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Acoustics — Audiometric test methods —

Part 2:
Sound field audiometry with pure tone and narrow-band test signals

Acoustique — Méthodes d'essais audiométriques —

Partie 2: Audiométrie en champ acoustique avec des sons purs et des bruits à bande étroite comme signaux d'essai

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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.

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.

International Standard ISO 8253-2 was prepared by Technical Committee ISO/TC 43, *Acoustics*.

ISO 8253 consists of the following parts, under the general title *Acoustics — Audiometric test methods*:

— *Part 1: Basic pure tone air and bone conduction threshold audiometry*

— *Part 2: Sound field audiometry with pure tone and narrow-band test signals*

— *Part 3: Speech audiometry*

Annexes A, B and C of this part of ISO 8253 are for information only.

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Introduction

ISO 6189 and ISO 8253-1 cover procedures for the determination of thresholds of hearing using pure tones presented to the subject by means of earphone or bone vibrator.

This part of ISO 8253 covers procedures for the determination of thresholds of hearing in a sound field. In general, sound field testing implies binaural listening to a test signal, presented by means of one or more loudspeakers in a test room. The test signal may be a pure tone, a frequency-modulated tone or a narrow band of noise. The acoustical characteristics of the sound field are determined by the choice of test signal, by the number and acoustical properties of the loudspeakers used, as well as by the acoustical characteristics of the test room.

Sound field audiometry may be used for various purposes, for example the evaluation of hearing acuity in young children and the determination of the functional gain of a hearing aid when worn by a particular listener.

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Acoustics — Audiometric test methods —

Part 2:
Sound field audiometry with pure tone and narrow-band test signals

1 Scope

This part of ISO 8253 specifies relevant test signal characteristics, requirements for free, diffuse and quasi-free sound fields, and procedures for sound field audiometry using pure tones, frequency modulated tones or other narrow-band test signals presented by means of one or more loudspeakers, primarily for the purpose of determining hearing threshold levels in the frequency range from 125 Hz to 12 500 Hz.

It does not include specifications for the use of hand-held loudspeakers.

Speech as a test signal is not covered.

The purpose of this part of ISO 8253 is to ensure that tests of hearing, using sound field audiometry, give as high a degree of accuracy and reproducibility as possible.

Examples of graphical representations of the results and a bibliography are given in annexes A and C.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 8253. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 8253 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 226:1987, *Acoustics — Normal equal-loudness level contours.*

ISO 266:1975, *Acoustics — Preferred frequencies for measurements.*

ISO 8253-1:1989, *Acoustics — Audiometric test methods — Part 1: Basic pure tone air and bone conduction threshold audiometry.*

IEC 225:1966, *Octave, half-octave and third-octave band filters intended for the analysis of sounds and vibrations.*

IEC 581-7:1986, *High fidelity audio equipment and systems; Minimum performance requirements — Part 7: Loudspeakers.*

IEC 645-1:1992, *Audiometers — Part 1: Pure tone audiometers.*

IEC 651:1979, *Sound level meters.*

3 Definitions

For the purposes of this part of ISO 8253, the following definitions apply.

3.1 air conduction: The transmission of sound through the external and middle ear to the internal ear.

3.2 otologically normal person: A person in a normal state of health who is free from all signs or symptoms of ear disease and from obstructing wax in the ear canals, and who has no history of undue exposure to noise.

3.3 threshold of hearing: The level of a sound at which, under specified conditions, a person gives 50 % of correct detection responses on a specified number of trials.

3.4 threshold sound pressure level: For a given listener, a specified signal and a specified manner of signal presentation, the sound pressure level at the reference point in the specific sound field, in the absence of the listener, which in the presence of the listener in the test position would correspond with the listener's threshold of hearing.

3.5 reference threshold sound pressure level: For a specific signal and a specified manner of signal presentation, the median value of the threshold sound pressure levels of a sufficiently large number of otologically normal test persons, of both sexes, aged between 18 years and 30 years inclusive, expressing the threshold of hearing at the reference point in the specific sound field.

3.6 hearing level: For a specified signal and a specified manner of signal presentation, the sound pressure level of this signal at the reference point in the specific sound field minus the appropriate reference threshold sound pressure level.

3.7 hearing threshold level: For a specified signal and a specified sound field, the threshold of hearing expressed either as hearing level or as sound pressure level.

