Cavities Between MILO 120 Loudspeakers and the Effect of the MILO 120-I Insert on Acoustical Response

by Perrin Meyer

This research is a continuation of our exploration into the effects of the trapezoidal "cavity" ("Do Cavities Between Arrayed Loudspeakers Affect Frequency Response?") created when trapezoidal (and rectangular) loudspeakers are splayed at large angles. We revisit those original experiments using improved computational tools and take a look at the cavity between MILO 120 high-power expanded coverage curvilinear array loudspeakers and the results of using the MILO 120-I insert to fill the void.

In early 2000, we compared filled-in versus non-filled cavities between splayed loudspeakers using careful outdoor measurements. Of our then-current loudspeaker models (UPA, CQ, MSL-4, and MTS4-A), the measurements showed little difference between filling in the cavity or leaving it unfilled – in fact, the loudspeaker with the most difference was the MTS4-A, which was designed not to be arrayed.

Our new research arrives at similar conclusions, using advanced computational acoustic modeling software and a higher degree of precision. Specifically, we examined the effects of using the MILO 120-I solid insert to fill the cavity between new MILO 120 curvilinear array loudspeakers.

MILO 120 and MILO 120-I Solid Insert

The MILO 120 loudspeaker is designed to be arrayed in vertical arcs; due to its increased vertical coverage (compared to the standard MILO loudspeaker), the space between loudspeakers is increased. The pivot point of rotation is at the front of the enclosure and therefore the front distance between the loudspeaker is fixed in the front, while the back is rotated to select the angle between the loudspeakers. Supported splay angles, using MILO 120's QuickFly® rigging, are 13 degrees to 19 degrees in 2 degree increments; these angles were chosen for optimal acoustic coupling with MILO 120's vertical coverage of 20 degrees. Since MILO 120 has the same physical dimensions as a standard MILO loudspeaker, these optimal angles create a cavity between two MILO 120 loudspeakers. While MILO 120 loudspeakers are designed to be used in homogenous arrays, they are also engineered to be used as downfill loudspeakers under a vertical array of standard MILOs. To give the vertical hang of MILO 120s (and MILOs) a "solid" look, we decided to design a solid insert with the same color and grille as the MILO/MILO 120s - the MILO 120-I insert. As part of the product development process, we started a research investigation into the acoustic effects of the insert; for good measure, we also duplicated our previous cavity measurements and analysis using two arrayed UPAs - confirming or refuting the results of those earlier experiments.

More Power = Better Understanding

A significant advance in our theoretical understanding comes from a computational acoustics software package called SYSNOISE ™. This software package computes three-dimensional acoustic predictions using a mathematical technique called the Boundary Element Method, or BEM. BEM can compute accurate near-field and far-field effects of three-dimensional sound radiation, diffraction and resonances caused by sound waves propagating around and between complex, solid objects. By modeling the three-dimensional geometry of splayed loudspeaker cabinets in SYSNOISE, it is possible to calculate the expected effect of a cavity insert. These theoretical predictions were then verified by careful outdoor free-field measurements.

Research Procedures

The following 12 figures present our research into the effects of the cavity between two MILO 120 loudspeakers, as well as the cavity effect between standard MILO cabinets with MVE Vertical Extension Bars (also known as "balcony bars"), M3D line array loudspeakers at maximum splay, and UPAs at 80 degrees of splay. Figures 3, 5, 6 and 9 do not show the frequency response of the indicated configuration with the cavity filled or the response with the cavity unfilled, but the difference between the filled and unfilled responses. Viewing this deviation between the responses makes it easy to grasp the effect of filling the cavity on the array's response. Since we are investigating resonances that occur below 500 Hz, we did not model the mid-high and high frequency horn sections of MILO 120. For the same reason, it is not necessary to differentiate between narrow and wide coverage versions of the UPA and CQ loudspeakers.

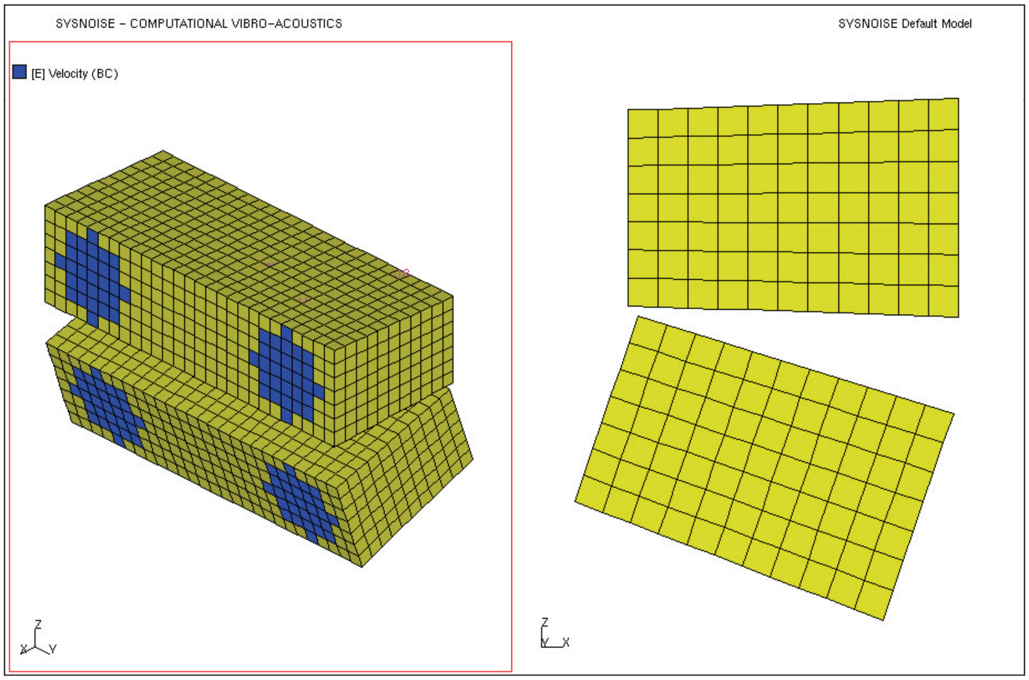


Figure 1 shows a SYSNOISE model mesh of two MILO 120 cabinets. In this figure, the front and side view are shown, and the blue mesh squares represent the velocity boundary conditions that correspond to the two 12 inch drivers.

