Electroacoustics — Hearing aids —

Part 8: Methods of measurement of performance characteristics of hearing aids under simulated in situ working conditions

The European Standard EN 60118-8:2005 has the status of a British Standard

ICS 17.140.50

British Standards

National foreword

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The UK participation in its preparation was entrusted to Technical Committee EPL/29, Electroacoustics, which has the responsibility to:

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Electroacoustics – Hearing aids Part 8: Methods of measurement of performance characteristics of hearing aids under simulated *in situ* working conditions

(IEC 60118-8:2005)

Electroacoustique –
Appareils de correction auditive
Partie 8: Méthodes de mesure
des caractéristiques fonctionnelles
des appareils de correction auditive
dans des conditions simulées
de fonctionnement *in situ*
(CEI 60118-8:2005)

Akustik –
Hörgeräte
Teil 8: Verfahren zur Messung der
Übertragungseigenschaften von
Hörgeräten unter simulierten
In-Situ-Bedingungen
(IEC 60118-8:2005)

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 29/584/FDIS, future edition 2 of IEC 60118-8, prepared by IEC TC 29, Electroacoustics, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60118-8 on 2005-12-01.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2006-09-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2008-12-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60118-8:2005 was approved by CENELEC as a European Standard without any modification.

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INTRODUCTION

Measurement methods that take into account the acoustical influence of the wearer on the performance of hearing aids are important, particularly when the results are to be used to assist in the fitting of hearing aids. The information obtained using this standard is likely to be more relevant to the fitting of hearing aids than that provided by publications concerned with type approval and quality control such as IEC 60118-0, and IEC 60118-7.

The methods specified in this standard require a device such as a manikin to simulate the presence of the wearer. It has been found necessary to establish certain guidelines for simulated *in situ* measurements of hearing aids. The recommended methods are described in this standard.

ELECTROACOUSTICS – HEARING AIDS –

Part 8: Methods of measurement of performance characteristics of hearing aids under simulated *in situ* working conditions

1 Scope

The purpose of this part of IEC 60118 is to describe methods for a test which simulates the acoustical effects of a median adult wearer on the performance of a hearing aid.

It establishes certain guidelines for simulated *in situ* measurements of hearing aids; it describes a simplified method for simulated *in situ* measurements of hearing aids and a description for determination of the directivity index (DI) of directional microphones in hearing aids in the horizontal plane.

In addition this second edition now specifies tolerances. Conformance to the specifications in this International Standard is demonstrated only when the result of a measurement, extended by the actual expanded uncertainty of measurement of the testing laboratory, lies fully within the tolerances specified in this International Standard extended by the values for U_{max}

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 60118-0:1983, *Hearing aids – Part 0: Measurement of electroacoustical characteristics*

IEC 60263, *Scales and sizes for plotting frequency characteristics and polar diagrams*

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

IEC 60959, *Provisional head and torso simulator for acoustic measurements of air conduction hearing aids*

3 Terms and definitions

For the purpose of this document, the following definitions apply:

3.1
sound pressure level
throughout this standard all sound pressure levels (abbreviated SPL) are referred to 20 μPa

3.2
pinna simulator
device which has the approximate shape and dimensions of a median adult human pinna

3.3
ear simulator
device for measuring the output sound pressure level of an earphone under well defined loading conditions in a specified frequency range. It consists essentially of a principal cavity, acoustic load networks and a calibrated microphone. The location of the microphone is chosen so that the sound pressure at the microphone corresponds approximately to the sound pressure existing at the human eardrum

3.4
occluded-ear simulator
ear simulator which simulates the inner part of the ear canal, from the tip of an ear insert to the eardrum

3.5
ear canal extension
device which connects the concha portion of the pinna simulator with the outer (reference plane) face of the occluded-ear simulator, simulating the outer part of the ear canal excluding the pinna

3.6
ear insert simulator
device used to represent the acoustic coupling between an earphone and the ear canal (e.g. an earmould or a similar device without a connecting tube)

3.7
manikin (head and torso simulator)
head and torso simulator extending downward from the top of the head to the waist and designed to simulate the acoustic diffraction produced by a median adult human head and torso. The head includes two pinna simulators, and contains at least one occluded-ear simulator

3.8
reference point of a subject or manikin
point bisecting the line joining the centres of the openings of the ear canals (at the junction between concha and ear canal) (see Figure C.1)

3.9
plane of symmetry of the manikin
plane passing through the reference point of the manikin that divides the left and right portions of the manikin into symmetrical halves (see Figure C.1)

3.10
axis of rotation of the manikin
straight line passing through the reference point of the manikin and lying in the plane of symmetry of the manikin, and having a direction that would be vertical if the manikin were mounted in a position corresponding to that of a standing person (and about which the manikin can be rotated) (see Figure C.1)

3.11
reference plane of the manikin
plane perpendicular to the axis of rotation containing the reference point of the manikin (see Figure C.1)

3.12
test point
reproducible position in the test space at which the sound pressure level is measured with the manikin absent and at which the reference point of the manikin is to be located for test purposes

3.13
reference input sound pressure level
free field sound pressure level at the test point in the absence of the manikin

3.14
test axis
line joining the test point and the centre of the sound source (see Figure C.2)

3.15
test plane (for measurement of the uniformity of the free field wavefront)
plane perpendicular to the test axis and containing the test point

3.16
azimuth angle of sound incidence
θ
angle between the plane of symmetry of the manikin and the plane defined by the axis of rotation and the test axis (see Figure C.2). When the manikin faces the sound source the azimuth angle of sound incidence is defined as 0°. When the right ear of the manikin faces the sound source, the azimuth angle is defined as 90°. When the left ear faces the sound source, the angle is defined as 270°

3.17
elevation angle of sound incidence
α
angle between the reference plane of the manikin and the test axis (see Figure C.2). When the top of the manikin points towards the sound source the elevation angle is defined as 90°. When the test axis lies in the reference plane, the elevation angle is defined as 0°

3.18
reference position of the manikin in the test space
position of the manikin in the test space that meets the following conditions:

– the reference point coincides with the test point, and
– the angles of azimuth and elevation are both equal to zero.

3.19
manikin unoccluded-ear gain
MUEG
difference between the sound pressure level in the unoccluded-ear simulator and the reference input sound pressure level. This will be a function of manikin position

3.20
manikin unoccluded-ear gain frequency response
MUEGFR
manikin unoccluded-ear gain expressed as a function of frequency, MFR (see 7.3) being a function of manikin position

3.21
simulated *in situ* gain
SISG
difference between the SPL in the ear simulator produced by the hearing aid and the reference input SPL. This will be a function of manikin position

3.22
simulated *in situ* gain frequency response
SISGFR
SISG expressed as a function of frequency

3.23
simulated insertion gain
SIG
difference between the SPL in the ear simulator produced by the hearing aid and the SPL in the ear simulator with the hearing aid absent. This gain is equal to SISG-MUEG. This will be a function of manikin position

3.24
full-on simulated insertion gain
SIG obtainable from a hearing aid with the gain control at maximum (full-on) and at stated settings of the other hearing aid controls

3.25
simulated insertion gain frequency response
SIGFR
SIG expressed as a function of frequency

3.26
manikin unoccluded-ear directional response
MDR
sound pressure level in the ear simulator at a stated frequency as a function of azimuth and/or elevation angle with the hearing aid absent

3.27
simulated *in situ* directional response
SISDR
sound pressure level in the ear simulator produced by the hearing aid as a function of azimuth and/or elevation angle at a stated frequency, gain value and input level

3.28

directivity index DI_{2D}

for the purpose of this standard DI_{2D} as a function of frequency is calculated from the SISDR as the difference between the sound intensity level for azimuth and elevation angle equal to 0° and the average sound intensity level for all azimuth angles and elevation angles, assuming rotational symmetry about an axis defined by the intersection of a vertical plane with zero azimuth angle and the reference plane.

