

## SKYDOME ACOUSTICAL MODEL

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### INTRODUCTION

In 1996, Engineering Harmonics was retained to investigate, test and re-tune the current sound system for Toronto's SkyDome. On the basis of this work and insight into the sound system, in 1997 SkyDome retained Engineering Harmonics again to prepare cost estimates and a plan to upgrade the systems. After receiving approval, Engineering Harmonics began a project to upgrade, replace and improve the system. This project involved the replacement and addition of loudspeakers, replacement of amplifiers and implementation of a digital audio transportation and DSP system. This article discusses the EASE computer model that was used to model the new loudspeakers for the lower two tiers of seating.

The existing sound system has long suffered from a balanced coverage problem. Due to architectural concerns during the construction of the building, the loudspeakers for the 100 and 200 Levels were not optimally placed. The loudspeaker placement lead to the creation of "hot spots" underneath the balconies and very poor coverage by the field.

While a centre cluster could easily cover the entire stadium, the moveable roof does not allow a speaker cluster to be permanently hung. Thus, a distributed system was designed. A series of loudspeakers were to be placed on the front of the 500 Level. These would provide coverage to the 100 and 200 Levels below. Each loudspeaker cabinet would have several drivers to cover the areas. As balconies obscure part of the 100 and 200 Levels, additional loudspeakers were to be installed underneath these overhangs. These speakers provide coverage for areas not covered by the new main loudspeakers.

In order to assist in the placement and design of the custom loudspeaker cabinets, the EASE computer program was used.

### MODEL DEVELOPMENT

The model was constructed from architectural plans of the building. Using the AutoCad program, a complete three-dimensional model was developed. Once completed in AutoCad, the model was then imported into the EASE program. Once in EASE, the painstaking process of defining acoustic surfaces began. Although the model only used a small number of different acoustic surfaces, for example smooth concrete, glass and Hussey Seating, the total number of surfaces totalled over 1500. Each one had to be set by hand.

After all of these surfaces were labelled, approximately eighty audience investigation areas were defined. However, once all of these acoustic surfaces and audience areas were defined it was determined that there was not sufficient memory left to add any of the loudspeakers.

Based on the symmetry of the building, it was thought that the building could be chopped in half along its North-South axis. As this would cut the surface and volume in half, it would have no effect on any reverberation calculations from the model. An acoustical mirror was added along the cut-axis; it had an absorption co-efficient of zero and hence did not add any surface area to the model.

A series of loudspeakers were then added to the model. Several areas were under investigation; they include the uncovered and covered parts of Level 100 and 200 and some loudspeakers at the North end of the building. These North end speakers were dropped from the project. Loudspeakers were added to the face of the 500 Level to cover the majority of Levels 100 and 200. As the areas near the concourse are covered, separate speakers were to be installed in those areas. Although two rings of speakers were designed for Level 100, for simplicity only one was modelled.

Each loudspeaker's exact position was computed using a spreadsheet program. Data for each loudspeaker type was supplied by the manufacturer from an existing product. Although these would not be the exact loudspeakers installed, the data would allow for an initial gauge of their placement and aiming.

Figure 1 shows the model as a wire frame; this gives a rough idea of its shape.

### INITIAL USE

Once all of the acoustic properties were defined and all of the various types of loudspeakers were entered, the model was useable. As a test of the model, an existing loudspeaker pair was entered into the model. It showed that there was an extreme build-up of energy near the top of the sections, especially 121. Closer to the field, the coverage dropped off drastically, as shown in Figure 2, for Sections 121 and 219. In all of these figures, the field is at the top of the picture. The bottom corresponds to the area closest to the concourse. Level 100 is the first seating level above the field; in the figure it is

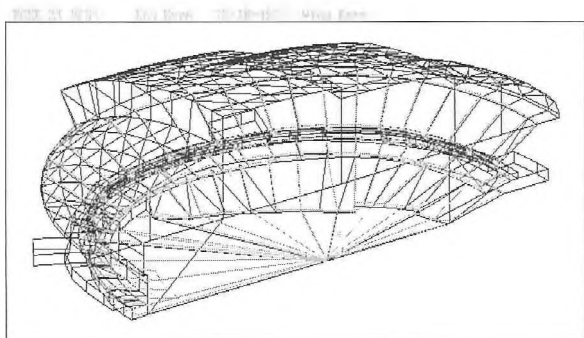


Figure 1: Wireframe Model

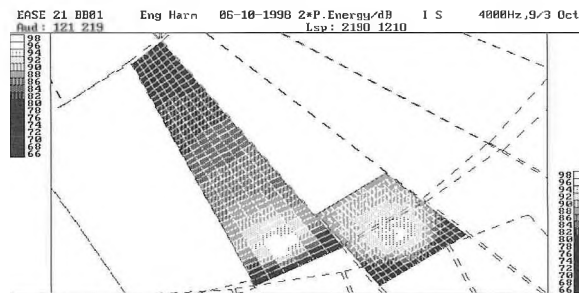


Figure 2: Coverage of Existing System

the larger of the two. The loudest areas correspond to the light colour, the quieter areas are darker. It is easy to see that the Level 100 coverage has a severe hotspot close to the loud-speaker. Patrons close to the field would not hear the program very well. For the proposed system, initial runs indicated that the system would be able to cover both the 100 and 200 Levels with no more than a 5 dB variance. Figure 3 shows the predicted coverage with the new system for Sections 121 and 219. The drop-off of coverage in Section 121 near the concourse is expected. Two rings of underbalcony speakers will be installed in that area; only the inner ring appears in the model. Thus, the coverage drops, as this loud-speaker is not in the model. Note that the overall coverage is even throughout the whole section.