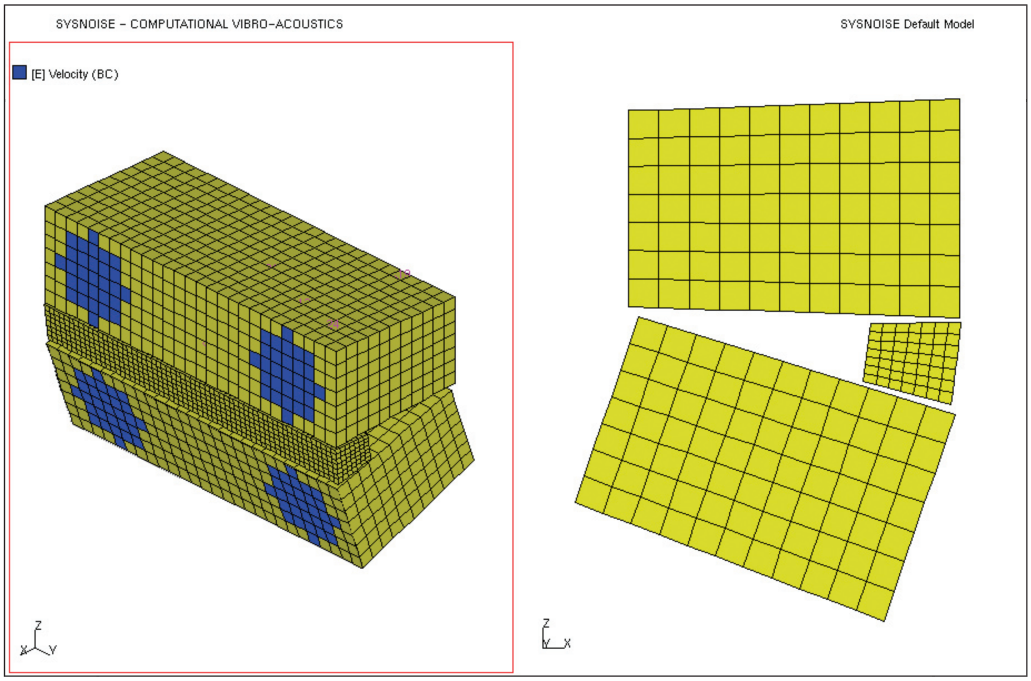


Figure 2 shows the same two MILO 120 cabinets, but now with the MILO 120-I insert.

BEM can calculate the pressure response of the four 12 inch drivers anywhere in three dimensional space. However, since BEM is a frequency domain model, each frequency is solved separately, requiring 5-15 minutes of number crunching per solution.

The frequency response plot in Figure 3 took over two days to compute—the main reason why loudspeaker modeling programs such as Meyer Sound MAPP Online® use simpler (but still very accurate) far-field models rather than BEM.

The agreement between the measured and the theoretical prediction is very good. Note, however, that the measured resonance is not as deep as the SYSNOISE theoretical prediction. This phenomena is no surprise—since SYSNOISE assumes perfect transducers and reflections, it tends to overestimate the

