INTERNATIONAL STANDARD

ISO 11904-1

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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)

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

Partie 1: Technique du microphone placé dans une oreille réelle (technique MIRE)

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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 3.

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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11904-1 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 (manikin technique)*

Annexes A and B of this part of ISO 11904 are for information only.

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 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 (microphone 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 of 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 of 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.	A 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 human subjects — 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 1:
Technique using a microphone in a real ear (MIRE technique)

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 miniature or probe microphones inserted in the ear canals of human subjects. 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 microphone-in-real-ear technique (MIRE technique).

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

This part of ISO 11904 is applicable in the frequency range from 20 Hz to 16 000 Hz.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 11904. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 11904 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 8253-2:1992, *Acoustics — Audiometric test methods — Part 2: Sound field audiometry with pure tone and narrow-band test signals*

IEC 60065, *Audio, video and similar electronic apparatus — Safety requirements*

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

IEC 60601-1, *Medical electrical equipment — Part 1: General requirements for safety*

IEC 60942, *Electroacoustics — Sound calibrators*

IEC 61094-1, *Measurement microphones — Part 1: Specifications for laboratory standard microphones*

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

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

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

1) Corrected and reprinted in 1995.

3 Terms and definitions

For the purposes of this part of ISO 11904, the following terms and definitions apply.

3.1
ear canal measurement position
position in the ear canal where the sound pressure is measured

3.2
ear canal sound pressure level
L_{ear}
equivalent continuous sound pressure level measured at the ear canal measurement position

NOTE When measured during exposure to sound under test, it is denoted $L_{ear,exp}$. When optionally measured during exposure to a reference sound field in the determination of the free-field or diffuse-field frequency response according to clause 10, it is denoted $L_{ear,FF}$ or $L_{ear,DF}$, respectively. When measured in one-third-octave frequency bands with nominal midband frequency f these are denoted $L_{ear,exp,f}$, $L_{ear,FF,f}$ and $L_{ear,DF,f}$.

3.3
human free-field frequency response
$\Delta L_{FF,H,f}$
difference, as a function of one-third-octave frequency bands f, between

— the sound pressure level at the ear canal measurement position with the subject exposed to a frontally incident plane sound wave, and

— the sound pressure level of the same sound field with the subject absent

NOTE 1 The free-field frequency response is identical to the amplitude of the head-related transfer function (HRTF) for frontal sound incidence.

NOTE 2 This definition is applicable to individual subjects and groups of subjects.

3.4
human diffuse-field frequency response
$\Delta L_{DF,H,f}$
difference, as a function of one-third-octave-frequency bands f, between

— the sound pressure level at the ear canal measurement position with the subject exposed to a diffuse sound field, and

— the sound pressure level of the same sound field with the subject absent

NOTE This definition is applicable to individual subjects and groups of subjects.

3.5
free-field related sound pressure level
$L_{FF,H}$
sound pressure level of a plane sound wave which will give rise to the measured ear canal sound pressure level $L_{ear,exp}$ when the test subject is exposed to a frontally incident plane sound wave

NOTE 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 $L_{H,Aeq}$, further abbreviated $L_{FF,H,Aeq}$).

3.6
diffuse-field related sound pressure level
$L_{DF,H}$
sound pressure level of a diffuse sound field which will give rise to the measured ear canal sound pressure level, $L_{ear,exp}$, when the test subject is exposed to a diffuse field

NOTE 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 $L_{H,Aeq}$, abbreviated to $L_{DF,H,Aeq}$).

3.7
open ear canal
ear canal in which possible foreign objects (such as microphone, supporting elements and electrical leads) occupy less than 5 mm^2 of the cross-sectional area at any position along the ear canal

3.8
blocked ear canal
ear canal in which a foreign body (for instance an earplug) occupies the total cross-sectional area at some position along the ear canal

3.9
partly blocked ear canal
ear canal which is neither fully open nor blocked

4 Measurement principle

Miniature microphones or probe microphones are placed to measure the sound pressure at a position in the ear canal, denoted as the ear canal measurement position. The subject is exposed to the sound source(s) in question, and the ear canal equivalent continuous sound pressure level is measured in one-third-octave frequency bands, $L_{ear,exp,f}$.

Each of the one-third-octave band levels is adjusted with the free-field or diffuse-field frequency response, $\Delta L_{FF,H,f}$ or $\Delta L_{DF,H,f}$, to obtain 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, $L_{FF,H,Aeq}$ or $L_{DF,H,Aeq}$.

The measurements may be carried out for one or both ears as appropriate. The free-field or diffuse-field frequency response is taken from clause 9, or determined for each individual subject and ear as described in clause 10.

NOTE The accuracy of the final result depends on a number of parameters (e.g. ear canal measurement position, number of subjects, and whether clause 9 or 10 is used).

