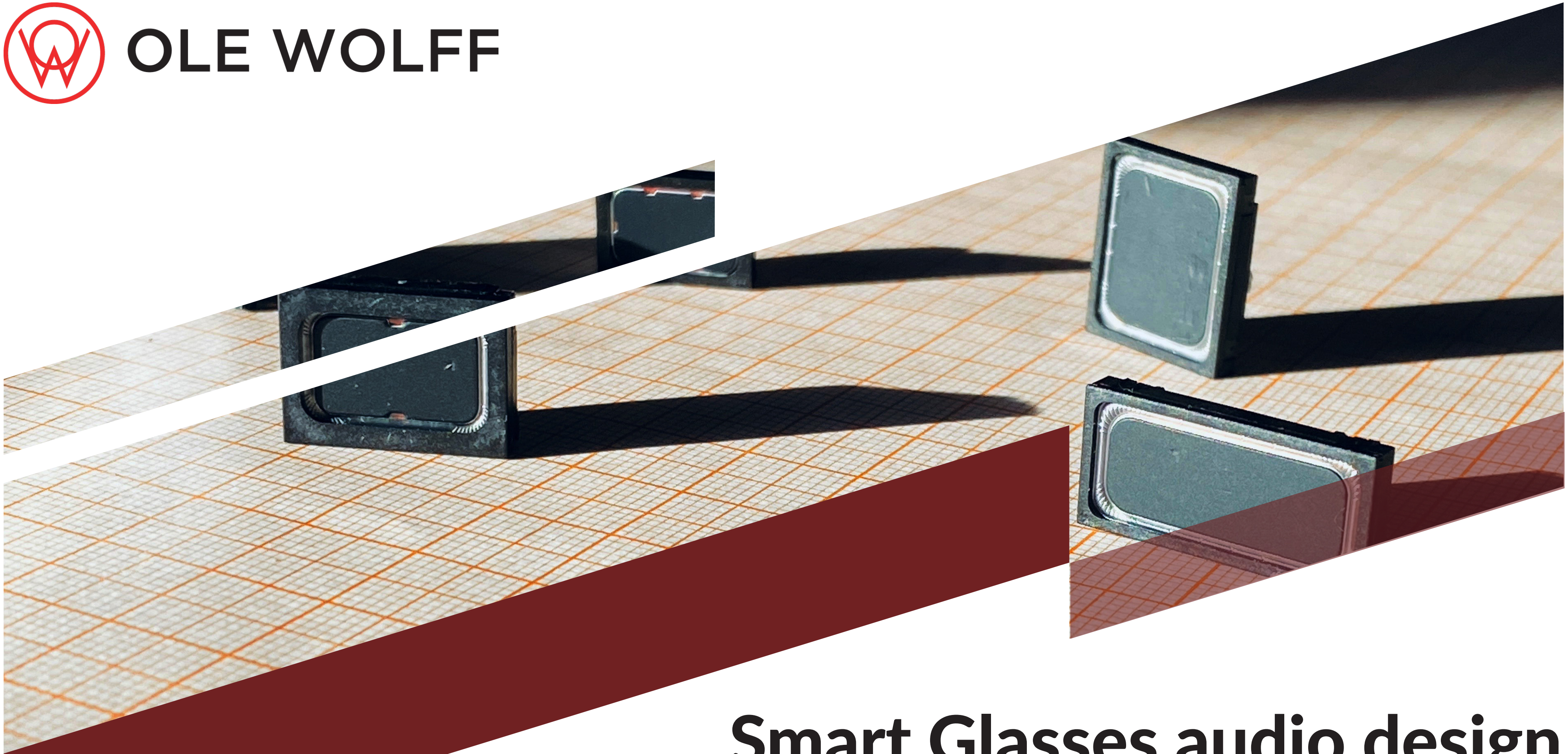
OLE WOLFF



Smart Glasses audio design using COMSOL simulation tool

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Scope

This White Paper deals with the use of the Comsol simulation tool in the design phase of micro acoustic devices interfacing with the air in a near or free field situation.
Under such conditions, the Lumped Element simulation method normally used for micro acoustics is far from accurate due to the presence of reflections and standing sound waves.

Examples of such devices could be Smart speakers (interfacing with the free field) & Smart Glasses (interfacing with the near field).

The topic in this paper will be on a Smart Glasses application, where two different designs are analyzed; namely a rear closed volume built-in of the speaker and another built-in, where the speaker is rear vented through a canal leading out to the free field in a certain distance from the sound outlet for avoiding acoustic short circuiting.