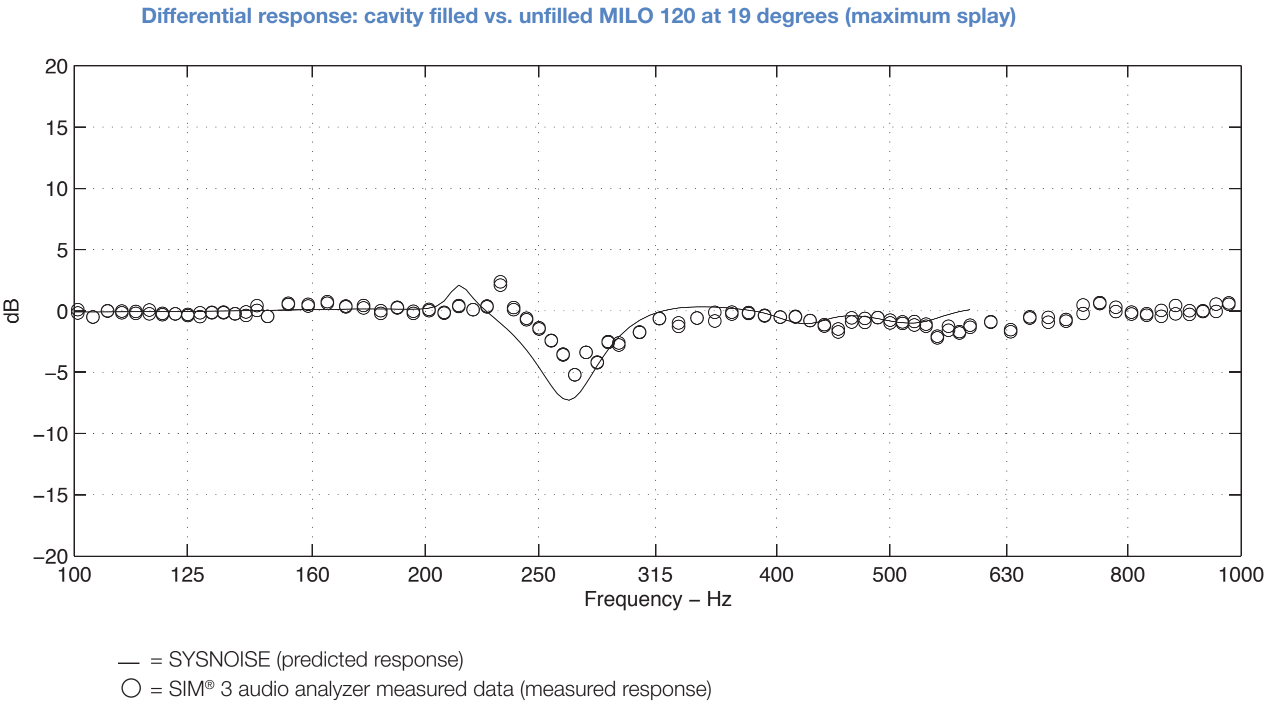


Figure 3

Figure 3 shows a 4-meter on-axis normalized magnitude frequency response plot of the acoustic pressure difference between the filled and unfilled cavity configurations. The SYSNOISE theoretical prediction shows a narrow (0.13 octave) 7 dB resonant dip at 266 Hz. The circles on the plot show actual free-field (outdoor) measured data. Essentially, we performed the exact same experiment as in SYSNOISE, but with two physical MILO 120 cabinets and a MILO 120-I insert.

measured results. The measured results show approximately a 5 dB resonant dip, which is 2 dB less than the SYSNOISE theoretical prediction.

There are a few other issues to keep in mind when looking at Figure 3:

- The frequency response is normalized, so we are only looking at the magnitude difference between the two MILO 120 cabinets with and without the insert. The figure does not show the raw frequency response of a MILO 120.

