Acoustic Modeling with JBL EASE

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Introduction

This is intended to serve as both an introduction to acoustical modeling using *JBL EASE* in conjunction with physical models produced in *Google Sketchup* and verification that the acoustical models are accurate. We will compare the acoustical models to actual room measurements of the real space. The chosen space is a stairwell located in Eaton Residential College on the Southern side of the University of Miami's campus.

Physical Modeling

The initial model of the room was made using *Google Sketchup*. For best results, we wanted to model the full staircase, but time constraints and processing limitations encouraged us to only model the first two flights of stairs. We found that excessively large amounts of surfaces (such as many individual stairs) bogged down *EASE*'s calculations. Figure 1 shows a cutaway view of our model. The actual model is fully enclosed.

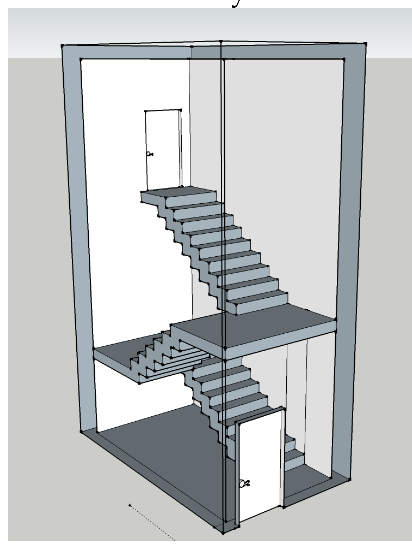

Figure 1: Sketchup *Model of Staircase*

Preparing the Model in *EASE*

The initial model in *EASE* was made by importing the *Sketchup* file. This provided us with a good wireframe to use to run our tests. A pair of loudspeakers was placed on the second floor with the audience area on the ground level. An audience area is the *EASE* equivalent to the listener's location. The materials of the walls and stairs were set to concrete to mimic the actual staircase. The doors were set to painted wood. Figure 2 shows the model in *EASE*.

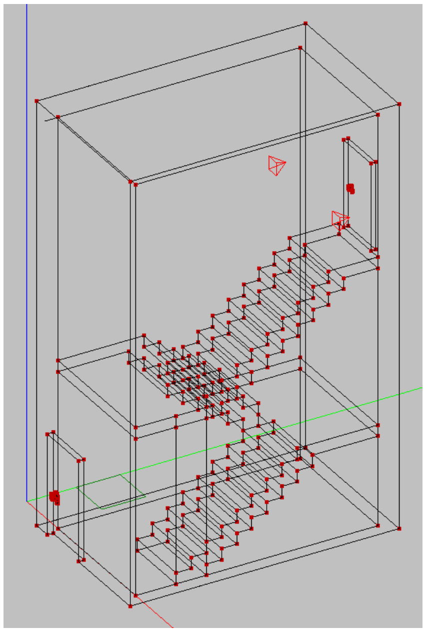

Figure 2: EASE *Model of Staircase*

EASE Acoustic Models

EASE provides the capability to run many different acoustical simulations. Only the most interesting of these tests were performed and will be detailed here. All simulations are calculated over a range of many frequencies.

Total SPL

Total SPL is the measure of total maximum loudness in the space produced by the two simulation loudspeakers. This total loudness is the sum of the direct level and any reflections, and is measured in A-weighted dB SPL.

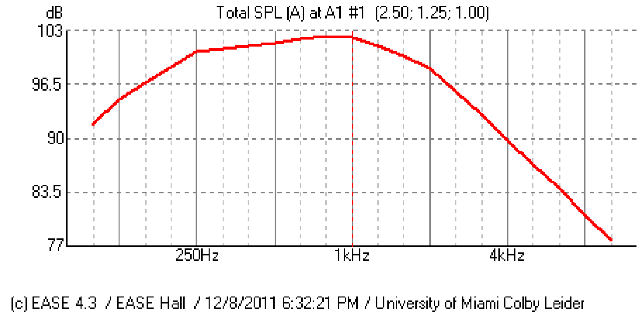

Figure 3: Total SPL simulation

Direct SPL

Direct SPL is the measure of loudness of only the direct sound from the speakers to the listener. Notice there is a severe dip at 2.5 kHz. This is indicative of a room mode at this frequency at the location of the audience area. There is another visible dip at 5 kHz, which is the first harmonic of this room mode.

