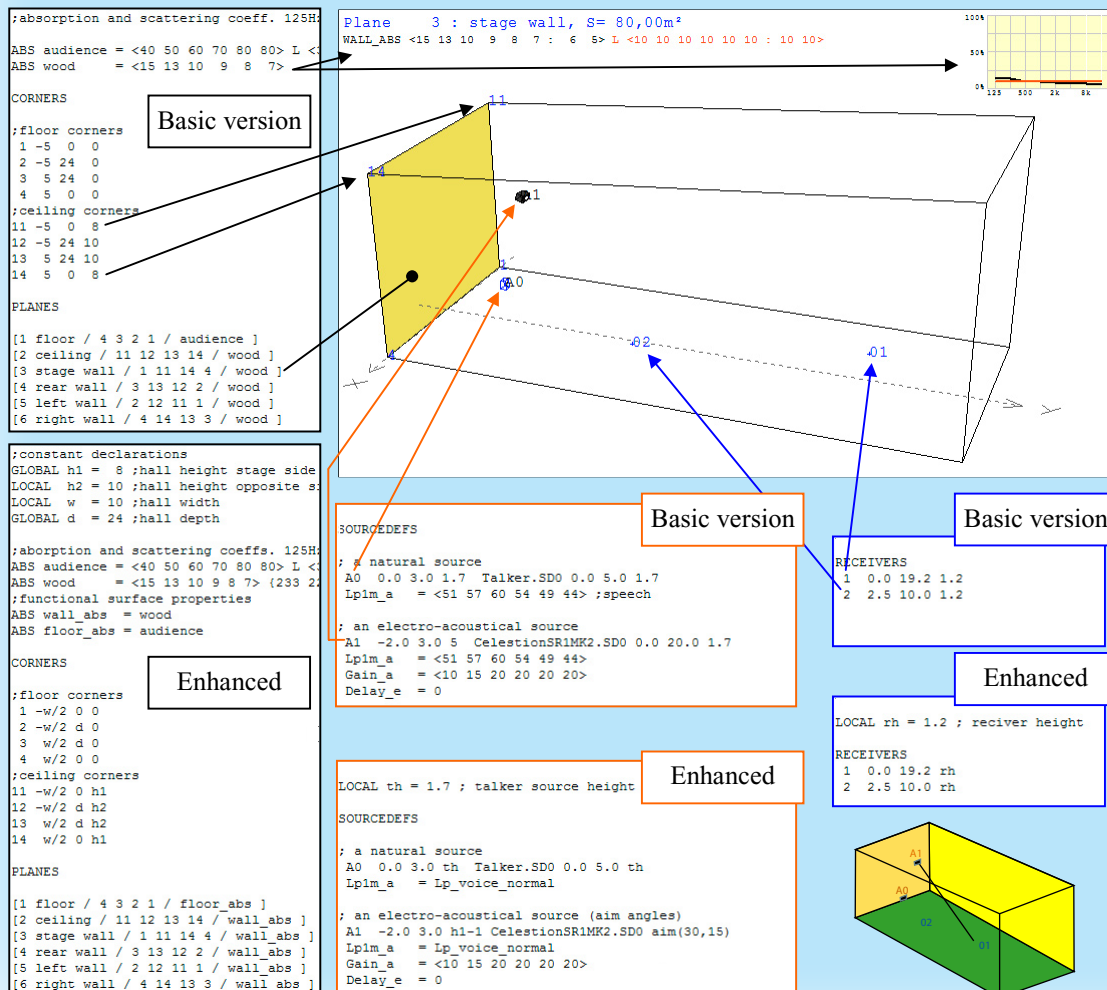Acoustical simulations require the consideration of space in three-dimensions. Acousticians have tra-

Figure 1 - This simple "sloped-shoebox" room shows the files that are associated with a room model. The GEO file structure allows basic entry of vertices and planes, but also allows advanced techniques that speed the process and make the model more versatile. A sample of each method is shown here. Mastery of the GEO file structure allows the full potential of the program to be realized.

ditionally constructed physical scale models of rooms for this purpose - a laborious and expensive task. The goal of an acoustical prediction program is to augment the process by supplementing the physical model with a virtual one. Sound behavior can then be considered by using computational algorithms that predict how it might reflect about the space. Using the physical and virtual model together can offset some of the shortcomings of each. Due to the cost constraints placed on many projects, a virtual model is often used instead of a physical one.