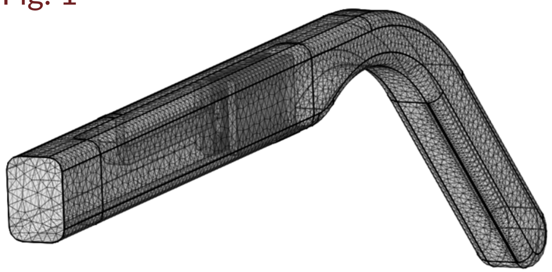
Lumped Parameter versus Comsol simulation

Lumped parameter simulation is ideal for acoustic designs where homogeneous pressure relations are present, meaning all dimensions in the acoustic circuit are smaller than the smallest wavelength of interest securing no standing waves are present inside the audio device.
This is to a high degree fulfilled in devices such as in earphones, hearing instruments and to a certain degree headphones, where a sealed or close to sealed condition to the ear is present.

For reference to the lumped parameter model and its elements, please visit Ole Wolff White Paper "*Designing Micro Loudspeakers for portable devices – Part 1*".

The Comsol simulation tool, however, is based on finite elements, where an acoustic structure is meshed (see *Fig. 1* of the meshed surface of the stem) meaning divided into very small areas, where Comsol performs a calculation on each mesh area and collects all data to a full simulation.

Fig. 1



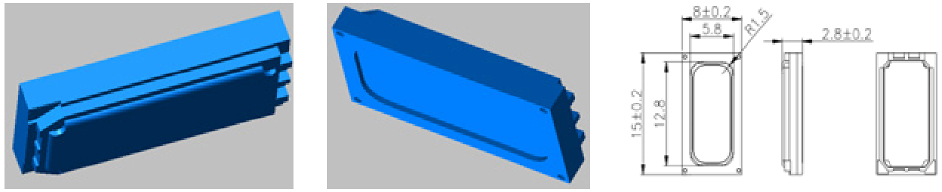
However, when micro speakers are used in near or free field applications, it makes sense to combine a lumped parameter model of the speaker with a Comsol model of the acoustic environment around the speaker.

The case study in this paper is based on such a combination of the electro and mechanical lumped parameter speaker circuits and a Comsol model of the acoustic environment encircling the speaker.

Micro loudspeaker OWS-081528TA-6 used in this study

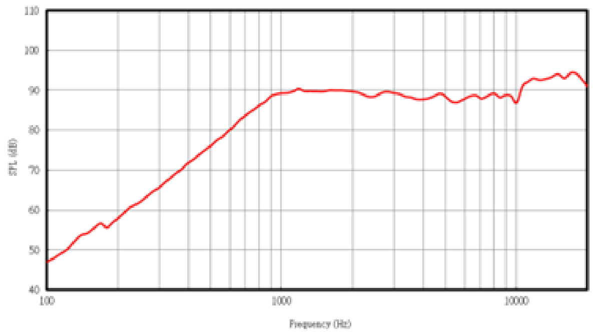
The micro speaker **OWS-081528TA-6** from Ole Wolff has a formfactor very suitable to be placed in Smart Glasses applications due to its small size **8x15x2.8mm**.

Fig. 2



The speakers free field frequency response is shown in *Fig. 3* revealing a very linear progression from 1kHz to higher than 10kHz proving its performance to cover wideband window as well as speech reproduction to a high degree.

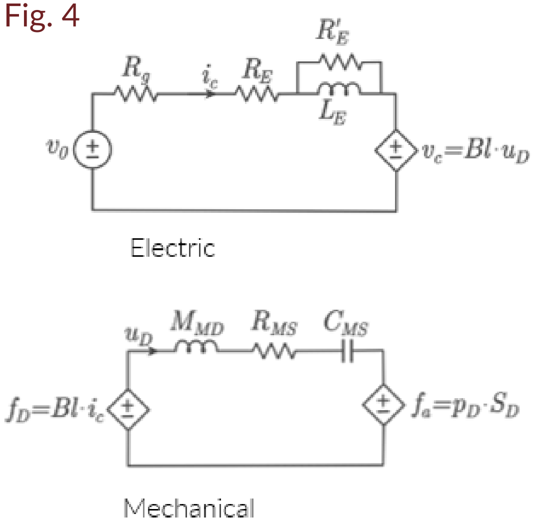
Fig. 3



(Source: 2.05Vrms/10cm distance and micro-speaker mounted in a sealed rear volume box of 1cm3).

The electro and mechanical lumped Parameter circuits are applied to the membrane in the acoustic model and the pressure on the membrane in the acoustic model is coupled back in the mechanical circuit. See *Fig. 4*:

Fig. 4



Smart Glasses case study 1: Closed rear volume

Case Study 1 concerns the **OWS-081528TA-6** speaker built into the Smart Glasses stem in a closed rear volume design. See *Fig. 5*.
The rear air volume is as small as 0.1ccm for saving space, assuring a very slender stem design. The sound outlet is positioned as close to the ear canal entrance as possible, meaning approx. 30mm.

