Document: Compact Horn Subwoofer Technology
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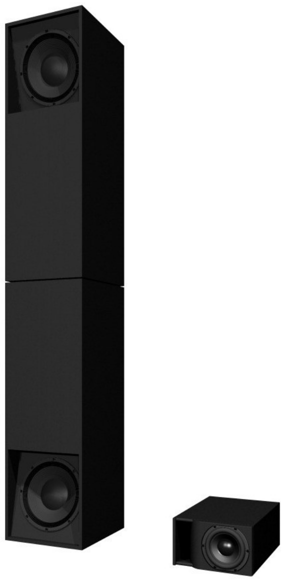

The Horn Sound in a smaller package

Increasing output capability and improving sound reproduction quality for subwoofers makes it realistic for even more music and movie enthusiasts to experience a difference that really matters – realistic low frequency reproduction.

The sound from a large bass horn system is addictive – the sense of realism, effortless impact and clean, powerful bass.

The Compact Horn Subwoofer technology introduces new methods for designing horn subwoofers with high performance in a smaller package:

- Compact rear loading horn with large rear chamber
- Additional damped channels in the horn increases usable bandwidth
- Utilize smaller and more powerful drivers
- Simulation design approach

The greater design flexibility makes it possible to design for higher output at both mid bass and lowest frequencies, in a smaller enclosure.

Compact Horn Subwoofer technology for high performance subwoofers is developed by Kvålsvoll Design.

Sound quality

It is the addictive sound that really differentiates a Compact Horn subwoofer from others. If you set up systems with conventional cabinets and Compact Horn subwoofers to compare, you will experience that the sound is different even when the systems are equalized to the same frequency response.

Type of enclosure is not a property that defines sound quality, it is the resulting frequency response, and nonlinear distortion and compression, in combination with acoustic coupling characteristics, that describes fully how it sounds. It is the execution of the design that matters, and the Compact Horn Subwoofer technology is a tool that gives greater flexibility in the design process.

However, the inherent nature of a horn loaded bass speaker automatically gives improved dynamics and better coupling to the room. The sound character from a Compact Horn bass system is something different - airy, tight, dynamic bass, with that sense of powerful sound even at lower listening volumes.

The Compact Horn Subwoofer technology gives flat response across a wide frequency range, together with the advantages of horn loading. This means lower distortion and none of the coloration often associated with horns.

Horn loading is very different from a simple closed box. In a horn the driver is acoustically loaded, in such a way that it is the force exerted by the drivers motor that makes the sound, rather than in a sealed box where it is the movement of the diaphragm that makes the sound. This difference is a major cause for the experienced differences in sound.

So, even though frequency response may be similar to an equalized closed-box system, there will be differences in transient behavior, phase response, dynamic non-linearity and acoustic coupling impedance that causes different sound characters.

Horn loading

Horn loading increases efficiency and output, but unfortunately requires a very large enclosure. Making the horn smaller is possible, but will lead to problems with resonances and uneven frequency response due to mismatch of the acoustic loading of the driver and radiation at the horn mouth.

At the lower end of the frequency band, an even response can be achieved by adjusting the rear chamber volume and the horn parameters to match the driver. If the rear chamber is made large, and the horn is made small compared to the wavelength, it will be a Helmholtz resonator – an ordinary vented box. Actually, it is apparent that there is no clear distinction between the system model for a horn and a vented box, it is the same physics at play, it is just that the acoustic loading changes as the enclosure changes from a large full-size horn all the way down to a small vented box.

Higher up in frequency there will be resonances and uneven response at the horn channels ½, ¾, 1/1 and-so-on wavelengths resonances. These can be removed or reduced by using different methods. Placing the driver at an offset lengthwise distance from the throat has been seen, also placing the driver inside the mouth so that it is offset lengthwise both from the throat and the mouth. It is also possible to reduce some resonances by using tuned tubes from the rear chamber.

Obviously if the horn is made short enough to move the first resonance out of the pass-band, the problem is solved. In ordinary vented designs the port resonance can be moved up in frequency to where damping material inside the enclosure is efficient, and in a subwoofer, the port can be rather long without causing any trouble since the bandwidth is limited to around 100Hz. A horn that is not too long may be used as-is, with reduced pass-band bandwidth.

Solving the usable bandwidth problem

The Compact Horn Subwoofer technology uses an additional damped and tuned horn channel inserted at a specific position in the main horn channel. This removes the first resonance and the air volume inside the damped channel adds to the system internal volume to increase low frequency extension.

By adding a second damped channel inserted from inside the rear chamber it is possible to even reduce the next resonance, thereby further increasing the usable pass-band. This channel can actually be made as a part of the rear chamber, where the shape and damping of the chamber then determines the resulting frequency response.

The damping channel can also be made as a Helmholtz resonator, where the volume of the chamber and the port dimensions must be accurately tuned, along with acoustic damping of the port.

Dimensions and acoustic damping of the damping channels are critical and is determined by simulation.

Illustration 1: Inside the V110 Compact Horn Subwoofer. The horn path with 2 damping channels and 2 smaller damping chambers is a complex construction.