3.29

SII weighted directivity index

$SIIDI_{2D}$

index calculated from the DI_{2D} by applying a band importance function representing the relative importance of the different frequencies for speech perception and as such obtaining a frequency independent index. The weighting factors used in the calculation are according to ANSI S3.5:1997 (see 7.6.4.2)

3.30

simulated insertion directional response D

SIDR

difference between SISDR and MDR

3.31

simulated *in situ* OSPL90 (output sound pressure level for 90 dB input SPL)

output sound pressure level in the ear simulator produced by the hearing aid at a specified frequency with the hearing aid gain control at maximum (full-on) and a reference input SPL of 90 dB

3.32

simulated *in situ* OSPL90 frequency response

simulated *in situ* OSPL90 expressed as a function of frequency

4 Limitations

4.1 The results obtained under simulated *in situ* conditions may differ substantially from results obtained on an individual person, due to anatomical variation of head, torso, pinna, ear canal, and eardrum. Care should therefore be taken when interpreting the results.

4.2 The methods recommended in this standard give information on the measurement of the following parameters that are considered important for the evaluation of the performance of a hearing aid as normally worn, and for which simulated *in situ* conditions are considered essential:

– full-on insertion gain;

– insertion frequency response;

– directional characteristics;

– simulated *in situ* OSPL90.

NOTE The accuracy and repeatability of results obtained under simulated *in situ* conditions cannot generally be expected to be as good as when using the free-field technique laid down in IEC 60118-0:1983. The use of simulated *in situ* conditions for the measurements of hearing aid parameters other than those listed above is therefore not included.

5 Test equipment

5.1 Acoustical requirements for the test space

5.1.1 The test space shall provide essentially free-field conditions over the frequency range 200 Hz to 8 000 Hz. Essentially free-field conditions are considered established when the sound pressure level at positions 100 mm in front of and behind the test point do not deviate from the inverse distance law (1/r law) by more than ±2 dB from 200 Hz to 400 Hz and ±1 dB from 400 Hz to 8 000 Hz.

5.1.2 The manikin shall be mounted in the test space so that all points of the head and shoulders of the manikin are λ/4 or more distant from the surfaces of the room, where λ is the wavelength of the lowest measuring frequency. The distance between the centre of the sound source and the test point shall be 1 m.

5.1.3 The test space shall be equipped with means that permit accurate and repeatable positioning of the manikin.

5.1.4 Unwanted stimuli in the test space such as ambient noise or electrical and/or magnetic stray fields shall be sufficiently low to ensure that test signals exceed the levels of unwanted noise by more than 10 dB.

5.2 Sound source

5.2.1 The sound source shall consist only of coaxial elements. In order to avoid reflections, the frontal surface of the sound source enclosure should be covered by a suitable absorbing material. Maximum linear dimensions of the frontal surface of the sound source shall not exceed 0,30 m.

5.2.2 Over the frequency range 200 Hz to 8 000 Hz, the sound source shall produce a uniform wave-front in the space to be occupied by the manikin which shall be determined as follows:

With the manikin absent, the SPL at four positions in the test plane 15 cm distant from the test point shall not differ by more than ±2 dB from the SPL at the test point. Two of the four positions are to be in the reference plane, to the left and right of the test point as viewed from the sound source; the other two are to be on the axis of rotation above and below the test point.

5.2.3 Over the frequency range 200 Hz to 8 000 Hz, the source shall be capable of producing sound pressure levels with a maximum tolerance of ±1,5 dB (see 5.7) over the range of 50 dB to 90 dB at the test point.

5.2.4 The frequency of the test signal shall not differ by more than 2 % from the indicated value.

5.2.5 The total harmonic distortion of the test signal shall not exceed 2 % for sound pressure levels up to 70 dB and 3 % for sound pressure levels greater than 70 dB and up to 90 dB, as measured at the test point.

5.3 Manikin

Annex C states the general requirements for a manikin.

5.4 Ear simulator

The ear simulator shall consist of an occluded-ear simulator in accordance with IEC 60711, together with an ear canal extension $7{,}5^{+0{,}02}_{-0}$ mm in diameter and 8,8 mm long with a tolerance of ±2 %, as measured from the outer face (reference plane) of the occluded-ear simulator to the bottom of the concha portion of the artificial pinna.

5.5 Ear insert simulator

The method of coupling the small earphone (receiver) to the ear, for example closed mould, open mould or no mould connections, shall be stated together with the lengths and diameters of any connecting acoustic tubes used.

5.6 Equipment for the measurement of occluded-ear simulator sound pressure level

The equipment used for measurement of the occluded-ear simulator sound pressure level produced by the hearing aid shall comply with the following requirements:

5.6.1 The calibration of the sound pressure level measurement system shall be within ±0,5 dB at a specified frequency.

NOTE The calibration of the microphone should be repeated sufficiently often to ensure that it remains within the permitted limits during measurements.

5.6.2 The pressure sensitivity level of the measuring microphone shall be within ±1 dB in the frequency range 200 Hz to 3 000 Hz and within ±2 dB in the range 3 000 Hz to 8 000 Hz relative to the pressure sensitivity level at 1 000 Hz.

5.6.3 Total harmonic distortion in the measuring equipment over the frequency range 200 Hz to 5 000 Hz shall be less than 1 % for sound pressure levels up to 130 dB and less than 3 % for sound pressure levels above 130 dB and up to 145 dB.

5.6.4 The sound pressure level corresponding to hum, thermal agitation and other noise sources shall be sufficiently low to ensure that the reading shall drop by at least 10 dB when the test signal is switched off.

For this purpose, a high-pass filter not affecting frequencies of 200 Hz and above may be employed.

5.6.5 The output indicator used shall give r.m.s. indication within ±0,5 dB for a signal crest factor of not more than 3.

NOTE 1 If, under certain conditions, it is necessary to use a selective system to ensure that the response of the hearing aid to the test signal can be differentiated from inherent noise in the hearing aid, the use of the selective system should be stated in the test report.

NOTE 2 It is well known that the type of output indicator employed may influence the test results significantly if a non-sinusoidal voltage is being measured. Such non-sinusoidal voltages may be present when making measurements with high input levels to the hearing aid.

5.6.6 Since the calibration of the occluded-ear simulator depends on ambient conditions, especially the atmospheric pressure, corrections for such dependence shall be made when necessary (see 6.2).

5.7 Equipment for automatic sweep frequency recording

The equipment shall be capable of maintaining at the test point all requisite sound pressure levels between 50 dB and 90 dB within such tolerances as specified in 5.2.3.

The uncertainty of the indicated frequency on a recorder chart shall be within ±5 %. The automatically recorded values shall not differ more than 1 dB from the steady-state value over the frequency range 200 Hz to 5 000 Hz and not more than 2 dB in the range 5 000 Hz to 8 000 Hz.

5.8 Equipment for calibration of free field sound pressure level

The calibration of the free field sound pressure level shall be within ±0,5 dB at a specified frequency. The free field sensitivity level of the measuring microphone shall be within ±1 dB in the frequency range 200 Hz to 5 000 Hz and within ±1,5 dB in the range 5 000 Hz to 8 000 Hz relative to the free field sensitivity level at a specified frequency (usually 1 kHz).

6 Test conditions

6.1 Choice of test point

With the position of the sound source fixed in the test space, a test point is chosen, so that the requirements of 5.1 are fulfilled.

The distance from the sound source to the test point shall be 1 m. This is considered to be sufficient to reduce interaction between the sound source and the manikin to an acceptable level when the latter is located at the test point.

6.2 Ambient conditions

Ambient conditions in the test space at the time of test shall be stated and kept within the following tolerances:

– temperature: (23 ± 5) °C;
– relative humidity: (20 to 80) %;
– atmospheric pressure: $(101{,}3^{+5}_{-20})$ kPa.

NOTE If these conditions cannot be achieved, actual conditions shall be stated. See also IEC 60068.

6.3 Manikin

In order to achieve repeatable results no clothing or wig shall be used on the manikin.