Creating the Model

In CATT-A, the virtual model construction can take place in a simple text editor. The CATT Editor is an advanced text editor which is included with the program. Rooms are made up of interconnected planes. The points at which they connect can be defined using the Cartesian coordinate system to designate an x, y, z coordinate for each. Each coordinate is a point in 3D space. The points can then be joined to form the floor, wall and ceiling planes. These planes are usually referred to as "faces" in modeling terms. The heart of CATT-A is the "GEO" file that contains the point and face definitions. The format is in its basic form quite simple, but has many advanced options. These include symbolic constants, math expressions, IF statements, object rotation, visual non-acoustical markers, division into multiple files, etc. The GEO file contains a section that lists each point, followed by a section that lists the combinations of points that form the room's faces. Once this data is entered, the program can compile the

data to display the room (Figure 1). The compilation process is very fast and the resultant display can be used to see the room as it is created. Debug files can be created to identify any problems with the model. Once the model builder is familiar with the process and has learned to think with a Cartesian mind set, room construction is logical and straightforward. For those who are AutoCAD™ literate, some AutoLISP™ routines are available to allow model generation in a 3D GUI environment.

At first exposure, it is easy to overlook the power of the GEO file. Once the user is acquainted with the structure, this format provides a very versatile means of constructing and modifying the environment. Some tasks can be executed more efficiently with this method than with a GUI.

The Surface Properties Module

The plane definitions must also include two important pieces of information required for simulations - surface absorption and scattering coefficients (Figure 2). These designations determine how sound will behave when it encounters the surface in the model. The absorption coefficient designates how much of the sound will be absorbed by the surface, and the scattering coefficient describes how much of the reflected sound is randomly scattered as it reflects off of the surface. The consideration of surface scattering is one of the most powerful features of CATT-A, and represents a significant improvement in simulation accuracy over methods that do not consider it. While this capability was once of more interest to acousticians that to sound

Figure 2 - Absorption and scattering coefficients are defined in the Surface Properties module. An extensive open database of materials is included with the program. Surface properties can also be designated on-the-fly in the project's GEO file. This method facilitates experimentation with surface properties by the designer.
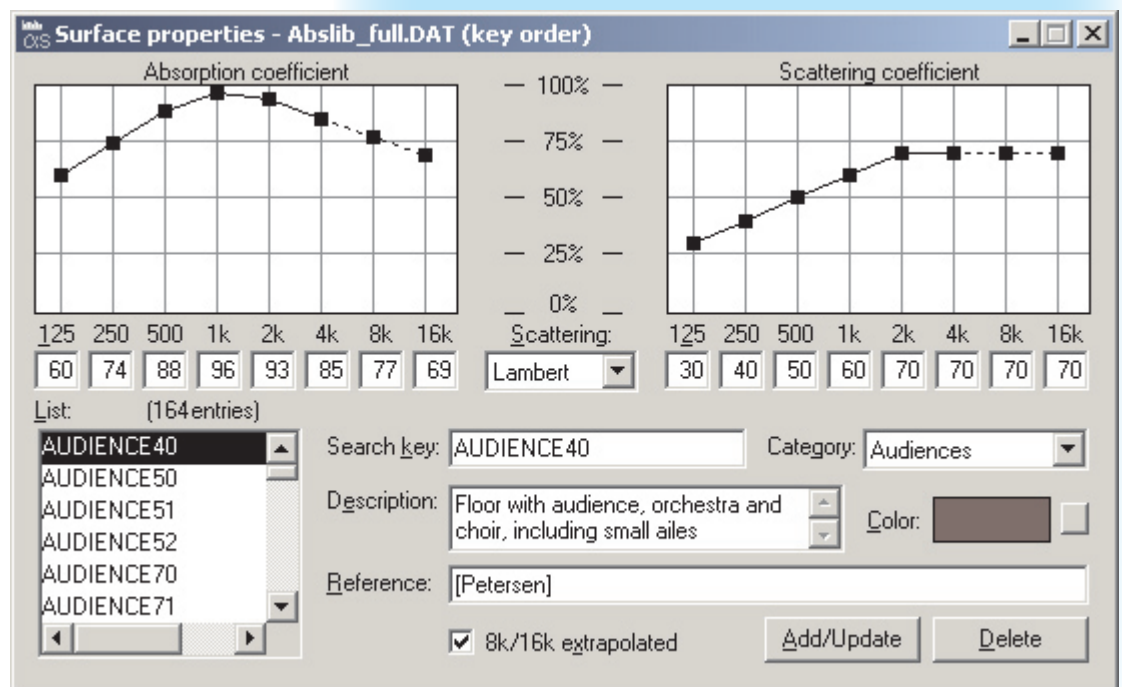
system designers, the subtleties of scattering make for much more realistic impulse responses and the auralizations that they may be used to create. Realistic auralizations can play a significant role in conveying the required sound system characteristics or acoustical changes to the client.