- While there is a measured difference between having and not having the insert, this frequency range is exactly where the low frequency build-up of curvilinear arrays occurs (for more information, see "User-Defined Equalization Curves with the LD-3"[1] and the IOA paper "Comparison of the Directional Point Source Model and BEM Model for Arrayed Loudspeakers"[2]. For instance, by deploying Meyer Sound's LD-3 compensating line driver and adjusting the "Array Correction" section, an array of MILO 120s with MILO 120-I inserts can be equalized by using a slightly different number of MILO cabinets versus the number of cabinets that would normally be dialed in for an array of MILO 120s without the insert.

- In a real-world situation, the effects of ground and other reflections, and of room resonances, are likely to have a larger effect than that of the insert, which only impacts a very narrow frequency range.

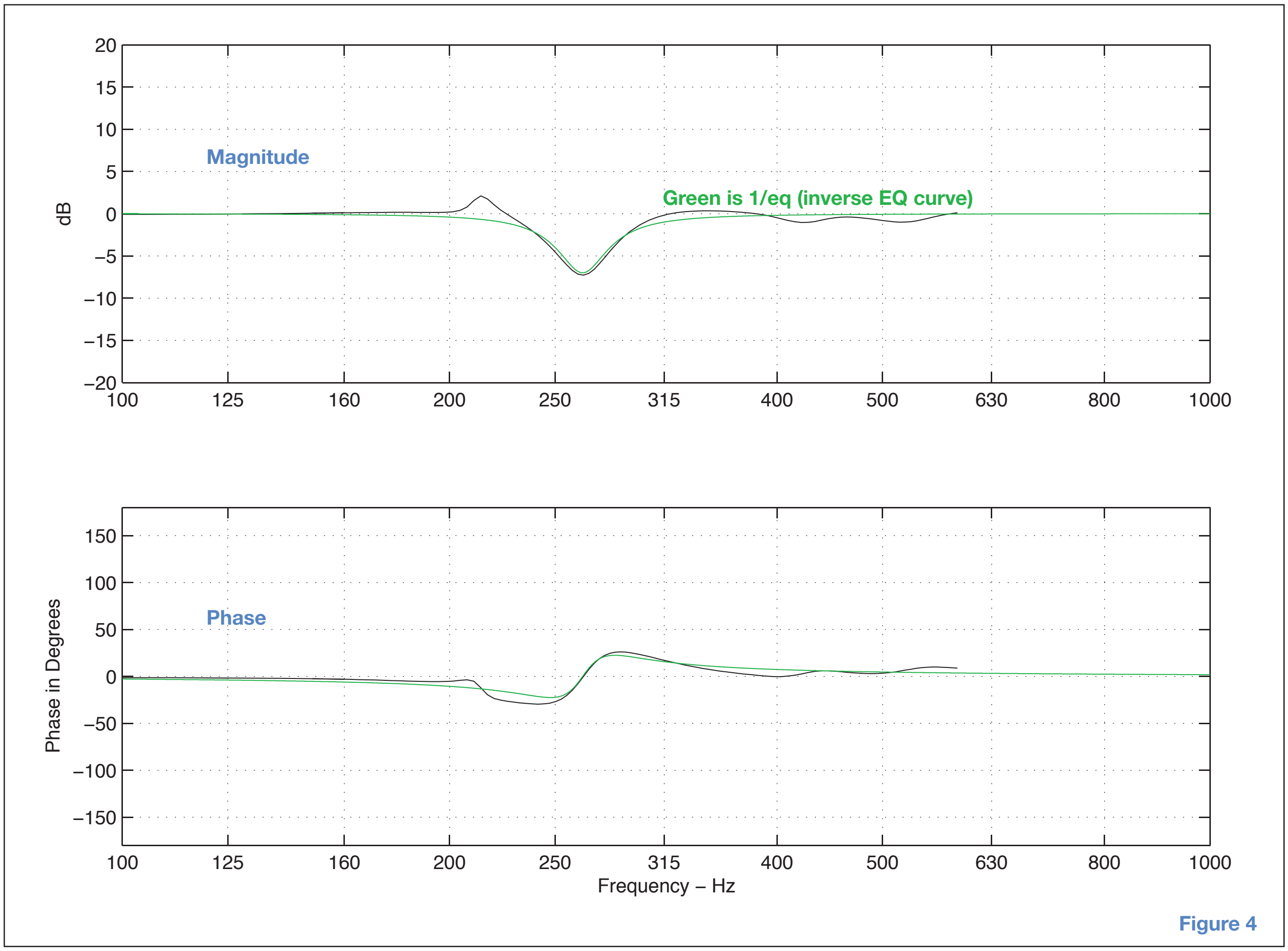
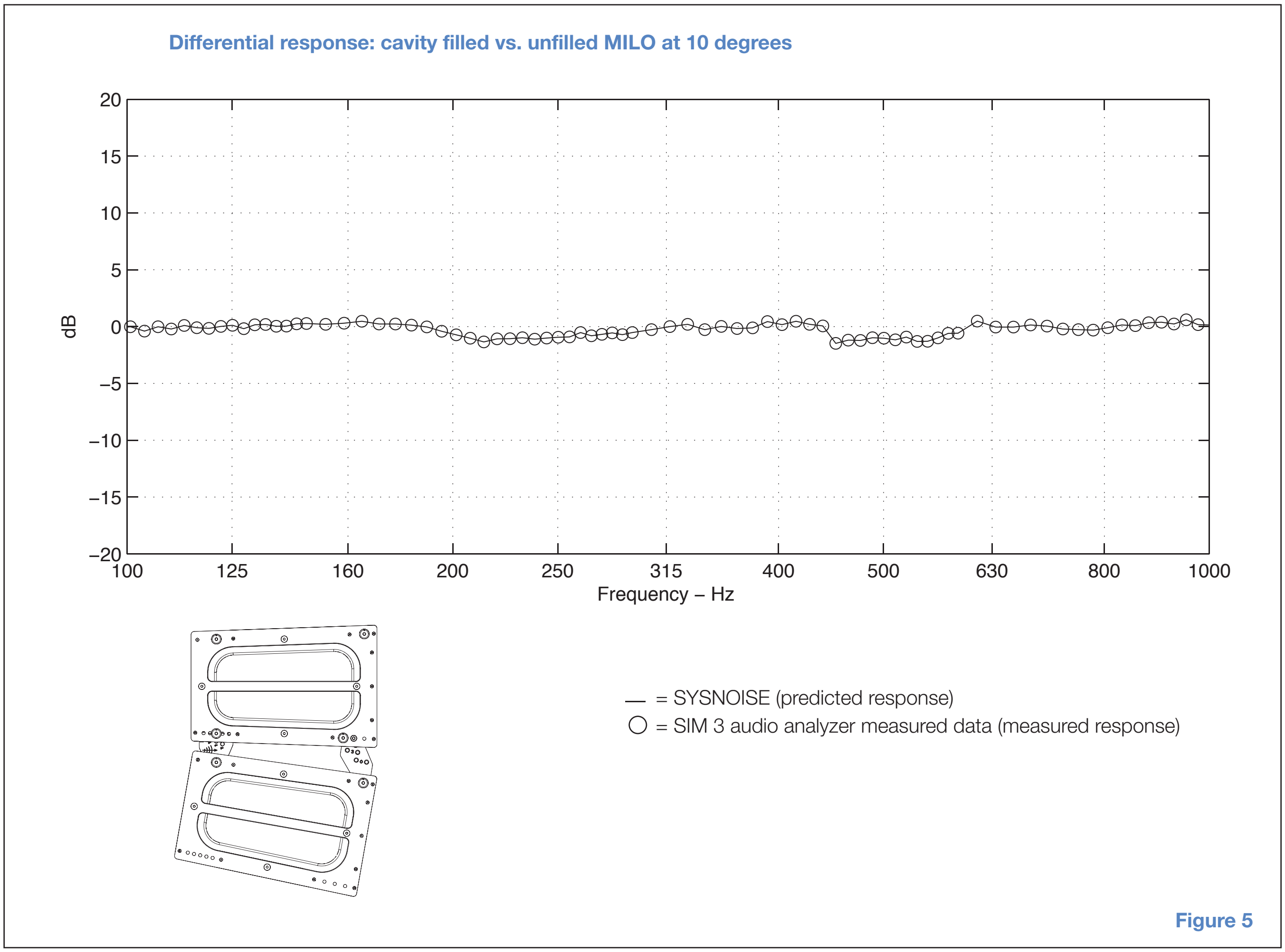


