INTERNATIONAL STANDARD

ISO 11904-2

First edition
2004-11-01

Acoustics — Determination of sound immission from sound sources placed close to the ear —

Part 2:
Technique using a manikin

Acoustique — Détermination de l'exposition sonore due à des sources placées à proximité de l'oreille —

Partie 2: Technique utilisant un mannequin

Reference number
ISO 11904-2:2004(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11904-2 was prepared by Technical Committee ISO/TC 43, *Acoustics*.

ISO 11904 consists of the following parts, under the general title *Acoustics — Determination of sound immission from sound sources placed close to the ear*:

— *Part 1: Technique using a microphone in a real ear (MIRE technique)*

— *Part 2: Technique using a manikin*

Introduction

ISO 11904 is a series of standards which specify methods for the determination of sound immissions from sources located close to the ear in which situations the sound pressure level measured at the position of the exposed person (but with the person absent) does not adequately represent the sound exposure.

In order to make it possible to assess the exposure by means of well-established criteria, the exposure of the ear is measured and subsequently converted into a corresponding free-field or diffuse-field level. The result is given as a free-field related or diffuse-field related equivalent continuous A-weighted sound pressure level, $L_{\text{FF,H,Aeq}}$ or $L_{\text{DF,H,Aeq}}$ when ISO 11904-1 is used, or $L_{\text{FF,M,Aeq}}$ or $L_{\text{DF,M,Aeq}}$ when ISO 11904-2 is used.

ISO 11904-1 describes measurements carried out using miniature or probe microphones inserted in the ears of human subjects (microphones in real ear, MIRE technique). ISO 11904-2 describes measurements carried out using a manikin equipped with ear simulators including microphones (manikin technique).

ISO 11904 may, for instance, be applied to equipment tests and the determination of noise exposure at the workplace where, in the case of exposure from sources close to the ears, the sound pressure level measured at the position of the exposed person (but with the person absent) does not adequately represent the sound exposure. Examples of applications are head- and earphones used to reproduce music or speech, whether at the workplace or during leisure, nailguns used close to the head, and combined exposure from a close-to-ear sound source and an external sound field.

When specific types of equipment are to be tested (e.g. portable cassette players or hearing protectors provided with radio receivers), test signals suitable for this particular type of equipment have to be used. Neither such test signals nor the operating conditions of the equipment are included in ISO 11904 but might be specified in other standards.

When workplace situations are measured, the various noise sources contributing to the immission should be identified. Operating conditions for machinery and equipment used might be specified in other standards.

Both parts of ISO 11904 strive for the same result: a mean value for a population of the free-field or the diffuse-field related level. ISO 11904-1 does this by specifying the mean of measurements on a number of human subjects; ISO 11904-2 does this by using a manikin, which aims at reproducing the acoustical effects on an average human adult. However, the two methods yield different measurement uncertainties which can influence the choice of method. Only the method described in ISO 11904-1 gives results which indicate the variance in a human population. Information on the uncertainties is given in Annexes A and B.

When using the MIRE technique for measurement of sound from earphones of insert and stethoscopic types, practical problems can occur with the positioning of microphones in the ear canal. When using the manikin technique, the head- or earphone has to be coupled to the pinna simulator and ear canal extension as far as possible in the way it is coupled to the human ear. In cases where head- or earphones or other objects touch the pinna, a possible deviation in stiffness or shape of the artificial pinna from human pinnae has a significant impact on the result and can even make the results invalid.

An overview of the differences between the two parts of ISO 11904 is given in Table 0.1.

Table 0.1 — Overview of differences between MIRE and manikin techniques

Parameter	ISO 11904-1	ISO 11904-2
Type of method	Microphone in real ear technique	Manikin technique
Limitation of the method	With earphones of insert and stethoscopic type, practical problems can occur with positioning of microphones in the ear canal.	Proper coupling may not always be obtained if the artificial pinna deviates from human pinnae in stiffness or shape. In some cases the exposed person cannot be replaced by a manikin, e.g., if the person has to operate equipment.
Main issues affecting accuracy	Number of subjects When tabulated values are used for $\Delta L_{FF,H}$ or $\Delta L_{DF,H}$: — calibration of ear canal microphone — accuracy in positioning of microphones in the ear canal When individual values are used for $\Delta L_{FF,H}$ or $\Delta L_{DF,H}$: — quality of reference sound field — stability of sensitivity and frequency response as well as position of ear canal microphone	Similarity of manikin to humans Calibration of manikin
Frequency range	20 Hz to 16 kHz	20 Hz to 10 kHz

Acoustics — Determination of sound immission from sound sources placed close to the ear —

Part 2:
Technique using a manikin

1 Scope

This part of ISO 11904 specifies basic framework measurement methods for sound immission from sound sources placed close to the ear. These measurements are carried out with a manikin, equipped with ear simulators including microphones. The measured values are subsequently converted into corresponding free-field or diffuse-field levels. The results are given as free-field related or diffuse-field related equivalent continuous A-weighted sound pressure levels. The technique is denoted the manikin technique.

This part of ISO 11904 is applicable to exposure to sound from sources close to the ear, for example during equipment tests or at the workplace to sound from earphones or hearing protectors with audiocommunication facilities.

