Hi-Res Audio Ear Simulator for Measurements at Very High Frequencies

GRAS Sound & Vibration

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Introduction

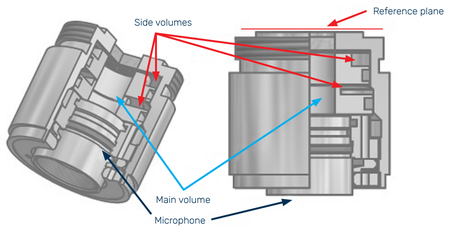
The standard IEC 60318-4 ear simulator (also referred to as the 711 ear simulator) is specified up to 10 kHz and has an undamped resonance around 13.5 kHz when measured at the coupler reference plane. A new ear simulator from GRAS based on the design of the original 711 ear simulator extends the frequency range up to 50 kHz for very high-frequency measurements of Hi-Res Audio products. This ear simulator also has a damped resonance to reduce the influence of the ear canal length resonance, so that influence of DUT placement is minimized.

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

Evolution of the 711 Ear Simulator

The IEC 60318-4 ear simulator is widely applied in verification of frequency response of acoustic products, e.g. in the consumer audio 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 ensures that the headphone is facing the same acoustic input impedance as a real human ear would provide.

An ear simulator based on the standard IEC 60318-4, e.g. 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.



Cross section of the standard 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. 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. This response makes it very difficult to make repeatable measurements above 8 kHz – 10 kHz.

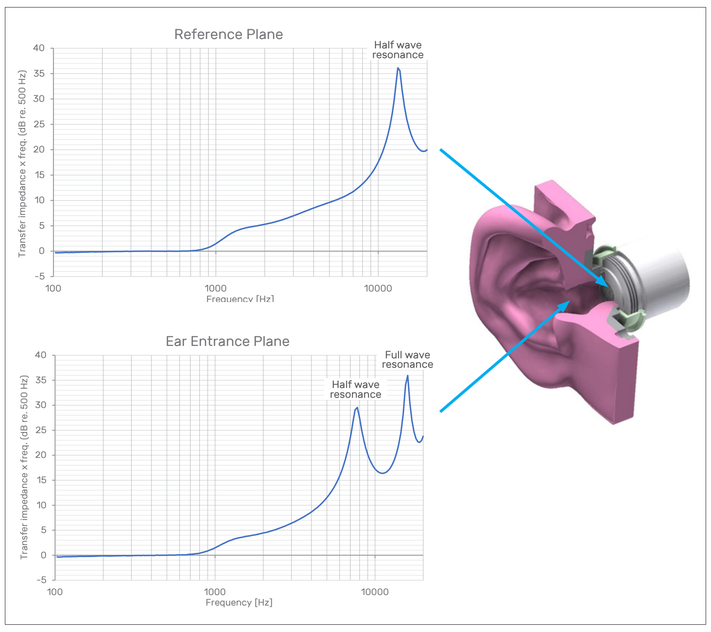


FIGURE 1
GRAS RA0045 Ear Simulator volume extended with anthropometric pinna (GRAS KB5000).

To avoid this unwanted response, GRAS designed the RA0401 High-Frequency Ear Simulator to minimize the effect of the undamped resonance at 13.5 kHz in order to accurately acquire and verify the high-frequency response of the DUT. This effect is obtained by using a built-in resonance damping system in the ear simulator. This damping system attenuates the resonance peak with approximately 14 dB and reduces the effects of the shifts caused by changes in DUT positioning in the ear canal. Thus, repeatable measurements up to 20 kHz are made possible, and the GRAS RA0401 is still 100% compliant with IEC 60318-4. For more information, see the white paper about GRAS RA0401 by Morten Wille, Oct 2017.

Today's challenges

New audio formats with wider frequency ranges have been introduced to provide the users with higher sound quality and better listening experience. This has led to a growing 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 20 kHz these are not adequate.

The new Hi-Res Audio Ear Simulator

The GRAS RA0403 Hi-Res Audio Ear Simulator is also based on the standardized IEC 60318-4 ear simulator and the updated 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 GRAS RA0403 Hi-Res Audio 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 new GRAS RA0403 Hi-Res Audio Ear Simulator are compared to the original 711 ear simulator, the GRAS RA0045, as well as the more recent GRAS RA0401 High-Frequency Ear Simulator. The sensitivity of the GRAS RA0403 Ear Simulator is significantly lower due to using a ¼" microphone which results in a higher noise floor. This means that the GRAS RA0403 Ear Simulator is not suited for low-level measurements, and that the GRAS RA0401 or the GRAS 43BB Low-noise Ear Simulator System would be a better choice.

	RA0045	RA0401	RA0403
Microphone	40AG (½")	40AG (½")	40BP (¼")
Frequency range (Hz)	100-10k	100-20k	100-50k
Sensitivity (mV/Pa)	12.5	12.5	1.6
Volume (mm3)	1260	1260	1260
Dynamic range (dB)	25-164	25-164	44-169
Ref. plane resonance freq. (Hz)	13500	13500	13500
IEC 60318-4 (711) Compliant	Yes	Yes	Compatible

TABLE 1
Specifications of RA0403 compared to RA0045 and RA0401.