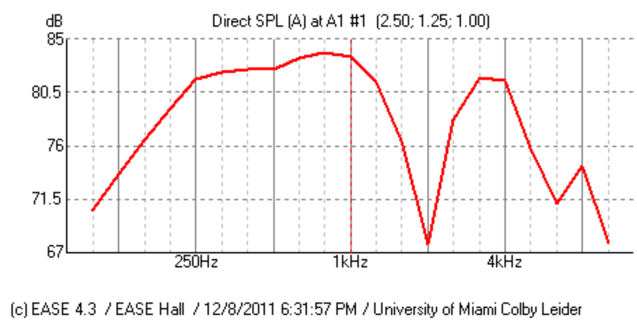

Figure 4: Direct SPL simulation

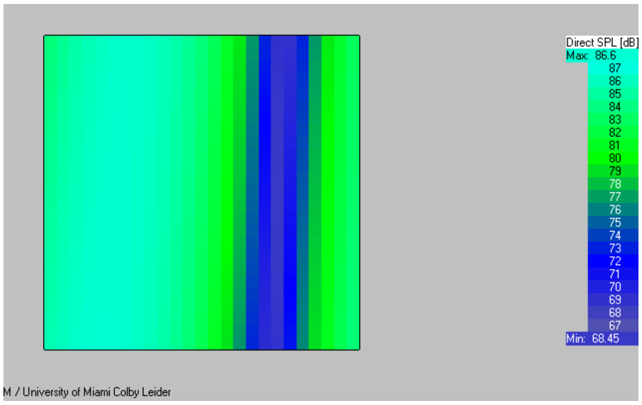

Figure 5: Color graph of Direct SPL

Direct/Reflected Ratio

The D/R ratio is the ratio of direct sound to reflected sound. By comparing the two previous SPL graphs, it logically follows that there is a higher ratio of reflected sound in higher frequencies than reflected frequencies.

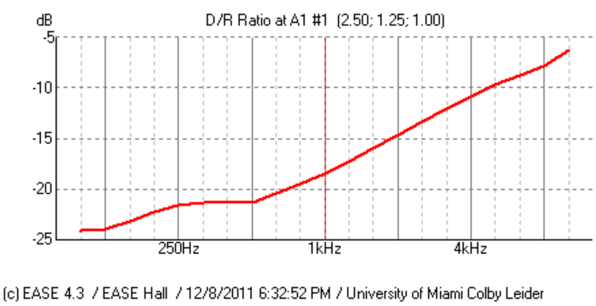

Figure 6: D/R Ratio simulation

Critical Distance

Critical distance is the distance at which the SPL of the direct and reverberant levels are the same. This is closely related to the Direct/Reverb ratio. It makes sense to think of this as the inverse of the D/R Ratio, because a lower D/R ratio implies a higher critical distance. It is interesting to note that high frequencies have a very low critical distance, meaning that higher frequencies are more quickly shrouded in a wash of reverb. This contributes to the bad intelligibility of the space, to be covered next.

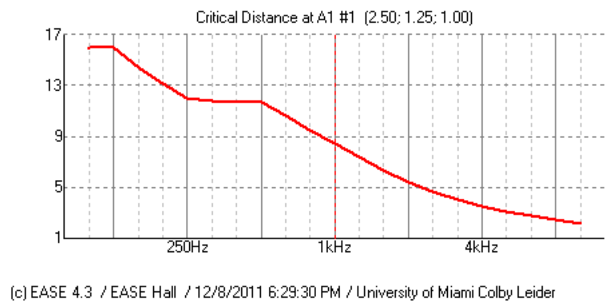

Figure 7: Critical Distance Simulation

Speech Transmission Index

Speech Transmission Index (STI) is a broad measure of speech intelligibility in a space. Values of 0.45 and higher are generally considered decent. As seen below, the stairwell is predicted to be very, very bad. This makes sense, as it is very difficult to understand someone in the real stairwell unless they are standing very close to you. Given that our test had the listener two floors below the source, this lack of intelligibility is expected.