6.4 Location of the hearing aid

6.4.1 Placement of the hearing aid on the manikin

The hearing aid shall be placed on the manikin in a way corresponding to actual use.

Body aids shall be placed 30 cm from the reference plane in the centre chest position, with the back of the aid held firmly on the surface of the manikin.

6.4.2 Connection of the earphone to the ear simulator

The right ear of the manikin shall be used, unless otherwise stated.

The type of ear insert simulator and any tubing employed shall be stated. The fit of the pinna simulator and ear canal extension shall be carefully observed to avoid leakage with closed canal tests.

6.5 Normal operating conditions for the hearing aid

6.5.1 General

The normal operating conditions for the hearing aid which apply for measurement purposes when no other conditions are prescribed, are:

6.5.2 Power supply

Either an actual battery of the type normally used in the hearing aid, partially discharged to avoid the typical high initial voltage, or a suitable power supply that simulates the voltage and internal impedance of real batteries of the type normally used, may be employed.

The type of power source used, the supply voltage and, in the case of a power supply, the internal impedance shall be stated.

The battery voltage measurements shall be within ±50 mV of the value specified.

6.5.3 Gain control

Full-on gain control position, reference test gain position or other positions used, shall be stated.

6.5.4 Other controls

The setting selected for the tone control shall be stated in the results. In general, the basic setting (that giving the widest frequency range) shall be selected in preference to settings in which the low or high frequencies are attenuated. If, however, there are reasons for regarding some other settings as more representative of the normal use of the hearing aid, these settings may be adopted provided they are clearly described in the results.

All other control settings should be chosen to give the highest OSPL90 and the highest acoustic gain. If the highest OSPL90 is not associated with the highest acoustic gain, the setting giving the highest OSPL90 shall be used.

6.5.5 Accessories used in connection with the hearing aid microphone opening

The particular accessories to be used shall be stated.

7 Measurements

7.1 General

7.1.1 The simulated insertion gain frequency response may be determined by two different methods, yielding the same results if the hearing aid is operating as a linear device:

– constant reference input SPL method (see 7.4)

– constant ear simulator SPL method (ipsilateral ear) (see 7.5).

Due to modifications to the sound field by the head and open ear canal the constant ear simulator SPL method will result in a considerably lower input SPL to the hearing aid than for the constant reference input SPL method at certain frequencies.

The advantage of the constant ear simulator SPL method, however, is that the same microphone system is used for measuring both input and output SPL. The method used shall be stated.

NOTE The use of a contralateral ear simulator as a controlling device is not recommended due to the probable lack of symmetry and its limitation for frontal sound incidence only.

7.1.2 Data should only be quoted for that part of the frequency range between 200 Hz and 8 000 Hz over which the output from the hearing aid falls by at least 10 dB when the signal source is switched off.

7.2 Adjustment of the reference input sound pressure level

- **Test procedure**

a) The free field calibrated microphone (see 5.8) is placed at the test point with the manikin absent.

b) The frequency of the sound source is varied over the range 200 Hz to 8 000 Hz. The electrical input signal to the sound source required to produce a constant stated reference input SPL is recorded (see 5.2.3).

NOTE For automatic frequency sweep recording tests, the reference input SPL can be kept constant using the microphone to control the equipment in compliance with 5.7. Recording of the electrical input signal can be conveniently undertaken using digital storage techniques or a tape recorder.

The use of equalizing filters only or a control microphone placed between the sound source and the test point has not generally been found to be satisfactory.

7.3 Manikin frequency response (MFR)

7.3.1 Purpose

The purpose of this test is to measure the performance of the manikin to provide a basis for determining the simulated insertion gain frequency response in accordance with the constant reference input SPL method.

7.3.2 Test procedure

a) The manikin is placed at the reference position (see 3.18).

b) The frequency is varied over the range 200 Hz to 8 000 Hz, keeping the reference input sound pressure level constant at 60 dB. The ear simulator SPL is recorded as a function of frequency.

NOTE For automatic sweep frequency recording tests, this is conveniently achieved by providing a stored electrical input signal to the sound source (see note to 7.2.1).

7.4 Full-on simulated insertion gain measured by the constant reference input SPL method

Test procedure

a) Perform the measurements described in 7.2 and 7.3.

b) With the manikin in the reference position, locate the hearing aid in accordance with 6.4.

c) Turn the hearing aid gain control full-on and set other controls to their required positions.

d) At a suitable frequency, set the reference input SPL to 60 dB. If this does not produce essentially linear input/output conditions in the hearing aid, the SPL should be reduced to 50 dB. Essentially linear input/output conditions are considered to exist if, at all frequencies within the range 200 Hz to 8 000 Hz, a change in the input SPL of 10 dB causes a change in the output SPL of (10 ± 1) dB. The input SPL shall be stated.

   NOTE For hearing aids with certain circuit arrangements, e.g. some push-pull aids, non-linear input-output characteristics may be observed over a large portion of the operating range.

e) Vary the frequency over the range 200 Hz to 8 000 Hz keeping the reference input SPL constant at the level determined in item d) above. Record the ear simulator SPL as a function of frequency.

f) Derive the full-on simulated insertion gain by subtracting the manikin unoccluded-ear SPL (determined in item b) of 7.3.2) from the simulated *in situ* SPL (determined in item e) above) at each frequency.

g) Plot the full-on simulated insertion gain as a function of frequency. The value may be reported for a specified frequency.

NOTE 1 In some cases with hearing aids having high gain, it may be convenient to adopt a lower gain setting than maximum for the measurement of the frequency response curve. In those cases, the gain setting should be stated.

NOTE 2 The procedures may be repeated for other stated control settings or other stated manikin positions.

7.5 Full-on simulated insertion gain measured by the constant ear simulator SPL method

An alternative procedure for determining the simulated insertion gain for a hearing aid is:

a) Place the manikin at the reference position with the hearing aid absent.

b) Vary the frequency over the range 200 Hz to 8 000 Hz and record the electrical input which the sound sources requires to produce a constant, stated, SPL in the ear simulator as a function of frequency. At a suitable frequency, adjust the electrical signal to the sound source to a level that produces an SPL of 60 dB in the ear simulator without an ear insert simulator or hearing aid present, as determined in item b) above. If this does not produce essentially linear input/output conditions in the hearing aid, reduce the SPL to 50 dB. Essentially linear input/output conditions are considered to exist in the hearing aid under test if, at all frequencies within the range 200 Hz to 8 000 Hz, a change in the input SPL of 10 dB causes a change in the recorded output of (10 ± 1) dB.

NOTE See note to 7.2.1. For hearing aids with certain circuit arrangements, for example some push-pull aids, non-linear input-output characteristics may be observed over a large portion of the operating range.

c) Place the hearing aid on the manikin in accordance with 6.4 and connect it to the same ear simulator as employed in item b) above.

d) Turn the hearing aid gain control full-on and set other controls to their required positions.

e) Vary the frequency of the sound source over the range 200 Hz to 8 000 Hz with the hearing aid present. Record the ear simulator SPL as a function of frequency.

f) Derive the full-on simulated insertion gain by subtracting the ear simulator SPL (determined under item b) above) from the recorded ear simulator SPL (determined in item e) above) at each frequency.

g) Plot the full-on simulated insertion gain as a function of frequency. The value may be reported for a specified frequency.

NOTE 1 In some cases with hearing aids having high gain, it may be convenient to adopt a lower gain setting than full-on for the measurement of the frequency response. The gain should be stated.

NOTE 2 The procedure may be repeated for other stated control settings and manikin positions.

7.6 Directional characteristics

7.6.1 Manikin unoccluded-ear directional response (MDR)

7.6.1.1 Purpose

The purpose of this test is to determine the directional response of the manikin without ear insert simulator or hearing aid present in order to determine the insertion directional response of a hearing aid.