Figure 2 shows the transfer impedance curves for the new RA0403 Hi-Res Audio 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 are clearly visible. The RA0401 extends the useful frequency range to 20 kHz, while the frequency range of the RA0403 extends up to 100 kHz with efficient damping of resonances up to 50 kHz.

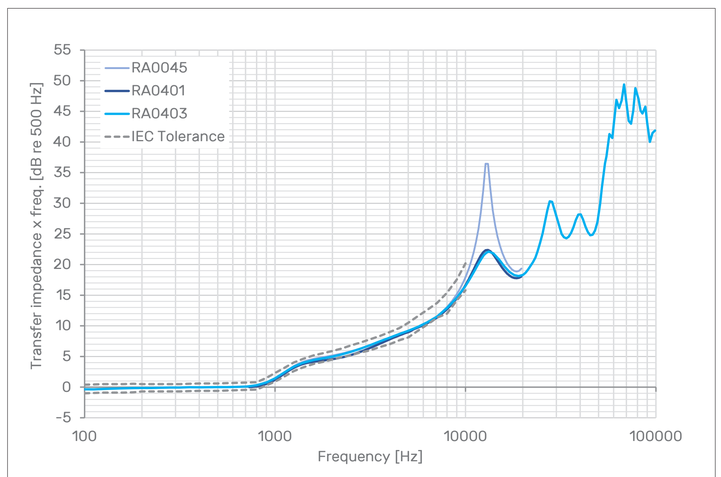


FIGURE 2
The extended frequency range obtained by RA0403 compared to frequency ranges of RA0045 and RA0401.

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 are specified to ± 3.2 dB.

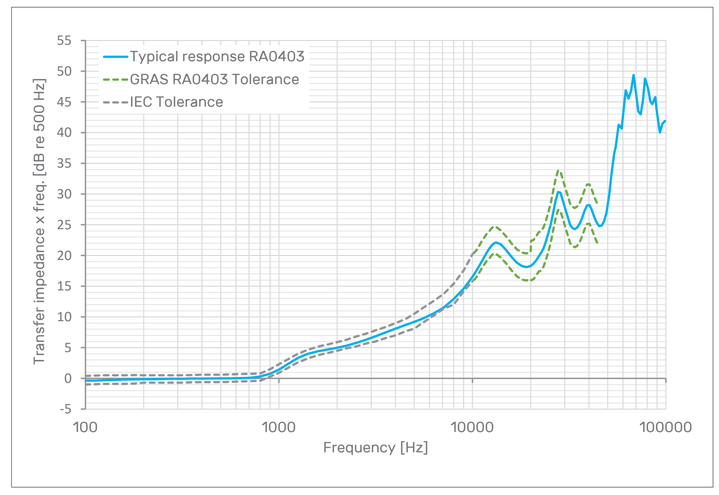


FIGURE 3
Transfer impedance of RA0403 with IEC tolerances and GRAS tolerances. The GRAS tolerances are specified up to 50 kHz.

Conclusion

The new GRAS RA0403 Hi-Res Audio Ear Simulator is designed to extend the useful frequency range up to 50 kHz. The extended frequency range is obtained by using a ¼" pressure microphone instead of a ½" microphone. The new ear simulator is compatible with the specifications in IEC 60318-4.

The damped resonance and small microphone footprint result in improved repeatability and extended frequency range. This makes it possible to evaluate and compare headphones in a very wide frequency range and, at the same time, makes it possible obtain more realistic THD measurements.

It uses a resonance damping system similar to that used in the RA0401 High-Frequency 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; Tsunoda, Hara & Nageno, 2017).

The only real drawback is the lower microphone sensitivity due to using a ¼" microphone that results in a higher noise floor.

The GRAS RA0403 Hi-Res Audio Ear Simulator is mechanically backwards compatible meaning it can replace the standard 711 ear simulator in an existing system or be used in a number of pre-configured, ready-to-use test solutions from GRAS such as the 43AG, the 45CA as well as the 45BB and 45BC KEMAR.

Please visit www.gras.dk for further information.

References

Standard IEC 60318-4: Electroacoustics -Simulators of human head and ear - part 4: Occluded-ear simulator for the measurement of earphones coupled to the ear by means of ear inserts

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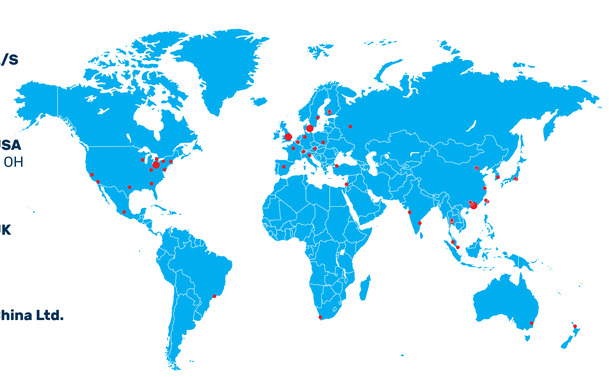

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GRAS is a worldwide leader in the sound and vibration industry. We develop and manufacture state-of-the-art measurement microphones to industries where acoustic measuring accuracy and repeatability is of utmost importance in R&D, QA and production. This includes applications and solutions for customers within the fields of aerospace, automotive, audiology, and consumer electronics. GRAS microphones are designed to live up to the high quality, durability and accuracy that our customers have come to expect and trust.