3.8 carrier frequency of a frequency-modulated tone: The average value of the periodically varying tone frequency. The carrier frequency is designated as the nominal test frequency.

3.9 frequency deviation: The maximum difference between the instantaneous frequency of the frequency-modulated tone and the carrier frequency.

3.10 reference point: The midpoint of a straight line connecting the listener's ear canal openings when positioned in the listening position in the sound field.

3.11 reference axis: An axis perpendicular to the radiating surface of the loudspeaker. For single radiator or horn loudspeakers, the axis passes through the geometric centre of the diaphragm or the horn. For multi-unit loudspeakers, the position of the axis is defined by the manufacturer.

3.12 free sound field: A sound field where the boundaries of the room exert a negligible effect on the sound waves.

3.13 quasi-free sound field: A sound field where the boundaries of the room exert only a moderate effect on the sound waves, fulfilling the requirements specified in 5.3.

3.14 diffuse sound field: A sound field which in a given region has statistically uniform energy density, for which the directions of propagation at any point are randomly distributed.

3.15 white noise: Noise whose power spectral density is independent of frequency.

3.16 noise bandwidth: The difference between the upper and lower band-edge frequencies of a noise band. At these frequencies the power spectral density of the noise is reduced to one-half of its average within the noise band.

3.17 centre frequency of a noise band: The geometric mean of the band-edge frequencies which define the noise bandwidth.

3.18 functional gain of a hearing aid: For a specified test signal, a specified type of sound field, a specified manner of signal presentation and for a particular listener, the difference in thresholds of hearing of the listener with and without the hearing aid.

4 Test signal characteristics

This part of ISO 8253 covers test signals that are either pure tones, frequency-modulated (FM) tones or narrow bands of noise.

4.1 Pure tones

Pure tones shall be used only in a free sound field which is in accordance with the specifications given in 5.1.

NOTE 1 In other types of sound field, pure tones may show large spatial variations in sound pressure level due to standing waves.

When test tones of fixed frequencies are used, they shall be chosen from the audiometric test frequencies given in IEC 645-1 or the frequencies given in ISO 266.

The actual frequency shall be within $\pm$ 2 % of the nominal frequency. This corresponds to the specification of a type 2 audiometer complying with the requirements of IEC 645-1.

4.2 FM tones

FM tones are defined by the following characteristics, which shall be reported:

a) carrier frequency;

b) waveform of modulating signal;

c) repetition rate of modulating signal;

d) frequency deviation.

The carrier frequency shall be chosen from the audiometric test frequencies as specified in IEC 645-1 or the frequencies given in ISO 266.

The waveform of the modulating signal shall be either sinusoidal or triangular with symmetrical rising and falling portions on a linear or on a logarithmic frequency scale.

The carrier frequency shall be within ± 3 % of its nominal frequency.

The repetition rate of the modulating signal shall be within the range from 4 Hz to 20 Hz with a tolerance of ± 10 % of its nominal value.

The frequency deviation shall be in the range from ± 2,5 % to ± 12,5 % with a tolerance of ± 10 % of its nominal value.

If the modulating waveform is sinusoidal, its total harmonic distortion shall not exceed 5 %. If it is triangular, its ramps shall not deviate from a linear form by more than 5 % of its amplitude. For the triangular waveform, the durations of the rising and falling portions shall not differ by more than 10 %.

4.3 Narrow bands of noise

The centre frequency and the bandwidth of a narrow band of noise shall be the same and have the same tolerances as the frequency response of filters complying with IEC 225, or shall comply with the specifications for narrow-band masking noise according to IEC 645-1. The centre frequency and the bandwidth shall be reported.

NOTES

2 When bandwidths exceed one-third octave, reference threshold sound pressure levels may differ from those valid for bandwidths up to one-third octave.

3 Signal power outside the passband, which is mainly determined by the slopes and stop-band rejection characteristics of the filter, may influence the results of sound field audiometry, in particular on hearing-impaired test subjects.

4.4 Harmonic distortion

If pure tones are available as test signals, the linearity of the complete system shall be such that the total harmonic distortion does not exceed 5 % at 125 Hz and 3 % at 250 Hz, 500 Hz and 1 000 Hz when measured acoustically at the reference point in the test room. These conditions shall be met over the whole dynamic range available.

NOTE 4 It is usually sufficient to measure the harmonic distortion at the maximum available output sound pressure level.