7.6.1.2 Test procedure

a) The manikin is placed in the reference position with the ear insert simulator and the hearing aid absent.

b) At a specified frequency, the input SPL is adjusted to produce a suitable SPL in the ear simulator, which should be stated.

c) At a stated angle of elevation (normally zero), the manikin is rotated around the axis of rotation and the SPL in the ear simulator is recorded as a function of azimuth angle.

d) The directional response, which is the difference between the ear simulator SPL at a given azimuth angle of sound incidence and the ear simulator SPL in the reference position, is plotted as a function of azimuth angle.

7.6.2 Simulated *in situ* directional response (SISDR)

7.6.2.1 Purpose

The purpose of this test is to determine the combined directional effects of the manikin and the hearing aid.

7.6.2.2 Test procedure

a) With the manikin in the reference position, locate the hearing aid in accordance with 6.4.

b) At a specified frequency, adjust the input SPL and/or the hearing aid gain setting in order to produce essentially linear input/output conditions in the hearing aid through one complete rotation of the manikin.

c) At a stated angle of elevation (normally zero), rotate the manikin around the axis of rotation and record the SPL in the ear simulator.

d) The simulated *in situ* directional response is the difference between the ear simulator SPL at a given azimuth angle of sound incidence and the ear simulator SPL in the reference position, plotted as a function of azimuth angle.

7.6.3 Simulated insertion directional response (SIDR)

7.6.3.1 Purpose

The purpose of this test is to compare the directional characteristics of the hearing aid on the manikin with those of the manikin alone.

7.6.3.2 Test procedure.

a) The manikin directional response (MDR) is determined in accordance with 7.6.1.

b) The simulated *in situ* directional response (SISDR) is determined in accordance with 7.6.2.

c) The simulated insertion directional response is the difference between SISDR and MDR, plotted as a function of frequency, with the azimuth angle as parameter.

NOTE This measurement may also be made with the constant ear simulator SPL method.

7.6.4 Directivity index and weighted directivity index

7.6.4.1 Purpose

The purpose of this test is to obtain indices describing the effect of directional characteristics of the hearing aid. The method is based on measurements only in the horizontal plane (elevation angle equal to 0°) but by assuming rotation symmetry the calculation is extended to the vertical plane.

7.6.4.2 Test procedure

The simulated in situ directional response (SISDR) is determined in accordance with 7.6.2 for elevation angle zero. Measurements should be carried out representing at least the 1/3 octave frequencies in the frequency range 200 Hz to 8 000 Hz and azimuth angles with maximum 10° spacing. For 10° spacing the DI_{2D} is calculated from the following formula :

$$DI(f) = 10 \lg \left[\frac{22{,}92}{\sum_{j=0}^{35} \left(\frac{10^{\frac{SISDR_j(f)}{10}}}{10^{\frac{SISDR_0(f)}{10}}} \right) \left| \sin \theta_j \right|} \right] \text{dB}$$

where

θ_j is the azimuth angle corresponding to j number;

$SISDR_j(f)$ is the simulated directivity response *in situ* corresponding to f frequency and to azimuth angle θ_j;

$SISDR_0(f)$ is the simulated directivity response *in situ* corresponding to f frequency and to azimuth angle 0;

$DI(f)$ is DI for f frequency.

NOTE The constant 22,92 is only valid for 36 measuring points with 10° spacing. If a different number of measuring points are used it should be recalculated.

The $SIIDI_{2D}$ is calculated from the following formula:

$$SIIDI_{2D} = 0{,}01 \cdot DI(200) + 0{,}01 \cdot DI(250) + 0{,}03 \cdot DI(315) + 0{,}04 \cdot DI(400) + 0{,}06 \cdot DI(500) + 0{,}07 \cdot DI(630) + 0{,}07 \cdot DI(800) + 0{,}08 \cdot DI(1\,000) + 0{,}09 \cdot DI(1\,250) + 0{,}09 \cdot DI(1\,600) + 0{,}09 \cdot DI(2\,000) + 0{,}09 \cdot DI(2\,500) + 0{,}08 \cdot DI(3\,150) + 0{,}08 \cdot DI(4\,000) + 0{,}05 \cdot DI(5\,000) + 0{,}04 \cdot DI(6\,300) + 0{,}02 \cdot DI(8\,000)$$

where the number between parentheses is the frequency in hertz.

7.7 Simulated *in situ* OSPL90 measurements

- **Test procedure**

a) With the manikin in the reference position the hearing aid is located in accordance with 6.4.

b) The gain control is turned full-on and other controls are set to their required positions.

c) At a suitable frequency, set the reference input SPL to 90 dB.

d) The frequency of the sound source is varied over the range 200 Hz to 8 000 Hz keeping the reference input SPL constant at 90 dB. The ear simulator SPL is recorded as a function of frequency.

7.8 Simplified method to measure simulated in situ and insertion gain response

7.8.1 Purpose

The described method reduces the simulated in situ and insertion gain response measurement to a measurement according to IEC 60118-0:1983, without the need for a manikin and a large anechoic chamber.

7.8.2 Requirements

7.8.2.1 Standard transformation curves

Known transformation of the free-sound-field to the microphone pick-up of the hearing aid.

In Annex A transformations for several hearing aid constructions can be found.

7.8.2.2 Signal source

If the hearing aid has non-linear characteristics, a signal source with digital memory is required to store the transformation response. In this way, for 60118-0 test conditions the same acoustic input for the hearing aid is maintained as for the measurement with manikin as described in 7.4

7.8.3 Test procedure

a) Calibrate sound field in accordance with 6.2.1 of IEC 60118-0:1983.

b) Add to the sound field the transformation curve as required for the construction of the hearing aid.

c) Measure the full-on acoustic gain frequency response in accordance with 7.3 of IEC 60118-0: 1983. The result of this measurement is equivalent to the simulated in situ gain.

d) Derive the full-on simulated insertion as described in 7.4 and by using the manikin unoccluded-ear gain as available in Annex B.

NOTE For CIC devices, Table A.1 assumes the receiver terminates at the reference plane as defined in IEC 60711. No provision is made for devices intended for deeper fittings.

8 Frequency response recording charts

All curves showing variation of a parameter with frequency shall be plotted on a grid having a linear decibel ordinate scale and a logarithmic frequency abscissa scale with the length of one decade on the abscissa scale equal to 50 dB on the ordinate scale, in accordance with IEC 60263.

9 Maximum permitted expanded uncertainty of measurements

The following table specifies the maximum permitted expanded uncertainty for a coverage factor of $k = 2$, associated with the measurements undertaken in this standard.

The expanded uncertainties of measurement given in the table, are the maximum permitted for demonstration of conformance to the requirements of this standard.

If the actual expanded uncertainty of a measurement exceeds the maximum permitted value given in Table 1, the measurement shall not be used to demonstrate conformance to the requirements of this standard.

Table 1 – Values of U_{max} for basic measurements

Measured quantity	U_{max}
Sound pressure level 200 Hz to 4 000 Hz	1,0 dB
Sound pressure level greater than 4 000 Hz	1,5 dB
Directivity index	0,5
Frequency	0,5 %

The measurement uncertainty is composed of several factors:

– uncertainty of equipment used, such as sound generators, level meters, measuring microphones, coupler etc.;

– tolerances of the acoustic coupling of the hearing aid to the coupler. Such tolerances could be related to diameter and length of tubing;

– accuracy and care of positioning the hearing aid in the test space.

Considering the above factors the measurement uncertainty can be determined.

NOTE It is good practice to validate the uncertainty by comparing measurement results with an accredited test laboratory.

The interpretation of the measurement uncertainty is different for the manufacturer, who has to guarantee the nominal data, and the purchaser.

Manufacturer production test limits: tolerance minus measurement uncertainty. Purchaser measurement acceptance limits: nominal data plus measurement uncertainty.

Annex A
(normative)

Free-field to hearing-aid-microphone transformation

A.1 Microphone location

Figures A.1 to A.4 and Table A.1 illustrate the microphone location for typical hearing aid constructions and the corresponding free-field to hearing-aid-microphone transformation.