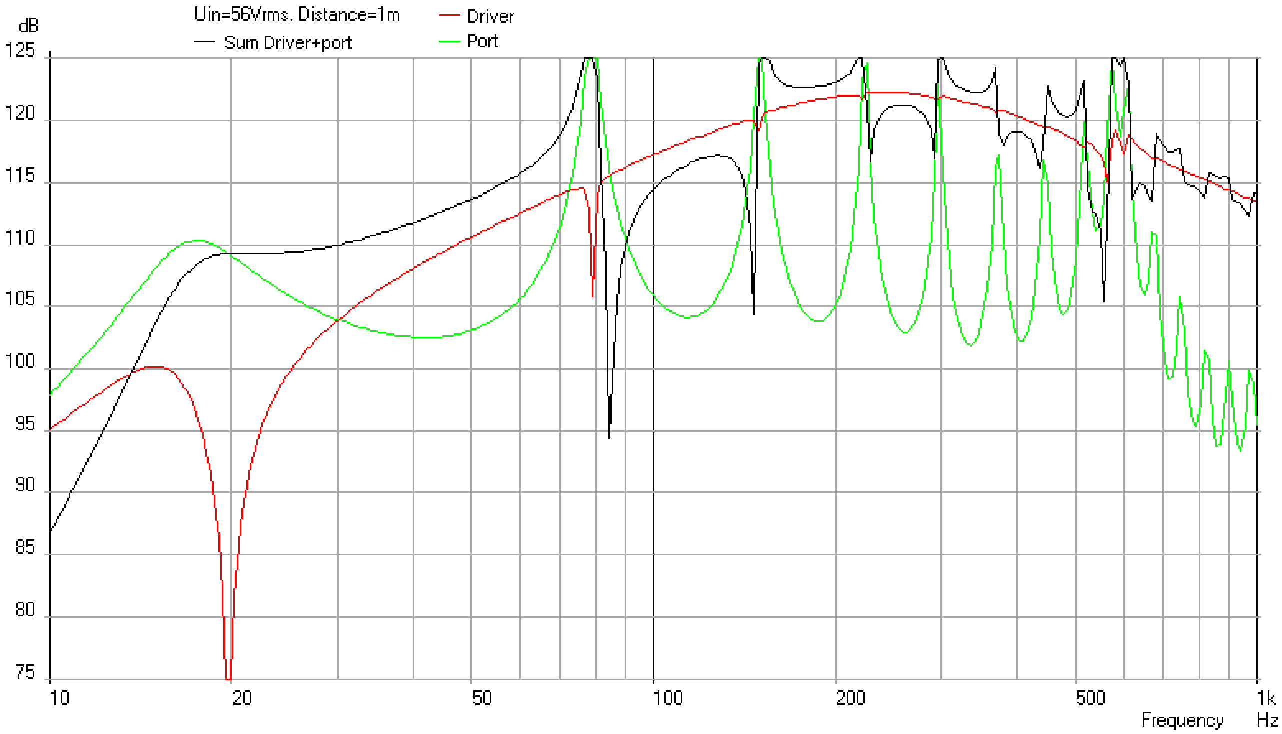

Illustration 2: Simulation of 70l small horn subwoofer showing resonance at 80Hz.