The harmonic distortion of loudspeakers can only be tested in a free sound field. Where only a quasi-free or a diffuse sound field is available, harmonic distortion may be measured electrically across the loudspeaker input terminal. The total harmonic distortion shall be less than 1 % and the loudspeaker shall comply with the specifications given in IEC 581-7:1986, clause 10.

If pure tones are not available as test signals, the linearity of the equipment shall be tested by connecting an external pure-tone generator to replace the original test signal source.

When narrow bands of noise are used as test signals, the output of the external pure-tone generator shall be set to a level 9 dB above the root mean square (RMS) value delivered by the test signal source when in normal use.

When FM tones are used as test signals, the RMS output level of the external pure-tone generator shall be equal to that delivered by the test signal source when in normal use.

4.5 Signal gating

The signal shall be presented either as singular sound bursts of a duration in the range from 1 s to 2 s or repeatedly gated on and off. The requirements given in IEC 645-1 regarding rise and fall times, on/off-times and on/off ratio as well as under- and overshoot shall be complied with when measured electrically at the loudspeaker terminals with pure tones as test signals.

NOTE 5 The reverberation characteristics of the test room may exert a significant influence on the decay of the acoustic test signal.

4.6 Signal level control

4.6.1 Step size

The signal level shall be variable in intervals of 5 dB or less.

4.6.2 Accuracy

The maximum accumulated error in the difference between any two signal level settings over the total signal level range of the attenuator shall not exceed 3 dB, as measured acoustically at the reference point. In addition, the specifications given in IEC 645-1 shall be complied with.

4.6.3 Dynamic range

In the frequency range from 500 Hz to 6 000 Hz, the test signal hearing level at the reference point shall cover at least the range 0 dB to 80 dB.

NOTE 6 It is desirable that the same test signal hearing level range be covered outside this frequency range.

4.7 Means and scales for calibration

The equipment shall provide means for adjusting the level of each test sound separately. The scale shall be expressed in hearing level or sound pressure level. Measurements shall be made with a sound level meter conforming to type 1 of IEC 651.

For pure tones and one-third-octave bands of noise in a frontally incident field, and for one-third-octave bands of noise in a diffuse sound field, reference threshold sound pressure levels corresponding to the normal binaural threshold of hearing as specified in ISO 226 shall be taken as reference threshold sound pressure levels. These data shall be used also for FM tones complying with the requirements of 4.2. For other combinations of test signal and sound field type, no standardized data exist.

NOTES

7 In practice, other angles of incidence are also used, e.g. 45°. No standardized reference threshold sound pressure levels presently exist. However, in annex B correction values for 45° and 90° angles of incidence are given.

8 It is recognized that in applications where only the differences in thresholds of hearing between two listening conditions are to be determined (e.g. with/without hearing aid), relative values of the test sound pressure level may suffice.

5 Sound field characteristics

The environment in which sound field audiometry is undertaken may vary considerably. Three types are specified that will allow a suitable sound field to be established in most situations in practice. Two well-defined types are specified, the free sound field and the diffuse sound field. In practice, it may not always be possible to meet these specifications, and therefore a third sound field, the quasi-free sound field, is described for the purposes of this part of ISO 8253. It is essential that the user determines which specification is appropriate to the sound field under consideration.

Sound pressure level measurements shall be made with a sound level meter complying with type 1 of IEC 651, with the exception of the measurements using a directional microphone given in 5.2 of this part of ISO 8253.

The signals for testing the sound field shall be the same as those to be used for audiometry.

5.1 Free sound field

To establish that free sound field conditions are adequately met, the following requirements shall be complied with.

a) The loudspeaker shall be arranged at the head-height of a seated listener, the reference axis being directed through the reference point. The distance between the reference point and the loudspeaker shall be at least 1 m.

b) With the test subject and the subject's chair absent, the sound pressure level produced by the loudspeaker at positions 0,15 m from the reference point on the left-right and up-down axis shall deviate by no more than ± 1 dB from the sound pressure level at the reference point for any of the test frequencies up to and including 4 000 Hz, and by no more than ± 2 dB for any of the test signals at frequencies above 4 000 Hz. The difference in sound pressure levels between the left-right positions shall not exceed 3 dB at any frequency above 4 000 Hz.

c) With the test subject and the subject's chair absent, the difference in sound pressure levels produced by the loudspeaker at points on the reference axis 0,15 m in front of and 0,15 m behind the reference point shall deviate from the theoretical value given by the inverse sound pressure distance law by no more than ± 1 dB for any of the test signals.