- Behind-the-ear instrument Figure A.1
- Full-concha instrument Figure A.2
- Canal size instrument Figure A.3
- Completely-in-the-ear canal instrument Figure A.4

A.2 Measurement conditions

- Manikin according to IEC/TR 60959 (KEMAR – large, right pinna DB-065)
- Ear simulator according to IEC 60711
- azimuth angle 0°
- elevation angle 0°

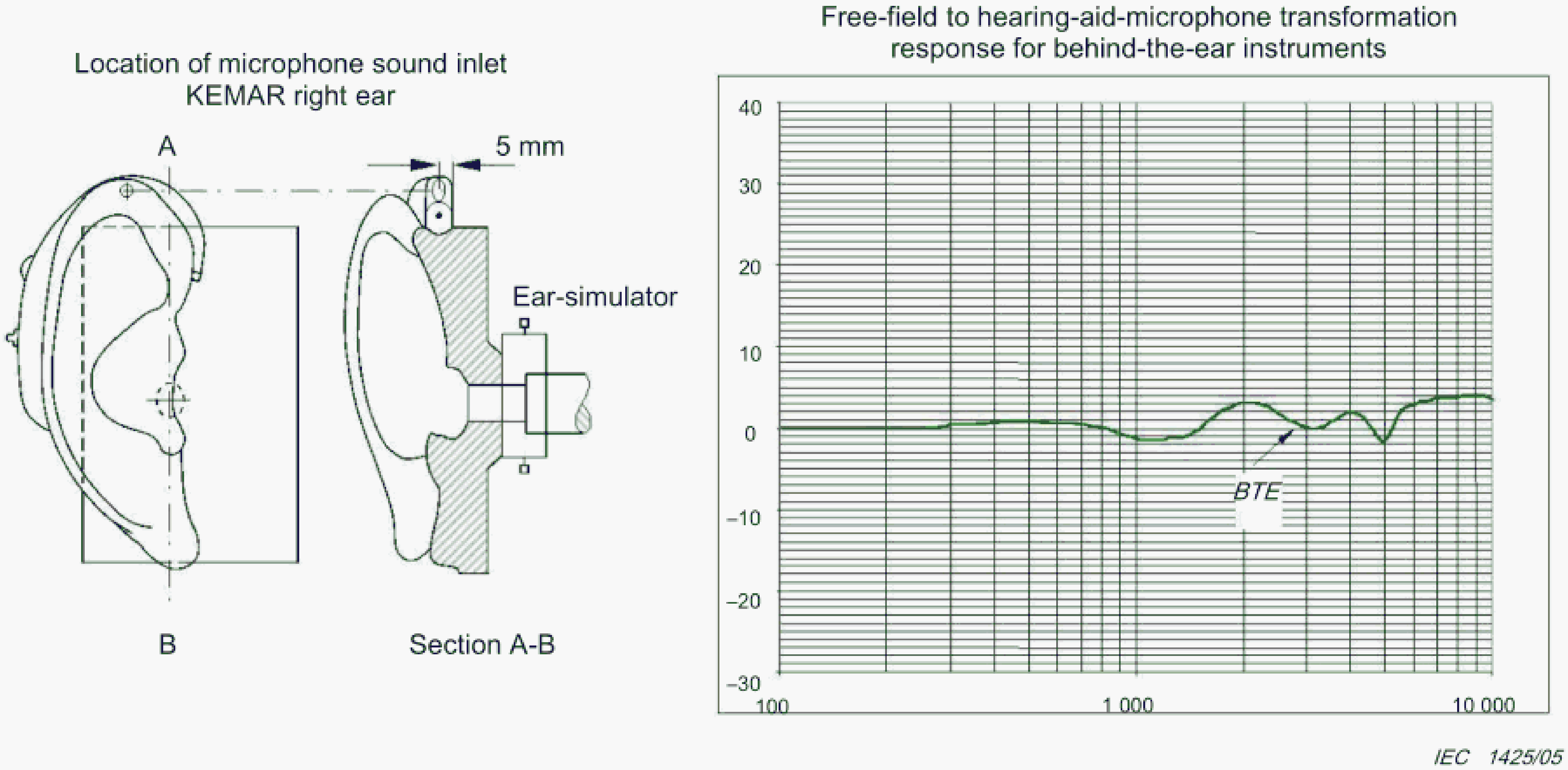

Figure A.1 – Microphone location and corresponding free-field to hearing-aid-microphone transformation for behind-the-ear instruments

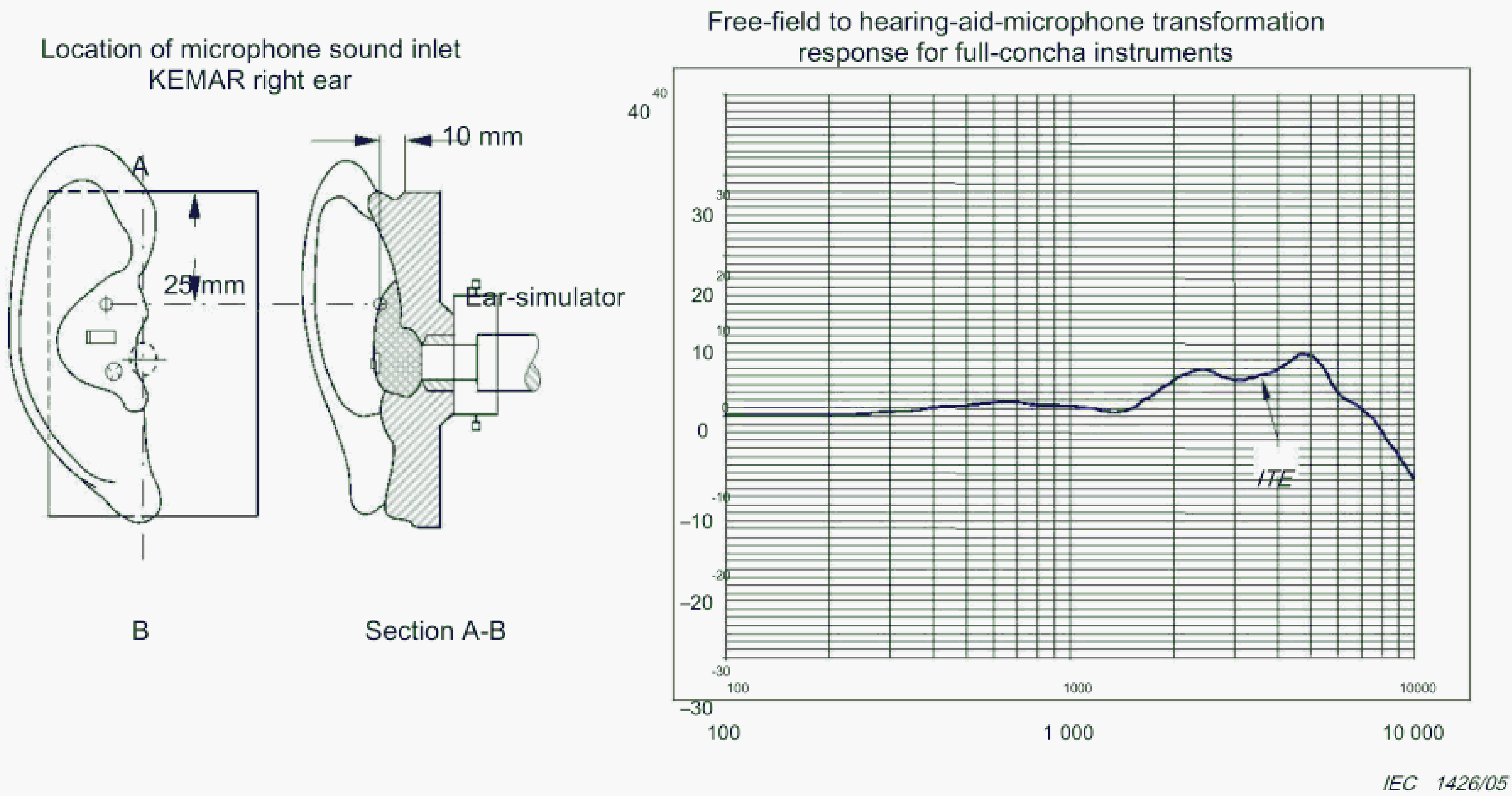

Figure A.2 – Microphone location and corresponding free-field to hearing-aid-microphone transformation for full-concha instruments