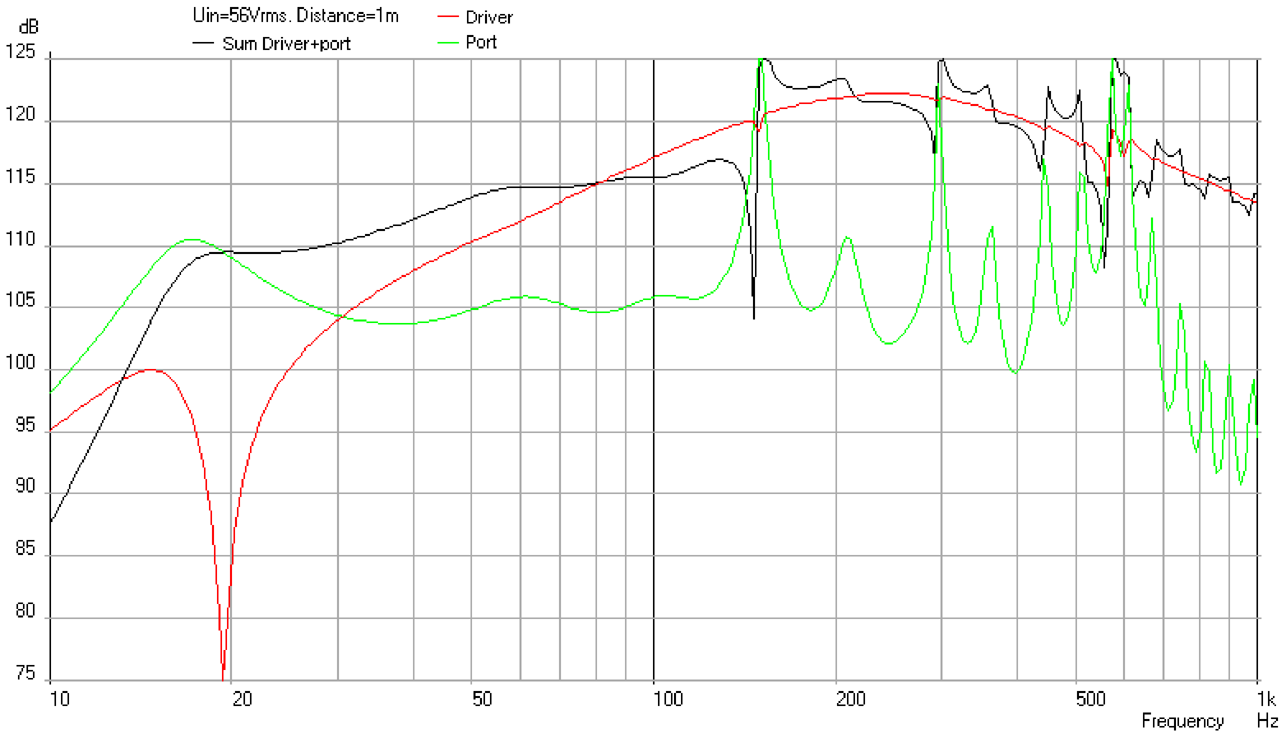

Illustration 3: Simulation of 70l Compact Horn subwoofer with tuned damping channel shows smooth response up to well above 100Hz. There is significant contribution from the port over a wide bandwidth, up to 60 - 80Hz, and the reduced driver cone excursion around 20hz makes for very usable output to below 18Hz.

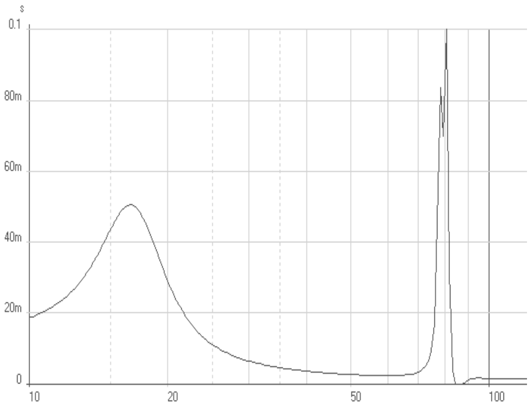

Illustration 4: Simulation group delay, 70l Compact Horn Subwoofer, no damping. Resonance at 80Hz can be observed as a peak in GD.

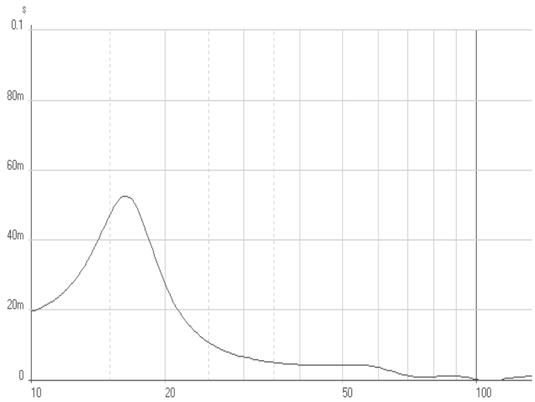

Illustration 5: Simulation group delay, 70l Compact Horn Subwoofer with damping. GD is now flat up to well above 100Hz.