Figure 4 points out another feature of this cavity resonance.

The top panel in figure 4 shows the normalized magnitude of the cavity resonance; the lower panel shows the phase difference of the resonance.The green trace shows a single 2nd Order Parametric EQ filter (CP-10). Note that the magnitude and phase of the CP-10 filter match the cavity resonance almost exactly. This means that the effect of the resonance difference can be equalized using a SIM 3 measurement system and parametric filters.



Using careful outdoor SIM 3 measurements, Figure 5 shows the effects of filling the cavity between two standard MILOs arrayed at 10 degrees with MVE bars.

The figure shows that this rigging option creates a shallow triangular cavity between the two MILOs. The normalized magnitude frequency difference plot shows that there is little effect due to filling this cavity versus leaving it open; in any real situation, reflections and resonances from the room itself will swamp this 2 dB measured difference.

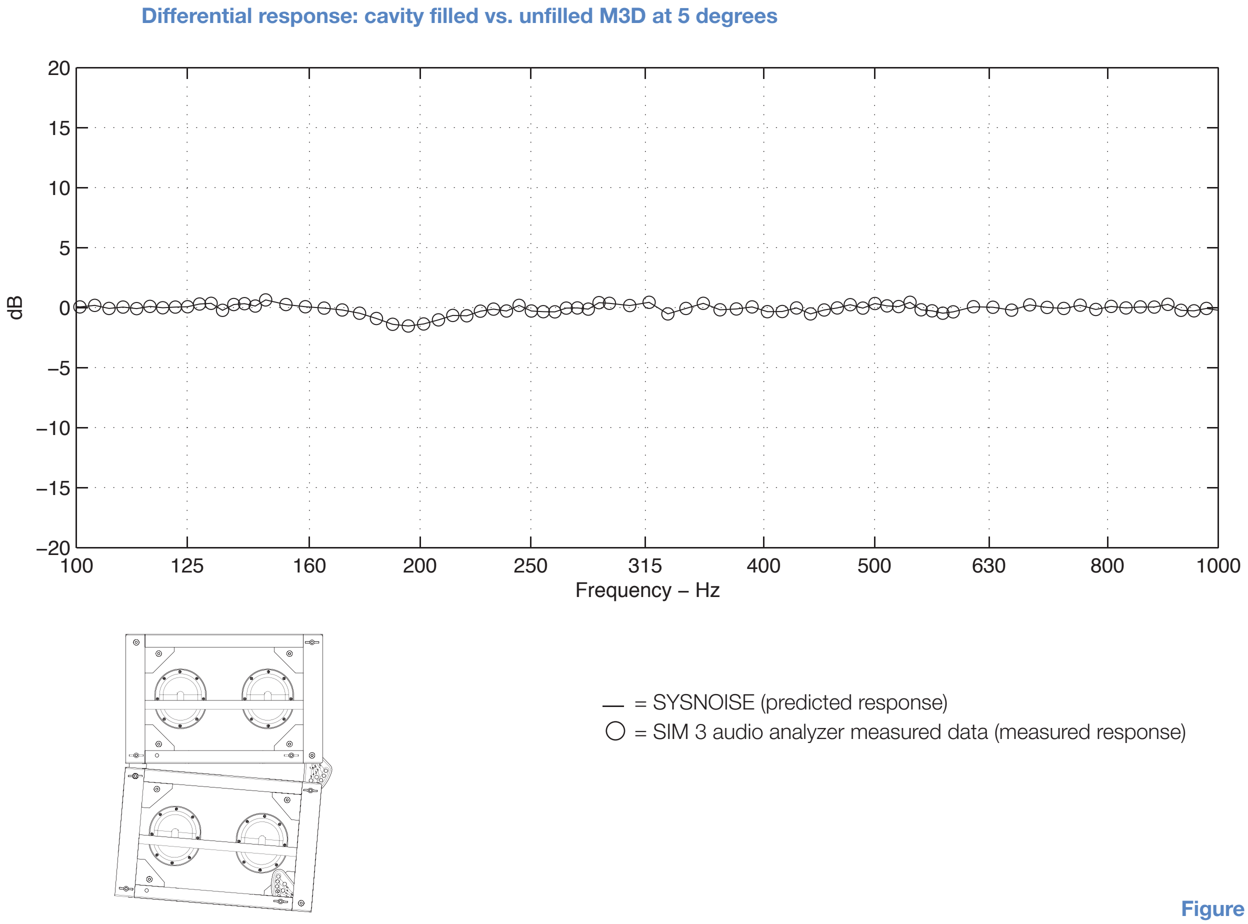


Figure 6

Similarly, figure 6 shows the small cavity formed when two (rectangular) M3D cabinets are splayed at the maximum 5 degrees allowed by the captive rigging.

Once again, the magnitude difference between filling this cavity and leaving it open is negligible.

In our previous report on cavity resonance, we concluded that for UPAs, CQs and MSL-4s, the effect of cavity resonances was minimal, based on careful free-field measurements. With our new computational tools, we decided to look back at this research and see what a new analysis would show.

