OLE WOLFF

The challenge of inappropriate HF response in Headphone drivers

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Scope

This White Paper focuses on the importance of the headphone driver's ability to reproduce a flat HF response, namely the frequency range above 8kHz. This frequency range addresses the clarity and maximum stereo effect of the music sound impression.

If the response is not flat, but contains numerous dips and valleys, the result will be a diffused/no clarity sound and a reduced stereo directivity. Especially the peaks will have a negative influence on the clarity of the sound because they add unwanted gain to the original sound signal and thereby colorization.
Especially, if the two drivers used in the headphone have a difference in the flatness of this frequency region, where the dips and valleys differ in amplitude and frequency, the music sound impression will be degraded.

Causes for HF peaks & valley in headphone FR response

Causes for peaks & valleys in the HF response of headphones can be divided in two:

- Caused by the driver itself
- Caused by reflections inside the headphones and the outer ear.

The peaks & valleys in the driver itself are ruled by local breakup modes in the diaphragm, where certain diaphragm areas move out of phase in relation to each other and the diaphragm is far from an ideal piston at higher frequencies. This behavior is shown in *Fig. 1*, where two different modes are visualized by means of laser detection of the diaphragm at the frequencies, where these peaks and valleys occur.

Fig. 1

The local resonators can also be seen on a waterfall plot measured on the driver in free field (*Fig. 2*), where they perform a post ringing just like a tuning fork and can be considered as local series and parallel resonators shown in *Fig. 3*.

Even though these local resonators also cause THD, this is not audible because the harmonics will be beyond the human ear`s upper frequency hearing ability, but the post ringing is audible, especially for the parallel resonators adding a dip, which amplifies the unwanted ringing.

Fig. 2

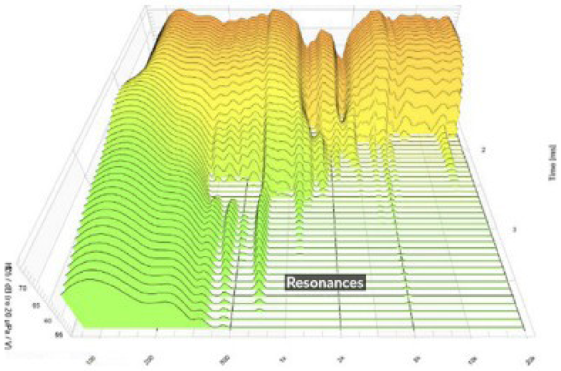
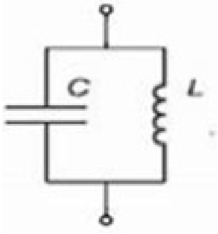


Fig. 3

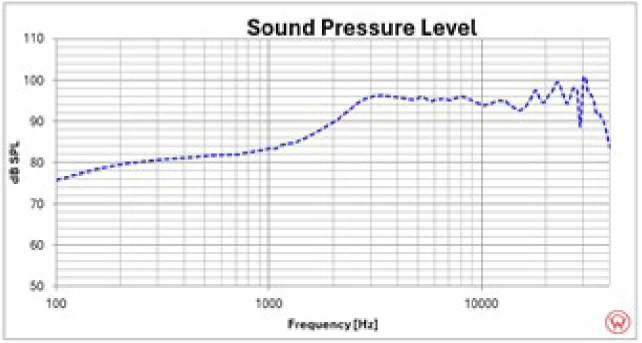


Driver in free field versus 711 coupler frequency response measurement

It is common practice to document a headphone driver`s performance by a free field frequency response, where a test microphone is placed in a short distance from the diaphragm of the driver, typically 5-30cm. Normally the driver is mounted in a 2pi baffle for avoiding acoustic short circuiting of sound waves at low frequencies.

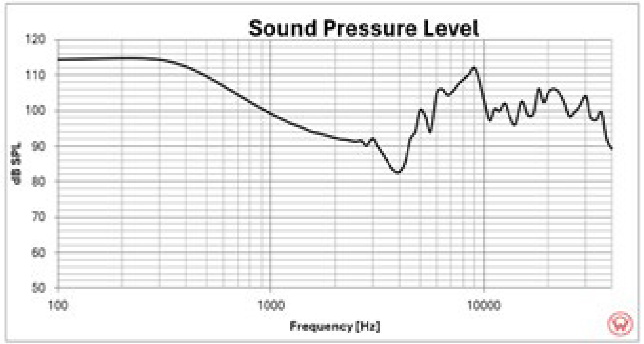
Such a typical free field frequency response of a driver is shown in *Fig. 4*.

Fig. 4



In addition, a measuring of the frequency response using a 711 coupler in a sealed condition up against the driver is very informative for simulation a headphone user situation, and here a very different result is achieved. (*Fig. 5*).

Fig. 5



A numerous peaks and valleys at mid to high frequencies can be observed caused by reflections inside the headphone and surface of the ear. Because a 711 coupler/artificial ear used has steel surfaces, these peaks & valleys have a very high Q factor. In a headphone user situation up against the human soft skin ear, the Q factors of these reflections will be much lower, but the reflections still exist.

While the reflections inside the headphones are hard/impossible to remove, the breakup modes in the driver`s diaphragm can be minimized by using very stiff composite material for the diaphragm as well as computer optimized geometry of the diaphragm, typically by means of Comsol or similar finite element software.

OW Ø40mm headphone driver using state-of-the-art diaphragm Technology

It is strongly recommended to use high class drivers having extreme stiff diaphragm technology because local resonators in less rigid diaphragm drivers have a tendency of being also more sensitive to different acoustic loads coming from the headphone internal design and different wearing positions rules by the end user.
For these reasons, Ole Wolff has developed advanced carbon composite diaphragm Ø40mm drivers and can offer these off the shelf for your next high end headphone project.

Fig. 6

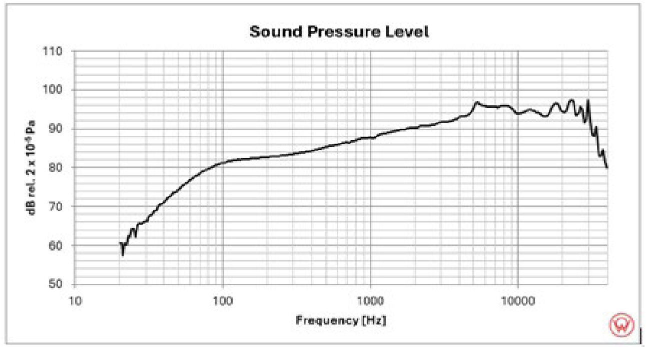


Fig. 6 shows a free field response of an Ole Wolff Ø40mm driver using the latest development of carbon diaphragm technology.

It should be noticed that at higher frequencies above approx. 8kHz there are no dips or valleys being higher/deeper in amplitude than approx. 3dB and the Q factors of these resonators are extremely low, assuring a crystal-clear music sound reproduction with natural stereo effect strictly following the electrical signals fed to the drivers.

Conclusion

Ole Wolff has a long experience in designing high-tech diaphragms using advanced high-tech materials like carbon in different composites promoting the desired properties in the diaphragm and thereby getting extremely close to an ideal piston behavior in our high-performance headphone drivers.

Please consult Ole Wolff to assure you the optimal foundation for your next headphone state-of-art project.