Fig. 5

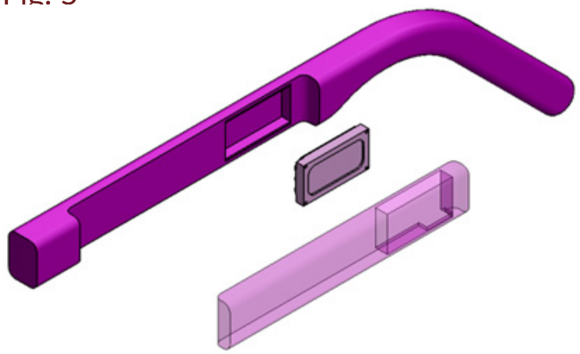
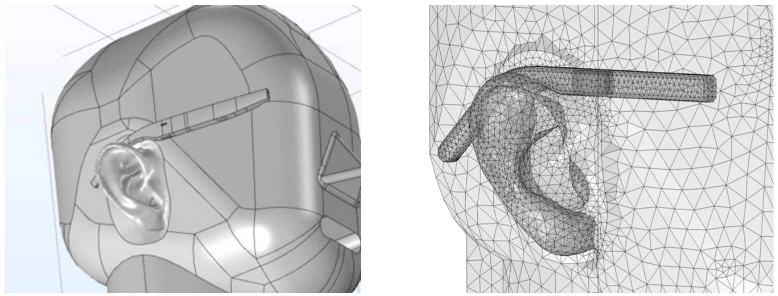


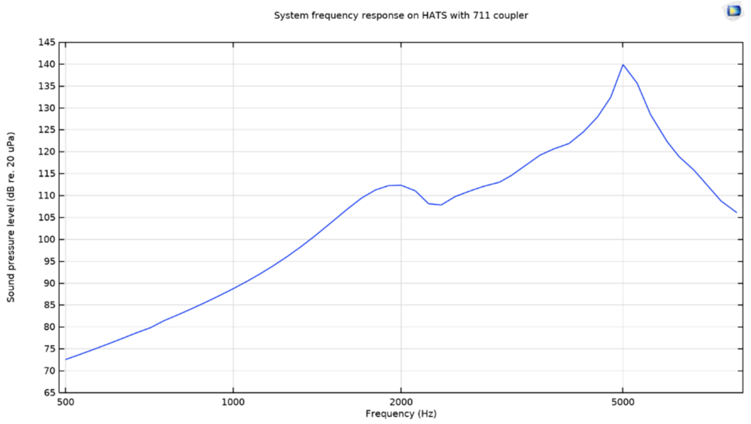
Fig. 6 shows the stem placed on the Head & Torso simulator and the meshed version.

Fig. 6



The corresponding Comsol simulation including the Head & Torso simulator (HATS) including the inner ear canal and eardrum simulated by the standardized 711 coupler can be seen in *Fig. 7* below.

Fig. 7

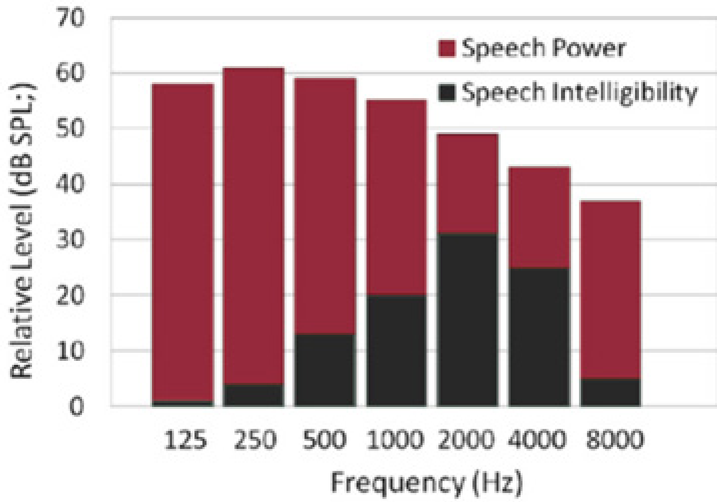


In other words, the sound pressure levels in the shown frequency span are what is reaching the eardrum and thereby perceived by the listener.

It can be noticed that this frequency response is very different from the previous in *Fig. 3* response of the same speaker in free field, but the response is heavily equalized by the very small rear volume sacrificing the bass frequencies as well as equalized by the ear canals Helmholtz resonator, raising the SPL level significantly at around 5kHz.