This part of ISO 11904 is applicable in the frequency range from 20 Hz to 10 kHz. For frequencies above 10 kHz, ISO 11904-1 can be used.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60942:2003, *Electroacoustics — Sound calibrators*

IEC 61260:1995, *Electroacoustics — Octave-band and fractional-octave-band filters*

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

ITU-T P.58:1996, *Head and torso simulator for telephonometry*

GUM:1993[1], *Guide to the expression of uncertainty in measurement*. BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 1995

1) Corrected and reprinted in 1995.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
manikin sound pressure level
$L_{M,exp,f}$
equivalent continuous sound pressure level in one-third-octave frequency bands with nominal midband frequency f, measured with the microphone of an ear simulator integrated in a manikin when the manikin is exposed to the sound under test

3.2
free-field frequency response for use with manikins
$\Delta L_{FF,M,f}$
average human free-field frequency response for use with manikins, corrected for the difference between the sound transmission inside the average human ear canal and the corresponding transmission of the manikin ear simulator

NOTE 1 For applicability with manikins, the eardrum reference is replaced by the output of the manikin ear simulator in tabulated values of $\Delta L_{FF,M,f}$.

NOTE 2 The free-field frequency response for use with manikins is identical to the amplitude of the head-related transfer function (HRTF) for frontal sound incidence.

NOTE 3 The human free-field frequency response is defined in ISO 11904-1.

3.3
diffuse-field frequency response for use with manikins
$\Delta L_{DF,M,f}$
average human diffuse-field frequency response for use with manikins, corrected for the difference between the sound transmission inside the average human ear canal and the corresponding transmission of the manikin ear simulator

NOTE 1 For applicability with manikins, the eardrum reference is replaced by the output of the manikin ear simulator in tablulated values of $\Delta L_{DF,M,f}$.

NOTE 2 The human diffuse-field frequency response is defined in ISO 11904-1.

3.4
free-field related sound pressure level determined with a manikin
$L_{FF,M}$
free-field sound pressure level determined with the method of this part of ISO 11904

NOTE 1 The definition may be applied to specific frequencies or frequency bands, weighted or unweighted levels, specific time weightings, etc., for instance “free-field related equivalent continuous A-weighted sound pressure level" (free-field related $L_{M,Aeq}$, also denoted $L_{FF,M,Aeq}$).

NOTE 2 The method is aimed at the mean free-field related sound pressure level that would be obtained with a large human population.

NOTE 3 The free-field related sound pressure level for a human subject is defined in ISO 11904-1.

3.5
diffuse-field related sound pressure level determined with a manikin
$L_{DF,M}$
diffuse-field sound pressure level determined with the method of this part of ISO 11904

NOTE 1 The definition may be applied to specific frequencies or frequency bands, weighted or unweighted levels, specific time weightings, etc., for instance "diffuse-field related equivalent continuous A-weighted sound pressure level" (diffuse-field related $L_{M,Aeq}$, also denoted $L_{DF,M,Aeq}$).

NOTE 2 The method is aimed at the mean diffuse-field related sound pressure level that would be obtained with a large human population.

NOTE 3 The diffuse-field related sound pressure level for a human subject is defined in ISO 11904-1.

4 Measurement principle

A manikin (head and torso simulator) is exposed to the sound source(s) in question and, for each of the ear simulators integrated in the manikin, the sound pressure level is measured in one-third-octave frequency bands, $L_{M,exp,f}$.

Each of the one-third-octave-band levels is adjusted with the free-field or diffuse-field frequency response for the manikin, $\Delta L_{FF,M,f}$ or $\Delta L_{DF,M,f}$, in order to obtain the corresponding free-field related or diffuse-field related one-third-octave-band sound pressure levels. These one-third-octave-band levels are adjusted using A-weighting constants, and subsequently combined to obtain the free-field related or diffuse-field related equivalent continuous A-weighted sound pressure level, $L_{FF,M,Aeq}$ or $L_{DF,M,Aeq}$.

The measurements may be carried out for one or both ears, as appropriate. The free-field or diffuse-field frequency response for use with manikins is taken from Table 1.

5 Instrumentation

5.1 Manikin (head and torso simulator)

The manikin used shall satisfy the requirements of ITU-T P.58:1996, 4.3 (first paragraph), 5.1 and 6.1, for the ear simulator and the acoustic characteristics of the manikin respectively.

The manikin used should be checked regularly for compliance with the requirements of ITU-T P.58:1996, 4.3 (first paragraph), 5.1 and 6.1.

In cases where sound sources (such as earphones or hearing protectors with communication facilities) touch the pinna, they shall be coupled to the pinna simulator and ear canal extension in a way as close as possible to the way it is coupled to the human ear.

NOTE In cases where head- or earphones or other objects touch the pinna, the deviation in stiffness or shape of the artificial pinna from human pinnae has a significant impact on the result and may even make the results invalid.

5.2 Check of calibration

The calibration of the microphones and the measuring equipment shall be checked as follows.

For checking the calibration of the measurement system together with the occluded ear simulator, an acoustic calibrator (class 1 according to IEC 60942:2003) shall be coupled to the occluded ear simulator. The sound pressure level shall, in this case, be measured without any frequency weighting.

NOTE This measurement is generally conducted with the aid of an adapter in the ear canal extension. It should be noted that the adapter will change the nominal value for the sound pressure levels of the acoustic calibrator.