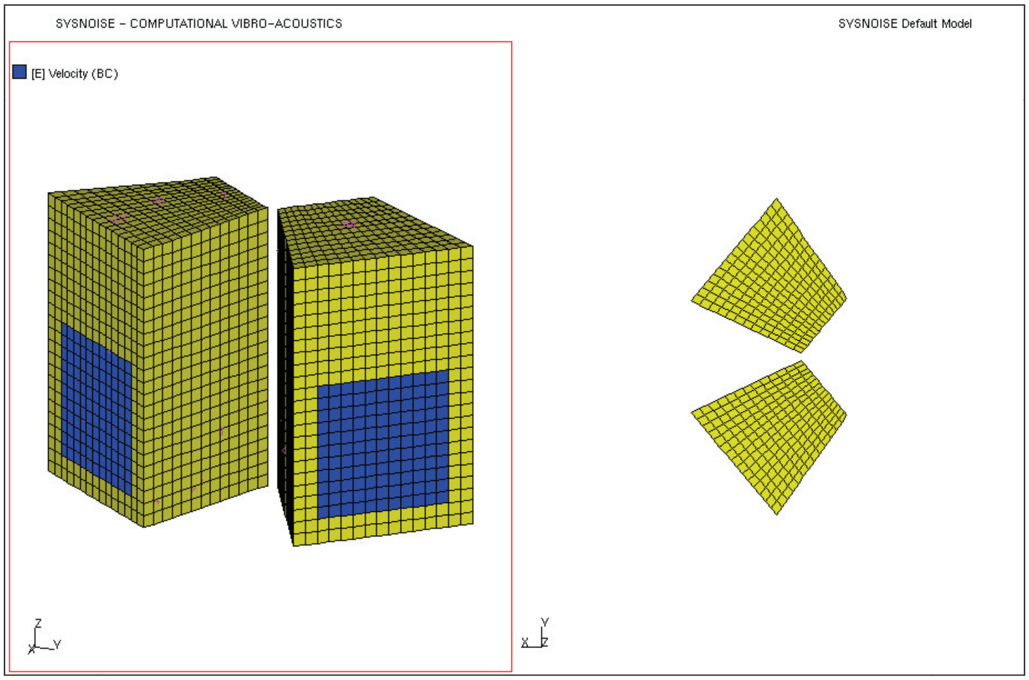


Figure 7

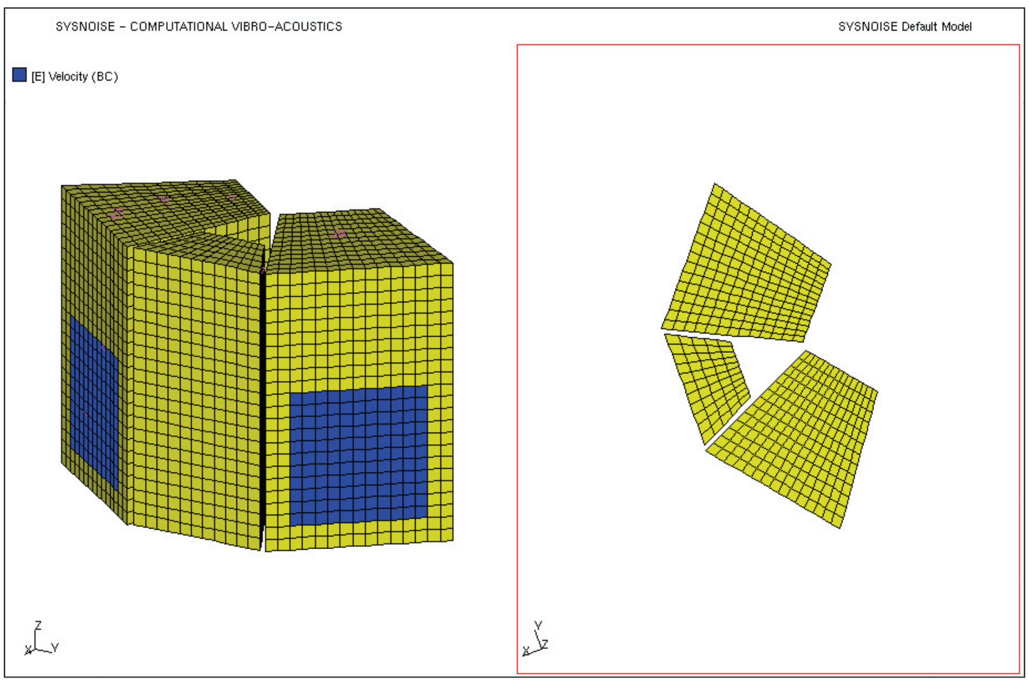


Figure 8

Figures 7 and 8 show the SYSNOISE mesh setup of two UPA's splayed with 80 degrees total spread between them. This is an extreme case of splaying, and the largest splay angle we recommend. As before, since we are only interested in low-frequency resonances, we do not need to model the high-frequency horn.

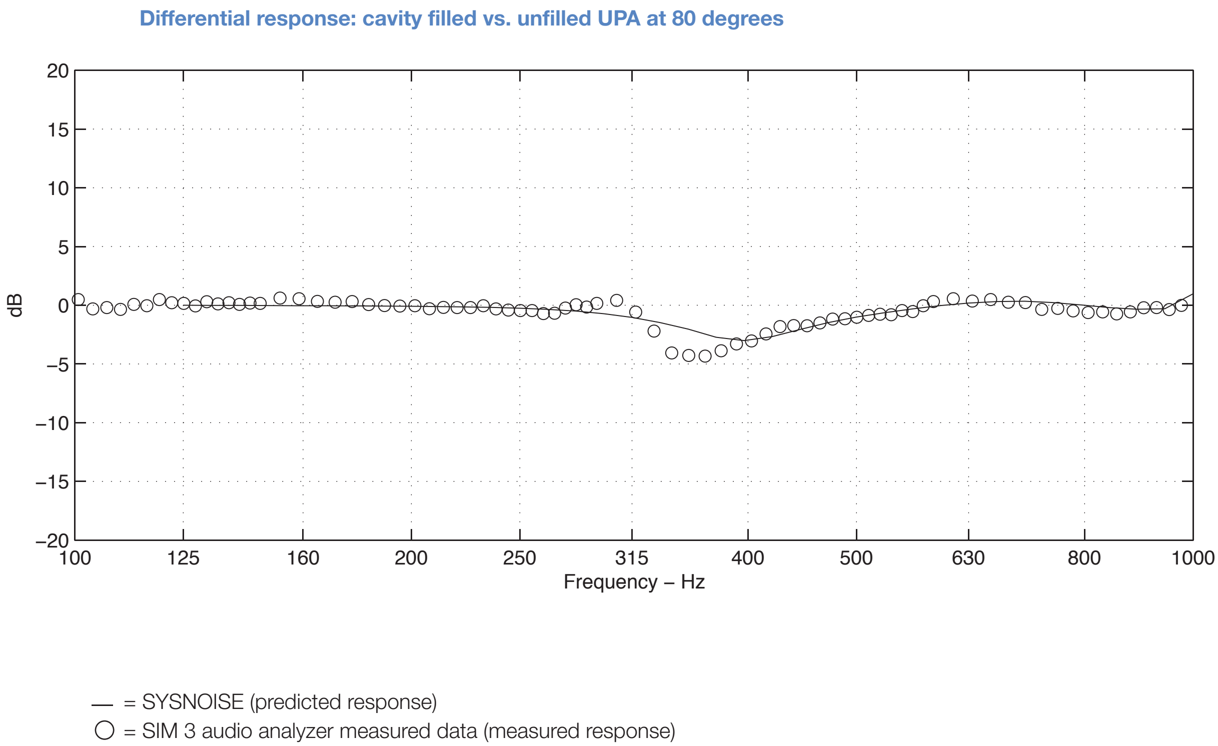


Figure 9

Figure 9 shows the normalized frequency response.

The smaller resonant effect has moved up in frequency and is shallower than with the MILO 120s. Since this is the largest splay angle recommended, it is a worst case scenario. Thus, UPAs (or other small trapezoidal cabinets) splayed at smaller angles would show even less of an effect. This confirms previous conclusions that the these effects are very small—particularly when acoustic resonances and reflections caused by the room itself are factored in.

Further Research Results

The next three figures show our continued investigation into the effects of the cavity resonance between MILO 120 cabinets, contrasting effects with and without an insert against those resulting from the use of a flat plate to block the cavity.