The Directivity Module

Most acousticians begin their room investigations using isotropic (omnidirectional) radiation of sound into the room. Sound system designers must also consider loudspeaker directivity. CATT-A uses three types of loudspeaker data in the modeling process. The following data descriptions are quoted from the CATT help files:

Type SD0 is interpolated from horizontal and vertical polar measurements entered at 15° steps. This format is most suitable for sources that are entered manually from polar data supplied on loudspeaker data-sheets or for creating generic loudspeaker types.

Type SD1 is based on full space measurements in 10° steps (often assuming symmetry so that only one-fourth or one-half of the values are actually measured). Intermediate values are interpolated. As measured and validated data become available they can be downloaded from the CATT Users' WWW page where also various types of file format converters can be found.

Type SD2 is based on the DLL Directivity Interface (DDI) defined by CATT-A and is capable of arbitrary data-format translation, array modeling and other

special functions. This format can be used to handle specialized loudspeaker types, such as steerable line arrays.

It's quite useful to allow the loudspeaker data to be handled with several different resolutions. There are times when the designer just needs an estimate and other times when more refinement is required. The position of the loudspeaker is described in one or more source (.LOC) files with the same x, y, z coordinate format used to describe the plane interconnections. The source file can also define variables or use coordinates and global variables defined in the GEO files e.g. to place a source 1m from a wall. If the wall moves so will the source.

The Prediction Module

The classical Sabine and Eyring equations are perhaps the simplest way to consider the sound energy storage capabilities of an enclosed space. They can produce accurate results as long as some basic criteria are met. They include the following:

1. Low average absorption (Sabine <10%, Eyring >10%).
2. Sufficiently uniform distribution of the absorption present.
3. A "mixing" geometry, meaning that all rays sent out will decay at similar rates so that e.g. vertical rays do not get quickly absorbed while horizontal rays linger and determine the decay.
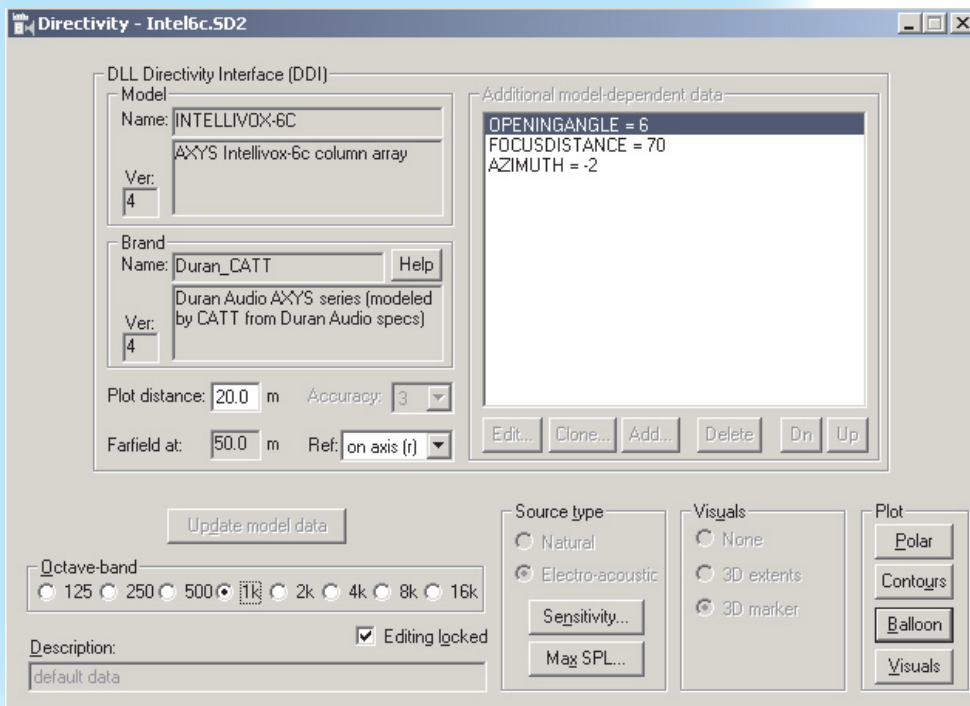

Figure 3 - The SD2 loudspeaker data format can be used to handle specialized loudspeaker types, such as steerable or curved line arrays. The designer can specify such parameters as aiming angle and focusing distance that are unique to this particular use of the product or the successive angle increments for curved arrays.

Figure 4 - The Directivity Module allows the parameters of the project's loudspeakers to be viewed and edited. Polars, balloons and contours can be viewed at one-octave resolution. The data can be created within CATT-A or imported from loudspeaker manufacturers.
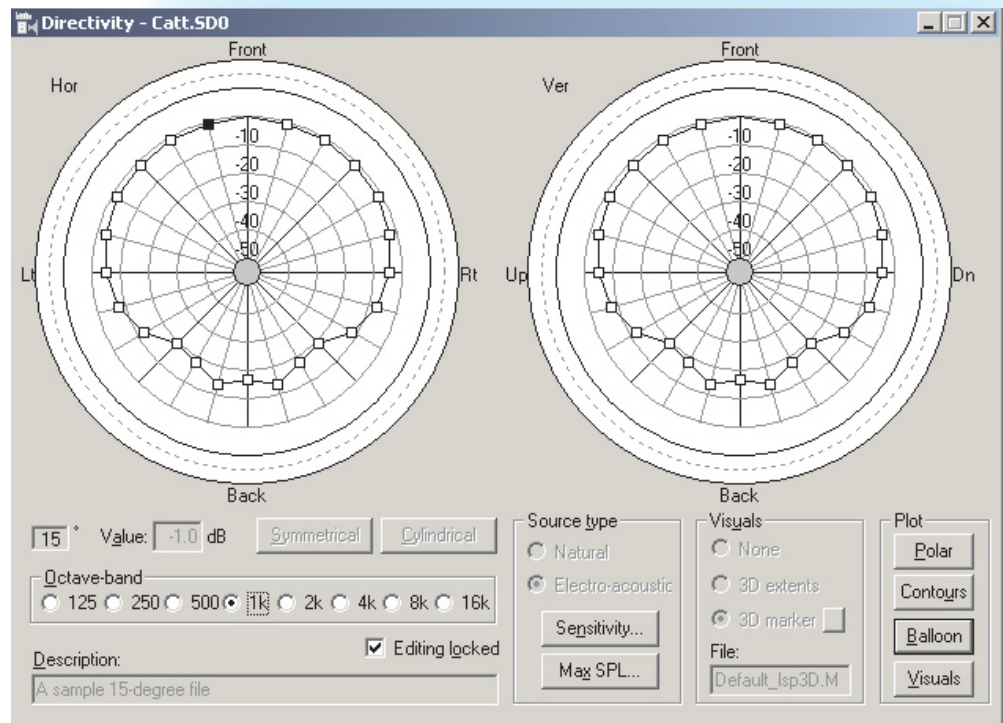
A relatively "shoebox-shaped" cathedral with low absorption might be a good candidate for the Sabine equation, while a low-ceiling cafeteria with a carpeted floor or absorptive ceiling would not. Violation of any of the listed criteria results in inaccurate reverberation calculations using the statistical equations. Unfortunately, most of the spaces that require sound reinforcement do not fit these criteria, so more specific methods of investigation are required. This is where programs like CATT-A can bring something new to the table. Within CATT-A, acoustical predictions can be conducted in several ways. The classical Sabine and Eyring statistical methods are provided, but are supplemented with advanced techniques that allow the designer to work beyond their assumptions. The prediction methods include:

Audience Area Mapping - Area specific acoustic data, such as the direct sound field, can be mapped onto audience planes. Any relatively horizontal room plane(s) can be designated as audience plane(s) and the mapping surface is placed at a selected height above those surfaces. The most accurate results will be achieved by "boxing in" an audience area and assigning the appropriate absorption and scattering coefficients. Colored maps are used to display the various metrics on the audience planes at one-octave resolution.
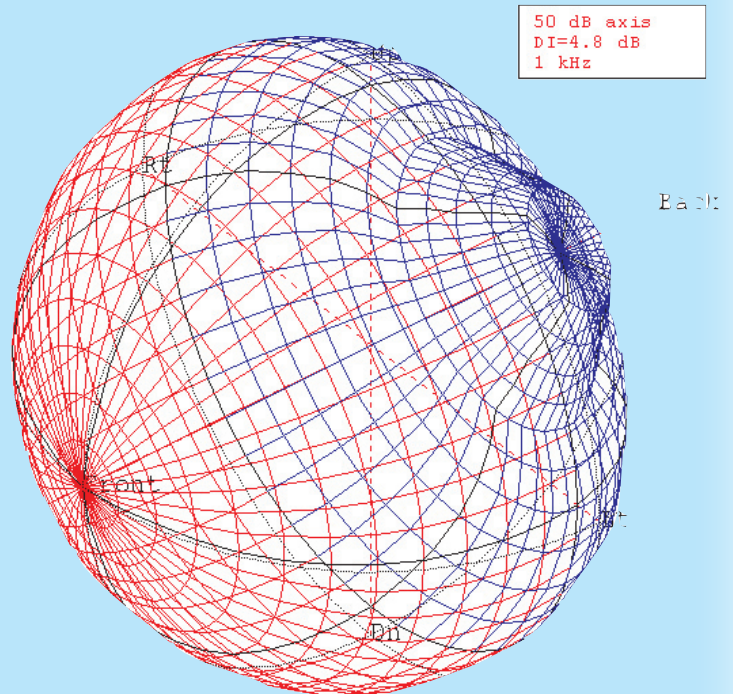
Individual seats can also be designated. This is required if echogram studies are to be conducted, since echograms will vary from seat-to-seat. A Receiver (.LOC) file is used to designate the discrete listener positions using Cartesian coordinates. Listeners can be turned on or off as desired and optionally have individual head directions. Just like a source file, a receiver-file can use variables and coordinates defined in the GEO files e.g. to place a receiver 0.4m above a seated audience plane.

Image-Source Method - An image-source technique can generate reflection data for specified listener seats. Plot files include:

Echograms - These show the level vs. time of energy arrivals at the designated position(s). Resolution is one-octave and the maximum reflection order is 9. The default value of 3 should work well for identifying room surfaces that are likely to produce problem reflections. First order diffuse reflections can also be considered.

