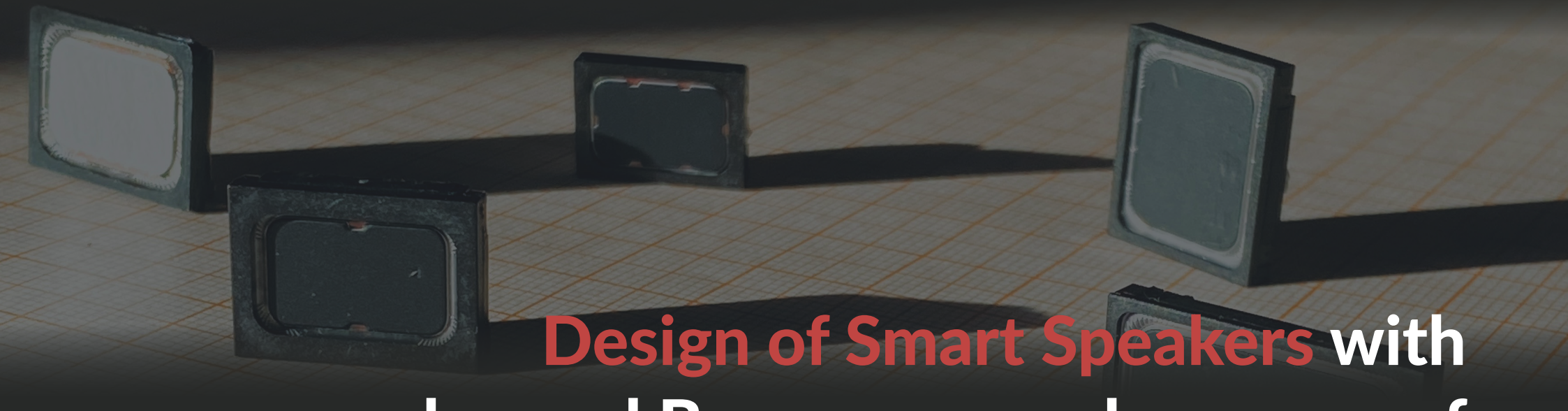
OLE WOLFF



Design of Smart Speakers with enhanced Bass response by means of Passive Radiator elements

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Scope

The design of Smart speakers has two major challenges:

- It needs the smallest possible size for being portable.
- It needs the ability to deliver maximum full bodied bass response.

These two parameters contradict each other, because a full-bodied bass needs access to air, which by nature is very limited in a small sound box.
This leads to a design solution taking advantage of **passive radiator (P.R.) technology.**

With the help from a P.R., an extra resonator can be tuned to be positioned slightly below the driver's resonance frequency F0, which will add intensity to the bass response even in small loudspeaker enclosures and thereby give improved sound experience.

This White Paper deals with the different aspects (advantages/ tradeoffs) existing in such a design.

Fig. 1



Model of a typical Smart Speaker.

What is a passive radiator element?

A passive radiator element is basically a loudspeaker without a magnet system and no voice coil. This means, it needs no electrical signal current but is rather a “slave diaphragm” following the sound pressure existing inside the loudspeaker cabinet. *(see Fig. 2)*

Fig. 2



By tuning the suspension compliance, moving mass, and diaphragm area (Sd), this self-contained resonator adds a pole to the frequency response, slightly improving bass performance.

This added bass comes at the cost of increased diaphragm excursion, which must be managed by a Smart Amp controlling the electrical signal to the driver.

A similar effect can be achieved with a bass reflex port tuned below the driver’s resonance frequency (F0). However, the box must be much bigger for similar performances and ports can introduce airflow distortion, while the P.R. design avoids these issues.

Mechanical vibration issues

The Smart Speaker is a self-contained (battery operated) device normally driven through a Bluetooth or Wifi connection and is typically placed on a hard surface like a table.

Due to the relatively high power (5-10W) supplied to the quite small Smart Speaker, mechanical vibrations are likely to occur. Even visible movements of the whole Smart Speaker are not unlikely.
Of course, this is unwanted and can be avoided by simply splitting the P.R. into two separate elements positioned on each side of the Smart Speaker.

The two elements cancel the vibrations by operating in opposite phase on either side of the enclosure (*see Fig. 3*).