5 Instrumentation

5.1 Ear canal microphone

The sound pressure in the ear canal shall be measured by a microphone, which is either

— a miniature microphone placed in the ear canal, or

— a probe microphone consisting of a microphone placed outside the ear and equipped with a probe tube placed in the ear canal; to prevent damage to the ear drum and the skin of the ear canal, the tube shall be made of a soft material.

The pressure response of the miniature or the probe microphone shall be without pronounced resonances, and it shall be known except for the situation described in 10.9. The response shall be checked by comparison with a calibrated pressure-type microphone which is in accordance with IEC 61094-1.

In the area of the concha, the microphone (including supporting elements and electrical leads) shall occupy an area not exceeding 10 mm^2 in any plane.

5.2 Reference field microphone

When individual free-field or diffuse-field frequency responses ($\Delta L_{FF,H}$ or $\Delta L_{DF,H}$) are determined as described in clause 10, a reference field microphone is used to determine the sound pressure level in the reference sound field with the subject absent. This microphone and the connected equipment used shall fulfil the requirements of IEC 61672-1 for a class 1 instrument, and shall have a known free-field or diffuse-field frequency response.

5.3 Check of calibration

The calibration of the microphones and the measuring equipment shall be suitably checked. For the reference field microphone, this shall be done using an acoustic calibrator complying with the requirements for class 1 of IEC 60942.

5.4 Filters

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

6 Subjects

Only persons free from inflammation and any other disease of the outer ear and the middle ear are suitable subjects. For measurements in the open ear canal, only persons whose ear canals are not too narrow, flat or severely bent, and who reveal no eardrum defects shall be chosen. If cerumen obstructs the ear canals, it shall be removed. All such required actions shall be carried out by a qualified person.

7 Use of ear canal microphone

7.1 Choice of ear canal measurement position

The ear canal measurement point shall be between the entrance to the canal and the eardrum, or, in the case of a blocked ear canal, between the entrance and the blockage, in either case preferably close to the centre axis of the canal.

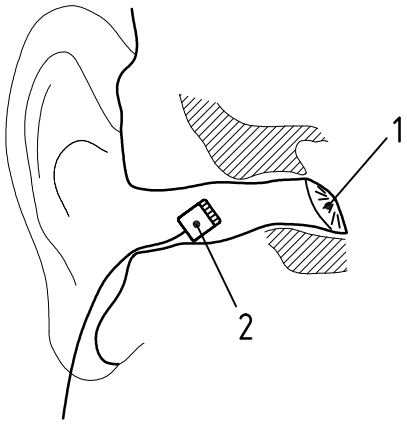
If data from Table 1 are to be used for the free-field or diffuse-field frequency response, only three selected ear canal measurement positions are possible, as stated in clause 9.

For each single subject the ear canal measurement position may be chosen independent of the choice for other subjects.

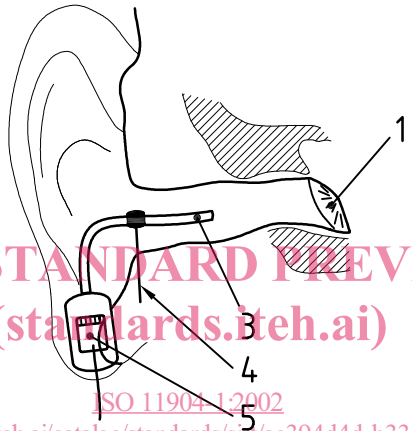
NOTE For earphones and headphones which occupy the majority of the volume immediately outside the ear canal entrance, the choice of a blocked or partly blocked ear canal can reduce the accuracy if the sound under test has significant narrow band components above approximately 3 kHz.

Due to the risk of damaging the eardrum, ear canal measurement position close to the eardrum should only be used by qualified persons and only when using a probe microphone with a soft plastic probe.

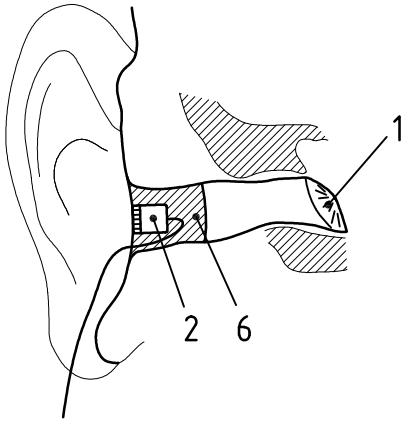
Examples of convenient ear canal measurement positions are illustrated in Figure 1.



a) Miniature microphone in the open ear canal



b) Probe microphone with the probe tube in the open ear canal



c) Miniature microphone at blocked ear canal

Key

1 Eardrum
2 Miniature microphone
3 Probe tube
4 Support wire
5 Microphone
6 Earplug

Figure 1 — Examples of ear canal microphones and their mountings