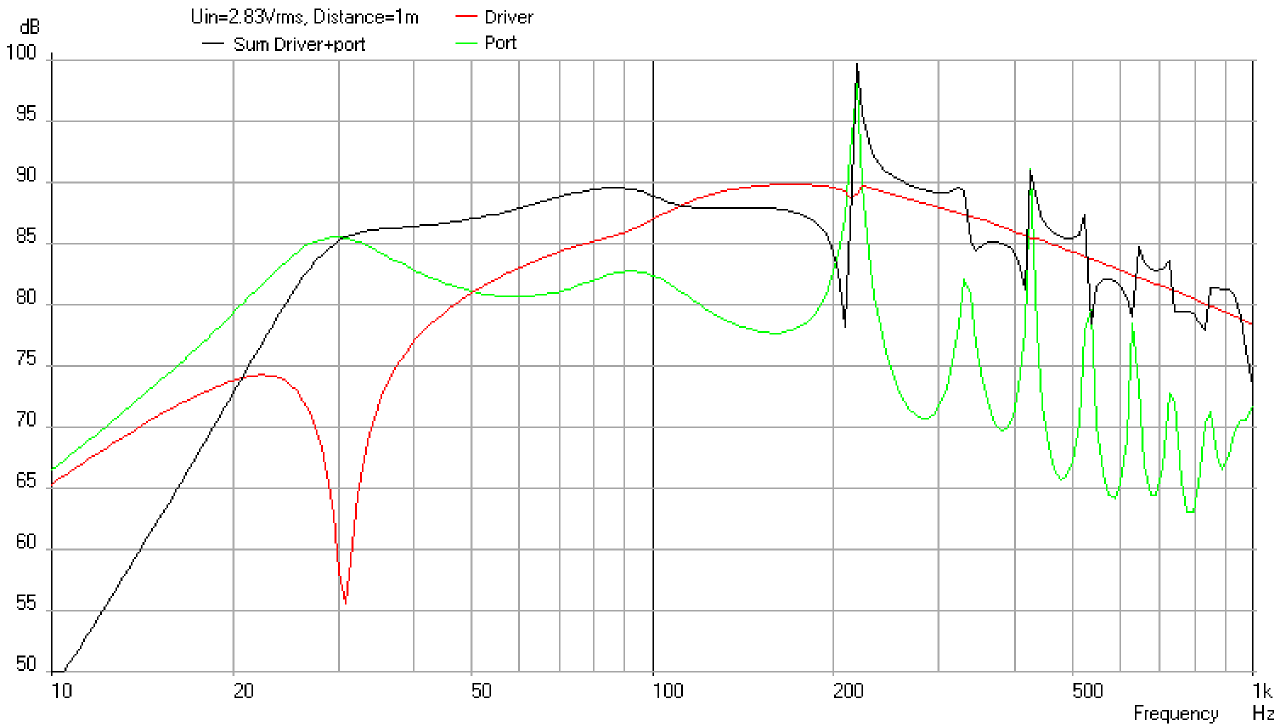

Illustration 6: Simulated response of a 14l Compact Horn Subwoofer. Note the significant contribution from the port all the way up to 100Hz.

The law of size-low-efficient

There is a relationship between low frequency extension, efficiency and cabinet size, which is determined by laws of physics – low and loud requires a big box. Today power is cheap, so efficiency can be sacrificed to some extent. Even so, larger output and deeper extension will require a larger box.

Increased overall efficiency

Driver parameters for flat frequency response down low demands lower BL and higher moving mass, which unfortunately reduces efficiency at upper and mid bass frequencies, leading to compression and limited output capability in this important range.

By sacrificing efficiency at the lowest frequencies, but still have more efficiency higher up in frequency, one can have some of both – small size, and higher overall efficiency.

The shape of the frequency response will then fall off towards the low end, and will need equalizing. This is not a problem with subwoofers, as signal processing is required anyway.

The acoustic loading of a small horn is ideal for drivers with high BL and high efficiency. In a good design the maximum output at lowest frequencies is typically 12dB larger than the comparable closed box, due to increased sensitivity and reduced cone excursion. Compared to ordinary vented boxes one difference is larger output at mid bass frequencies, partly due to the more powerful driver, but also the contribution from the port has wider bandwidth. For a small box, the vented enclosure would not work very well at low frequencies due to acoustic overloading of the port, while the small horn can be designed to handle the output of large displacement drivers.

Acoustic distortion effects

In vented boxes port compression and distortion can significantly limit the usable output. A horn is not affected by the same limitations as the radiation area usually is much larger. Even for a small horn design with large rear chamber, the port area can be much larger than the typical vented port.

Port radiation area

The radiation area must be large enough to avoid compression and distortion. This is a problem with small vented boxes tuned low, because the air velocity is too high relative to radiation area. For larger vented enclosures, more than 200-400l, this is not so much of a problem because the port area can be larger. And even though the air velocity in the port is even higher due to the larger drivers increased displacement, performance will be better because a larger area can handle larger velocities.

It is most important to have a largest possible radiation area around the mouth. This is because the pressure loss per unit distance is very large at the mouth, causing flow separation and as a consequence losses and distortion.

Minimum size requirements

Inside the rear chamber and through out the horn channel both acoustic pressure and flow velocity easily reach high values where non-linear behavior is significant. Smaller dimensions gives higher pressure and velocities, and this means there will be a physical limit to how low and loud a given size enclosure can be, regardless how much power and cone excursion the driver can handle. Sound pressure levels in excess of 160dB is easily reached inside a small horn.

Practical sizes for compact horn subwoofers due to acoustic pressure and flow limits:

12-20l: 30Hz extension, 100-105dB/1m/2π
30-60l: 20Hz extension, 105-110dB/1m/2π
70-120l: 20Hz extension, 110-120dB/1m/2π