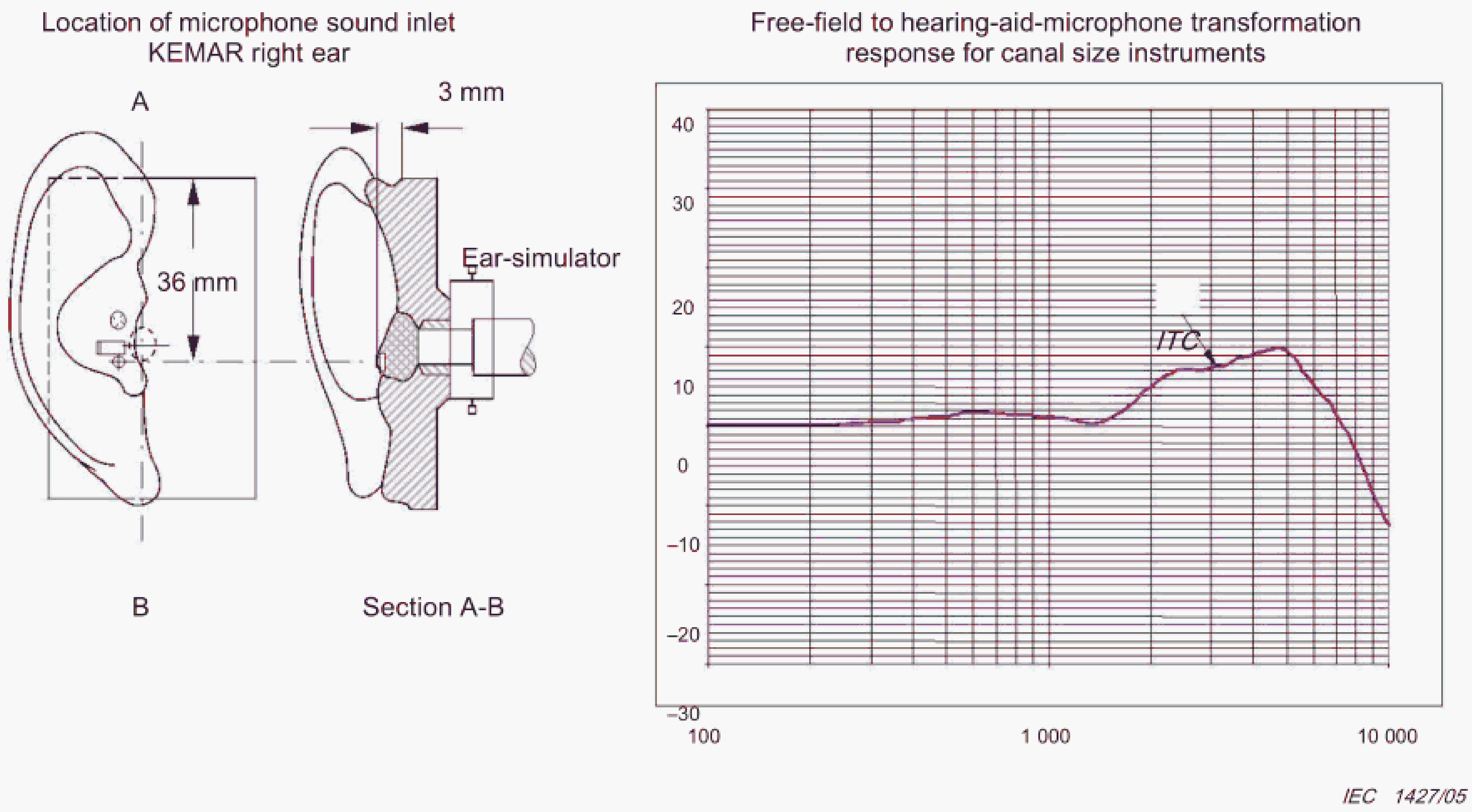

Figure A.3 – Microphone location and corresponding free-field to hearing-aid-microphone transformation for canal size instruments

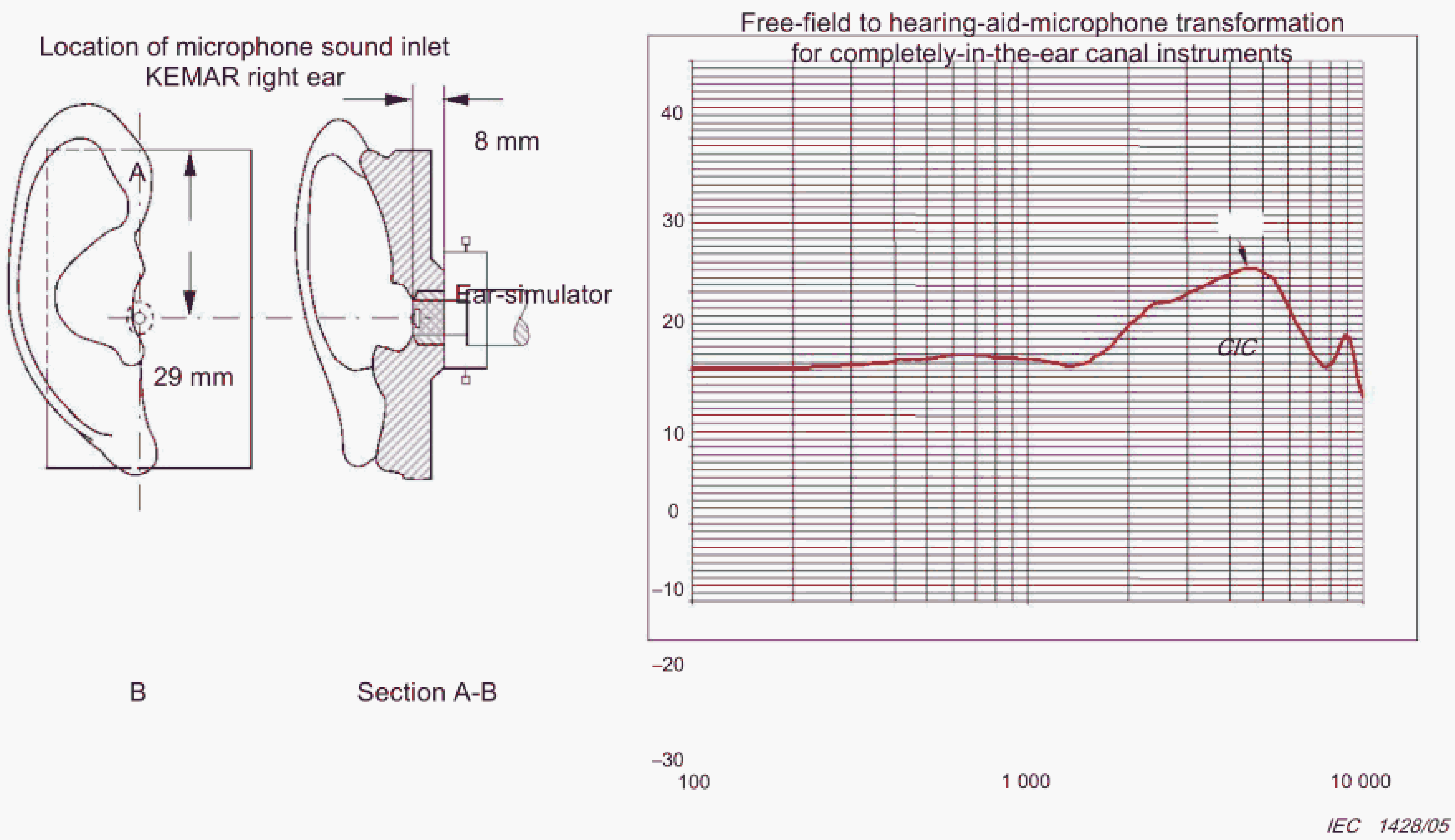

Figure A.4 – Microphone location and corresponding free-field to hearing-aid-microphone transformation for completely-in-the-ear canal instruments