Reflection History - This displays the travel path of the sound energy as a ray in the model, as well as the direction of arrival at the listener seat. This is useful for identifying room surfaces that should be treated.

I.S. Space - This display shows the calculated image sources imposed on a graphic of the room. These "virtual sources" could be replaced with correctly timed and band-limited loudspeakers to emulate a real room in an anechoic chamber.

The RTC Algorithm - Perhaps the most powerful feature of CATT-A is the Full Detailed Calculation option. This option uses a Randomized Tail-corrected Cone-tracing algorithm (RTC) to generate echograms that visually resemble measured room data (Fig. 5). The Help files give the details of the origins of this algorithm, but I can summarize by saying that it is the result of a great deal of research coupled with some educated assumptions and compromises to produce echograms that are realistic while at the same time computationally efficient. An optional Auralization module is available for CATT-A that will allow the result of the RTC to be convolved with dry program material. This brings the sense of hearing into the room modeling process.

Those familiar with the ISO3382 standard for acoustic metrics will already be familiar with the results of the RTC algorithm. This forms an important bridge between measurement and prediction, since in a perfect world the predicted and measured data would be identical. In practice, the correlation will be highly dependent on the construction of the model, which is highly dependent on the model builder's understanding of acoustics, the workings of the prediction platform, and the limitations of geometrical acoustics.

All tools have their strengths and weaknesses. The strength of CATT-A is as an acoustical prediction tool. The efficient code, RTC algorithm, and powerful auralization module make it especially attractive to acoustical consultants. Its weakness is that some would-be users may get discouraged before they are proficient with the user interface and GEO files. This isn't a "point and click" application and the user will have to dig into it to realize its full potential. But once familiar with the GEO file format, the user can interact with the model in a powerful and efficient manner. The background to the features and the use of the GEO format is that in room acoustics consulting, it is highly likely that the room will change due to interaction with the architect. The structured GEO options can save considerable time, especially if changes are anticipated so that parts of the geometry are modeled in a parametric manner.

The CATT-A package also includes viewer applications that can allow 3D "fly throughs" of a model as well as viewing of echograms and other plot files. These small executables can be distributed to customers without a license.
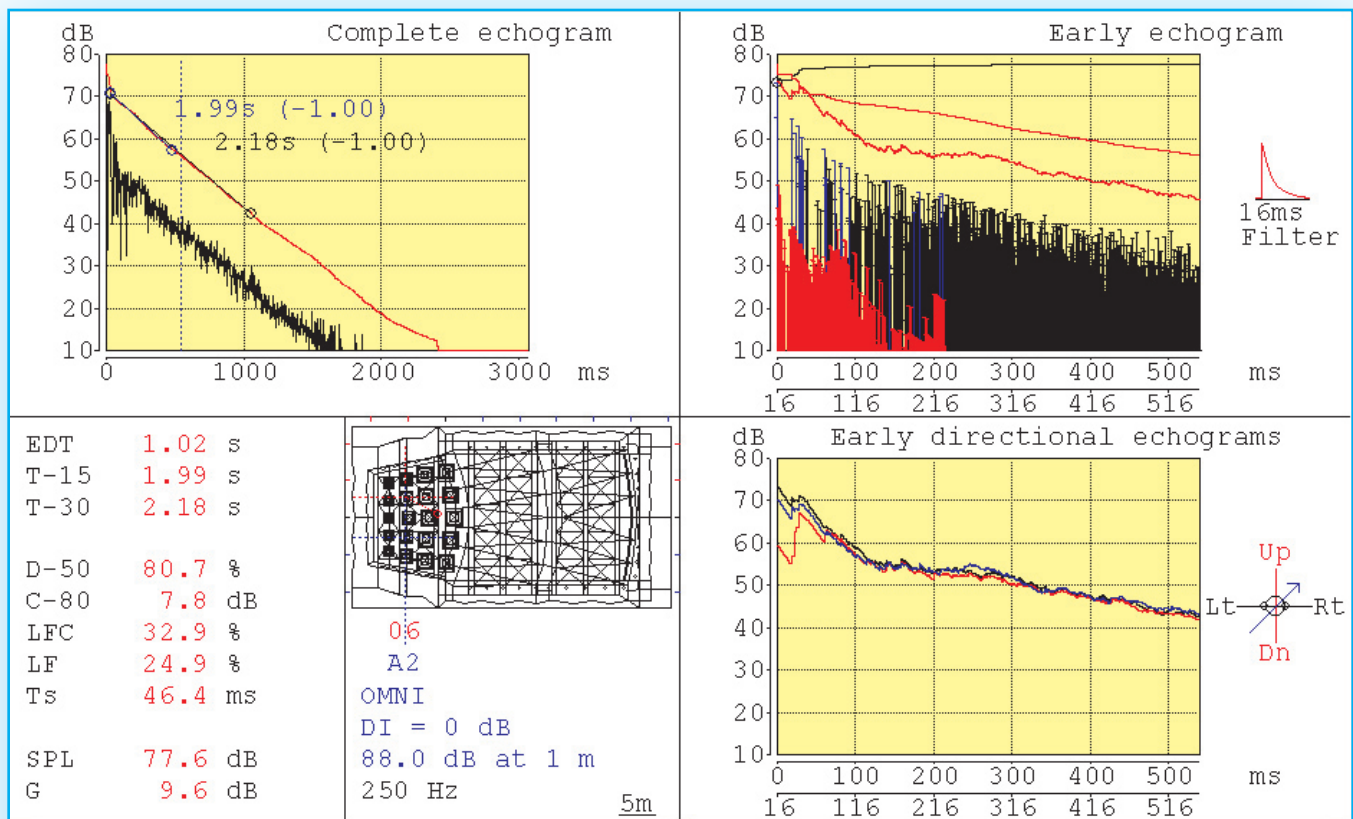
Help in Time of Need

