APPLICATION NOTE

Ear Simulator for Telephonometry
Use of Wideband Ear Simulator Type 4195

Wideband Ear Simulator Type 4195 has been designed to match the ear simulators in Head and Torso Simulator Type 4128-C for measurements on telephone handsets. Type 4195, therefore, provides a very realistic acoustical load to the telephone handset being tested and easily shows acoustic differences between handsets as they appear in real use. This feature is vital when designing telephone handsets optimised for improved sound quality.

Features
- Conforms to ITU-T P.51 Type 3.2 realistic acoustic load (both high- and low-leak versions)
- ½″ microphone and preamplifier included
- Individually calibrated (in accordance with ITU-T P.57)

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Description

Wideband Ear Simulator for Telephonometry Type 4195 supplements Ear Simulator for Telephonometry Type 4185, and conforms to the IEC 60318–1 standard.

Type 4195 offers improved performance at both the low and the high end of the frequency range (up to 8.0 kHz), making it suitable for measurements on wideband telephones. This performance is obtained using a simplified pinna simulator, which adds an ear-canal extension and a cavity to the IEC 60318–4-compliant Coupler UA-1305. The cavity has carefully controlled leakage to the exterior (opening selectable in two grades).

This design has been adopted as an option to the European CTR8 Standard for ISDN handset telephones and is implemented in the new wideband recommendations within ETSI and ITU–T.

All relevant calibration data are supplied on both a calibration chart and a calibration data disk. The data are stored both in a text file format (ASCII format) suitable for import to common spreadsheets and in the (legacy) binary data format of Audio Analyzer Type 2012.

Low- and High-leak Pinna Simulators
The simplified pinna simulator of Type 4195 has two well-defined leak options from the cavity to the exterior to simulate the average real-ear loss for telephone handsets that are held either comfortably tight (low-leak pinna) or loosely (high-leak pinna) against the human ear. The two grades of leakage are obtained by using two different pinna simulators. The high-leak pinna has a controlled opening consisting of a number of holes. The low-leak pinna has two very thin precision slits.

Type 4195 was made with the anatomically shaped Type 3.3 ear simulator as a reference. The acoustic behaviour of Type 4195 is, therefore, very close to that of the anatomically shaped pinna simulator. Type 4195 measures at the Drum Reference Point (DRP). By using the individually measured frequency sensitivity responses supplied with the ear simulator, the measurements can be referred to the Ear Reference Point (ERP).

Type 4195 is recommended for measurements on supra-aural and supra-concha earphones, sealed and unsealed, and for both high and low impedance (covering practically all kinds of earphone design). It can be used in a wide frequency range, from 100 Hz to 8 kHz.

Brüel & Kjær

Assembly

Wideband Ear Simulator Type 4195 includes the following accessories:
- ½″ Microphone Preamplifier Type 2669
- IEC 60318−4-compliant Coupler UA-1305
- Low-leak Simplified Pinna Simulator UA-1304
- High-leak Simplified Pinna Simulator UA-1448
- Soft Seal YJ-0892
- Microphone Cable AO-0419 (LEMO to LEMO)
- LEMO to 7-pin Brüel & Kjær Adaptor ZG-0350

Fig. 1
Parts assembly for Wideband Ear Simulator Type 4195
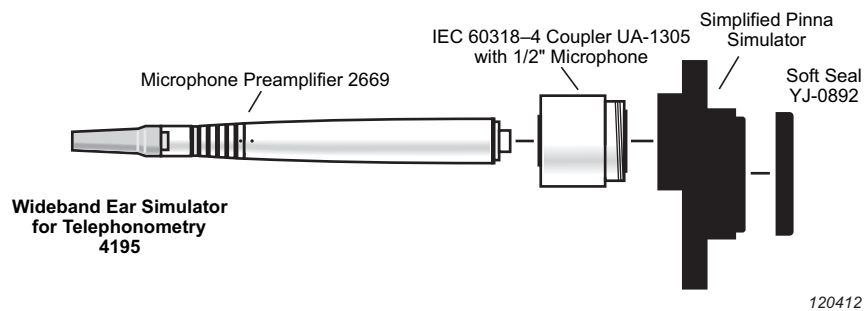
The ear simulator is equipped with Soft Seal YJ-0892 to ensure a good seal between the coupler and handset surfaces, and to protect the latter from being scratched when mounting the handset for testing. Soft Seal YJ-0892 is attached to the simplified pinna simulator. The IEC 60318−4-compliant coupler is screwed into the simplified pinna simulator, and Microphone Preamplifier Type 2669 is screwed into the IEC 60318−4-compliant coupler, which contains a ½″ microphone. This assembly is shown in Fig. 1.