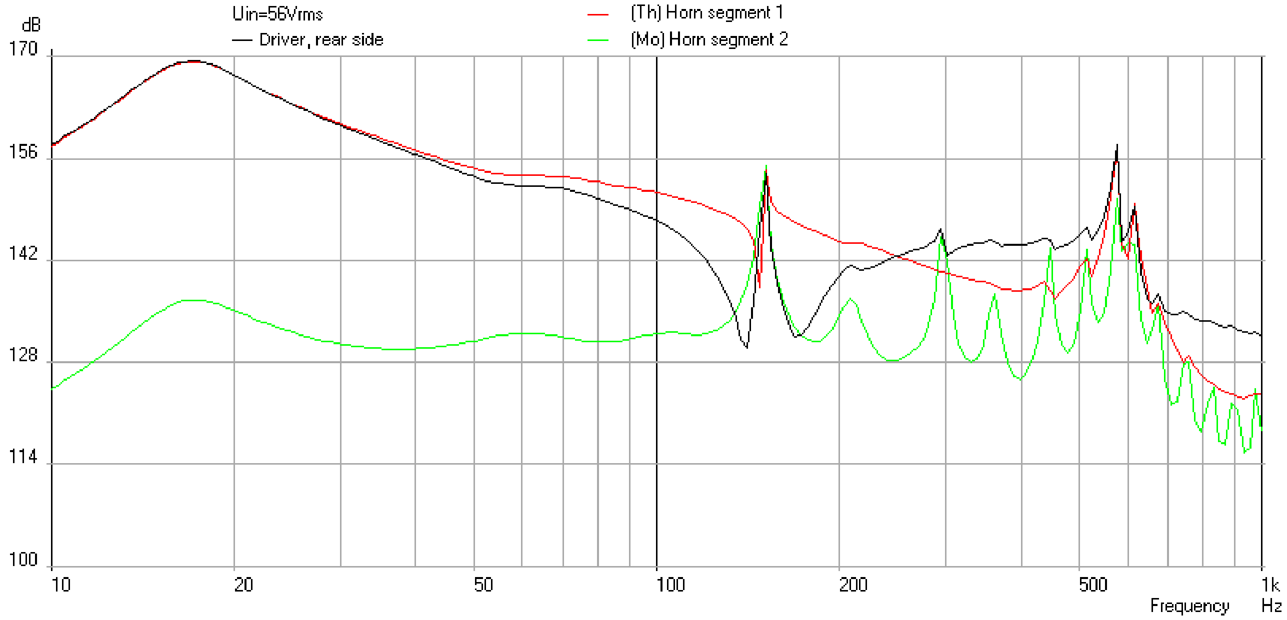

Illustration 7: Pressure inside the 70l Compact Horn Subwoofer.