Fig. 3

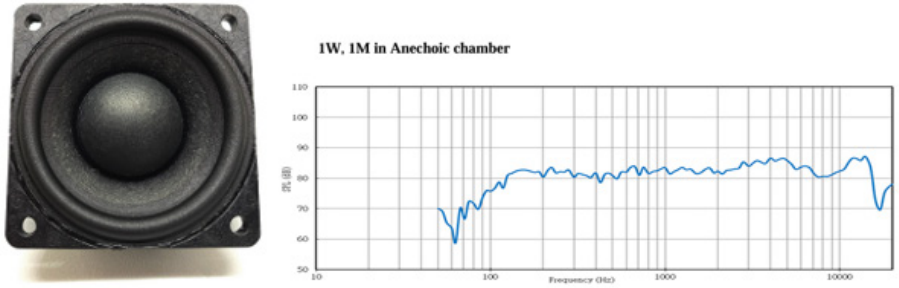


Case Study with the 48mm Ole Wolff driver (OWS 4848)

This section will lead you through the theoretical aspects of a P.R. Smart Speaker design, having the Ole Wolff driver OWS4848 as the sound source.

This driver is very powerful and delivers a broad frequency response with a minimum of distortion.
The driver and its frequency response in free field (2pi baffle) is shown in *Fig. 4*.

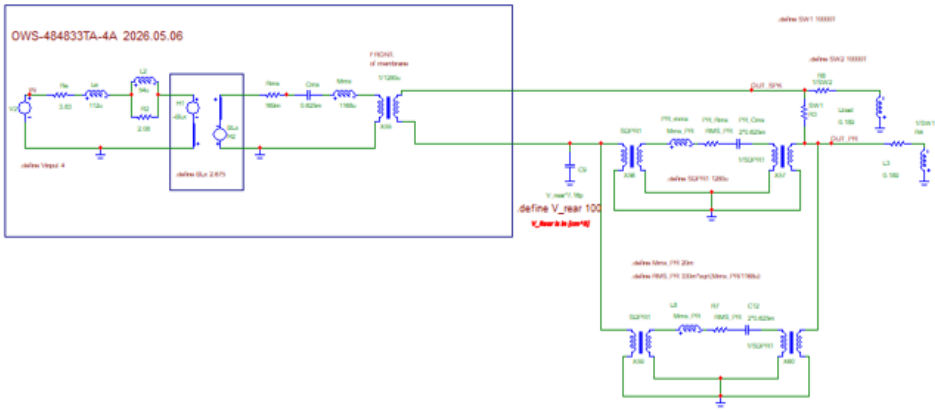
Fig. 4



The design chosen is a closed box cabinet with an inner air volume of 150ccm, which represents the majority of Smart Speakers today.

The corresponding lumped parameter network is shown in *Fig. 5*, where two P.R. are represented in parallel to avoid mechanical vibrations. (seen to the right in the network).

Fig. 5



The parameters for the 4848 driver and the two P.R. elements are:

4848 driver:

- Re 3.83 ohm
- Le 112uH
- BL 2.08 Tm
- Rms 0.169
- Mms 1.168 gram
- Cms 0.625 m/N

PR element:

- SD like speaker 1280mm^2
- Mms =20grams
- Cms 2 * Cms for speaker = 1.25mm/N
- Rms = 1.24

Simulations show an enhanced low frequency response adding approx. 5 - 10dB in the frequency range of 50 – 100Hz without equalization. (*Fig. 6*)

Fig. 6

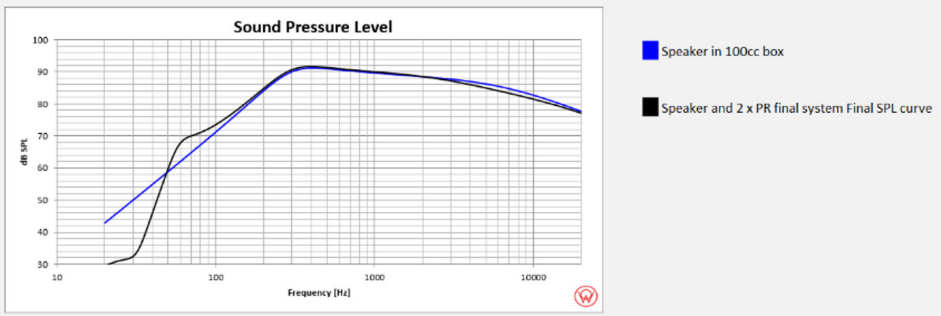
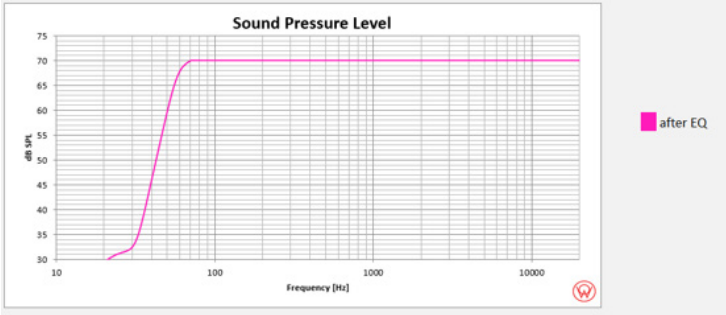


