DDalFarra **Grimm Audio LS1 Design Analysis** Nov 22, 2015

Purpose: determine diffraction response of the wide Grimm LS-1 baffle to predict if it provides more "constant directivity" as claimed by Grimm.

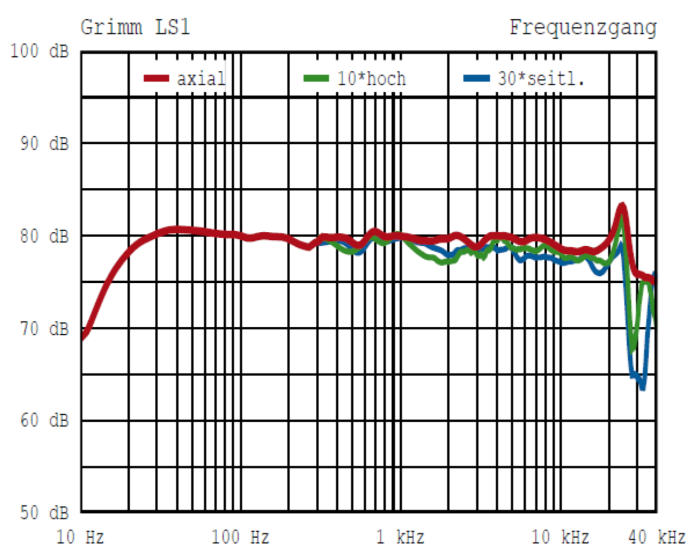
Grimm Audio LS1 Reference Studio Monitors Specifications

http://www.grimmaudio.com/pro-products/loudspeaker/ls1/

Frequency response: 55Hz-30kHz +/-0.5dB. 45Hz-40kHz -3dB (Low corner is user-settable between 35Hz and 100Hz, Q=0.7 or 0.5)
Crossover function: 1.55kHz LR4, sum corrected to minimum phase
Internal volume: 14 liters
Height: 1450mm, 1150mm available on demand
Width, depth: 520mm x 160mm
Drivers: 22cm Seas Excel and the tweeter a Seas 27mm DXT
Cabinet Volume: 14L (from Dutch review)

Design Philosophy: "What we can do is decide where to put the baffle-step frequency. Psychoacoustics tells us that below about 300Hz the ear will no longer clearly discern direct sound, first reflections or reverberant sound. Presumably the evolutionary background of this is that the vocal range starts here. Anyhow, we can live with a transition to omni below 300Hz. If we can get reasonable, constant directivity above that, we have a design spec!" "doing it right means: a single unit per "way", spaced closely together on a baffle of at least 20" wide. Now, wide baffles have a reputation of less than stellar imaging. This is because diffraction artefacts become audible as distinct reflections whereas on narrow baffles they are perceived only as colouration. The solution is simple enough: generously round off the edges"

From http://www.grimmaudio.com/site/assets/files/2737/audio_mai_2013_grimm_ls1_testbericht.pdf



Grimm LS1 Cabinet

A physical speaker wasn't available, so dimensions were estimated from a high res picture from Grimm's website. The dimensions were estimated using Paint's ruler, and normalized by the basket flange dimension of the Seas Excel 22cm driver mounted horizontally on center. Parallax and aspect ratio of the picture was very accurate based on dimensions taken off the snip

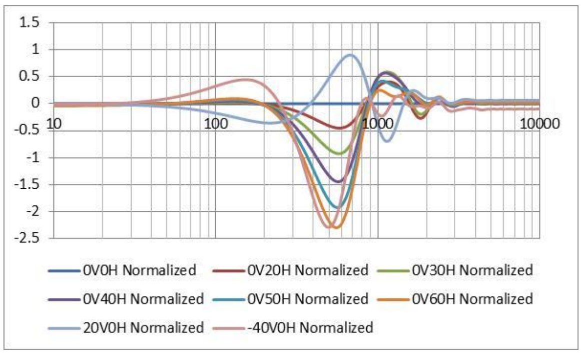
Calculating dimensions

- Reference measurement uses W22 flange: (361-69) = 292 = 220.6 mm. Scale = 0.7555 = 1 mm
- Width = 672*0.755 = 507.7 mm = 20.0"
    - advertised by Grimm = 520 mm, so there may be ~ 2% error on these estimates
- Height = 709*0.755 = 535.6 mm = 21.1"
- Side Roundover radius = 95*0.755 = 71.8 mm = 2.8"
- Bottom Roundover radius = 82*0.755 = 61.9 mm = 2.4"
- Woofer vertical center = 215*0.755 = 162.4mm from top = 6.4" (14.7" from bottom)
- Tweeter vertical center = 434*0.755 = 327.9 mm from top = 12.9" (8.2" from bottom)