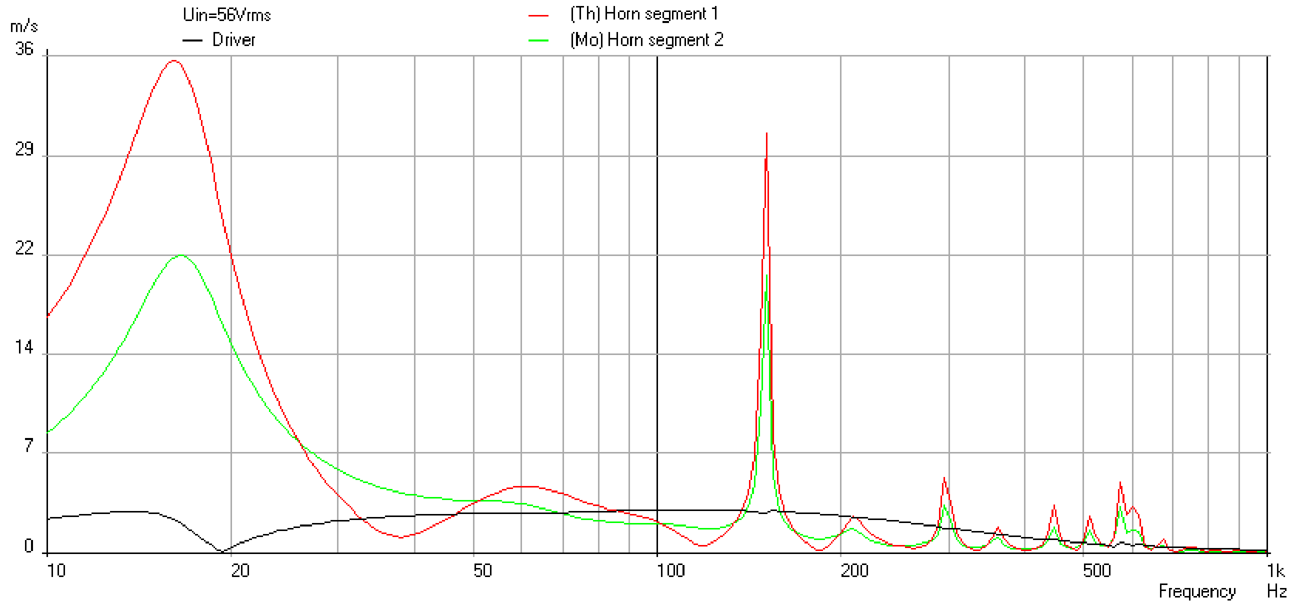

Illustration 8: Air velocity inside the 70l Compact Horn Subwoofer

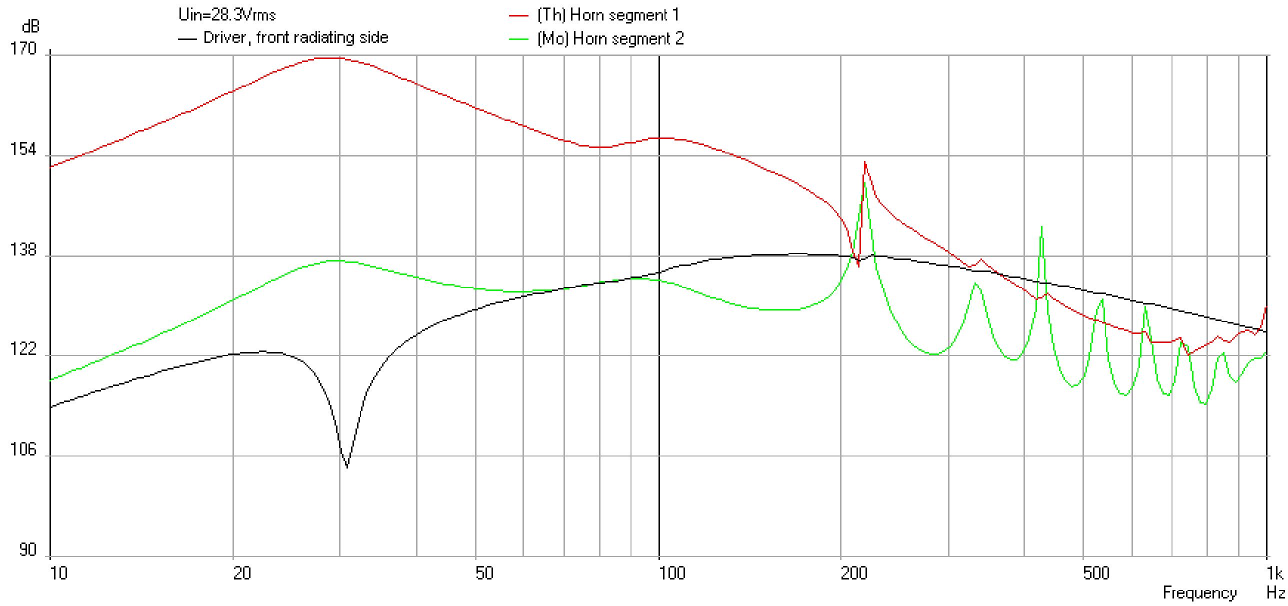

Illustration 9: Pressure inside a 14l Compact Horn Subwoofer show levels comparable to the larger 70l design.

Accuracy and predictability of simulations

The simulation will be a quite accurate representation of a real-world physical build, when the model is precise and contains enough detail for the horn path, damping materials, driver parameters.

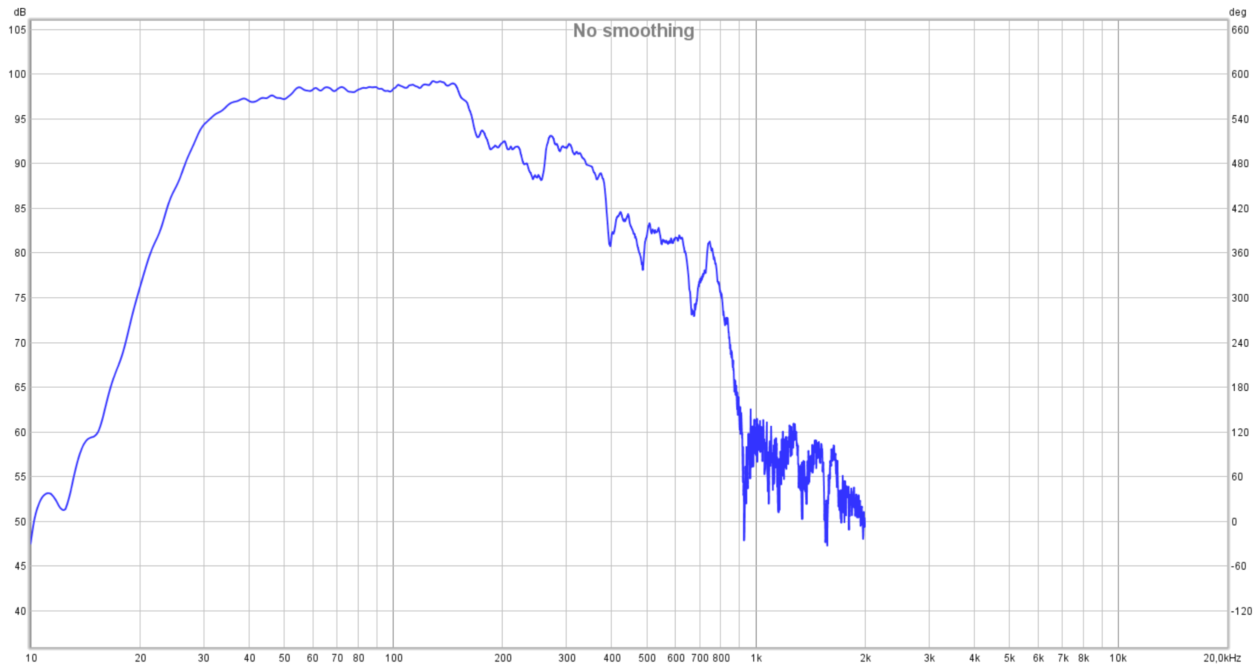

Illustration 10: Frequency response of the small S6-14 measured 2PI. Compare to Illustration 6. Roll-off below 30Hz is steeper due to dsp processing, above 100Hz tuning of the damping channel and low-pass dsp processing causes differences.