However, this reduced bandwidth in this application compared to the free field bandwidth shown in *Fig. 3* is acceptable due to the main purpose of the sound performance in Smart Glasses focused on speech intelligibility and to a minor degree on music reproduction. (See graph for speech intelligibility bandwidth peaking at around 2-4kHz in *Fig. 8)*.

Fig. 8

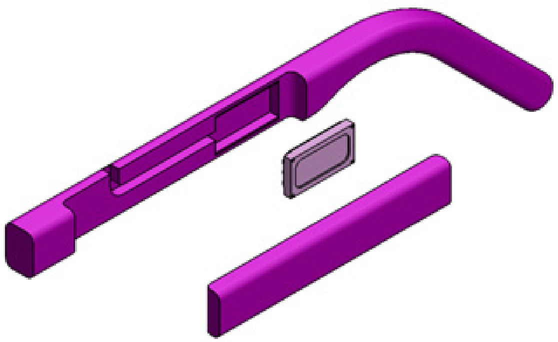


Smart Glasses case study 2: Rear venting

Case study 2 focuses on the **OWS-081528TA-6** speaker integrated into the stem of the smart glasses. The speaker features a rear-vented design, where a canal connects the back of the speaker to the open air at a certain distance from the front sound outlet.
This configuration helps minimize acoustic short-circuiting (see *Fig. 9*).

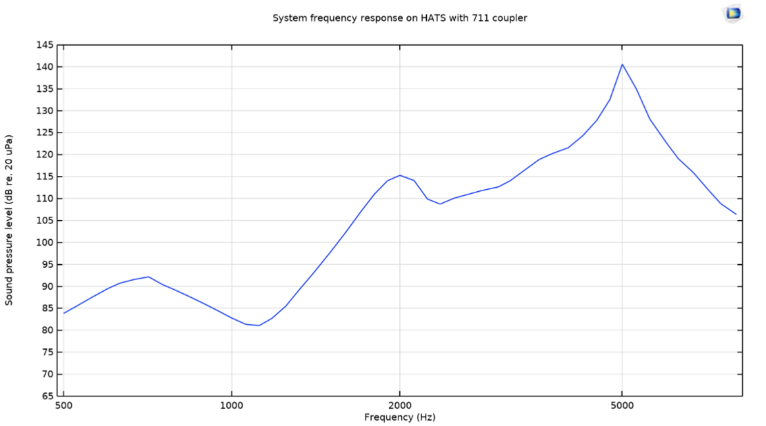
All other parameters are equal to the ones in **case study 1**.

Fig. 9



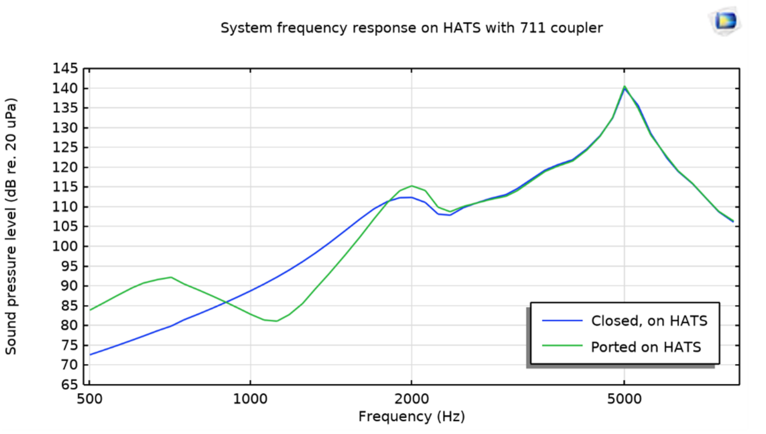
The corresponding Comsol simulation including the Head & Torso simulator (HATS) and including the inner ear canal and eardrum simulated by the standardized 711 coupler can be seen in *Fig. 10*.

Fig. 10



When comparing this response with the response for the closed rear volume (*Fig. 11*), we notice that the rear vented design has a raised sensitivity at the lowest frequency span, where formant frequencies of the human speech are present.
As a result, speech recognition will be improved compared to the stem design with closed rear volume (**case study 1**).

Fig. 11



Conclusion

Comsol simulations for micro-acoustic applications in near-field or free-field environments is a powerful tool. They help reduce the number of laboratory tests needed on physical prototypes. In this case, they are used to assess the audio performance of Smart Glasses.
The result is obviously the savings on development costs as well as a reduction of the timeline in the given project planning.

Ole Wolff master a full Comsol acoustic library, as well as the engineering competences needed to run these sophisticated finite element simulations. This goes hand in hand with all the other development tools Ole Wolff offers, such as advanced Lab. measurements, prototyping, full documentation on their acoustic product portfolio etc.

All what characterize Ole Wolff as a preferred project partner for vendors of portable audio devices.