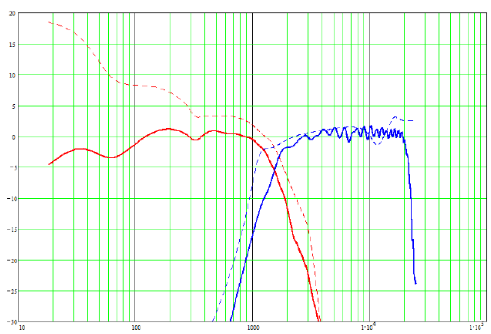
Grimm LS1 Cabinet Diffraction and Directivity Control

Woofer diffraction over horizontal and vertical angles were compared, normalized to on axis response. This simulates the response difference off axis, for flat on axis, if the native driver response can maintain it's off axis response as well. Restated, it determines how well the design can maintain constant directivity

- For this analysis, 2.5 m (8.2 feet) distance was assumed.
- Piston diameter 6.6" (220cm2). Directivity will cause less illumination of the baffle edge
- Baffle edge radius = 2.8". This will be a source of error as program assumes all edges are the same radius. LS1 bottom radius is only 2.4" and there is no top radius
- Files format "xVyH", x and y are vertical and horizontal angles, and "M" is used for minus
- Diffraction and Boundary Simulator 1.20 was used.
  - "Off axis rolloff" was not selected in simulator
- Vertical angles shown are +20deg (standing at listening location) and -40 degrees (floor bounce first reflection).



Within 30 degrees horizontal, diffraction response was +0.5, -1 dB. The native response of the W22 (see Appendix I will pull the 500 to 600Hz hole down ~ another 0.5 dB, however it should correct the baffle peak at 1 kHz, bringing that down to ~ -0.5 dB, flattening the curve. Note that the Seas driver may be custom for the LS-1, but this analysis will be quite close. At 1.55 kHz, the crossover to a tweeter in a shallow waveguide with moderately controlled directivity helps maintain flatness at 30 degrees off axis. As shown, there is very little difference in diffraction off axis above 2 kHz for such a wide baffle so the tweeter response won't be analyzed.



These outcomes correlate very well with the measured speaker responses on the first page.

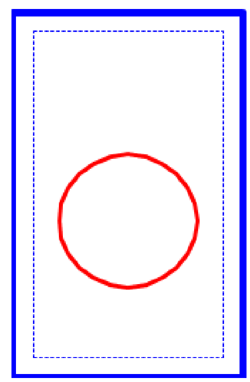
Not shown in the LS-1 review however is an anticipated ~ 5 dB dip from ~ 600Hz to 1.2 kHz at 60 degrees off axis, due to the inevitable beaming of the W22 (see Appendix I) exacerbated by ~ 1 dB greater reduction in SPL at 600 Hz (relative to 30 deg off axis), due to the change in diffraction response. A smaller driver will have less beaming, but what about the diffraction of a narrow box? Let's see!

Comparison to Standard “2 Way” Design

Does the LS-1 wider baffle and larger woofer buy any theoretical directivity control advantage compared to a standard 2 way design using 6.5” driver in a narrow enclosure? While each design has its own trade-offs, the Grimm LS-1 attempts to minimize the apparent size, within its design choices, so will be compared to a typical narrow but deep box. The Grimm cabinet is 14L, ~ 0.5 ft3. The popular Dayton Audio cabinet is used as a baseline for comparison.

http://www.parts-express.com/dayton-audio-twc-050ch-050-cu-ft-2-way-curved-speaker-cabinet-cherry--302-723