Calibration

During manufacture the ear simulators are calibrated according to ITU−T Rec. P.57. The acoustic input impedance and the frequency sensitivity response are individually measured.

Acoustic Impedance

The acoustic impedance is defined as the acoustic input impedance of the ear simulator, as seen from the ERP. It is measured using a specially designed impedance probe containing a built-in high acoustic-impedance sound source and a calibrated probe microphone. When the impedance probe is mounted on the ear simulator, the tip of the probe microphone is positioned exactly at the ERP. By measuring the sound pressure at the ERP from the high acoustic-impedance sound source, the acoustic input impedance of the ear simulator can be calculated. The impedance is shown in dB relative to 1 acoustic ohm (1 Pa·s/m^3). See Fig. 2 and Fig. 3.

Fig. 2
Typical acoustic impedance for the ear simulator and the standardised ITU−T Rec. P.57: Type 3.2, low-leak curve to which Wideband Ear Simulator Type 4195 complies
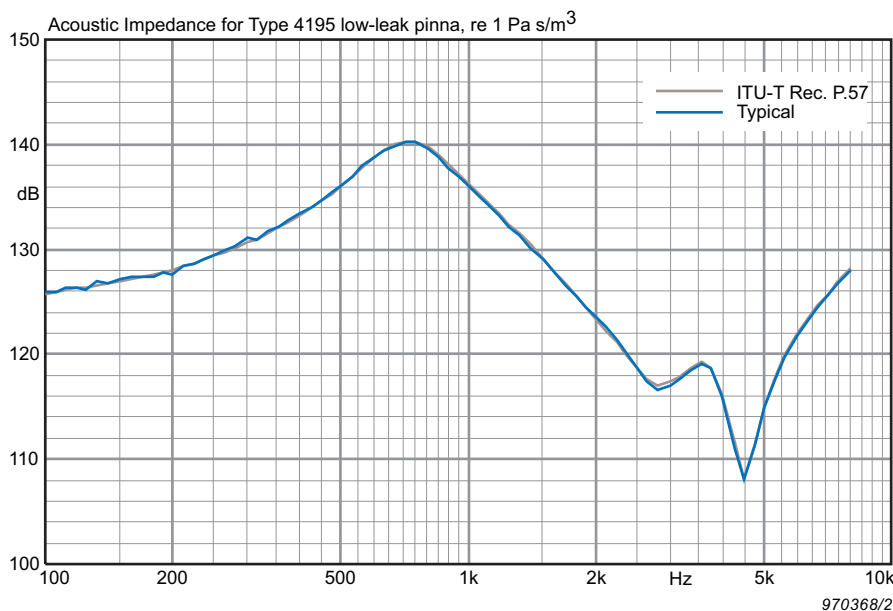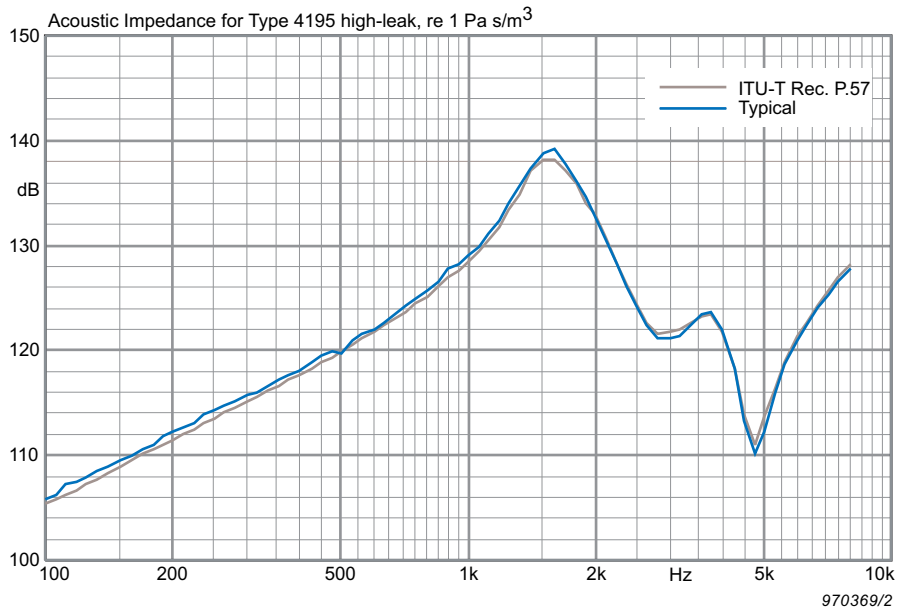
Fig. 3