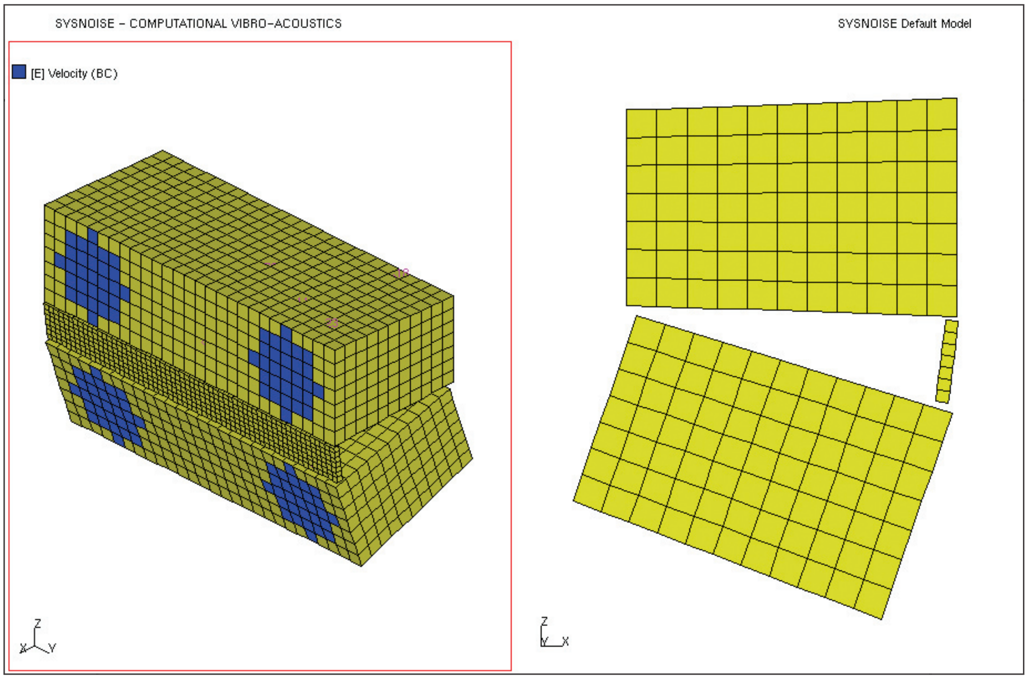


Figure 10 shows a SYSNOISE BEM mesh that, instead of filling the cavity with an insert, blocks the cavity with a flat plate—leaving the sides open.

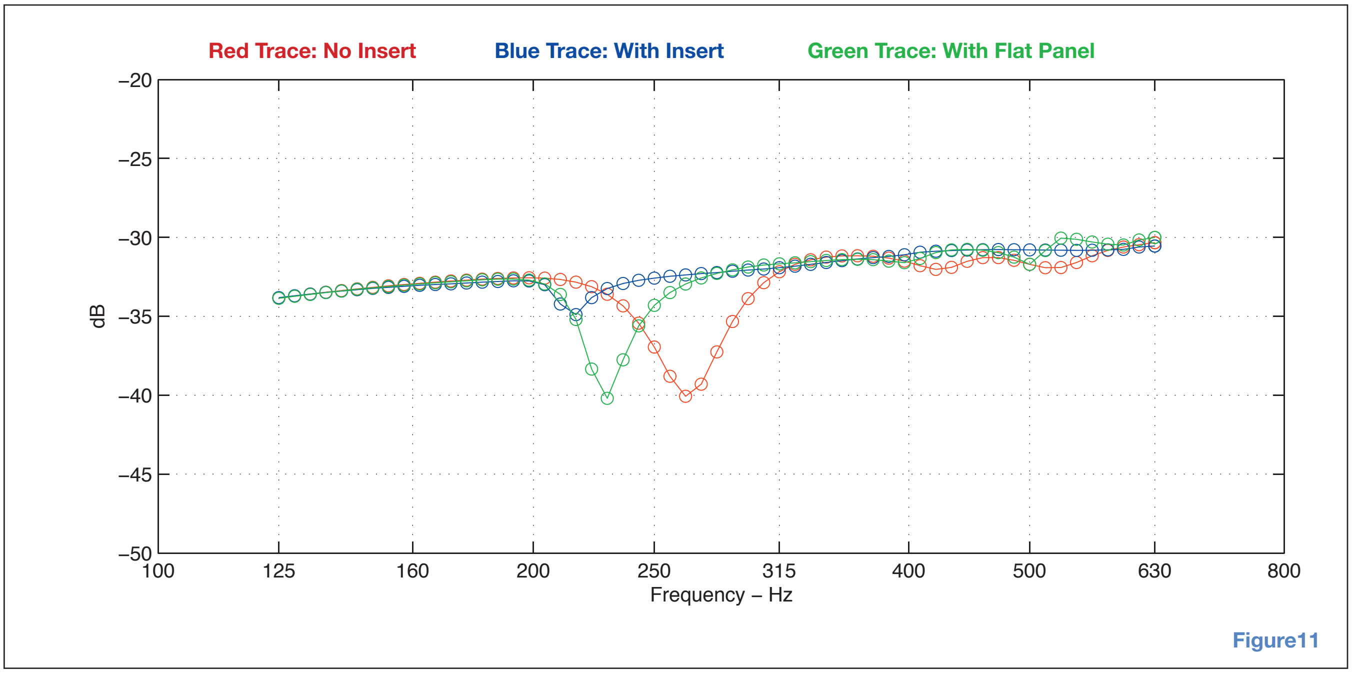


Figure 11 shows the SYSNOISE theoretical predictions. The red trace corresponds to the setup of our earlier Figure 1 (no insert); the blue trace shows the predicted frequency response of the setup of Figure 2 (with insert); the green trace shows the predicted frequency response of the flat panel blocking the cavity.