The frequency response of the measuring system without the occluded ear simulator may be measured using suitable electrical input signals.

5.3 Filters

Signals shall be analysed with one-third-octave-band filters complying with the requirements for class 1 of IEC 61260:1995.

6 Determination of free-field or diffuse-field related equivalent continuous A-weighted sound pressure level

6.1 Measurement of manikin sound pressure level

With the manikin exposed to the sound under test, the equivalent continuous sound pressure levels for each one-third-octave frequency band should be measured with each ear simulator. The frequency range shall cover all frequencies of significance for the test purposes, and a signal-to-noise ratio of at least 10 dB shall be guaranteed in each one-third-octave frequency band. If only one ear simulator is used, this shall be stated.

The measurement period shall be chosen to give a proper representation of the exposure. For the one-third-octave frequency band with the midband frequency f, the measurement period t shall be as follows:

— for $f \leqslant 2\,000$ Hz:

$$t \geqslant \frac{5\,000}{f}$$

— and for $f > 2\,000$ Hz:

$$t \geqslant 2{,}5 \text{ s}$$

NOTE 1 The specifications given refer to random noise; for other test signal types, other periods may be used as long as the measurement uncertainty is not increased.

The level in each one-third-octave frequency band shall be corrected for the pressure frequency response of the microphone of the ear simulator.

NOTE 2 The pressure frequency response of the microphone can be obtained from the manufacturer's calibration data.

The result, the manikin one-third-octave-band sound pressure level during exposure to the sound under test, is denoted $L_{\text{M,exp},f}$.

If only sounds from sources coupled directly to the ears are to be taken into account, only the head of the manikin (without torso) is required for the measurements.

6.2 Conversion to free-field or diffuse-field related sound pressure level

To obtain the free-field or diffuse-field related one-third-octave band sound pressure level, $L_{\text{FF,M},f}$ or $L_{\text{DF,M},f}$, the free-field or diffuse-field frequency response for use with manikin, $\Delta L_{\text{FF,M},f}$ or $\Delta L_{\text{DF,M},f}$, shall be subtracted from the manikin sound pressure level, $L_{\text{M,exp},f}$:

$$L_{\text{FF,M},f} = L_{\text{M,exp},f} - \Delta L_{\text{FF,M},f} \quad (1)$$

$$L_{\text{DF,M},f} = L_{\text{M,exp},f} - \Delta L_{\text{DF,M},f} \quad (2)$$

$\Delta L_{\text{FF,M},f}$ or $\Delta L_{\text{DF,M},f}$ shall be taken from Table 1.

Table 1 — Free-field and diffuse-field frequency response for use with manikins

One-third-octave midband frequency Hz	Free-field frequency response $\Delta L_{\mathrm{FF,M},f}$ dB	Diffuse-field frequency response $\Delta L_{\mathrm{DF,M},f}$ dB
⩽ 100	0	0
125	0,4	0,3
160	0,8	0,6
200	1,2	0,9
250	1,5	1,2
315	1,5	1,4
400	1,7	1,8
500	2,1	2,3
630	2,5	3,2
800	2,2	4,0
1 000	1,7	4,6
1 250	3,8	6,0
1 600	8,4	8,1
2 000	12,9	11,4
2 500	15,6	15,0
3 150	15,6	14,2
4 000	14,2	11,9
5 000	10,6	9,8
6 300	4,0	8,5
8 000	2,0	11,0
10 000	−0,3	7,1

NOTE 1 Data have been taken from Reference [8].

NOTE 2 The mean human blocked-entrance data from Reference [9] have been transferred to the "manikin eardrum" using the blocked entrance to the "manikin eardrum" transfer function for ear simulators according to IEC 60711 (see Reference [8]). Systematic deviations are found for exposure to sound sources placed close to the ear measured with manikins, compared to MIRE measurements using human subjects. For compensation, the frequency responses listed in this table differ from frequency responses of manikins specified in ITU-T P.58 or IEC 60959.

6.3 A-weighting and summation

The free-field or diffuse-field related equivalent continuous A-weighted sound pressure level, $L_{\mathrm{FF,M,Aeq}}$ or $L_{\mathrm{DF,M,Aeq}}$, shall be calculated using A-weighting constants A_f specified in IEC 61672-1, and the following formulae:

$$L_{\mathrm{FF,M,Aeq}} = 10 \lg \left\{ \sum_f 10^{(L_{\mathrm{FF,M},f} + A_f)/10} \right\} \text{ dB} \tag{3}$$

$$L_{\mathrm{DF,M,Aeq}} = 10 \lg \left\{ \sum_f 10^{(L_{\mathrm{DF,M},f} + A_f)/10} \right\} \text{ dB} \tag{4}$$

7 Test report

As a minimum, the following information shall be included in the test report:

a) date and place of measurements, reference to this part of ISO 11904, together with the name of the measuring institution and the person responsible for the measurements;

b) description of all relevant information about the sound under test, the source(s) emitting it, operating conditions, frequency range (see 6.1), etc.;

c) description of the measurement place, with special consideration of the acoustical properties;

d) description of the instrumentation, including information about measurement period(s), and date and place of calibration;

e) description of the manikin used, including choice of ear simulators (left or right side, or both);

f) for each ear simulator of the manikin, the values of $L_{\mathrm{M,exp},f}$, $L_{\mathrm{FF,M},f}$ or $L_{\mathrm{DF,M},f}$ and $L_{\mathrm{FF,M,Aeq}}$ or $L_{\mathrm{DF,M,Aeq}}$; data may be given graphically;

g) estimation of the measurement uncertainty according to GUM (an example is given in Annex B); other relevant information influencing the measurement results.

