COMPUTER MODELING & AURALIZATION OF HOME THEATERS

By

Peter D'Antonio
RPG Diffusor Systems, Inc.
Upper Marlboro, MD 20774

As the processing power of desktop computers continues to increase, complex modeling tasks are becoming possible. In the architectural industry, renderings and computer walkthroughs are becoming more and more commonplace. The concept of surface attributes is now being extended to acoustical modeling. In addition to room surfaces having a finish, color, and other conventional attributes, they can now also have lighting, thermal, sound absorption and diffusion attributes. What this means is that we are now able to predict the acoustical performance of various room designs and surface treatment and actually listen to the room before it is built! While optical architectural rendering is a relatively mature field, acoustical rendering, or "auralization" as it is referred to, is in its fledgling years. This is due to the fact that visible light wavelengths are very small compared to the surfaces they are illuminated, satisfying the geometrical specular assumption. On the other hand, acoustical wavelengths are comparable and sometimes larger than the surfaces that scatter or absorb sound, thus increasing the importance of diffusion and diffraction. While boundary element methods offer the greatest accuracy in predicting scattering, geometrical acoustics is the preferred approach due to its speed and increasing accuracy. This increasing accuracy is in part due to improved scattering coefficients and diffraction modeling. While the first 100 years of architectural acoustics has addressed standardized measurement and evaluation of absorbing materials, the characterization of scattering surfaces is only now in its infancy. Standards organizations are now studying methods to evaluate surfaces and to determine scattering coefficients for geometrical modeling programs.

The use of geometric computer room modeling is becoming a useful predictive tool in large performance spaces. A recent round robin comparisons between prediction and experimental measurements has shown good agreement when diffusion was included in the model. Acousticians are now beginning to apply computer modeling to smaller critical listening rooms, such as recording studios and home theaters. This presentation will review the necessary steps required to go from a 3D room model to an acoustical prediction and auralization of a virtual home theater.

The process begins with a 3D room drawing. Each of the room surfaces is described by a plane. Each plane is assigned an absorption and diffusion coefficient to characterize how sound is scattered from the surface. In Figure 1we see a typical model of a home theater. The model

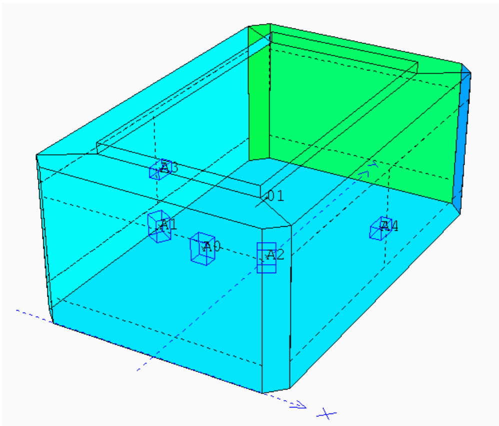

Figure 1. 3D model of a dipole surround 5.1 home theater.

includes sources (A0-A4), receiver (01), and absorption and diffusion coefficients for appropriate surface planes. A directivity pattern and frequency response is assigned to all of the sources. Figure 2 illustrates a typical dipole directivity pattern for the surround dipoles (A3 and A4).

Room acoustics prediction, in general, is the process where, using geometrical acoustics, octave-band echograms are predicted based on a

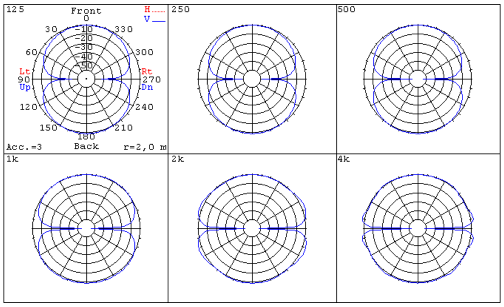

Figure 2. Typical dipole radiation directivity pattern.

3D CAD model of a room. Frequency dependent material properties (absorption, diffusion) are assigned to room surfaces and frequency dependent source directivities are assigned to sound sources. From these echograms a great number of numerical measures of e.g. speech intelligibility, and reverberation time can be estimated.

To study the effect of strong early reflections, the echogram can be analyzed. The reflection history reveals the directions of source emission and reception by the listener. Diffuse reflections (red) are also shown.

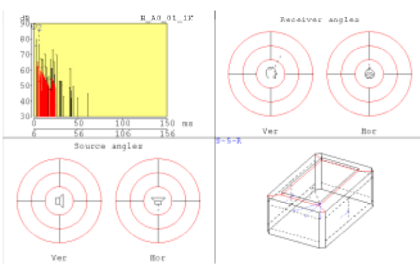

Figure 3. Early time echogram, source emission angles and receiver angles, and reflection history showing a ceiling bounce from the center speaker.

The full impulse response can be analyzed to determine all of the objective parameters, Figure 4, that acousticians have equated with perception. These parameters can also be mapped for inspection, Figure 5.

Auralization is the process where predicted octave-band echograms are converted to binaural impulse responses, Figure 6, that can be convolved with anechoically recorded music or speech giving an impression of how the music or the speech would sound if replayed in the modeled hall. The process involves digital signal processing and Head-Related Transfer Functions (HRTFs). In addition to binaural responses directive microphone, stereo, and B-format responses are possible. Convolution with anechoic material is made either directly in software or via special hardware.

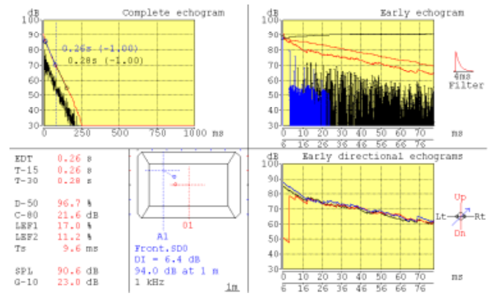

Figure 4. Objective parameters determined from complete echogram for right speaker. Directional echograms also shown.

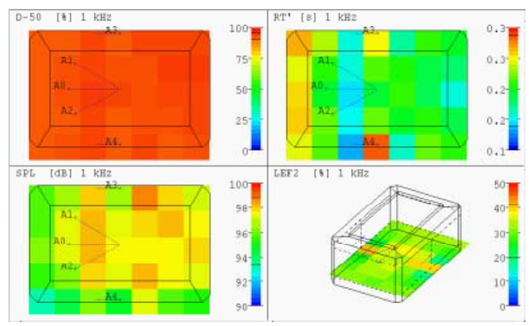

Figure 5. Objective parameters for the 1 kHz octave band can be mapped. For example, D50 (clarity), RT (reverberation time), SPL (sound pressure level) and LEF2 (lateral energy fraction) can be mapped

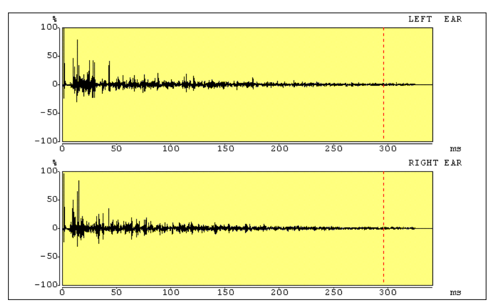

Figure 6. Binaural impulse responses are convolved with anechoic music or speech to auralize the source in the virtual room.