Typical acoustic impedance for the ear simulator and the standardised ITU – T Rec. P.57: Type 3.2, high-leak curve to which Wideband Ear Simulator Type 4195 complies

Acoustic Impedance for Type 4195 high-leak, re 1 Pa s/m^3

ITU-T Rec. P.57
Typical

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Frequency Sensitivity Response

The frequency sensitivity response (also referred to as the DRP to the ERP transfer function) is defined as the modulus of the ratio of output voltage of the ear simulator to input sound pressure at the ERP, normalised to 0 dB at 1 kHz. The frequency sensitivity response is measured under open-ear conditions by mounting the artificial ear in a large plane baffle and exposing it to a plane incident wave perpendicular to the baffle. The sound pressure at the ERP is then measured using a calibrated probe microphone together with the output voltage of the ear simulator, both as a function of frequency. The frequency sensitivity response can then be calculated as the ratio of the measured output voltage of the ear simulator to the measured input sound pressure at the ERP. For practical reasons, the frequency sensitivity response is also measured under closed-ear conditions. The frequency sensitivity response is used as a correction function. Normally the open-ear response is used. The closed-ear frequency sensitivity response is primarily used for diagnostic purposes, for example, to interpret differences between handset measurements made with the two different ear simulators.

The frequency sensitivity responses for Type 4195 are shown in Fig. 4 and Fig. 5. The correction is obtained by dividing the measured data by the frequency sensitivity response (as a post-processing operation on the measurement data).