Annex A
(informative)

Example of sources of measurement uncertainty

A.1 General

This annex is identical in both parts of this International Standard. The uncertainty of the final result depends on whether the MIRE technique (as described in ISO 11904-1) or the manikin technique (as described in this part of ISO 11904) has been used.

For the MIRE technique, a key issue is the extent to which a limited number of subjects represent a population, and whether data for the free-field or diffuse-field frequency response have been taken from tables or determined individually. For the manikin technique, the corresponding issue is the extent to which the manikin represents an average human subject.

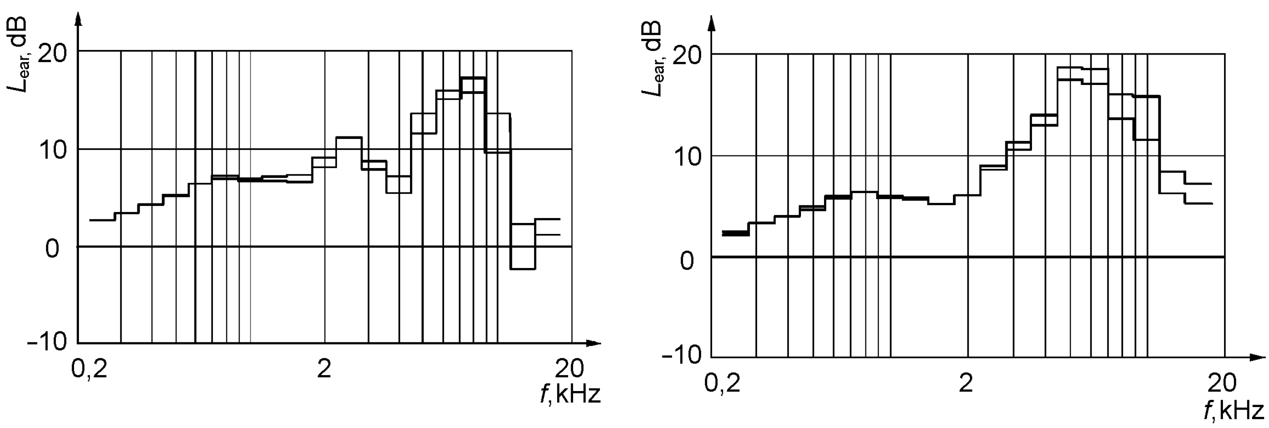
Table A.1 gives an overview of the impact on the final result of some typical sources of measurement uncertainty when using the two parts of ISO 11904. Some typical magnitudes of selected sources of measurement uncertainty are given in A.2 to A.4. The information may be useful for estimating the uncertainty of a measurement and, for the MIRE technique, for determining the required number of subjects in order to achieve the desired uncertainty.

In addition, each of the parts of ISO 11904 contains a separate annex with an example of an uncertainty calculation for the respective technique.

Formulae and data in this annex have been taken from Reference [8].

A.2 Inaccurate position of ear canal microphone

Figure A.1 shows examples of errors from inaccurate positioning of the ear canal microphone.



a) Open entrance **b) Blocked entrance**

Figure A.1 — Example of change in sound pressure level for a 3 mm displacement of ear canal measurement position with open and blocked entrance

Table A.1 — Overview of typical sources of measurement uncertainty and their impact in various situations

Source of measurement uncertainty	ISO 11904-1 MIRE technique		ISO 11904-2 Manikin technique
	$\Delta L_{FF,H}$ or $\Delta L_{DF,H}$ taken from table	$\Delta L_{FF,H}$ or $\Delta L_{DF,H}$ determined individually	$\Delta L_{FF,M}$ or $\Delta L_{DF,M}$ taken from table
Inaccurate calibration of reference-field microphone, or inaccurate data used for its frequency response	–	+	–
Inaccurate calibration of ear canal or manikin microphone, or inaccurate data used for its frequency response	+	o	+
Unstable sensitivity or frequency response (between measurements) of ear canal or manikin microphone	–	+	–
Inaccurate position of ear canal microphone	+ (see A.2)	o	–
Deviation of reference sound field from intended sound field	–	+	–
Deviation of manikin from human population	–	–	+ (see A.4)
Use of finite number of subjects	+ (see A.3.2)	+ (see A.3.3)	–
Variations in the sound under test	+	+	+

+ has direct impact on final result,

o cancels in final result,

– not applicable.

A.3 Use of finite number of subjects

A.3.1 General

The fact that only a limited number of subjects are used results in a statistical uncertainty of the result. Two terms may contribute:

— statistical variation in $L_{ear,exp,f}$, and

— statistical variation in $\Delta L_{FF,H,f}$ or $\Delta L_{DF,H,f}$.

