An Improved Loudspeaker Frequency Response by Using a Structure of Rigid Absorptive Panel in a Vented Cabinet

B. Riccardo[1]

[1]Community Professional Loudspeakers, Chester, PA, USA
rbalistreri@communitypro.com

Abstract: When placing a loudspeaker in a cabinet, standing waves inside the cabinet affect the frequency response with ripples. This peaks and dips due to pressure cancellation inside the cabinet have an effect on the diaphragm displacement and generating sound out from the vents. At those frequencies, if it was in a condition of total absorption of the sound waves at the back of the diaphragm, the transducer would otherwise have a much smoother response. The solution of placing sound absorbent material inside the cabinet to reduce standing waves makes the volume of the cabinet appear bigger, but the outcome of too much damping material inside the cabinet can cause a loss in performance at the low frequency response when the transducer is actually designed for a given box volume.
This paper explores, through simulation in the COMSOL Multiphysics® software, how, by using rigid panels of absorbent material, and their optimized placement, achieve a smoother frequency response without losing bass performance.

Keywords: Loudspeakers, Sound Absorption, Standing Waves, Frequency Response, Vented Loudspeaker Cabinet.

1. Introduction

The cabinet purpose is to insulate the sound generated by the back side of the diaphragm from the front as they are of opposite value in terms of pressure and they have tendency to cancel in the low frequency if the driver would be i.e. used in free air. The shape of the cabinet and the material constituent the cabinet gets extremely important as well, just to give an example, parallel surfaces would maximize internal reflections and its corresponding standing waves, or choosing highly resonating construction material which would vibrate and add "coloration" to the sound of the cabinet. The issue taken in consideration here are the standing waves in the cabined that do affect the displacement of the diaphragm of the speaker driver, in fact they appear to it as pressure buildup at the back of the cone and or null nodes where pressure drops due to cancellation. As such the normal behavior of the driver (that is usually represented by its frequency response on a big baffle measured in an anechoic environment) is altered and what would be otherwise smooth translation from the electric signal to acoustic pressure is now showing peaks and dips in its response curve. In the case of vented loudspeakers in some configurations the buildup of those waves would eventually come out from the port opening and contribute to irregularities in the frequency response of the loudspeaker that can eventually be seen with the aid of this simulation tool.

1.1 Proposed Improvements

The geometry of the cabinet is chosen to have the sides shaped as a wedge, main purpose being different than improving sound quality, as more of clustering when placing more units together, it does help in the issue of standing waves anyway.

The first idea is to reduce the standing waves by getting rid of the inside reflections by means of placing absorbent material lining on the inner walls of the cabinet. As consequence of the above measure, the absorption of the waves in the cabinet reduces the sound pressure level that is actually necessary to activate the port of the cabinet to resonate with the volume to boost the low frequency response making it less efficient and alters the coupling of the driver to the volume of the cabinet that now appears increased.

1.2 Purpose of the Study

In this case the placement of rigid panels on certain locations inside the cabinet is explored to minimize standing waves, yet maintaining levels of sound pressure in the cabinets to sustain low frequency boost of the vented cabinet.

2. COMSOL implementation

The model is inspired by two existing demonstrations for the acoustic package, the “Loudspeaker Driver in a Vented Enclosure” and the “Absorptive Muffler”. There are thus two physics involved in the simulation, the Acoustic Shell interaction and Pressure Acoustics, both in the Frequency Domain.

The moving parts of the loudspeaker driver are modeled as shells and the force that drives the diaphragm is regulated by a value of voltage (V_0 set at 4 Volts in this case) that with the definition of the complex blocked impedance given for the driver regulates the driving force

$$Fe = \frac{BlV_0}{Z_b} - v \cdot \frac{(Bl)^2}{Z_b}$$

where *Bl* is the flux value the voice coil sees times its wire length, Z_b represents the above mentioned impedance of the voice coil without any mechanical displacement (void of resonances, this can be derived by simulation or in a practical way by measuring it in the operational frequency range with the driver not being magnetized or by injecting glue to the gap so that the coil is then blocked from displacing), and v is the cone velocity that is taken into consideration here as back EMF generating force.

