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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

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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, $L_{FF,H,Aeq}$ or $L_{DF,H,Aeq}$ when ISO 11904-1 is used, or $L_{FF,M,Aeq}$ or $L_{DF,M,Aeq}$ 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
$L_{\mathrm{M,exp},f}$
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
$\Delta L_{\mathrm{FF,M},f}$
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 $\Delta L_{\mathrm{FF,M},f}$.

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
$\Delta L_{\mathrm{DF,M},f}$
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 $\Delta L_{\mathrm{DF,M},f}$.

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
$L_{\mathrm{FF,M}}$
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 $L_{\mathrm{M,Aeq}}$, also denoted $L_{\mathrm{FF,M,Aeq}}$).

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
$L_{\mathrm{DF,M}}$
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 $L_{\mathrm{M,exp},f}$.

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, $L_{\mathrm{FF,M},f}$ or $L_{\mathrm{DF,M},f}$, the free-field or diffuse-field frequency response for use with manikin, $\Delta L_{\mathrm{FF,M},f}$ or $\Delta L_{\mathrm{DF,M},f}$, shall be subtracted from the manikin sound pressure level, $L_{\mathrm{M,exp},f}$:

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

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

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

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

One-third-octave midband frequency	Free-field frequency response	Diffuse-field frequency response
	$\Delta L_{FF,M,f}$	$\Delta L_{DF,M,f}$
Hz	dB	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.