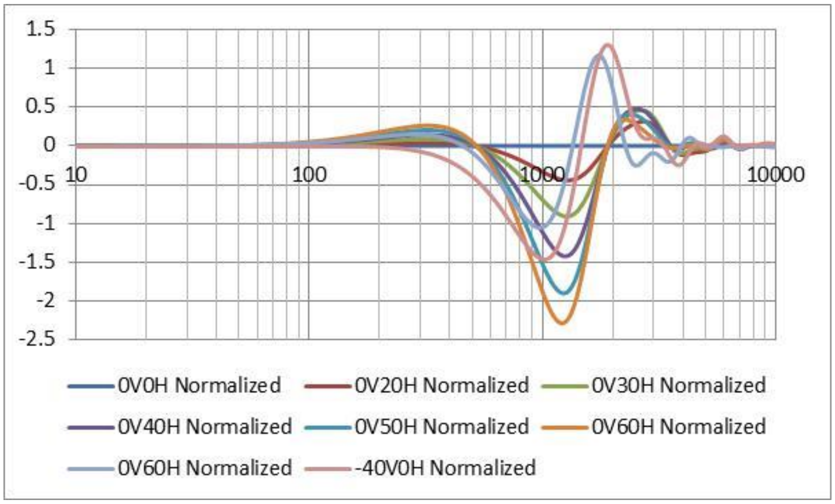
DAYTONAUDIO



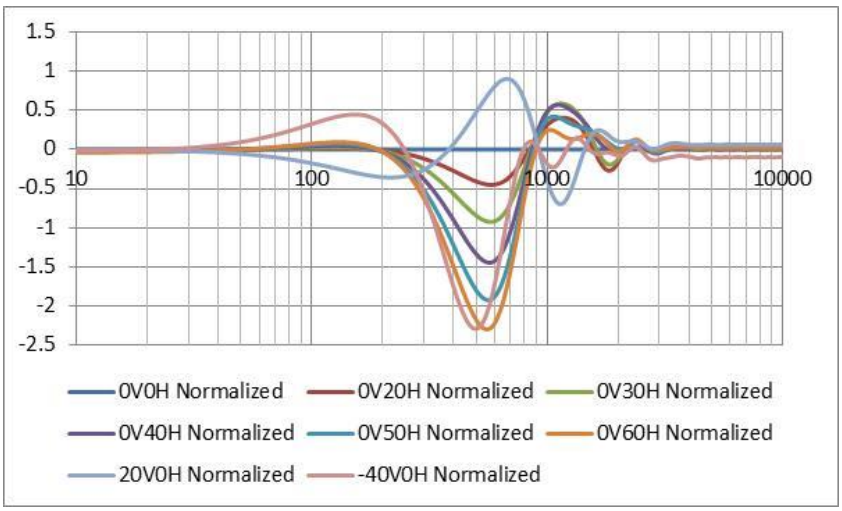
Woofer diffraction for this box was simulated, using the same parameters as the LS1 simulation but changing for

- Baffle dimensions 14" H x 8.5" W Front
- Piston diameter 5.0” (126 cm2), assuming the Seas W18E (Appendix II)
- Baffle edge radius = 0.75”
- Woofer mounted middle of cabinet horizontally, and center 6” up from bottom of cabinet

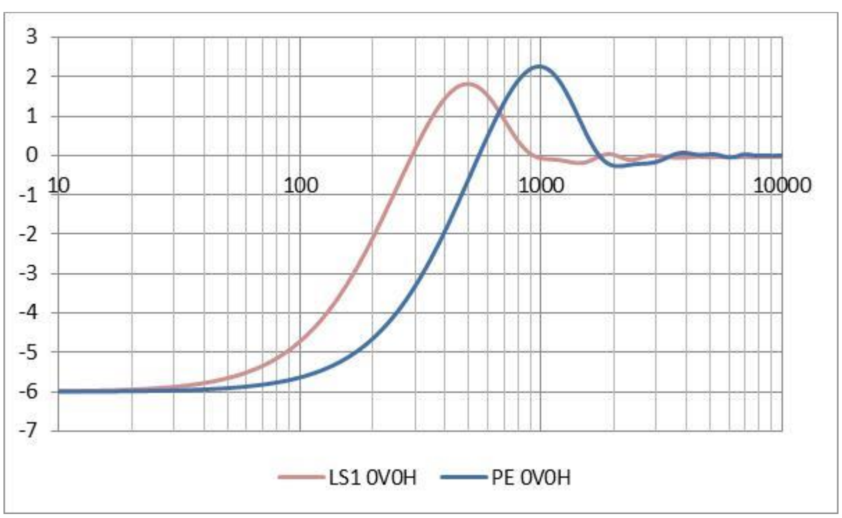
With no further ado, here's the PE box diffraction outcome, normalized to on axis:



Again for comparison, the LS-1:



And the baseline on-axis diffraction simulations:



<u>Observations</u>

Improvements provided by the LS-1 design philosophy:

- ~ 0.5 dB less diffraction peaking (**larger roundovers**): Less EQ required in the crossover. Note: its unknown how accurate the simulator is when compensating for roundovers, but this general conclusion holds.
- The larger baffle pushes the off axis diffraction *peak* below the crossover range, and into the range where the greater directivity of the larger driver reduces it (**larger baffle, larger driver**). This is probably one of the largest benefits of the large baffle/large woofer design. A large baffle, small driver will not exhibit the same benefits.
- The response differences off axis relative to on axis are pushed further below the critical mid-range, and may be less audible and less bothersome. They are also pushed into the transition region closer to where the room modal response dominates timbre, and so the notches may become less audible only because they are in a region where the room's own peaks and dips are becoming more audible.
- The larger woofer has the potential to potentially reduce excursion related distortion.
- Unrelated to baffle size, I believe mounting the tweeter under the woofer stabilizes image height in reproduction, but this has no relation to baffle width or driver size.