Table A.1 – Numerical data for the various free-field to hearing-aid-microphone transformation responses

Frequency Hz	BTE dB	ITE dB	ITC dB	CIC dB
100	0,1	0,2	0,2	0,2
103	0,1	0,2	0,2	0,2
106	0,1	0,2	0,2	0,2
110	0,1	0,2	0,2	0,2
113	0,1	0,2	0,2	0,2
117	0,1	0,2	0,2	0,2
120	0,1	0,2	0,2	0,2
124	0,1	0,2	0,2	0,2
128	0,1	0,2	0,2	0,2
132	0,1	0,2	0,2	0,2
136	0,1	0,2	0,2	0,2
140	0,1	0,2	0,2	0,2
145	0,1	0,2	0,2	0,2
149	0,1	0,2	0,2	0,2
154	0,1	0,2	0,2	0,2
158	0,1	0,2	0,2	0,2
163	0,1	0,2	0,2	0,2
169	0,1	0,2	0,2	0,2
174	0,1	0,2	0,2	0,2
179	0,1	0,2	0,2	0,2
185	0,1	0,2	0,2	0,2
191	0,1	0,2	0,2	0,2
196	0,1	0,2	0,2	0,2
203	0,1	0,2	0,2	0,2
209	0,1	0,3	0,2	0,2
215	0,1	0,3	0,2	0,2
222	0,1	0,3	0,2	0,2
229	0,1	0,3	0,3	0,4
236	0,1	0,3	0,3	0,4
244	0,1	0,4	0,4	0,5

Frequency Hz	BTE dB	ITE dB	ITC dB	CIC dB
251	0,1	0,4	0,4	0,5
259	0,1	0,4	0,4	0,5
267	0,1	0,5	0,4	0,5
275	0,1	0,5	0,5	0,5
284	0,2	0,5	0,5	0,6
293	0,2	0,6	0,5	0,6
302	0,4	0,6	0,6	0,6
311	0,4	0,6	0,6	0,6
321	0,4	0,6	0,6	0,6
331	0,5	0,6	0,6	0,7
341	0,5	0,7	0,7	0,8
352	0,5	0,8	0,7	0,8
363	0,5	0,8	0,7	0,9
374	0,6	0,9	0,9	0,9
386	0,6	1,0	0,9	1,0
398	0,7	1,1	1,0	1,1
411	0,7	1,2	1,2	1,3
423	0,8	1,3	1,2	1,3
437	0,8	1,3	1,2	1,2
450	0,8	1,3	1,3	1,3
464	0,8	1,3	1,3	1,3
479	0,8	1,3	1,3	1,3
494	0,8	1,3	1,3	1,4
509	0,8	1,4	1,3	1,4
525	0,8	1,5	1,5	1,5
541	0,7	1,5	1,6	1,6
558	0,7	1,7	1,8	1,8
575	0,6	1,7	1,8	1,8
593	0,6	1,7	1,8	1,9
612	0,6	1,8	1,8	1,9

Frequency Hz	BTE dB	ITE dB	ITC dB	CIC dB
631	0,6	1,8	1,8	1,9
651	0,6	1,8	1,8	1,9
671	0,6	1,8	1,8	1,9
692	0,4	1,8	1,8	1,9
713	0,4	1,8	1,7	1,8
736	0,3	1,7	1,7	1,7
759	0,2	1,6	1,6	1,7
782	0,2	1,6	1,5	1,6
807	0,1	1,4	1,5	1,5
832	-0,1	1,4	1,5	1,5
858	-0,3	1,4	1,5	1,5
884	-0,6	1,4	1,5	1,5
912	-0,7	1,4	1,3	1,5
940	-1,0	1,3	1,3	1,4
970	-1,1	1,3	1,3	1,4
1000	-1,3	1,3	1,3	1,4
1031	-1,4	1,3	1,3	1,3
1063	-1,4	1,2	1,2	1,3
1096	-1,5	1,1	1,1	1,2
1131	-1,5	1,0	1,0	1,1
1166	-1,4	1,0	0,9	1,0
1202	-1,4	0,9	0,8	0,9
1240	-1,2	0,7	0,6	0,8
1278	-1,2	0,6	0,5	0,6
1318	-1,2	0,5	0,4	0,5
1359	-1,1	0,5	0,4	0,5
1402	-0,9	0,6	0,5	0,6
1445	-0,6	0,7	0,6	0,7
1491	-0,3	0,9	0,9	0,8
1537	0,1	1,2	1,1	1,1

Frequency Hz	BTE dB	ITE dB	ITC dB	CIC dB
1585	0,8	1,6	1,6	1,7
1634	1,2	2,0	1,8	1,9
1685	1,6	2,3	2,3	2,3
1738	2,1	2,7	2,7	2,7
1792	2,4	3,1	3,1	3,2
1848	2,5	3,6	3,9	3,9
1905	2,9	3,8	4,5	4,5
1965	3,1	4,2	4,8	5,2
2026	3,2	4,6	5,3	5,9
2089	3,2	5,0	5,8	6,4
2154	3,2	5,2	6,1	6,9
2222	3,0	5,4	6,5	7,4
2291	2,8	5,7	6,7	8,0
2362	2,6	5,9	7,0	8,5
2436	2,2	5,9	7,2	8,6
2512	1,8	5,8	7,2	8,7
2590	1,4	5,5	7,2	8,9
2671	1,0	5,2	7,2	8,9
2754	0,8	4,9	7,1	9,0
2840	0,4	4,8	7,1	9,3
2929	0,3	4,6	7,3	9,6
3020	0,1	4,5	7,4	9,9
3114	-0,1	4,5	7,6	10,2
3211	-0,1	4,5	7,6	10,4
3311	0,1	4,7	7,7	10,7
3415	0,3	4,8	8,1	11,0
3521	0,8	5,0	8,5	11,3
3631	1,0	5,2	8,7	11,6
3744	1,4	5,3	8,7	11,9
3861	1,8	5,5	8,9	12,1

Frequency Hz	BTE dB	ITE dB	ITC dB	CIC dB
3981	2,0	5,8	9,1	12,3
4105	1,9	6,1	9,3	12,5
4233	1,6	6,4	9,4	12,8
4365	1,2	6,9	9,6	13,0
4501	0,6	7,3	9,8	13,1
4642	-0,2	7,7	9,9	13,1
4786	-1,3	7,7	9,9	13,1
4936	-1,7	7,6	9,7	12,9
5089	-1,2	7,4	9,2	12,5
5248	0,0	6,8	8,8	12,1
5412	1,4	6,2	8,1	11,8
5580	2,3	5,2	7,1	10,7
5754	2,6	4,1	6,4	9,7
5934	2,8	3,3	5,5	8,7
6119	3,0	2,6	4,7	7,3
6310	3,3	2,1	4,1	6,2
6506	3,3	1,9	3,6	5,2
6709	3,4	1,5	3,1	4,2
6918	3,6	1,2	2,1	2,9
7134	3,6	0,7	1,0	1,9
7356	3,7	0,2	-0,1	1,2
7586	3,7	-0,4	-0,8	0,4
7822	3,7	-1,1	-2,2	0,3
8066	3,9	-1,8	-3,3	0,7
8318	4,1	-2,9	-4,8	1,6
8577	4,1	-3,6	-6,0	3,2
8844	4,1	-4,4	-7,7	4,4
9120	4,1	-5,3	-9,2	4,2
9404	4,1	-6,2	-10,3	1,8
9698	3,9	-6,9	-11,4	-1,5
10000	3,5	-7,8	-12,4	-3,5

Annex B
(normative)

