Hi-Res Ear Simulator for Measurements at Very High Frequencies

By Kristian Gøtsche-Rasmussen, Morten Wille and Per Rasmussen

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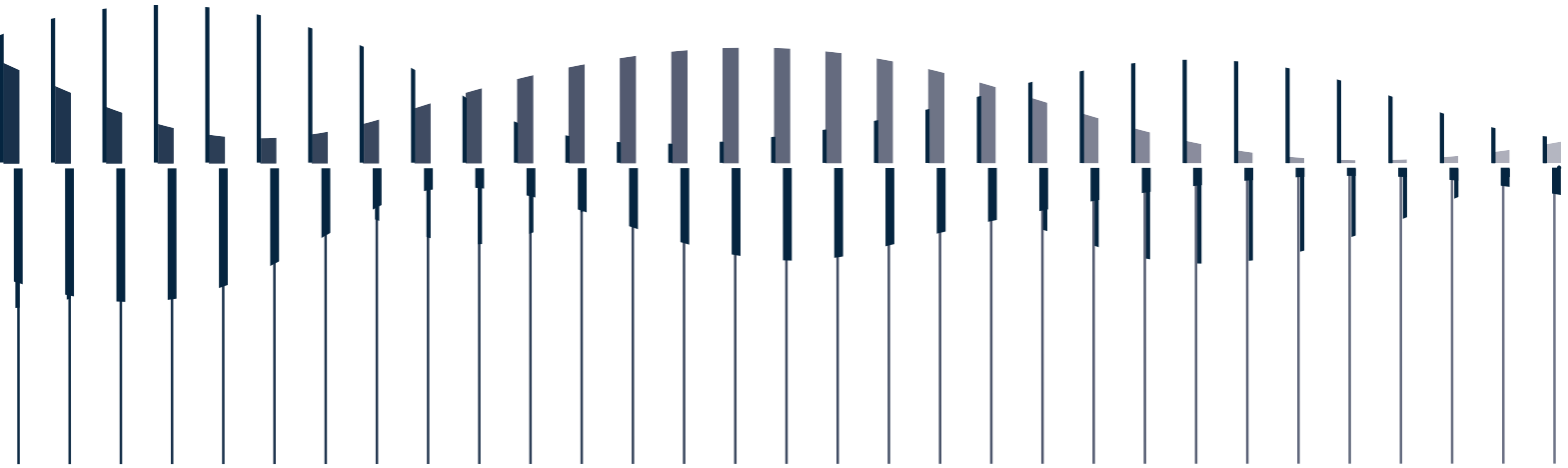

GRAS Sound & Vibration

Hi-Res Ear Simulator for Measurements at Very High Frequencies

By Kristian Gøtsche-Rasmussen, Morten Wille and Per Rasmussen

The new GRAS Hi-Res Ear Simulator is designed to extend the useful frequency range up to 50 kHz. The extended frequency range is obtained by using a 1/4" pressure microphone instead of a 1/2" microphone. The new ear simulator is compatible with the specifications in IEC 60318-4.

It uses a resonance damping system similar to that used in the RA0401 High Resolution Ear Simulator, but extends the useful frequency range to 50 kHz and therefore meets the 40 kHz requirement of the Hi-Res standard for high performance headphones (2014) as described in for example Tsunoda, Hara & Nageno, 2015, Tsunoda, Hara & Nageno, 2016, and Tsunoda, Hara & Nageno, 2017.

The damped resonance and small microphone footprint result in improved repeat-ability and extended frequency range and makes it possible to evaluate and compare headphones in a wide frequency range with frequency response, THD, noise floor, etc.

The Hi-Res Ear Simulator is part of a number of pre-configured, ready-to-use test solutions from GRAS such as the 43AG, the 45CA, and the 45BB and 45BC KEMAR. Visit gras.dk for further information.

The GRAS Hi-Res Ear Simulator is available in two versions:
RA0403 is externally polarized, RA0404 is prepolarized.