Drawbacks from the LS-1 Design philosophy:

- The larger baffle pushes the off axis diffraction *null* out of the crossover range, and into the range where the wider dispersion of the tweeter can't help to fill it in (**larger baffle**).
- The larger driver results in greater off axis holes from 600Hz to 1.2 kHz. While the diffraction hole depth is same (relative to on axis) of a narrow cabinet, the larger driver has more beaming (**larger driver)** (see Appendices).

<u>Conclusions:</u>

The LS-1 is a carefully designed system where the baffle width was chosen to counteract the specific driver's change in response off axis out to 30 degrees, leading to greater flatness within a 30 degree listening window. Since the design is optimized for near field recording, this is staple requirement. The trade-offs are larger off axis nulls due to the larger woofer. However

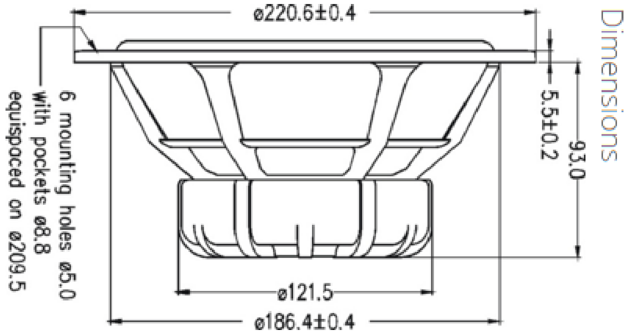
- The wider baffle decreases the off axis response from 200 to 700 Hz by ~ 3 dB, relative to the standard narrow baffle. Stated another way, equalized to flat on axis, the LS-1 (or other large baffle designs) will have up to (the full spherical diffraction would need to be calculated to arrive at an exact value) 3dB less power response in this frequency range than a narrow monitor. A speaker with excess 600Hz can sound "hollow", so this tuning will be the opposite of that (less hollow than pure accuracy?), but can also reduce the clarity of bass lines or thin outguitars.
- The similar is of course true for the narrow box. Equalized to flat on axis, the narrow monitor will have up to (same caveat for full spherical diffraction) 3dB less power response from 700Hz to 1.2 kHz than a wide baffle speaker. A speaker with less energy in this range can sound less "punchy". The 500Hz to 1KHz region produces 35% of the intelligibility, while the range from 1 to 8KHz produces just 5% of the power but 60% of the intelligibility. So the wider speaker may sound offer enhanced intelligibility.

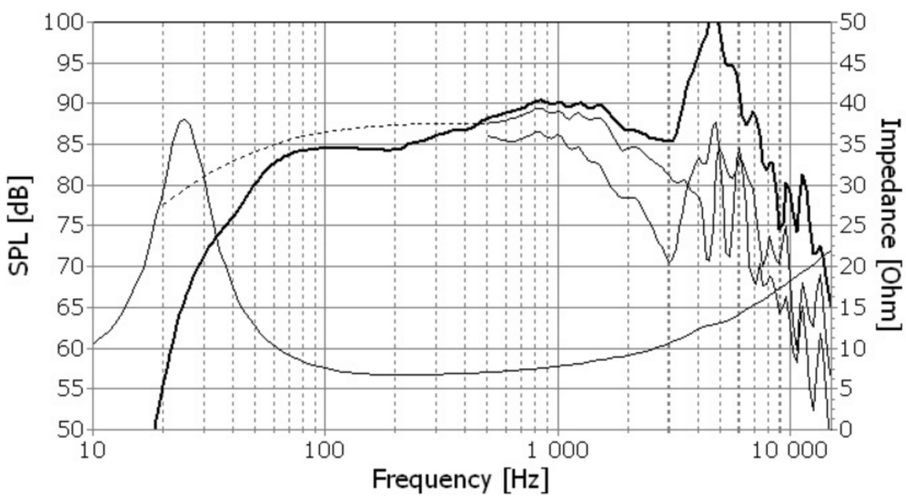
I think it is these last attributes: differences in power response; that probably most distinguishes the sound of the LS-1 relative to an equally well designed narrow monitor: it puts the power response “hole” in a different frequency range than a narrow monitor. This is akin to providing less “power” BDC while maintaining a flat on axis response.