On the Pressure Acoustic simulation, which uses a modified version of the Helmotz equation,

$$\nabla \cdot \left(-\frac{\nabla p}{\rho} \right) - \frac{\omega^2 p}{c^2 \rho} = 0$$

the rigid absorptive panels are described as Poroacoustic domains using a Delany-Bazley model. The panels have given the apparent density of the panels to be ρ_{ap}=48kg/m^3 so that the Flow Resistivity relationship from Bies and Hansen was calculated from

$$\mathrm{Rf} = \frac{3.17 \cdot 10^{-9} \cdot \rho_{ap}^{1.53}}{d_{av}^2} = 11.8\mathrm{k}\ (\mathrm{kg/m^3\ s})$$

where d_{av} is the diameter of the fibers approximated in this case to 10µm for the glass fiber as assumed similar to loose glass fiber whool.

3. Model

Half of the cabinet geometry was considered (Figure 1) and plane symmetry was utilized to simplify simulation. A domain of Air and a Perfectly Matched Layer Domain (PML) was placed on the outer region to take care of reflections of pressure waves in the domain.

Two versions were compared to show results in this paper, one without the panels and another with panels located in strategic places to eliminate some of the detrimental behavior of the cabinet. The two are compared here in the following pictures (Figure 2 and 3).

The idea behind it is to see where the response of the speaker does present strong cancellations and look at how pressure waves shows the periodicity of the standing waves in the cabinet for that frequency, then locate the panel so that those are maximally absorbed thus reducing the output dips or peaks depending on the target.

4. Conclusions

The Multiphysics capabilities show how useful such tool it can be in otherwise time consuming and guess work approach. The graph of the sensitivity (Figure 4) shows how the placing of those panels does smooth the response curve when comparing the frequency response with the model without panels (black dotted curve).

There is some evident loss in certain low frequencies (100-150Hz in the simulated, much lower in the prototypes) but the idea is that this approach opens the door to a way to find a targeted optimized solution without just filling up the cabinet with sound absorbent material.

The incongruence in the simulated behavior of the speaker versus measured on the frequency at which the loss happens is probably to be attributed to the different frequency dependent absorbent coefficient of the panel to the model and a more detailed adaptation should be attempted to the behavior of experimental data, as it happens in the range 200Hz-1.5kHz.

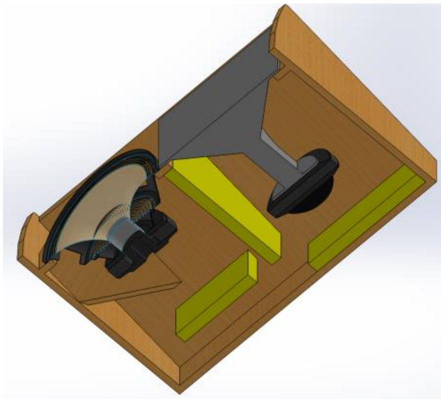

Figure 1. A section of the loudspeaker cabinet that will be used in the model.

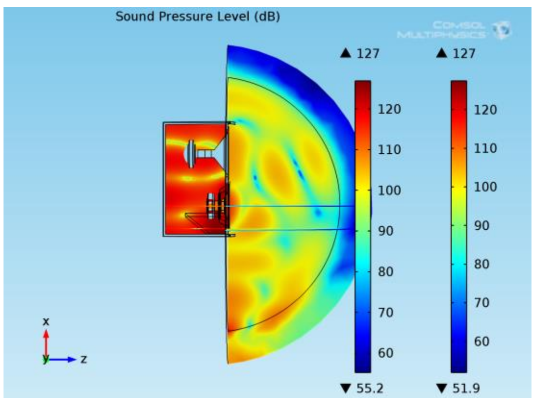

Figure 2. SPL of the speaker at a frequency of 783Hz with the cabinet not having panels.

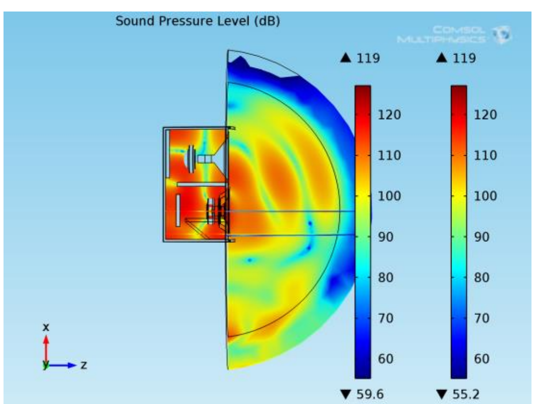

Figure 3. SPL of the speaker at same frequency but with panels.