The variance of tabulated data which can be used for $\Delta L_{FF,H,f}$ or $\Delta L_{DF,H,f}$ is assumed to be very small and is ignored (A.3.2). However, this does not mean that use of tabulated data necessarily gives the smallest deviation in the final result, since correlation between the two terms can cause individual characteristics in the two terms which cancel out (A.3.3).

A.3.2 Using tabulated data for free-field or diffuse-field frequency response

The standard deviation of the mean free-field related sound pressure level (across subjects), $\sigma(\overline{L_{\mathrm{FF,H},f}})$, or the standard deviation of the mean diffuse-field related sound pressure level (across subjects), $\sigma(\overline{L_{\mathrm{DF,H},f}})$, can be calculated from

— the standard deviation (across subjects) of the ear canal sound pressure level, $\sigma(L_{\mathrm{ear,exp},f})$, and

— the number of subjects, n:

$$\sigma(\overline{L_{\mathrm{FF,H},f}}) \approx \sigma(\overline{L_{\mathrm{DF,H},f}}) \approx \sqrt{\frac{\sigma^2(L_{\mathrm{ear,exp},f})}{n}} \qquad \text{(A.1)}$$

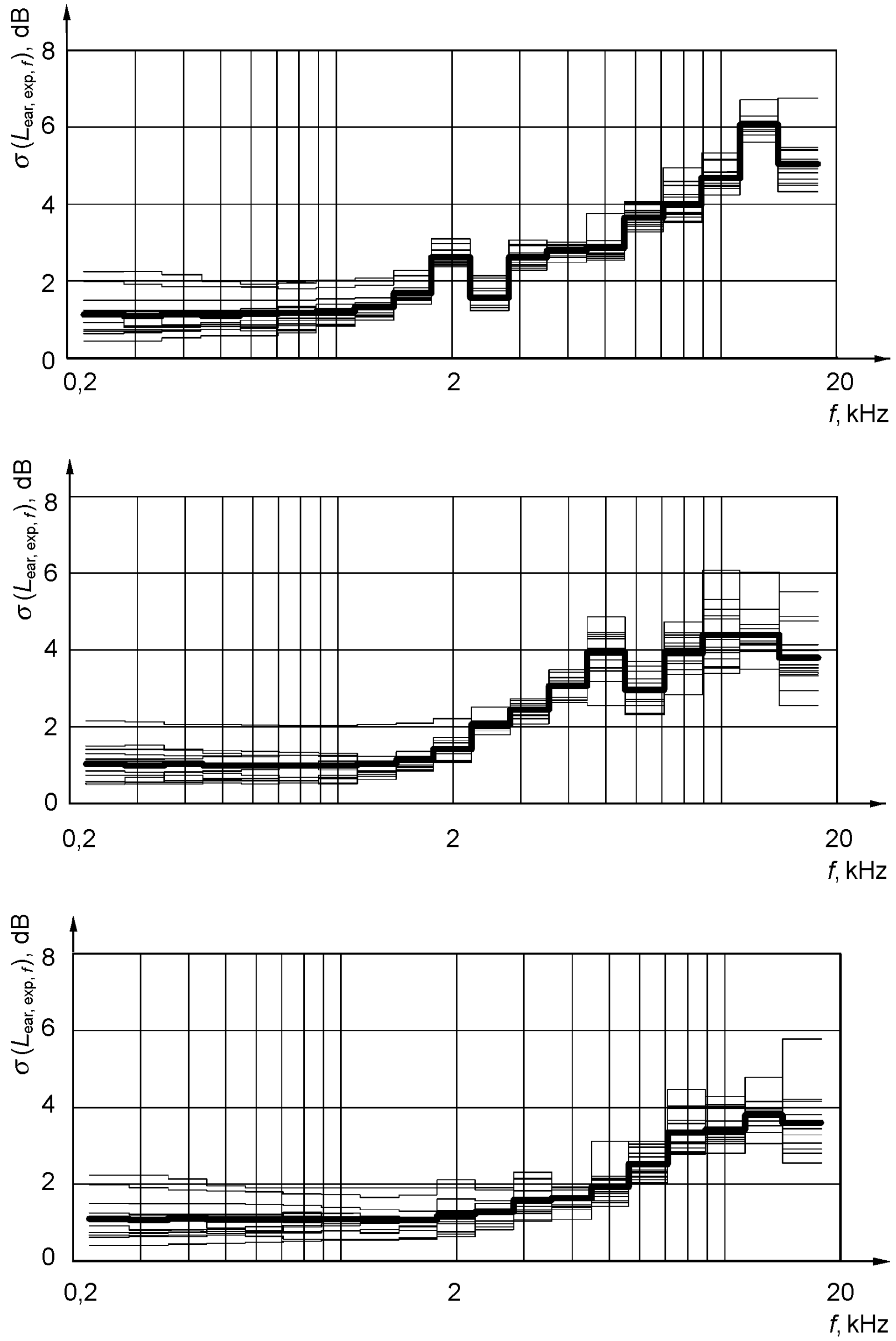
Examples of values of $\sigma(L_{\mathrm{ear,exp},f})$ for ear canal measurement positions at the eardrum, open ear canal entrance and blocked ear canal entrance are shown in Figure A.2.