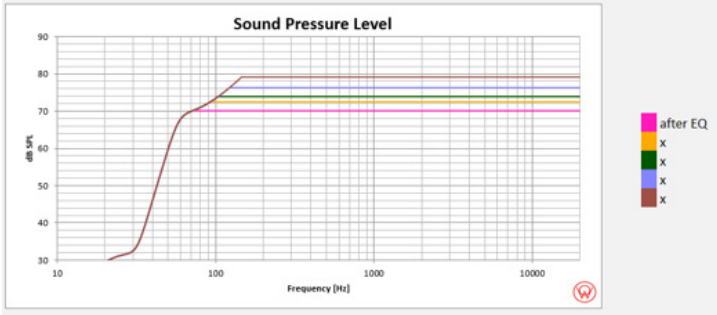
Fig. 7 shows the SPL delivered at low level (70dB SPL, 1m), where a superior linearity from 50Hz - 20kHz is achieved by equalization.

Fig. 7



At higher SPL levels than 70dB, the frequency response must be equalized for allowing high sound pressure levels exceeding the contribution from the P.R. elements. (*Fig. 8*)

Fig. 8



Performance wise, the P.R. design contributes at low to medium SPL levels with enriched bass response and will gradually reduce its contribution at higher sound pressure levels.
In below simulation (*Fig. 9*) SPL delivered by the active driver (red curve) and the corresponding SPL delivered by the P.R. (green curve) is shown.

Fig. 9

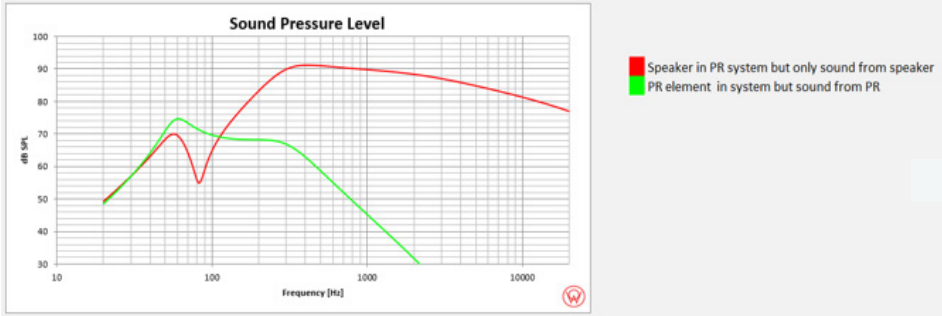
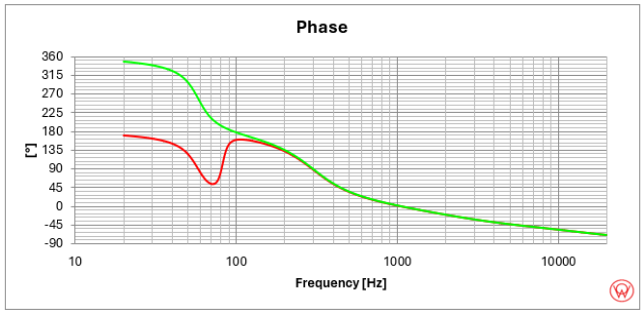


Fig. 10 below shows the corresponding phase of the SPL delivered by the active driver and the P.R. and what is noticed is that they are in counter phase below the resonance frequency of the P.R.

Fig. 10



This leads to the rationale that the sound signal level must be brought to zero below the resonance of the P.R. (in this case approx. 60Hz), which else only will add distortion and no SPL to the total delivered sound.

Conclusion

The OWS4848 speaker is an excellent choice when designing a Smart Speaker portable device taking advantage of P.R. and can be tuned to perfection regarding desired frequency response and overall performance.

Ole Wolff will support you in all stages of your Smart Speaker design project, assuring the best possible outcome.

Please consult Ole Wolff for further information.