Frequency Sensitivity Response for Type 4195 low-leak pinna, re 1 kHz

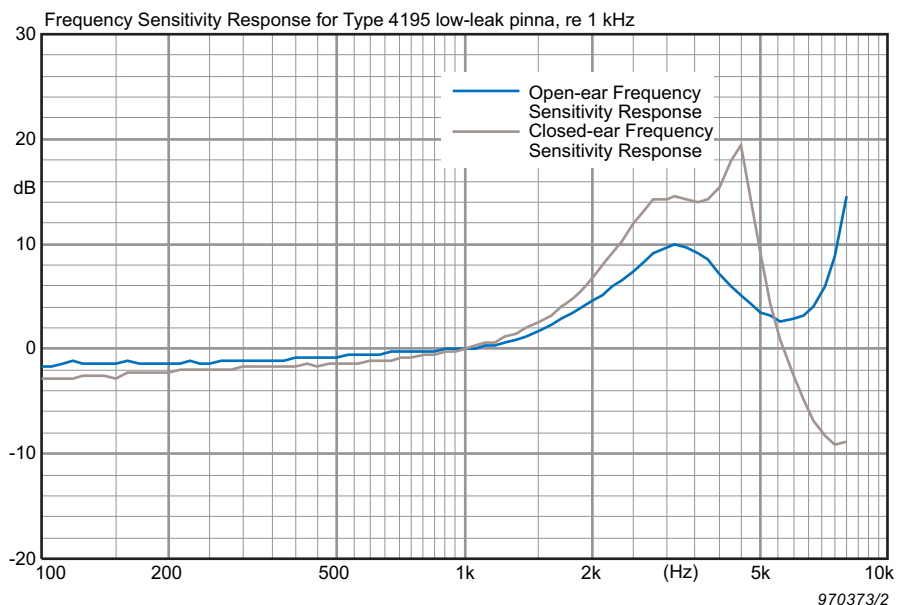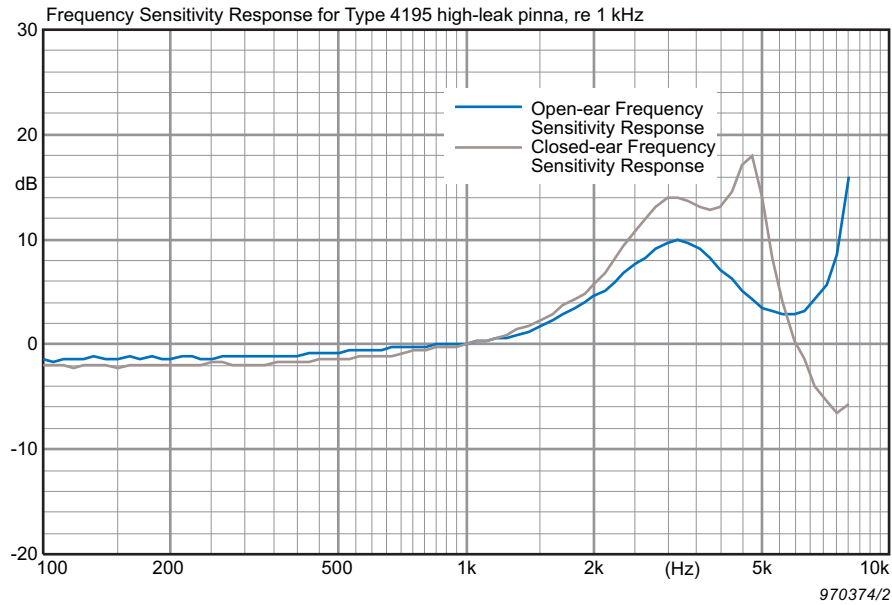Open-ear Frequency Sensitivity Response
Closed-ear Frequency Sensitivity Response

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Frequency Sensitivity Response for Type 4195 high-leak pinna, re 1 kHz

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Open-ear Frequency Sensitivity as a Correction Function

Using the open-ear frequency sensitivity response as a correction function with Type 4195, measurements made on any telephone handset can be referred to the equivalent sound pressure at ERP required to calculate loudness rating or to check results against specifications, based on measurements referred to ERP. When calculating loudness rating (RLR), no LE correction is required, since the leakage is already provided by the artificial ear.

Absolute Sensitivity

The absolute sensitivity at 1 kHz (in V/Pa) is defined as the ratio of the absolute output voltage of the ear simulator to input sound pressure at the ERP. The absolute sensitivity is specified on the calibration chart for both open and closed-ear conditions. The sensitivities can be verified using Sound Calibrator Type 4231 and, if using Type 4195, the supplied Calibration Adaptor DP-0939. See Fig. 6 for calibration setup.

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Normally the calibration level, P_{4231}, produced by Type 4231 mounted on a ½″ microphone is 94 dB SPL. But if an extra volume is added, for instance, caused by the presence of a coupler unit or by the adaptor used for the calibration, the sound pressure produced by the calibrator will be affected.

Also, the required measurement conditions influence the calibration. When using the calibrator, the ear simulator is exposed to closed-ear conditions. Therefore, when calibrating, it is the sensitivity according to closed-ear conditions that is measured. As it is the open-ear sensitivity that is of interest, the calibration data must be transformed to refer to this situation.

The required sensitivities can therefore be found if the calibration level of the sound calibrator is corrected. The calibration level must be corrected by a factor $P_{\Delta V}$ for any added volume and, in order to obtain the open-ear sensitivity, must be corrected by a factor $P_{\Delta(\text{open} - \text{closed})}$ to take into account the change in sensitivity when going from closed-ear to open-ear conditions.

