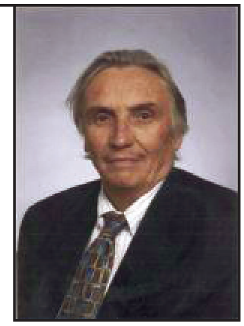


CAMPBELL'S CORNER - BY DICK CAMPBELL

This is Your Brain on BEM



Here it comes – to a PC near you – BEM! Boundary Element Modeling. This method of looking at acoustic wave behavior has been around for a long time. We have all seen vibration analysis of automobile panels and musical instruments. The software has been expensive and extremely complicated to use. Expect an announcement in mid-2008 of a new easy-to-use software entry in the field that works with rooms (currently in beta-a).

Origins

This new software was originally designed for accurate internal resonant analysis of loudspeaker cabinets, cones and horns. I asked the program author if it could be applied to buildings and he "thought so." Some weeks later I received an example program to test and I was astonished.

Compatibility

The source files are text scripts and together they compile a set of instructions on the building geometry, wall impedance, level of detail, analysis frequencies and location of the point source. An entire wall can also be a source. The script that defines geometry is organized as points and planes so translation to/from current ray-tracing software should be straightforward. This had been done successfully for CATT-A, using a rather simple model from the BEM author, as seen in Figure 1.

Modal Behavior

As you can see from the BEM result in Figure 2, at 78Hz the dynamic range of SPL in different parts of the space can be as much as 30dB. Most of us have experienced this when walking around a space excited at one modal frequency. It is startling to me to see where these "fields" gather in the building. Notice that as you walk along the center of the space at 78Hz radiating from a point source, the SPL can go from 94dB to 67dB. You might just notice that!

Ray-tracing technique becomes problematic at or below the Schroeder frequency ($F_{Schroeder}$) given as:

$$F_{Schroeder} \approx \frac{4c}{\sqrt{\pi a}} - \frac{cS}{16V}$$

where
c = 344 m/s
a = 33.6 metric sabins
S = 343 m^2 boundary area
V = 336 m^3 room volume

This works out to 113Hz for the model shown, assuming a diffuse field. The CATT-A ray tracing result shows 400Hz for $F_{Schroeder}$ using the computed reverberation time in the short formula (admittedly an apples-to oranges comparison for this non-Sabin space):

$$F_{Schroeder} \approx 2000\sqrt{\frac{T_{30}}{V}}$$

Some researchers recommend twice or even three times this frequency below which modal behavior may cause errors in ray tracing (or cone tracing) methods. It appears that a combination of ray-tracing and BEM would be desirable for a complete analysis of room behavior. It would be pointless to run BEM above the $F_{Schroeder}$ because the modal density is high enough to be not noticeable. Below the $F_{Schroeder}$ it might be prudent to look at BEM to see how the modes gather.

The Future

What's next? My list: (1) expressing wall impedance in terms of absorption coefficient; (2) adding directivity to the source (low priority at low frequencies); (3) input scripts more like those used by room-acoustic programs; (4) wavelength-significant objects in the space -- you make your own list!

My ultimate test for BEM? Seat dip. I want to see the wave action over the top of rows of seats (modeled as 250Hz Helmholtz resonators). *dc*