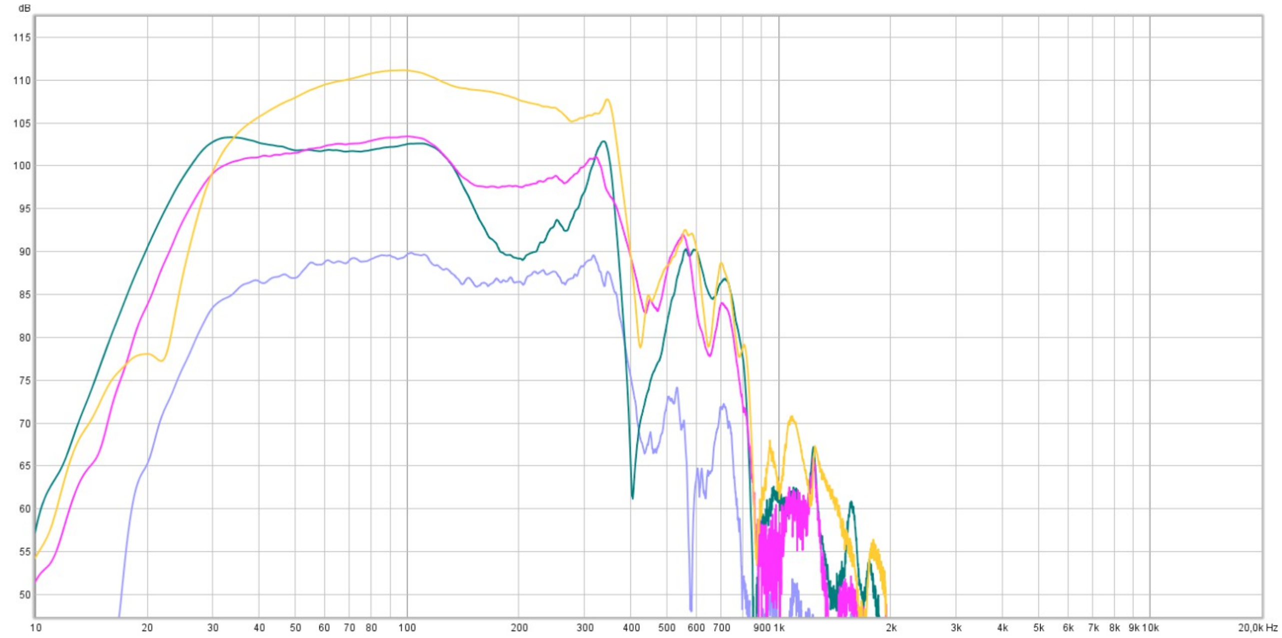

Illustration 11: Measured frequency response of the small V6. Near-field driver (orange), port top (green), port middle (pink), 1m 2PI (blue). Measurements are used for tuning and to confirm that the real-world version matches the simulated response well within acceptable limits.

Compact Horn examples

Several Compact Horn subwoofers has been designed and built, some of them can be purchased from Kvålsvoll Design, they are presented on the web pages, in the Products & Services section: www.kvalsvoll.com/Services/p1.htm.

The V-series utilize a vertically large horn mouth, which becomes acoustically large in the upper bass range.

Illustration 12: V-Series Compact Horn subwoofers - four models in different style and shape and size.

Illustration 13: V80 (black, behind) and V6030 (white) Compact Horn bass-systems in Room 2.

Illustration 14: V6 is very small, easy to place, and looks great.

Illustration 15: V6020 Compact Horn is a moderately sized full-range alternative.

Illustration 16: V6 units ready for shipping.

The T6050 is a small mid-bass horn, intended for use in the 50Hz-200hz range, it has quite decent output at around 122dB 1m/2PI maximum.

Illustration 17: T6050 midbass horn.

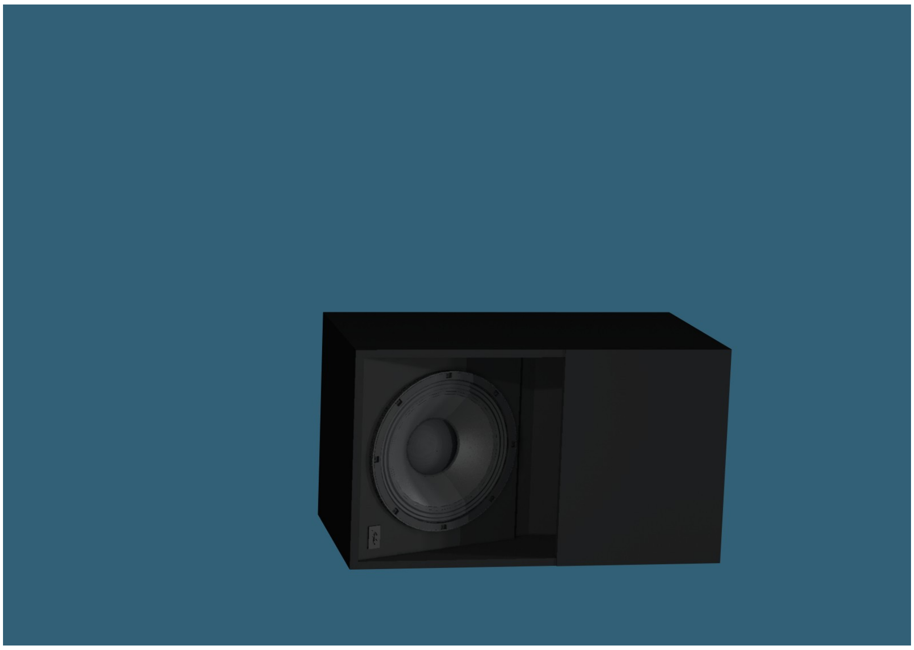

Illustration 18: T6050 midbass horn.