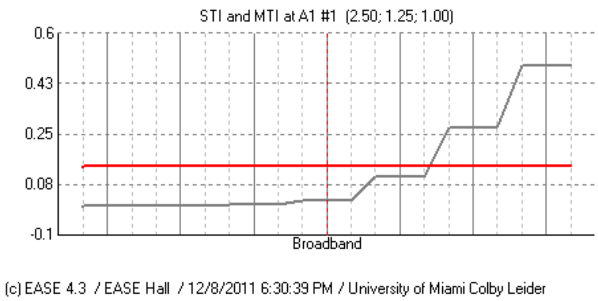

Figure 8: STI simulation

Articulation Loss

Articulation Loss (AL Cons) is a measure of the percentage of consonants lost in the space. Lower percentages of AL Cons means a higher percentage of syllables will be understood. As is seen below, this space falls at just about 82% Articulation loss, meaning the majority of syllables will be unintelligible in the stairwell. This follows directly from our simulation of STI.

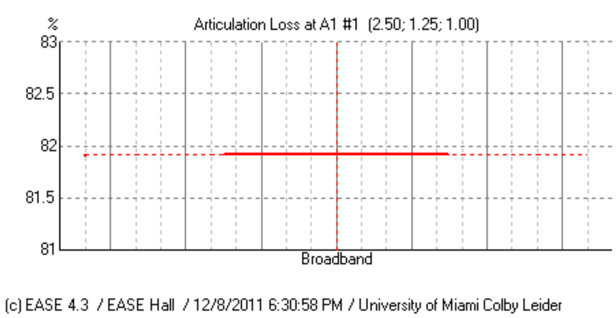

Figure 9: AL Cons simulation

Articulation Index

Articulation Index is a measure of the intelligibility of hearing speech in a space. The closer this value is to 1.0, the better the intelligibility. As seen below, the stairwell model has an AI value of 1 across the frequency sweep. This is a surprising result, as all the other tests point to a distinct lack of intelligibility. This could mean either this graph is supposed to be interpreted as 1/100 or some initial data was set up incorrectly.

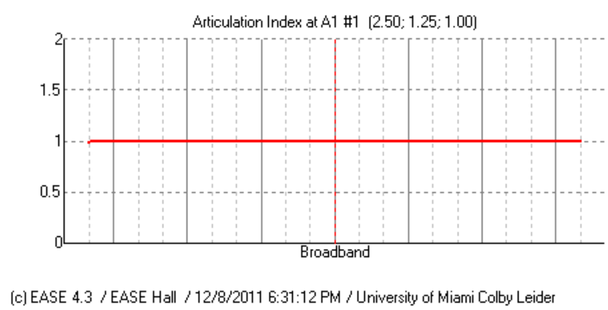

Figure 10: AI Simulation

Ray Tracing

Ray tracing is the act of drawing the direct sound and the first reflection of the direct sound in a desired space. It serves as a visual representation as to why a listener on the bottom floor will not be able to understand a speaker on the top floor very well.

Notice how only one ray makes it to the bottom floor. This shows that most of the sound the listener will hear is most likely a reflection, with direct sound levels being very low.

