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OVERHEAD CANOPY DESIGN

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When designing a diffuser, the requirements of visual aesthetics and acoustics must be considered, and these are often in conflict. Unless diffusers are visually acceptable to the architect, they are unlikely to be used. Curved surfaces are common in modern architecture. Spurred on by the availability of new materials and computer aided design, architects are increasingly designing prestigious buildings where large flat surfaces appear to be outlawed in principle. Curved diffusers are therefore appealing, because they can complement modern architectural trends. They can have a form which blends with other structures in a modern building and they do not have to look like an obvious add-on. As we have seen optimal canopy design is achieved by designing an optimal base shape and aperiodically configuring it to minimize periodicity effects. Therefore, we will describe the two basic ingredients in Optimized Canopy Design:

- Shape Optimization
- Aperiodic Modulation

THE SHAPE OPTIMIZER

The concept of the Shape Optimizer is to allow the architect or acoustician to draw a desired shape motif of an overhead canopy element and to then have a computer program optimize the shape, tilt and spacing of an array of these canopy elements, staying true to the constraints on shape, depth and length of the element, to produce uniform coverage over the frequency range of interest. To accomplish this three design ingredients are needed:

- **An accurate mathematical model to predict scattering from the surface.** Boundary Element Method (BEM) predictions were verified against numerous experimental measurements and found to be extremely accurate. The disadvantage of using a BEM model is that it can be very slow on complex shapes, but as computing power increases this should be less of a limitation.

- **A figure of merit to evaluate the performance.** The diffusion coefficient described in AES-4id-2001 was used as a single figure of merit to evaluate the uniformity of scattering. The diffusion coefficient is the spatial autocorrelation of the 1/3-octave polar responses.

- **An optimization algorithm or intelligent search engine to adjust the shape during the search.** The downhill simplex algorithm was used to search for the global minimum. This is needed so that potential shapes can be tried and tested in a logical manner, rather than on a random trial and error basis. A usual analogy for a 2D optimization is finding the lowest point on a hilly landscape while blindfolded. One would start downhill on the assumption that this will lead to a lower elevation. The optimization algorithm must make similar decisions, but shape optimization has many more degrees of freedom and the search for the best shape (lowest elevation) must be made in the fewest steps. The downhill simplex algorithm is very robust and can allow for non-linear constraints.

The procedure is skematically illustrated in Figure 1 and outlined as follows:

Step 1: Mathematically describe the architectural motif using Fourier Series, 1D Cubic and 2D Bicubic Spline formulations
Step 2: Describe the source using a spherical Green's function or a cylindrical Hankel function
Step 3: Divide the surface into boundary elements 1/6 the size of the maximum wavelength as seen in Figure 15 Bottom.
Step 4: There is a differential equation for each boundary element. Determine the surface pressures by solving these equations
Step 5: Project the surface pressures to the observation points
Step 6: Determine the diffusion coefficient (performance metric) from each source to each receiver in each 1/3rd octave band for each shape
Step 7: Query the optimization algorithm or search engine for the next shape to evaluate
Step 8: Iterate until the shape satisfies the acoustical specifications
Step 9: Export a dxf of the shape to a CNC to create a mold
Step 10: Manufacture the canopy element

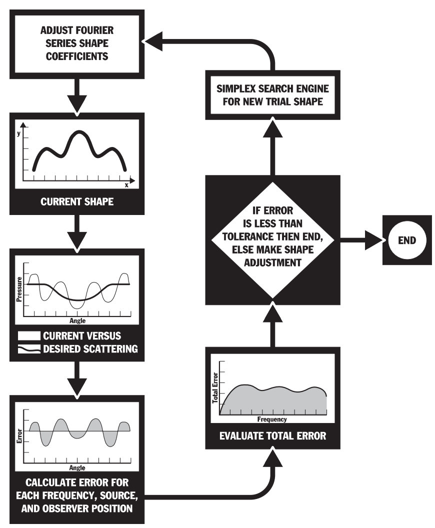

Figure 1. Iterative optimization process

In the next issue, we continue discussion of the Shape Optimizer.