Illustration 19: Testing the T6050 midbass horn in Room2.

The small S6-14 has decent output down to 30Hz, one of the very first Compact Horn designs to be built and tested.

Illustration 20: S6-14 compact horn subwoofer and CD.

Illustration 21: S6-14 rendering.

The T6018 is a moderately sized full-range alternative, bass down to below 20Hz in small size.

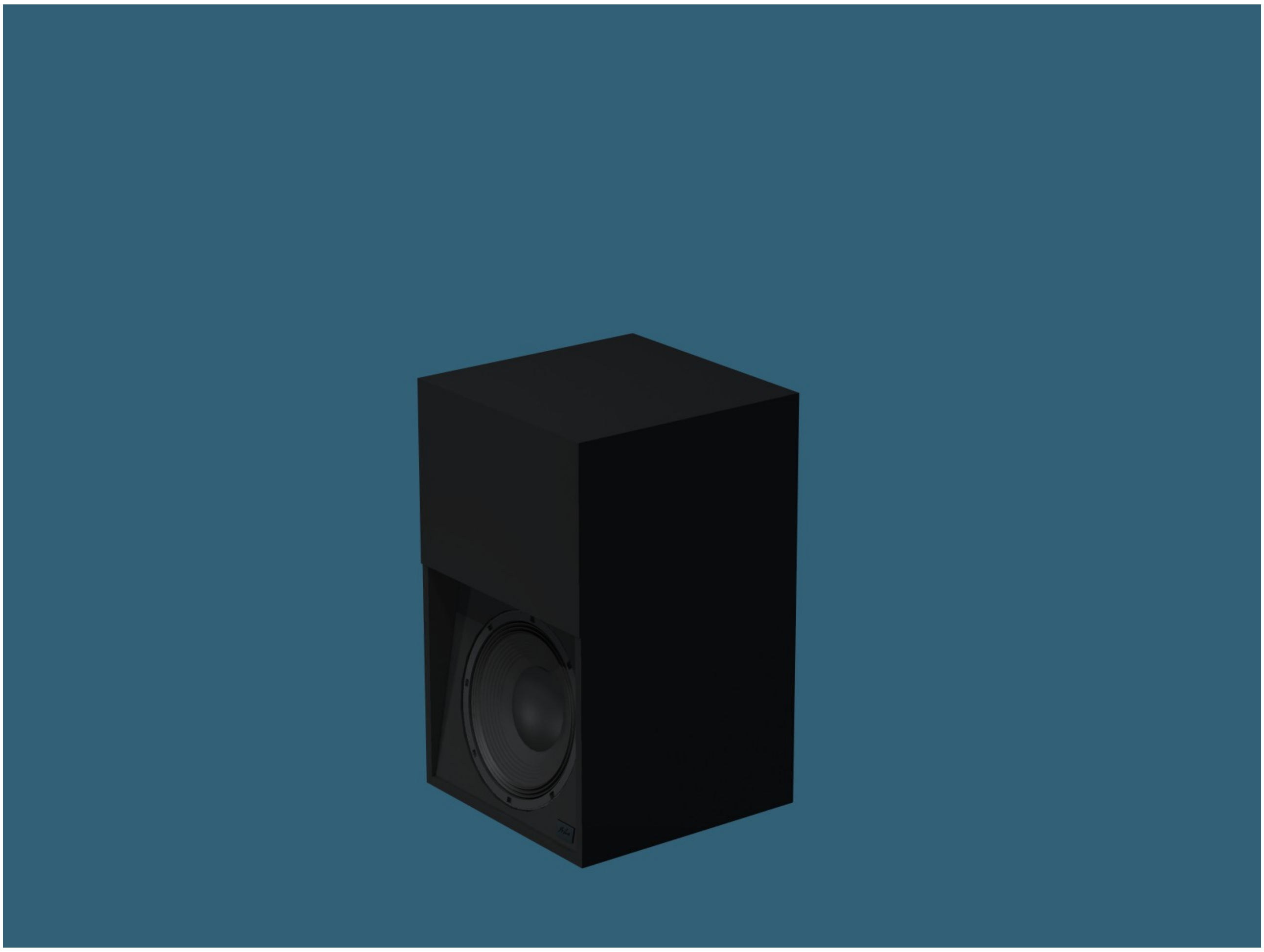

Illustration 22: T6018: 42cm x 42cm x 68cm, full-range.

Illustration 23: T6018.

Articles on horn-bass and Compact Horns

On the web pages, in the blog-section, there are several articles about bass, bass-systems and horn bass. "What is horn-bass" attempts to describe what this horn bass sound is all about:

What is horn-bass: https://www.kvalsvoll.com/blog/2017/12/30/what-is-horn-bass/

Norsk (Norwegian) version: https://www.kvalsvoll.com/blog/2017/12/30/hva-er-hornbass/