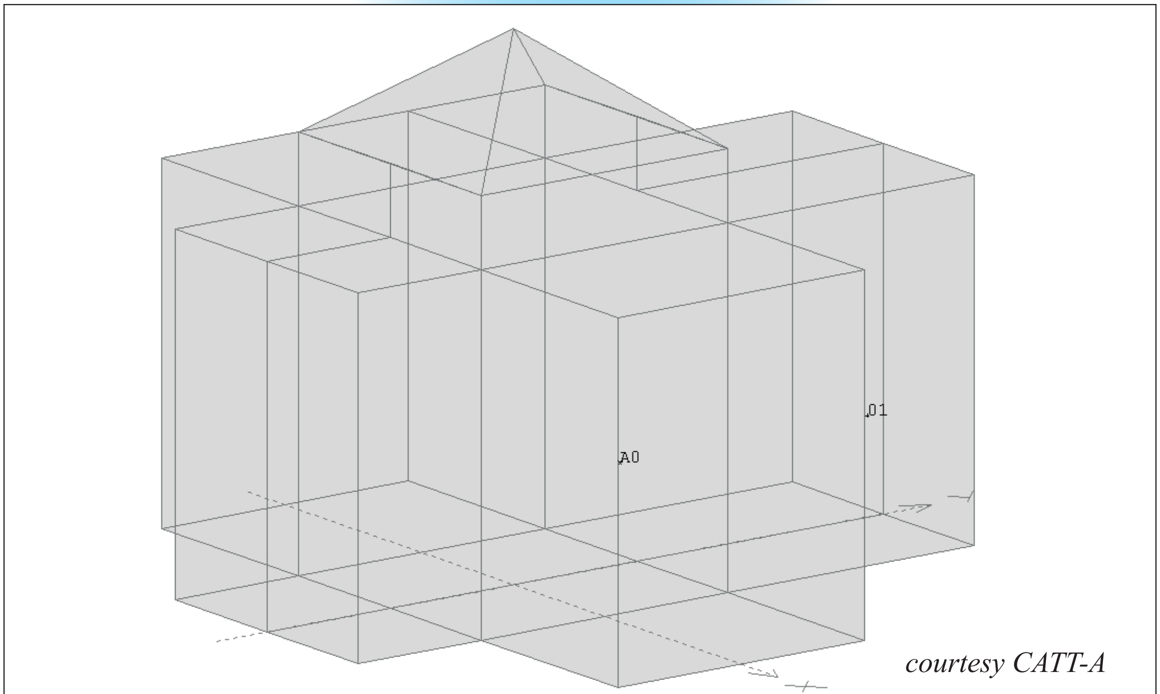


Figure 1 - The room model exported for use in a geometric acoustic modeling program.

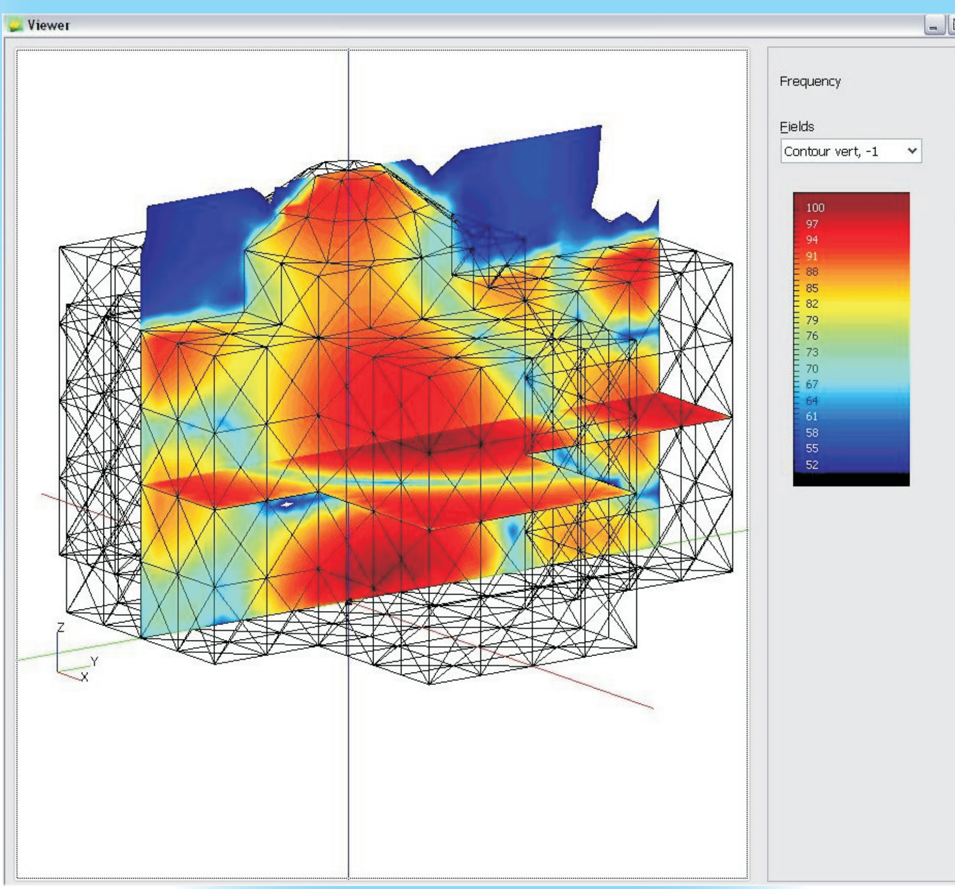


Figure 2 - The SPL distribution on a vertical plane as determined by the BEM.