An example calculation shows that, for eight subjects and for frequencies up to and including the 5 kHz one-third-octave frequency band, $\sigma(\overline{L_{\mathrm{FF,H},f}})$ and $\sigma(\overline{L_{\mathrm{DF,H},f}})$ will typically be below 1,0 dB for the eardrum, below 1,4 dB for the open entrance, and below 0,7 dB for the blocked entrance.

a) Eardrum

b) Open entrance

c) Blocked entrance



NOTE Data are for 14 headphones (thin line) and their mean (heavy line).

Figure A.2 — Examples of $\sigma\,(L_{\mathrm{ear,exp},f})$ for three ear canal measurement positions

A.3.3 Free-field or diffuse-field frequency responses determined individually

The standard deviation of the mean free-field related sound pressure level (across subjects), $\sigma(\overline{L_{\mathrm{FF,H},f}})$, or the standard deviation of the mean diffuse-field related sound pressure level (across subjects), $\sigma(\overline{L_{\mathrm{DF,H},f}})$, can be estimated from

— the standard deviation (across subjects) of the free-field related sound pressure level, $\sigma(L_{FF,H,f})$, or the standard deviation (across subjects) of the diffuse-field related sound pressure level, $\sigma(L_{DF,H,f})$, and

— the number of subjects, n:

$$\sigma(\overline{L_{FF,H,f}}) = \sqrt{\frac{\sigma^2(L_{FF,H,f})}{n}} \tag{A.2}$$

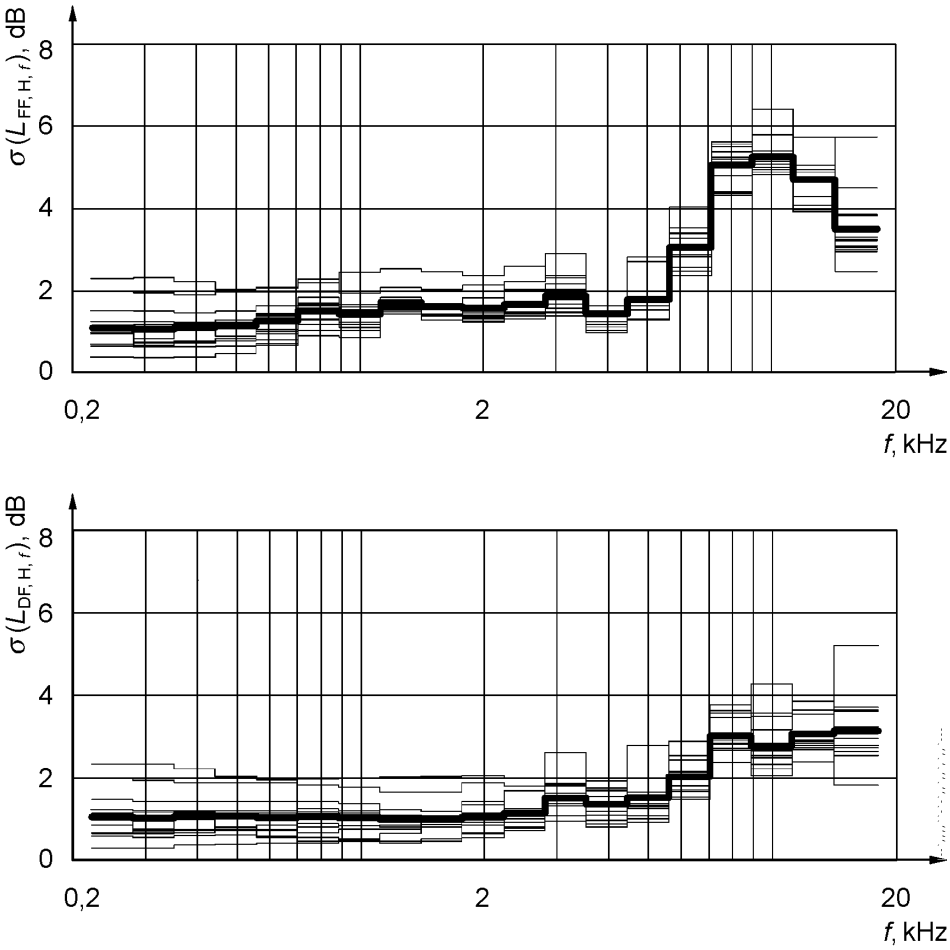
$$\sigma(\overline{L_{DF,H,f}}) = \sqrt{\frac{\sigma^2(L_{DF,H,f})}{n}} \tag{A.3}$$

Examples of values of $\sigma(L_{FF,H,f})$ and $\sigma(L_{DF,H,f})$ are shown in Figure A.3.

An example calculation shows that, for eight subjects and for frequencies up to and including the 5 kHz one-third-octave frequency band, $\sigma(\overline{L_{FF,H,f}})$ will typically be below 0,7 dB, and $\sigma(\overline{L_{DF,H,f}})$ will typically be below 0,6 dB.

a) Free field

b) Diffuse field



NOTE Data are for 14 headphones (thin line) and their mean (heavy line).