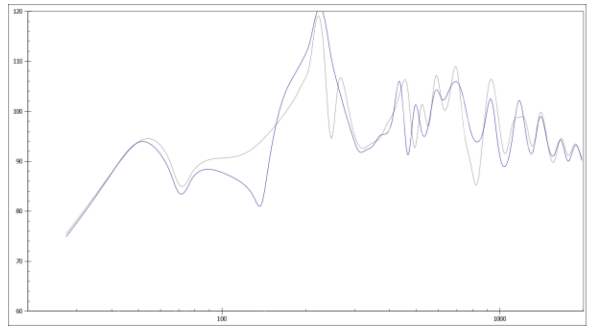

Figure 4. Simulated sensitivity graph of the speaker with panels (blue) and without (black dotted).

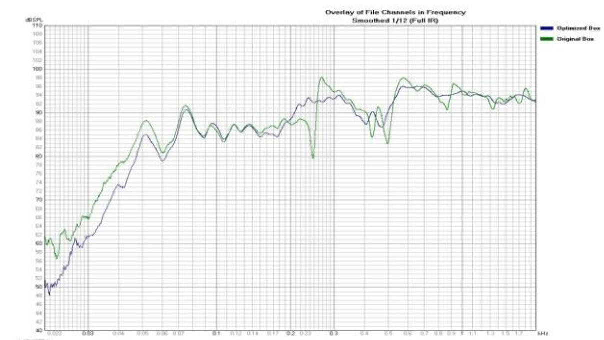

Figure 5. Measured SPL graphs of the speaker withpanels (blue) and without (red).

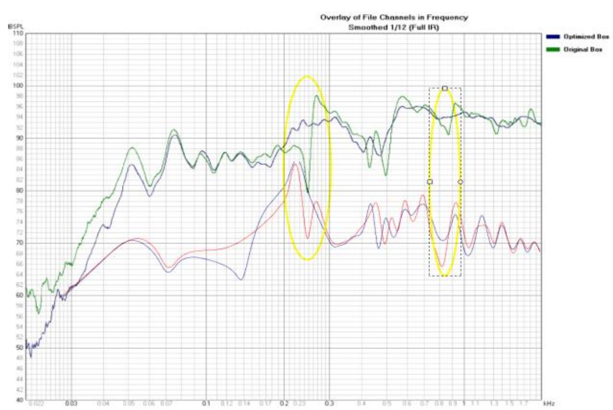

Figure 6. Measured versus simulated graphs of the speaker with highlighted areas of interest.

Note that Figure 5 was an experimental measurement not done in anechoic environment but functional for the purpose of comparing the effect of the absorptive panels in the location as simulated.

In Figure 6 measurement and simulation graphs are placed in the same plot and it is to be noted the improvement effect on the frequency response at the area correspondent to a region around 800Hz (placed in evidence with yellow and dotted rectangle) in terms of visualization the same observation can be done over the SPL emitting at the front of the speaker in the two conditions and how it is more uniformly diffusing in Figure 3 with the aid of the absorptive panels.

8. References

[1] Ovidiu Vasile / Gilbert-Rainer Gillich, Finite Element Analysis of Acoustic Pressure Levels and Transmission Loss of a Muffler, *Advances in Remote Sensing, Finite Differences and Information Security*, **ISBN: 978-1-61804-127-2**, 43-48 (2014)

[2] Support Tutorial Document, *Loudspeaker Driver in a Vented Enclosure*, COMSOL (2014)

[3] A. Neville Thiele, Loudspeakers in Vented Boxes: Part I and II, *Journal of the Audio Engineering Society*, **Vol. 19**, pp. 382-392 471-483 (1971)

[4] Richard H. Small, Vented Box Loudspeaker Systems, *Journal of the Audio Engineering Society*, **Vol. 21**, pp. 363-372 438-444 549-554 635-639 (1973)

9. Acknowledgements

The author would like to thank Bruce Howze and my supervising manager David Minton at Community Professional Loudspeakers for the patience and support, my colleague, Hadi Sumoro for experimental measurements associated to the speakers and technical support, Wei Guo and Linus Andersson for their technical support at COMSOL.