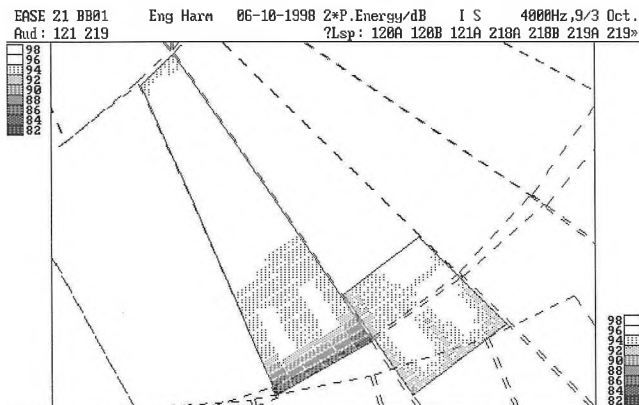


Figure 3: Predicted Coverage of New System

### SOUND TESTS

To gauge the effectiveness of the model, the companion program to EASE, called EARS, was used. A ray-tracing reflectogram was created in the EASE model. This was then imported into the EARS program. It is then possible to convolve this room response with a "dry" signal. This process took approximately 36 hours of computation on our computer. The initial result was less than satisfactory.

As we were familiar with the room response of the SkyDome, we were able to listen to the model and realise that it was not as reverberant as the actual room. We determined that the model was simply not carrying the ray-tracing far enough. It was truncating the result, which caused it to underestimate the reverberation time. We adjusted the settings and forced EASE to follow through on the rays until they were really "gone". Once this was done, EARS was much better able to show the interaction of the loudspeaker system with the room.

### REFINEMENTS

Having obtained results from the model and thoroughly examining them to determine their validity, we were assured that the model was predicting correctly. The manufacturer had now constructed the custom cabinet for the loudspeaker drivers. Up until this point, we were using "prototype data". The drivers for the cabinet were existing and well documented but in the model, they were in a standard cabinet - not the custom one for this project.

After they were constructed, the manufacturer measured them in their plant and we received new data for the main loudspeaker. Various tests were then conducted with this data. It led us to be-

lieve that the cabinets were not angled properly. The cabinets were about 5 degrees off; the coverage pattern did not reach to the end of the 100 Level well enough.

Various tests were run by changing the down angle of the loud-speaker enclosure. It was determined that they would need to be roughly 4 degrees steeper. While the coverage for the mid-range driver was fine at the built angle, the more directional horn was not achieving its target level of coverage. With this information, we realised that they would have to be mounted differently. A wedge was developed that would allow the loudspeaker to be moved out such that the entire level would be covered properly.

Figure 4 shows the coverage for the 100 and 200 Levels with the face aimed down 36 degrees. The coverage is much stronger near the field and drops off by the concourses. This is of concern because the loudspeaker would be too loud on the field. At 42 degrees, as in Figure 5, the coverage is more even. After careful examination of the coverage over all frequency bands, it was determined that the optimal angle was around 42 degrees.

### CONCLUSIONS

The model was a massive undertaking. It frequently taxed the limits of the EASE program. It was not used as the end authority for loudspeaker placement. It was used as a design tool to quickly evaluate different placements and aiming angles. It was also used to evaluate the performance of loudspeakers from several different manufactures.

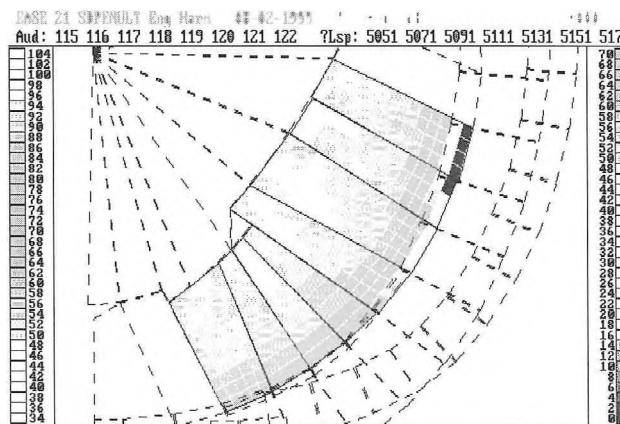


Figure 4: 4kHz at 36 degrees

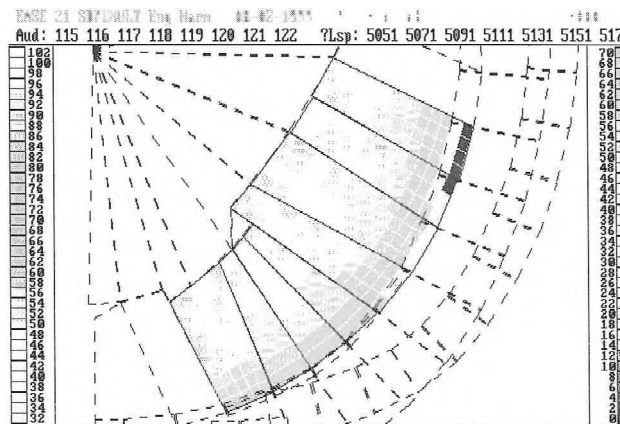


Figure 5: 4kHz at 42 degrees