NOTE 9 These requirements can only be met in an anechoic room.

5.2 Diffuse sound field

To establish that diffuse sound field conditions are adequately met, the following requirements shall be complied with.

a) With the test subject and the subject's chair absent, the sound pressure level measured with an omnidirectional microphone at positions 0,15 m from the reference point on the front-back, right-left and up-down axes shall deviate by no more than ± 2,5 dB from the sound pressure level at the reference point for any of the test signals. Furthermore, the difference between levels for the extreme right-left positions shall not exceed 3 dB. The orientation of the microphone shall be kept the same at each position.

b) At frequencies of 500 Hz and above, the sound pressure levels at the reference point shall be within 5 dB for the two directions of measurement that give maximum and minimum readings

of the incident sound energy when measured with a directional microphone with a front-to-random sensitivity index of 5 dB. For other directional microphones, the relationship between front-to-random sensitivity index and the allowable field variation is given in table 1.

5.3 Quasi-free sound field

To establish quasi-free sound field conditions, the following requirements shall be complied with.

a) The loudspeaker shall be arranged at the head-height of a seated listener, the reference axis being directed through the reference point. The distance between the reference point and the loudspeaker's reference point shall be at least 1 m.

b) With the test subject and the subject's chair absent and all other normal working conditions maintained, the sound pressure levels produced by the loudspeaker at positions 0,15 m from the reference point on the left-right and up-down axis shall deviate by no more than ± 2 dB from the sound pressure level at the reference point for any of the test signals.

c) With the test subject and the subject's chair absent, the difference in sound pressure levels produced by the loudspeaker at points on the reference axis 0,10 m in front of and 0,10 m behind the reference point shall deviate from the theoretical value given by the inverse sound pressure distance law by no more than ± 1 dB for any of the test signals.

The usable frequency range of the quasi-free sound field is defined by the frequency range within which these requirements are complied with.

Table 1 — Microphone requirements for diffuse sound field measurement

Values in decibels

Microphone front-to-random sensitivity index	Allowable field variation
⩾ 5	5
4,5	4,5
4	4
< 4	microphone not suitable

NOTES

1 The test should be carried out in a sufficient number of directions, which depend on the type of microphone and the characteristics of the loudspeaker arrangement and include at least the two planes where maximum and minimum sound pressure levels may be expected.

2 More than one loudspeaker is necessary to produce the desired sound field. The loudspeakers may require to be fed with non-coherent electrical signals to reduce the effects of standing waves.

6 Ambient noise levels in the test room

The ambient noise levels in the test room shall comply with the requirements given in table 2. If lowest hearing threshold levels other than 0 dB are to be measured in a particular test room, the appropriate maximum ambient sound levels are obtained by adding to the values of table 2 the value of the lowest hearing threshold level to be measured.

7 Preparation and instruction of test subject

In the preparation and instruction of test subjects, as well as other conditions for the audiometric tests, comply with the requirements of and follow the procedures given in ISO 8253-1:1989, 4.6, 5.1 and 5.2, as applicable. In addition, the subject shall be instructed to keep his/her head at the reference point, to avoid movements, and to face in the required direction.

NOTE 10 Some means should be provided to assist the test subject to maintain this head position.

8 Determination of hearing threshold level

The audiometric test may be conducted using a manual, an automatic-recording or a computer-controlled audiometer. The testing may be monaural or binaural.

The position of the reference point relative to the loudspeaker(s) shall be clearly defined and identified.

Ensure that the type of test stimulus is consistent throughout the test and is noted on the audiogram. Arrange for the order of presentation when using a manual or computer-controlled audiometer to be from 1 000 Hz upwards, followed by the lower frequency range. Carry out a repeat test at 1 000 Hz.

The presentation and interruption of test signals, familiarization, and measurements and calculations of hearing threshold levels shall comply with the relevant requirements of ISO 8253-1:1989, 6.2 to 6.4.

NOTE 11 For low-frequency signals with high levels, the risk of vibro-tactile perception of the test signal should be considered.