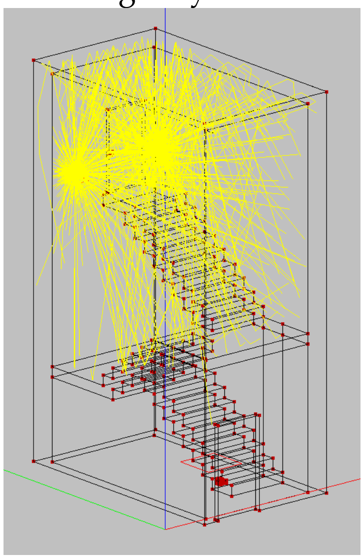

Figure 11: Ray Tracing – 3D view

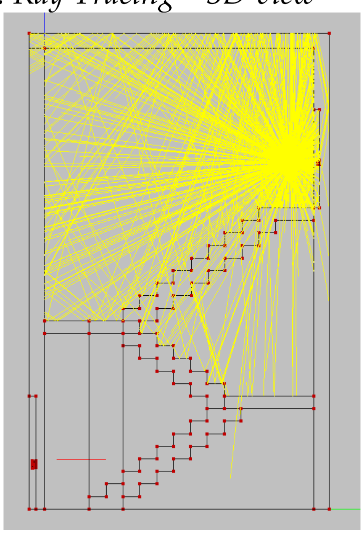

Figure 12: Ray Tracing – Side View

Impulse Response

EASE has the ability to generate an impulse response of what the modeled space will sound like. We used this feature to create an impulse response and compare it to the actual measured impulse response of the stairwell. The graphical comparison of the FFT of the impulse responses can be seen below.

It is interesting to note that the synthesized room has a higher bass frequency response than the real room. This is most likely because the model only contains two floors, when the real staircase has four. The real room is also offset up by about 20dB, which can probably be linked to background noise in the stairwell.

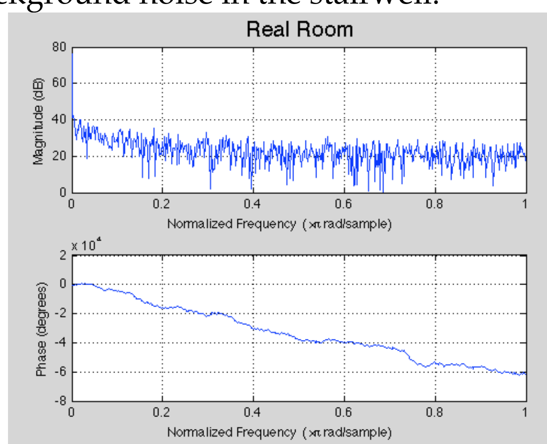

Figure 13: FFT of actual impulse response

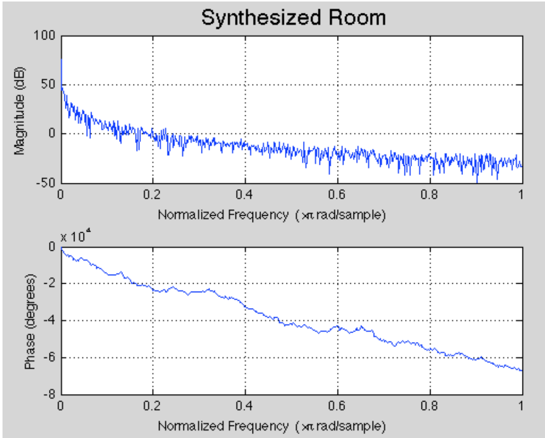

Figure 14: FFT of sim. impulse response

Conclusion

EASE is a very powerful piece of software that allows for very accurate modeling of physical spaces. We have confirmed its accuracy here by comparing it to the real stairwell that the model was based on. Despite being only half the size, our model exhibits a strikingly similar behavior to the real staircase. *EASE* even produced really nice looking graphs without much of a hassle.

EASE's greatness is not without its shortcomings, however. Because it is so powerful, it was sometimes very tricky to use. Assigning surfaces their material type had to be done one at a time. This project had over 200 surfaces, making this process very tedious. Cryptic error messages made debugging the model a pain, and setting up the tests was counterintuitive. The loudspeakers, by default, have too high of a power rating for most rooms and you must manually lower the power rating until it is at an acceptable level.

Despite these shortfalls, *EASE* is still very good at producing a useful output. We learned much about the different aspects of acoustical testing and how something as simple as adding a second loudspeaker can completely change the response of a room. Moving forward, if I ever find myself designing a room for a specific auditory purpose, I'll be sure to model it in *EASE* first and produce these simulations to ensure that the room will react as desired.

References

Ease v4.3: Tutorial and User Guide. 2009. Berlin, Germany: Renkus-Heinz, Inc.

Long, M. *Architectural Acoustics*. 2006. Burlington, MA: Elsevier Academic Press.