I can see how this could be “interpreted” as more accurate. With less energy in the lower frequencies, there is less upward masking, therefore more perceived detailed.   It’s impossible to ascertain if it’s truly more accurate, as true accuracy would involve a perfect engineer capturing the live event perfectly on his recording system, and a playback system with the same on axis and directivity as the recording system.   So, is the LS-1 design or are other wide baffle systems more accurate than a narrow monitor? This is impossible to tell due to the circle of confusion. Is the LS-1 a very well-engineered loudspeaker with a relatively unique choice of trade-offs for the consumer? Definitely!

Epilogue: The LS-1 design brief on the Grimm Audio web site contains a comparison of LS-1 directivity to that of a narrow M-T-M. This is misleading as it’s an apples and oranges comparison. The negative effects of the MTM under discussion were due to two woofers increasing off axis comb filtering, along with the greater diffraction presented to the tweeter by the 2 woofers vs 1 woofer. Neither of these drawbacks will be worse relative to the LS-1 for a well-designed narrow M-T.

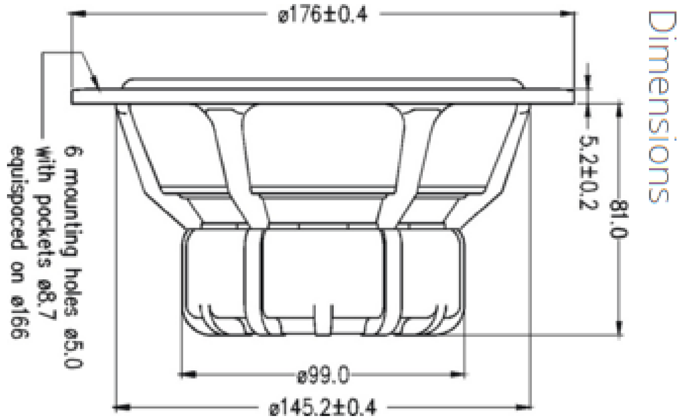
Appendix I: E0022-08S W22EX001



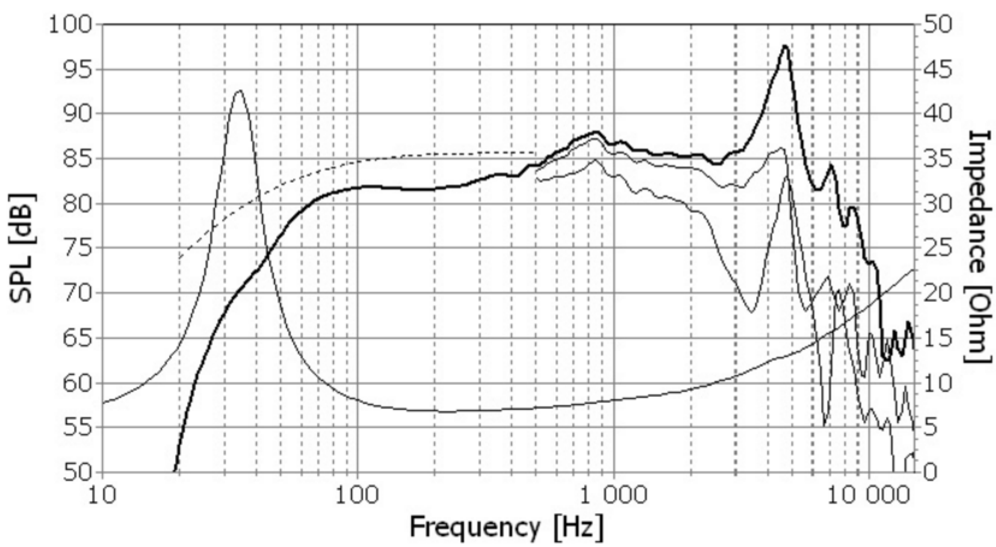


The frequency responses above show measured free field sound pressure in 0, 30, and 60 degrees angle using a 21L closed box. Input 2.83 VRMS, microphone distance 0.5m, normalized to SPL 1m.The dotted line is a calculated response in infinite baffle based on the parameters given for this specific driver.

Appendix I: E0018-08S W18E001



Frequency response



The frequency responses above show measured free fi eld sound pressure in 0, 30, and 60 degrees angle using a 12L closed box. Input 2.83 VRMS, microphone distance 0.5m, normalized to SPL 1m.The dotted line is a calculated response in infinite baffle based on the parameters given for this specifi c driver. The impedance is measured in free air without baffl e using a 2V sine signal.