Table 2 — Maximum permissible ambient sound pressure levels in one-third-octave bands, L_{max}, for sound field audiometry

Mid-frequency of one-third-octave band, Hz	Maximum permissible ambient sound pressure levels, L_{max} (ref. 20 μPa), dB	
	Lowest test tone frequency	
	125 Hz	250 Hz
31,5	52	60
40	44	53
50	38	46
63	32	41
80	27	36
100	22	32
125	17	25
160	14	18
200	12	12
250	10	10
315	8	8
400	6	6
500	5	5
630	5	5
800	4	4
1 000	4	4
1 250	4	4
1 600	5	5
2 000	5	5
2 500	3	3
3 150	1	1
4 000	− 1	− 1
5 000	1	1
6 300	6	6
8 000	12	12
10 000	14	14
12 500	15	15

NOTES

1 Using the values given in table 2, the lowest hearing threshold level to be measured is 0 dB, with a maximum uncertainty of + 2 dB due to ambient noise. If a maximum uncertainty of + 5 dB due to ambient noise is permitted, the values in table 2 may be increased by 8 dB. The values are derived from ISO 8253-1, assuming binaural listening conditions.

2 When narrow-band noise is used as a test signal, maximum permitted ambient sound pressure levels should be somewhat lower than those specified in table 2.

3 With most of the current sound level meters, it is difficult to measure sound pressure levels below 5 dB.

8.1 Monaural testing

If testing is to be monaural, either occlude the non-test ear with a hearing protector or mask it. Use narrow-band noise masking only when pure tones or FM tones are used as test signals, but not when narrow-band noise is used as the test signal. Report the type of hearing protector used when the non-test ear is occluded.

NOTES

12 The sound attenuation obtained by occlusion is often in practice moderate and may thus give rise to measurement errors, particularly when testing an ear that is considerably less sensitive than the occluded non-test ear.

13 When masking is used, the presentation of the masking noise through an insert earphone may be of advantage.

8.2 Binaural testing

In binaural testing, it is often impossible for the test subject to determine if the test signal is being heard through both or only one ear. Thus, a hearing threshold level determined by means of binaural testing represents a binaural threshold of hearing or is dominated by the more sensitive ear.

NOTE 14 The test subject may be instructed to indicate where the test signal is heard, i.e. right, left or both. However, the subject should be reminded of the primary task, i.e. to respond to the faintest signal heard.

9 Testing with a hearing aid

If the functional gain of a hearing aid when worn by a particular listener is to be determined, use the procedures given in clauses 7 and 8.

10 Screening audiometry

Perform sound field screening audiometry in accordance with ISO 8253-1:1989, clause 9.

NOTE 15 It is recognized that hand-held loudspeakers are sometimes used for screening purposes. Resultant variations in the distance between the loudspeaker and the test subject may cause large variations in sound pressure levels and thus the test situation may not meet the requirements of clause 5.

11 Reporting of data

Together with the results from sound field audiometry, the following shall be reported:

— type of sound field;

— type of audiometer used (manual, automatic-recording or computer-controlled);

— type and characteristics of the test signal;

— position of test subject relative to loudspeaker(s);

— identification of reference for the scale of signal level (hearing level or sound pressure level);

— lowest measurable hearing threshold level due to ambient noise if other than 0 dB;

— whether the non-test ear was occluded and, if so, how.

If screening audiometry has been performed, state the screening level.

11.1 Equipment calibrated by hearing level

If the equipment for sound field testing is calibrated in terms of hearing level, either tabulate the results or plot them as an audiogram, as described in clause 10 of ISO 8253-1:1989. Examples of symbols and an audiogram are shown in annex A. Identify the audiogram as being derived using the sound field concerned. Note and report the use of masking or of occlusion of the non-test ear.

11.2 Equipment calibrated by sound pressure level

If the equipment for sound field testing is calibrated in terms of sound pressure level, either tabulate the results or present them graphically. See annex A for an example.

NOTE 16 It is recommended that the same scales for the abscissa and ordinate as for the audiogram in 11.1 are used, however with opposite direction of the ordinate, and appropriately marked.

12 Maintenance and calibration of equipment

12.1 General

Correct calibration of audiometric equipment is highly important for reliable results. In order to ensure this, the following scheme, consisting of three stages of examinations and calibration procedures is recommended.

Stage A: Routine examination and listening tests

Stage B: Periodic electroacoustic tests

Stage C: Basic calibration tests