The corrected calibration level to obtain the open-ear sensitivity is then given by:

$$P_{4231, \text{ corrected}} \text{ (open ear)} = P_{4231} + P_{\Delta V} + P_{\Delta(\text{open} - \text{closed})}$$

The corrected level to obtain the closed-ear sensitivity is given by:

$$P_{4231, \text{ corrected}} \text{ (closed ear)} = P_{4231} + P_{\Delta V}$$

The calibration levels to obtain the open and closed-ear sensitivities are given in Table 1.

Table 1

Actual calibration levels using Sound Calibrator Type 4231 to find the absolute open- and closed-ear sensitivities at 1 kHz

	Calibration Adaptor	$P_{4231,\ corrected}$ (open ear)	$P_{4231,\ corrected}$ (closed ear)
Type 4195 low-leak	**DP-0939**	98.2 dB	98.0 dB
Type 4195 high-leak	**DP-0939**	84.7 dB	85.4 dB

Equivalent Diagrams

Electrical equivalent diagrams can be set up based on the mechanical properties of the ear simulator. This concept makes it possible to perform computer simulations that show the effect of the acoustic loading presented by the ear simulator.

The electrical equivalent diagrams for the IEC 60318−4-compliant Coupler UA-1305 and the low- or high-leak simplified pinna simulators can be combined to give an equivalent diagram for the complete Type 4195 ear simulator. The cross-sections in Fig. 7 show the physical construction of the coupler and the low- and high-leak pinna simulators with the associated acoustical component names.

Fig. 7

Cross-section of IEC 60318−4-compliant Coupler UA-1305 fitted with low-leak simplified pinna simulator and separate high-leak simplified pinna simulator. The electrical component names refer to the separate electrical equivalent diagrams

IEC 60318 – 4 Coupler and Low-leak Simplified Pinna Simulator

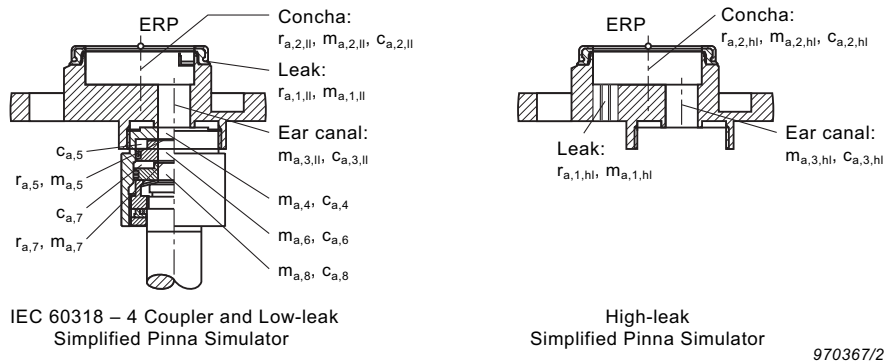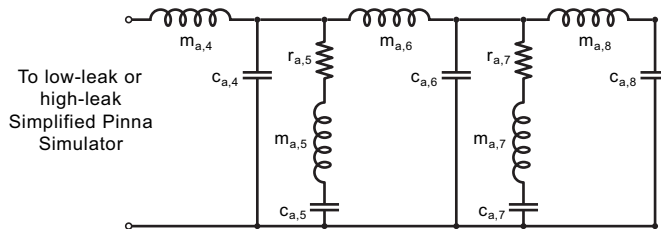High-leak Simplified Pinna Simulator

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Fig. 8 to Fig. 10 show the equivalent diagrams and associated component values for the coupler and the low- and high-leak simplified pinna simulators, respectively. The equivalent diagrams are obtained using an impedance type analogy. The circuits are seen from the acoustic side with associated component values in acoustic units.
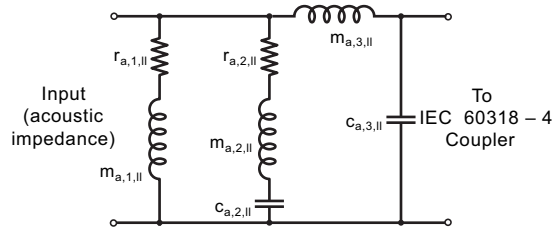
Fig. 8