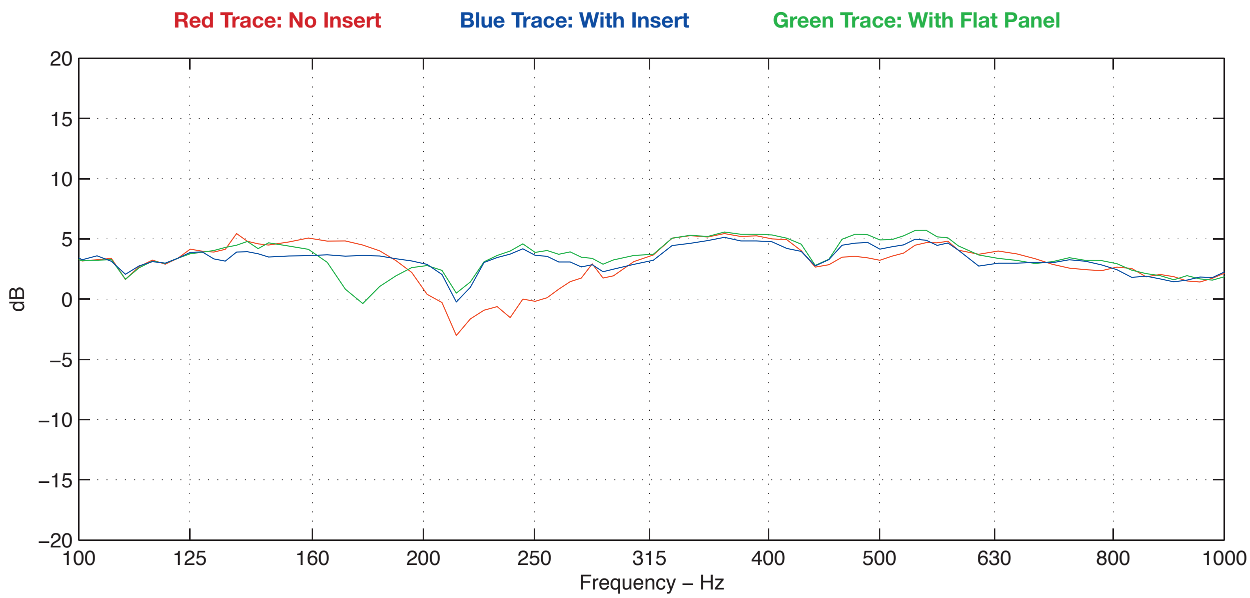


Figure 12

Figure 12 shows careful outdoor SIM 3 measurements using the same physical setup as the SYSNOISE model setup. As before, the "smoothest" response uses the insert. However, the different cavity resonance center frequency between the red trace and the green trace is very interesting. Note that with these measurements we can clearly see the front panel causing the center frequency of the resonance to decrease. This excellent correlation between theoretical prediction and experimental data gives us a high degree of confidence that the SYSNOISE BEM model is capturing the relevant acoustical physics of cabinet diffraction and scattering.

MILO 120 Acoustical Predictions Using MAPP Online

As the preceding discussion makes clear, BEM is a powerful numerical method for predicting the interactions of sound waves with complex geometries and cavities. However, BEM is computationally expensive, taking approximately 48 hours to produce the frequency response data used in this report. For this reason, MAPP Online uses another accurate, yet faster, far-field model of acoustic interaction, described in the IOA paper "Comparison of the Directional Point Source Model and BEM Model for Arrayed Loudspeakers"[1]. This far-field model is unable to model the effects of near-field cavities or cavities filled with solid inserts, however, as this paper has shown, the effect of this cavity is small (≈ 5 dB). In addition, other research we have conducted has shown that the difference between the far-field model and actual measurements is also small - usually on the order of 3 dB to 4 dB in a narrow frequency band where the mutual baffling of the cabinets causes the model to differ slightly. In a previous paper ("MAPP Online Low Frequency Polar Acquisition"[3]), we explained how we collect accurate low-frequency polar data for Meyer Sound loudspeakers using a combination of BEM calculations and accurate half-space measurements. This combination creates polar data that, in conjunction with the MAPP Online far-field model, produces predictions that are theoretically closer to an array with solid inserts. To verify this, we set up two MILO 120s in the Meyer Sound anechoic chamber and measured the system with and without the MILO 120-I insert. We then compared these frequency response measurements to the ones predicted by MAPP Online. The MAPP Online predictions were closer to the measured frequency responses of the MILO 120 system with the MILO 120-I insert, as expected.

Conclusions

The MILO 120-I insert improves the acoustic response of arrayed MILO 120s (and MILO 120s used as downfill under standard MILOs). Without the MILO 120-I insert, at maximum splay there is a narrow-Q 5 dB resonant dip at 260 Hz. Both theoretical SYSNOISE Boundary Element Method predictions and careful outdoor measurements confirm the slight acoustic improvement that the MILO 120-I provides. The resonant dip is minimum phase; it can be measured with a SIM 3 analyzer and equalized with CP-10 complementary phase parametric filters if the MILO 120-I insert is not used. This resonant dip (at 260 Hz) is exactly where all the M Series arrays have appreciable array gain (where the LD-3 is commonly cutting 10-15 dB). Without the

MILO 120-I, customers should make use of less low-mid cut as described in User-Defined Equalization Curves with the LD-3.

In addition:

- Two standard MILOs splayed at 10 degrees with the MVE Bars (Balcony Bars) show almost no acoustic difference when the cavity is filled in or left open in careful outdoor measurements.
- Two M3Ds at maximum splay show almost no acoustic differences between the cavity filled in or left open in careful outdoor measurements.
- Two UPAs with insert and without insert show very little acoustic difference (4 dB), even at 80 degree splay, in both SYSNOISE theoretical predictions and careful outdoor measurements. Since 80 degrees is the maximum recommended angle between either the UPA or CQ, there will be almost no acoustic difference between arrays of CQs, UPAs and other loudspeakers at smaller splay angles.
- When MAPP Online is used to predict the acoustic response of a MILO 120 system, the resultant predictions are the same as if MILO 120-I inserts were used.

Papers Referenced

1. User-Defined Equalization Curves with the LD-3
   http:// www.meyersound.com/ld-3_paper (700k PDF)

2. IOA paper Comparison of the Directional Point Source Model and BEM Model for Arrayed Loudspeakers
   http:// www.meyersound.com/point_source (2.4Mb PDF)

3. MAPP Online Low Frequency Polar Acquisition
   http:// www.meyersound.com/polar_data_report (3Mb PDF)

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