Introduction

The IEC 60318-4 Ear Simulator is widely applied in the verification of frequency response of acoustic products, e.g. in the audio (consumer) industry, but also for measurements on hearing aids. It is recognized for its ability to simulate the acoustic load as presented by the ear. Placing a headphone on a standardized ear simulator, e.g. a GRAS RA0045 Ear Simulator according to IEC60318-4 ensures that the headphone is facing the same acoustic input impedance as a real human ear would provide.

An ear simulator based on the IEC 60318-4 standard, e.g. the GRAS RA0045 Ear Simulator is therefore necessary to obtain a realistic acoustic transmission line from the output of the transducer (e.g. a headphone or a hearing aid) placed in a known measurement plane (e.g. the ear entrance point) to the ear-drum point in the ear simulator.

However, the traditional IEC60318-4 (GRAS RA0045) ear simulator has an undamped length resonance at 13.5 kHz. This is related to the half-wavelength distance from the ear simulator input reference plane to the microphone position. As the resonance is related to the main volume length, the resonance frequency will shift if the length is altered.

In most practical situations the Device Under Test (DUT) will not be positioned precisely at the reference plane of the ear simulator. Figure 1 shows a typical setup, where the main volume of the GRAS RA0045 Ear Simulator is extended with an ear canal and exterior pinna (e.g. the GRAS KB5000 Anthropometric Pinna). This will change the ear canal length and thereby the resonance frequency so that both the half-wave and full-wave resonances can be seen below 20 kHz.