Electrical equivalent diagram and associated component values for IEC 60318−4-compliant Coupler UA-1305

IEC 60318 – 4 Coupler:

$r_{a,5}\ =\ 50.6 \times 10^{6}\ \dfrac{Pa \times s}{m^{3}}$

$r_{a,7}\ =\ 31.1 \times 10^{6}\ \dfrac{Pa \times s}{m^{3}}$

$m_{a,4}\ =\ 78.8\ \dfrac{kg}{m^{4}}$

$m_{a,5}\ =\ 9.4 \times 10^{3}\ \dfrac{kg}{m^{4}}$

$m_{a,6}\ =\ 132.3\ \dfrac{kg}{m^{4}}$

$m_{a,7}\ =\ 983.8\ \dfrac{kg}{m^{4}}$

$m_{a,8}\ =\ 153.5\ \dfrac{kg}{m^{4}}$

$c_{a,4}\ =\ 0.9 \times 10^{-12}\ \dfrac{m^{5}}{N}$

$c_{a,5}\ =\ 1.9 \times 10^{-12}\ \dfrac{m^{5}}{N}$

$c_{a,6}\ =\ 1.5 \times 10^{-12}\ \dfrac{m^{5}}{N}$

$c_{a,7}\ =\ 2.1 \times 10^{-12}\ \dfrac{m^{5}}{N}$

$c_{a,8}\ =\ 2.1 \times 10^{-12}\ \dfrac{m^{5}}{N}$

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Type 4195 low-leak:

$$r_{a,1,ll} = 1.7 \times 10^6 \ \frac{Pa \times s}{m^3}$$

$$r_{a,2,ll} = 250 \times 10^3 \ \frac{Pa \times s}{m^3}$$

$$m_{a,1,ll} = 982.2 \ \frac{kg}{m^4}$$

$$m_{a,2,ll} = 38.5 \ \frac{kg}{m^4}$$

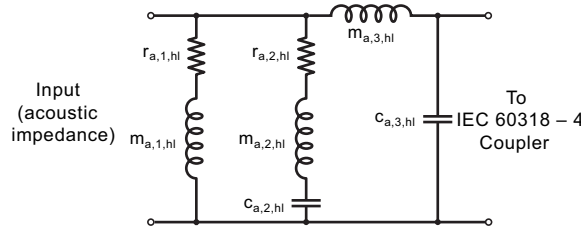$$m_{a,3,ll} = 271.6 \ \frac{kg}{m^4}$$

$$c_{a,2,ll} = 32.5 \times 10^{-12} \ \frac{m^5}{N}$$

$$c_{a,3,ll} = 3.1 \times 10^{-12} \ \frac{m^5}{N}$$

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Fig. 10

Electrical equivalent diagram and associated component values for the High-leak Simplified Pinna Simulator UA-1448

Type 4195 high-leak:

$$r_{a,1,hl} = 280 \times 10^3 \ \frac{Pa \times s}{m^3}$$

$$r_{a,2,hl} = 300 \times 10^3 \ \frac{Pa \times s}{m^3}$$

$$m_{a,1,hl} = 250 \ \frac{kg}{m^4}$$

$$m_{a,2,hl} = 45.9 \ \frac{kg}{m^4}$$

$$m_{a,3,hl} = 271.6 \ \frac{kg}{m^4}$$

$$c_{a,2,hl} = 25 \times 10^{-12} \ \frac{m^5}{N}$$

$$c_{a,3,hl} = 3.1 \times 10^{-12} \ \frac{m^5}{N}$$

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Fig. 11 and Fig. 12 show the simulated acoustic impedances of the Type 4195 with low- and high-leak simulators, respectively, based on the electrical models. Although the equivalent diagrams are based on the mechanical properties of the ear simulator, they constitute a compromise between complexity (good simulation of reality) and simplicity (poorer simulation of reality). As a consequence, some of the component values have been adapted to give the best simulation of the acoustic impedance.
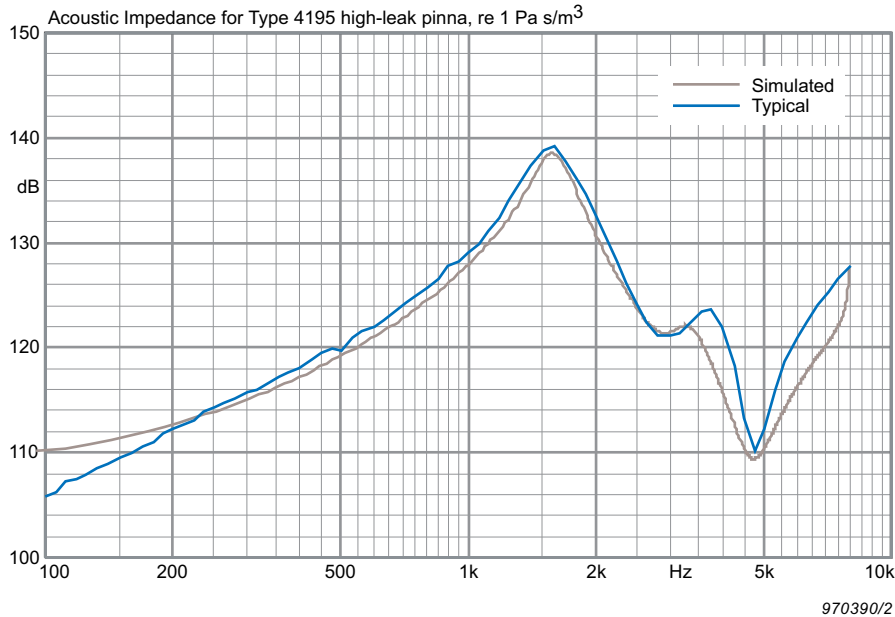
Fig. 11

Simulated acoustic impedance for Low-leak Simplified Pinna Simulator UA-1304, compared to typical measured impedance curve

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Acoustic Impedance for Type 4195 high-leak pinna, re 1 Pa s/m³

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Specifications

Compliance with Standards

CE , ⓒ	CE-mark indicates compliance with: EMC Directive and Low Voltage Directive. C-Tick mark indicates compliance with the EMC requirements of Australia and New Zealand
Safety	EN/IEC 61010−1: Safety requirements for electrical equipment for measurement, control and laboratory use. UL 61010B−1: Standard for Safety – Electrical measuring and test equipment
EMC Emission	EN/IEC 61000−6−3: Generic emission standard for residential, commercial and light industrial environments. CISPR 22: Radio disturbance characteristics of information technology equipment. Class B Limits. FCC Rules, Part 15: Complies with the limits for a Class B digital device.
EMC Immunity	EN/IEC 61000−6−1: Generic standards – Immunity for residential, commercial and light industrial environments. EN/IEC 61326: Electrical equipment for measurement, control and laboratory use – EMC requirements. **Note:** The above is only guaranteed using accessories listed in this Product Data sheet.
Temperature	IEC 60068−2−1 & IEC 60068−2−2: Environmental Testing. Cold and Dry Heat. Operating Temperature: −5 to +40°C (41 to 104°F) Storage Temperature: −25 to +70°C (−13 to +158°F)
Humidity	IEC 60068−2−78: Damp Heat: 90% RH (non-condensing at 40°C (104°F))
Mechanical	Non-operating: IEC 60068−2−6: Vibration: 0.3 mm, 20 m/s², 10−500 Hz IEC 60068−2−27: Shock: 1000 m/s² IEC 60068−2−29: Bump: 1000 bumps at 250 m/s²

General Specifications

STANDARDS
Acoustic performance according to ITU−T Recommendation P.57 section 5.3.2, Type 3.2

DIMENSIONS
Height: 126 mm (5″)
Max. Diameter: 60 mm (2.4″)

WEIGHT (WITHOUT PREAMPLIFIER TYPE 2669)
107 g (3.8 oz.)

Environmental Calibration Conditions

STATIC PRESSURE
101.3 ±3.0 kPa

TEMPERATURE
23 ±3°C (73.4 ±5.4°F)

RELATIVE HUMIDITY
60 ±20%

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