Figure A.3 — Examples of $\sigma(L_{FF,H,f})$ and $\sigma(L_{DF,H,f})$ when individual values of $\Delta L_{FF,H,f}$ and $\Delta L_{DF,H,f}$ are used

A.4 Deviation of manikin from human population

A possible deviation of the manikin from an average human subject results in uncertainty. Two terms can contribute:

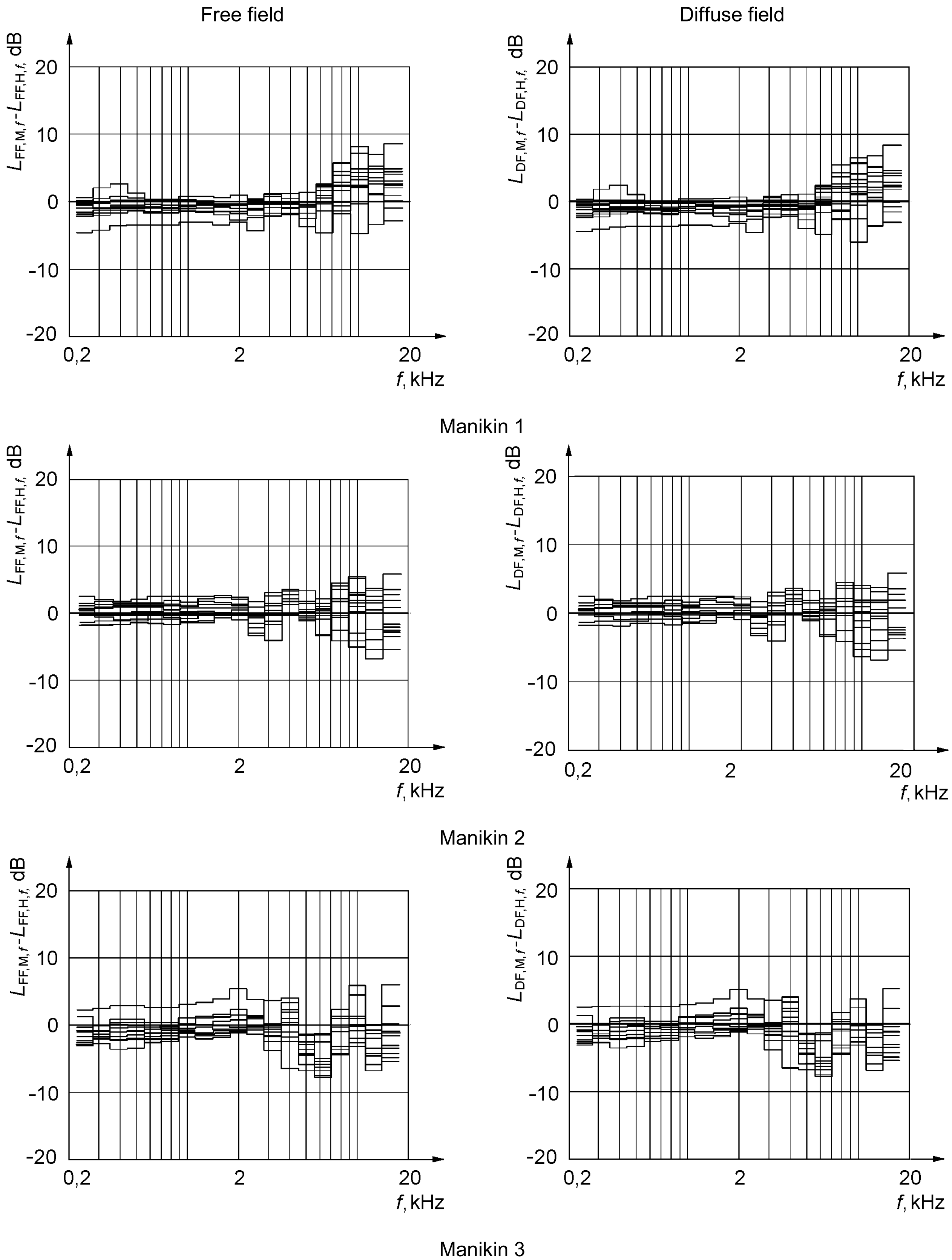
— the deviation in $L_{\mathrm{M,exp},f}$, and

— the deviation in $\Delta L_{\mathrm{FF,M},f}$ or $\Delta L_{\mathrm{DF,M},f}$.

Assuming that tabulated data for $\Delta L_{\mathrm{FF,M},f}$ or $\Delta L_{\mathrm{DF,M},f}$ are correct, the second term is zero.

Figure A.4 shows examples of deviations of results obtained with the manikin technique from those obtained with the MIRE technique using a large group of human subjects.

For frequencies up to and including the 5 kHz one-third-octave frequency band, deviations are typically below 2,5 dB for $L_{\mathrm{FF},f}$ and below 2 dB for $L_{\mathrm{DF},f}$. However, some combinations of headphone and manikin deviate considerably more, in particular for certain frequency bands.



NOTE For the manikin technique, tabulated data were used for $\Delta L_{FF,M,f}$ and $\Delta L_{DF,M,f}$.

Figure A.4 — Examples of deviations of $L_{FF,f}$ or $L_{DF,f}$ measured with manikin technique from similar data measured with MIRE technique using a large group of humans (data for three manikins)

Annex B
(informative)

Example of an uncertainty analysis

The following is an example of how the measurement uncertainties could be estimated for a hypothetical determination of $L_{FF,M,Aeq}$ or $L_{DF,M,Aeq}$ from a supra-aural, open-type earphone fitted on the manikin. It should not be assumed to be an exhaustive list of possible uncertainties, nor a guide to typical values, but just an example of an uncertainty analysis for a specific situation. The analysis complies with the rules given in the GUM.