The Help files included with CATT-A are exceptional. They describe each feature in full detail and provide the theory behind the calculations. A capable demo version of the software is available for download and can be used to get acquainted with the room building process. The demo version of the program with the accompanying Help files will provide a valuable addition to anyone's audio library. A significant but undocumented "feature" of this platform is the email support given by the author, Dr. Bengt-Inge Dalenback. Others that I have spoken with have received the same high level of support that I enjoyed during my initiation to CATT-A.

CATT-A is not a newcomer to the modeling scene. It has included advanced features such as frequency dependent "diffuse reflection" for over a decade, with much feedback from users regarding how to refine its use in room modeling. The DLL array modeling interface was also pioneered in CATT-A in the late 1990's.

Conclusion

Sound system designers who are not modeling spaces are missing out on one of the greatest advancements in design practice in the last half century. One can only imagine what Sabine and his contemporaries could do with such programs. CATT-A is an advanced acoustical design tool that is aimed at the acoustical design community. Sound system designers who conduct serious acoustical investigations as part of the design process will appreciate the benefits of advanced acoustical modeling. *pb*

EDT	1.02 s	
T-15	1.99 s	
T-30	2.18 s	
D-50	80.7 %	
C-80	7.8 dB	
LFC	32.9 %	
LF	24.9 %	
Ts	46.4 ms	
SPL	77.6 dB	
G	9.6 dB	