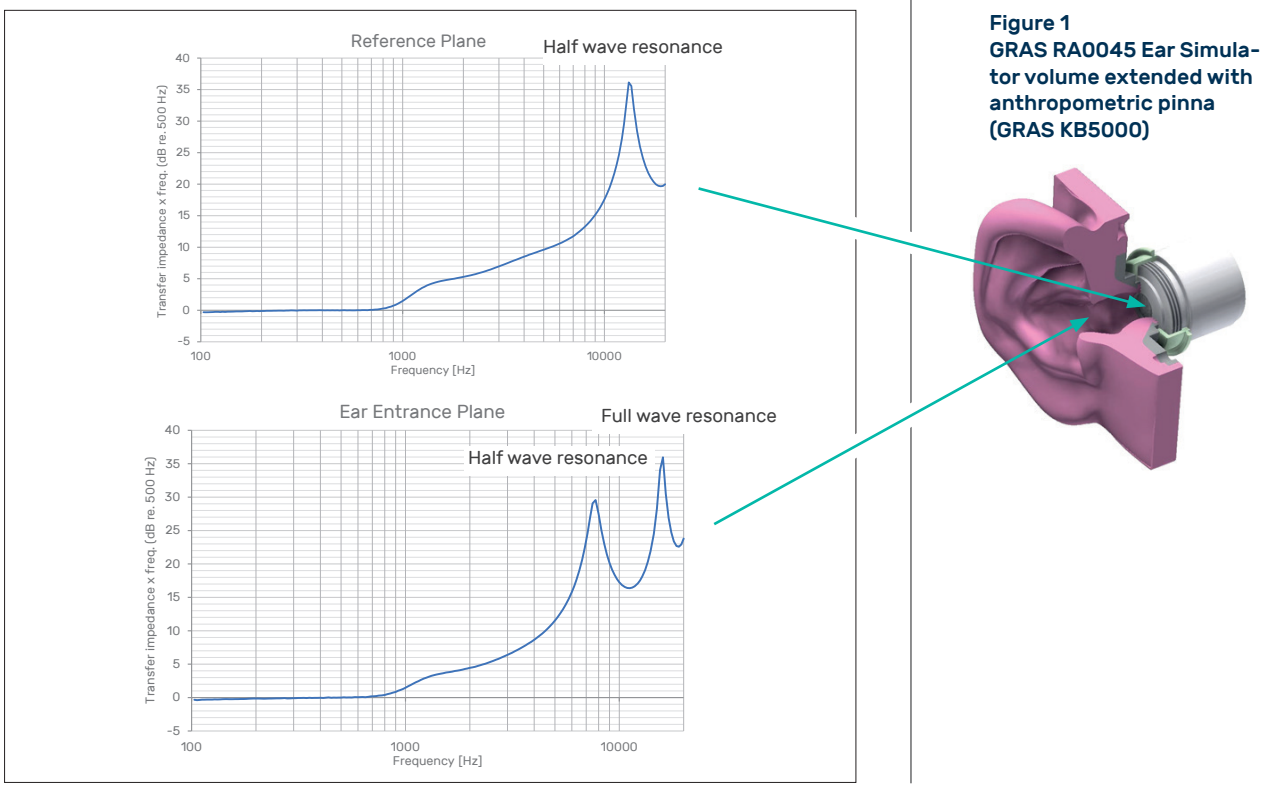

Figure 1
GRAS RA0045 Ear Simulator volume extended with anthropometric pinna (GRAS KB5000)

The GRAS RA0401 High-Frequency Ear Simulator is designed to minimize the effect of the undamped resonance at 13.5 kHz to accurately acquire and verify frequency responses. This is obtained by using a built-in resonance damping system in the ear simulator. This attenuates the resonance peak by approximately 14 dB and reduces the effects of the shifts caused by changes in DUT positioning in the ear canal. For more information, see the white paper about GRAS RA0401 (Wille, 2017). It can be downloaded from gras.dk.

The problem: Measurements of higher frequencies

New audio formats with wider frequency range have been introduced to provide the users with higher sound quality and better listening experience. This has led to the demand for precise and relevant test methods to effectively validate and optimize designs and concepts.

Modern hi-res audio formats offer frequency ranges above 50 kHz and as the internationally standardized ear simulators were primarily designed for use below 10 kHz these are not adequate.

The solution: The new GRAS RA0403/04 Hi-Res Ear Simulator

The Hi-Res Ear Simulator RA0403/04 is based on the standardized IEC 60318-4 ear simulator and the RA0401 High-Frequency Ear Simulator, but extends the frequency range of interest to 50 kHz. The extended frequency range has been obtained by using a high frequency ¼" microphone in the ear simulator together with a resonance damping system and at the same time carefully adjusting the ear simulator impedances so that they are the same as in the IEC 60318-4 ear simulator for frequencies below 10 kHz.

The RA0403/04 Hi-Res Ear Simulator simulates the acoustic transmission line (resonances in the ear) which can be further extended by including the pinnae and thus the diffractions in the exterior sound field.

Specifications and Data

In Table 1, the specifications for the RA0403 are compared to those of RA0045 and RA0401. The sensitivity is lower for the RA0403 Ear Simulator which results in a higher noise floor. This means that the RA0403 Ear Simulator is not suited for low-level measurements and a GRAS 43BB Low-noise Ear Simulator System would be a better option. The resonance frequency for the three ear simulators is the same.

	RA0045	RA0401	RA0403
Microphone	40AG (1/2")	40AG (1/2")	40BP (1/4")
Frequency range (HZ)	100-10k	100-20k	100-50k
Sensitivity (mV/Pa)	12.5	12.5	1.6
Volume (mm^3)	1260	1260	1260
Dynamic range (dB)	25-164	25-164	44-169
Ref. plane resonance freq. (Hz)	13500	13500	13500

Table 1
Specifications of RA0403 compared to RA0045 and RA0401.
Specifications for RA0404 are the same as for RA0403, except that a 40BD microphone is used and the upper dynamic limit is 166 dB.

Figure 2 shows the transfer impedance curves for the new RA0403 Hi-Res Ear Simulator compared to the traditional RA0045 and the RA0401. It can be seen that the three ear simulators are identical in the frequency range up to 10 kHz, as specified in IEC 61038-4.

Above 10 kHz, the effects of the damping system used in RA0401 and RA0403 can clearly be seen. The RA0401 extends the frequency range to 20 kHz, while the frequency range of the RA0403 extends up to 100 kHz, with efficient dampening of resonances up to 50 kHz.