The uncertainties were estimated for measurements using the following conditions:

— a suitable (HATS) manikin (see Reference [7]) for the specific earphone measured;

— pink noise or noise which simulates speech and music according to IEC 60268-1 as test signal input to the earphone;

— standardized values for the ITU-T P.58 free field or the ITU-T P.58 diffuse field frequency response of the manikin;

— the mean result of three fits and measurements.

The uncertainty analysis was carried out for the final result of $L_{FF,M,Aeq}$ or $L_{DF,M,Aeq}$. The value of $L_{FF,M,Aeq}$ or $L_{DF,M,Aeq}$ as a function of influencing components was approximated by a linear model.

For this example (see Table B.1), figures are given for the conditions specified above and for a well-experienced laboratory. In practice the calculation would have to be repeated if there were different conditions (e.g. other test signals, other types of earphones). The expanded uncertainty is obtained by multiplying the combined standard uncertainty by a coverage factor k = 2, providing a coverage probability of approximately 95 %.

The uncertainty arises from seven different sources. The component due to repeatability is evaluated as a type A uncertainty and the remaining components are evaluated as type B uncertainties.

Table B.1 — Uncertainty analysis

Component	**Standard uncertainty** dB
Microphone sensitivity level and sound pressure level meter uncertainty	
The uncertainty of L_{Aeq} associated with the calibration of the manikin's microphones and the use of a precision sound level meter is assumed to be ± 0,2 dB. The semi-range is 0,2 dB with a rectangular distribution. This is equivalent to a standard uncertainty of 0,2 dB / $\sqrt{3}$ = 0,12 dB	0,12
Deviation of the individual manikin	
The uncertainty of L_{Aeq} associated with deviations of the manikin used for the measurements from humans (for example form, flexibility, size) and the deviation of that manikin's $\Delta L_{FF,M,f}$ or $\Delta L_{DF,M,f}$ from the standardized frequency response (ITU-T P.58) is assumed to be not more than ± 1,1 dB. The semi-range is 1,1 dB with a rectangular distribution. This is equivalent to a standard uncertainty of 1,1 dB / $\sqrt{3}$ = 0,64 dB	0,64
Deviation of standardized manikin frequency response	
The deviation of the standardized manikin's frequency response $\Delta L_{FF,M,f}$ or $\Delta L_{DF,M,f}$ from that of human subjects results in an uncertainty of L_{Aeq} of ± 1 dB. The semi-range is 1 dB with a rectangular distribution. This is equivalent to a standard uncertainty of 1 dB / $\sqrt{3}$ = 0,58 dB	0,58
Test signal level	
The uncertainty of L_{Aeq} associated with deviations of the test signal of the target test signal is ± 0,12 dB.	0,12
Climate deviation	
The climate in the laboratory for the measurements was within a range where such measurements usually are carried out [e.g. (21 ± 2) °C, and (50 ± 15) % RH]. The uncertainty of L_{Aeq} associated with climate deviation is ± 0,4 dB. The semi-range is 0,4 dB with a rectangular distribution. This is equivalent to a standard uncertainty of 0,4 dB / $\sqrt{3}$ = 0,23 dB	0,23
Repeatability	
Found from the standard uncertainties of repeated measurements of L_{Aeq}	0,50
Rounding error	
The result is quoted with a resolution of 0,1 dB, giving a semi-range of this component of ± 0,05 dB with a rectangular distribution. This is equivalent to a standard uncertainty of 0,05 dB / $\sqrt{3}$ = 0,03 dB	0,03
Combined and expanded uncertainty The combined standard uncertainty of L_{Aeq} is found by adding the squares of each standard uncertainty and then taking the square root which gives 1,08 dB. The expanded uncertainty with k = 2 is 2,2 dB.	

Bibliography

[1] ISO 11904-1, *Acoustics — Determination of sound immission from sound sources placed close to the ear — Part 1: Technique using a microphone in a real ear (MIRE technique)*

[2] IEC 60268-1, *Sound system equipment — Part 1: General*

[3] IEC 60268-7:1996, *Sound system equipment — Part 7: Headphones and earphones*

[4] IEC 60711, *Occluded-ear simulator for the measurement of earphones coupled to the ear by ear inserts*

[5] IEC 60959, *Provisional head and torso simulator for acoustic measurements on air conduction hearing aids*

[6] EN 50332-1, *Sound system equipment: Headphones and earphones associated with portable audio equipment — Maximum sound pressure level measurement methodology and limit considerations — Part 1: General method for "one package equipment"*

[7] RICHTER, U and FEDTKE, T. Determination of noise immission from headphones and earphones by means of different Head and Torso Simulators. *6th ICSV, Copenhagen*, 1999, pp.1019-1026

[8] HAMMERSHØI, D., MØLLER, H. Determination of noise immission from sound sources close to the ears. In preparation

[9] MØLLER, H., SØRENSEN, M. F., HAMMERSHØI, D. AND JENSEN, C. B. Head-related transfer functions measured on human subjects. *J. Audio Eng. Soc*., **43**, No. 5, 1995, pp. 300-321

ICS 17.140.01

Price based on 16 pages