06
A2
OMNI
DI = 0 dB
88.0 dB at 1 m
250 Hz

The echogram is interesting because it is across the stage from source A2 to receiver 06. Here we see some as yet unexplained results but potentially useful. You can see the energy being returned to the stage causing a flattening of the Schroeder curve along with a burst of first-order diffuse reflections (in red). I like what I see here because the on-stage EDT is quite rapid, but the T_{60} is long. For the musicians this indicates high ensemble definition but a nice RT on stop chords.
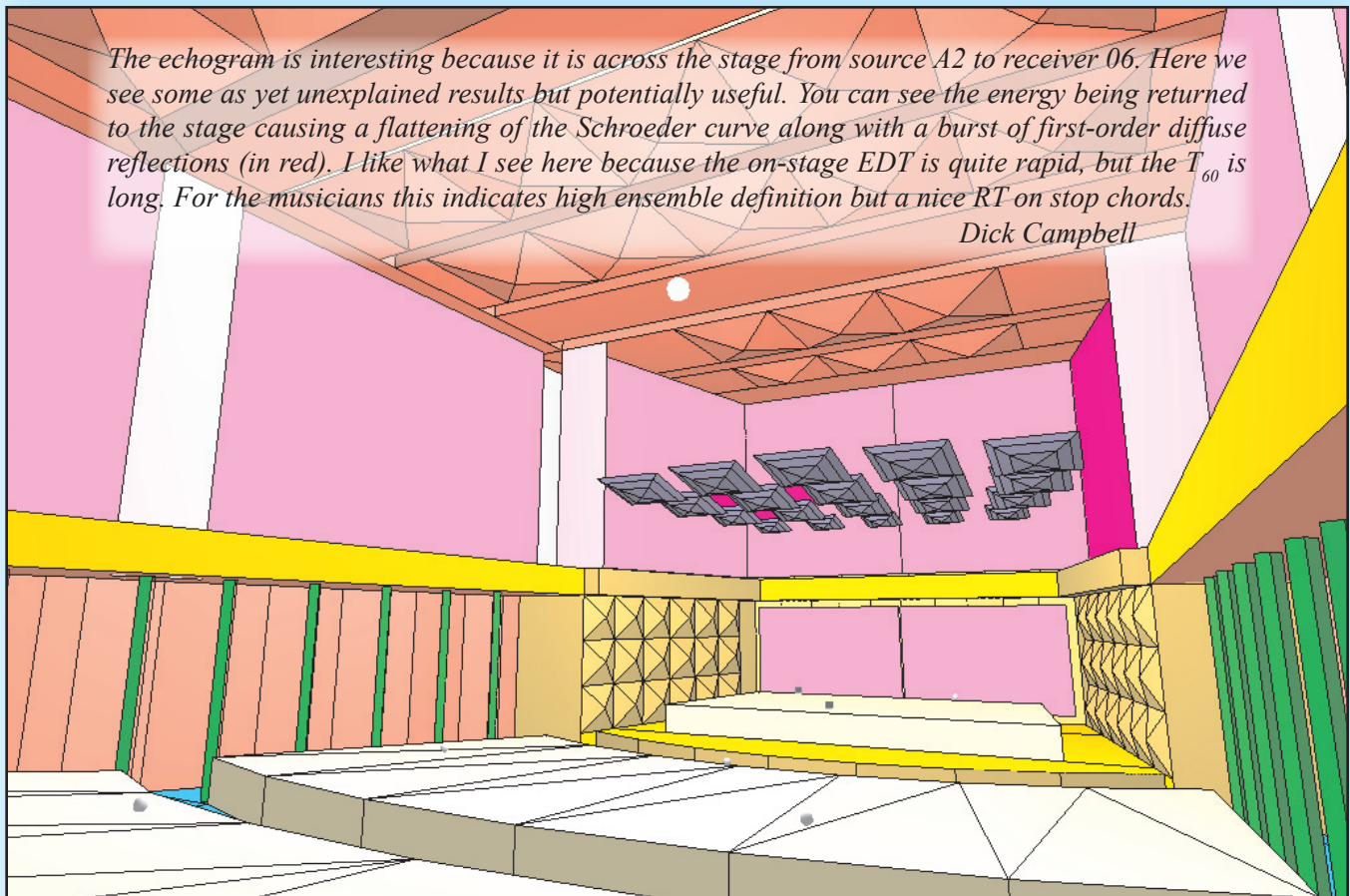
Dick Campbell

Fig. 5 - This CATT-A model of a high school performing arts auditorium was provided by Dick Campbell of Bang-Campbell Associates. It includes retractable curtains for adjusting the room's acoustics to the type of performance.