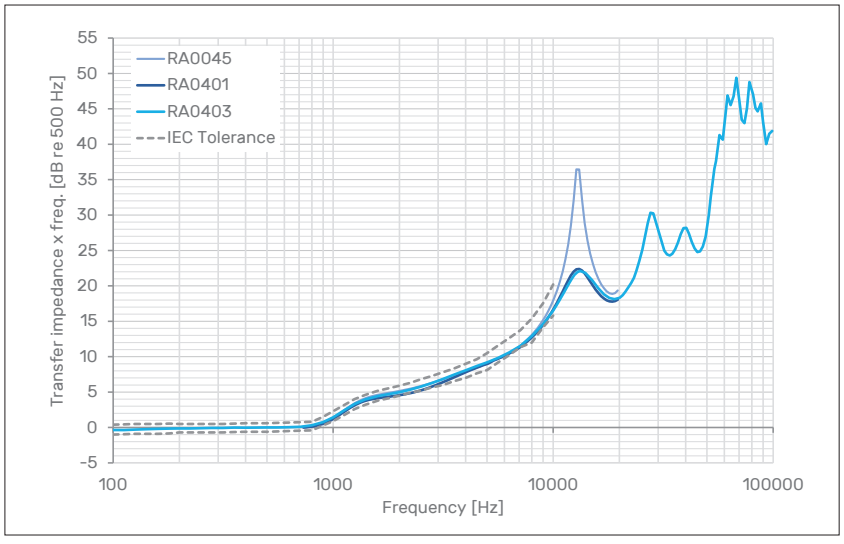

Figure 2
The extended frequency range obtained by RA0403/04 compared to frequency ranges of RA0045 and RA0401

Tolerances of the RA0403 Ear Simulator

In Figure 3, the transfer impedance and tolerances of the new RA0403 Ear Simulator are shown. Tolerances for the RA0403 Ear Simulator are the same as for RA0401 below 20 kHz, i.e. following IEC 60318-4 tolerances for frequencies 0.1-10 kHz and the GRAS specified tolerances (± 2.2 dB) from 10-20 kHz. From 20-50 kHz the tolerances have been specified to ± 3.2 dB.

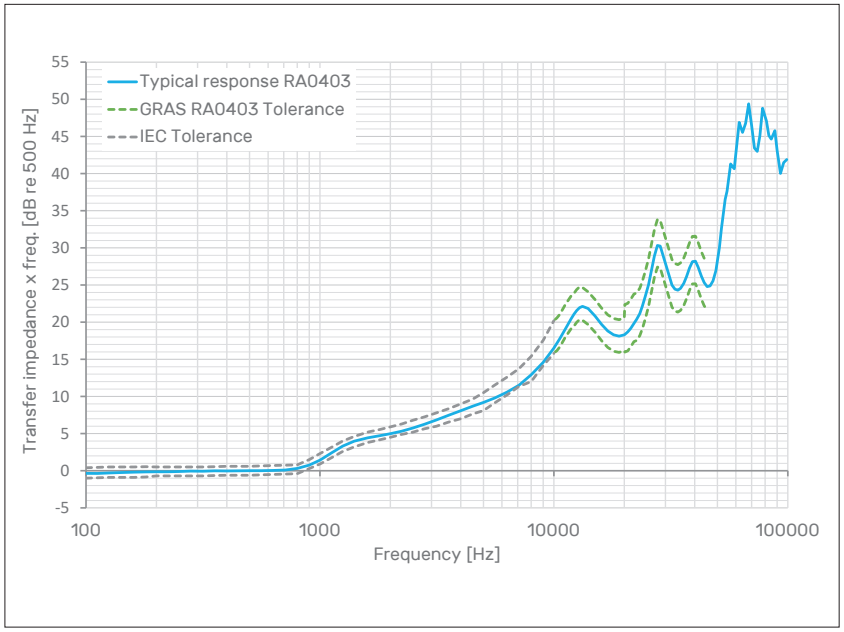

Figure 3
Transfer impedance of RA0403 with IEC tolerances and GRAS tolerances. The GRAS tolerances are specified up to 50 kHz.

References

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