Manikin unoccluded-ear gain (open ear response)

Figure B.1 and Table B.1 illustrate the manikin unoccluded-ear gain measurement conditions

- Manikin according to IEC/TR 60959
- Ear simulator according to IEC 60711
- Azimuth angle 0°
- Elevation angle 0°
- Large pinna (red)
- Right ear

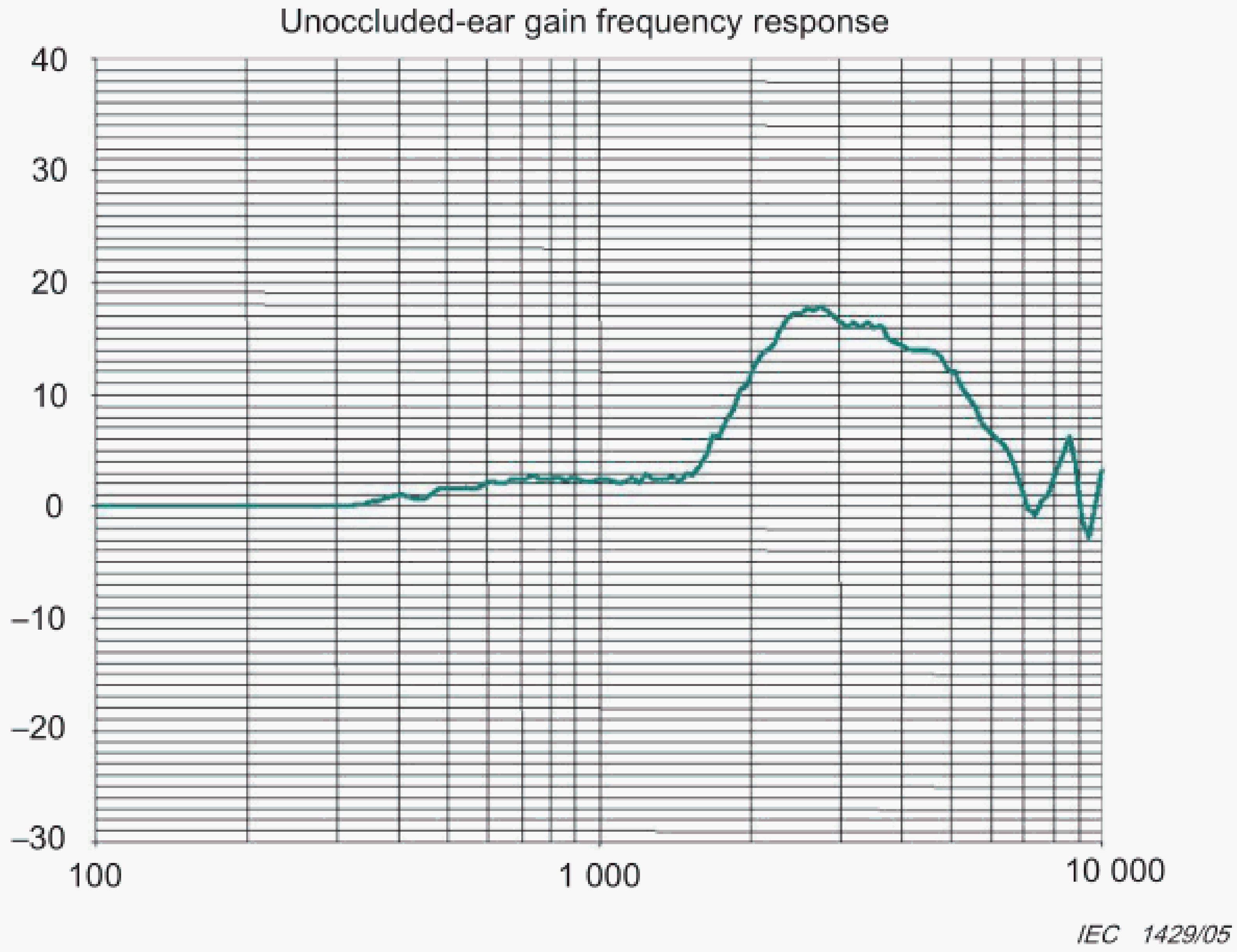

Figure B.1 – Manikin unoccluded-ear gain frequency response

Table B.1 – Numerical data of manikin unoccluded-ear gain frequency response

Frequency Hz	Unoccluded ear gain dB	Frequency Hz	Unoccluded ear gain dB	Frequency Hz	Unoccluded ear gain dB	Frequency Hz	Unoccluded ear gain dB	Frequency Hz	Unoccluded ear gain dB
100	0	251	0	631	2	1585	3,6	3981	14,4
103	0	259	0	651	2	1634	4,8	4105	14,1
106	0	267	0	671	2,5	1685	6,4	4233	14
110	0	275	0	692	2,4	1738	6,3	4365	14
113	0	284	0	713	2,5	1792	7,8	4501	14
117	0	293	0	736	2,8	1848	8,7	4642	13,8
120	0	302	0	759	2,4	1905	10,4	4786	13,3
124	0	311	0	782	2,4	1965	10,9	4936	12,3
128	0	321	0	807	2,5	2026	12,5	5089	12
132	0	331	0,1	832	2,6	2089	13,3	5248	10,8
136	0	341	0,1	858	2,3	2154	14	5412	9,8
140	0	352	0,4	884	2,6	2222	14,5	5580	8,8
145	0	363	0,4	912	2,4	2291	15,7	5754	7,6
149	0	374	0,7	940	2,2	2362	16,8	5934	6,8
154	0	386	0,9	970	2,2	2436	17,2	6119	6,1
158	0	398	1,1	1000	2,5	2512	17,2	6310	5,8
163	0	411	1	1031	2,5	2590	17,6	6506	5
169	0	423	0,8	1063	2,3	2671	17,5	6709	3,5
174	0	437	0,7	1096	2	2754	17,9	6918	1,5
179	0	450	0,7	1131	2,2	2840	17,5	7134	-0,2
185	0	464	1,2	1166	2,6	2929	17	7356	-0,8
191	0	479	1,5	1202	2,1	3020	16,5	7586	0,5
196	0	494	1,5	1240	2,9	3114	16,1	7822	1,1
203	0	509	1,5	1278	2,5	3211	16,5	8066	2,8
209	0	525	1,6	1318	2,5	3311	16,1	8318	4,4
215	0	541	1,7	1359	2,5	3415	16,5	8577	6,3
222	0	558	1,5	1402	2,7	3521	16	8844	4
229	0	575	1,7	1445	2,2	3631	16,2	9120	-1,3
236	0	593	2	1491	3	3744	14,9	9404	-2,8
244	0	612	2,2	1537	2,8	3861	14,7	9698	-0,1
								10000	3,4

Annex C
(informative)

General requirements for a manikin

The specifications for a suitable manikin are given in IEC/TR 60959.

The following general properties are listed as essential for measurement purposes:

- The dimensions of the head and torso of the manikin should correspond to a carefully determined anthropometric median derived from the combined population of adult males and females.
- The pinnas of the manikin should have shape, dimensions and flexibility that have been carefully determined to correspond as much as possible to average adult human pinnas as derived from the combined population of males and females.
- One or two ear simulators should be mounted in the head of the manikin in correct relation to the pinna(s).
- The free field-to-ear simulator microphone transformation (the manikin unoccluded-ear gain frequency response, MFR) at 0°, 90°, 180° and 270° azimuth angles of sound incidence with an elevation angle of 0° should be similar to the average adult human free field to eardrum transformation over the range 200 Hz to 8 000 Hz.
- The manikin should be symmetrical about a front-to-back plane that passes through the reference point and that contains the axis of rotation.
- The manikin should have suitable reference marks or fixtures for establishing the correct location of the head with respect to the torso, for establishing the correct position of the axis of rotation, for setting the angles of incidence and for matching the locations of the reference point and the test point.
- The surface of the manikin should be non-porous with an acoustic impedance high compared to that of air.

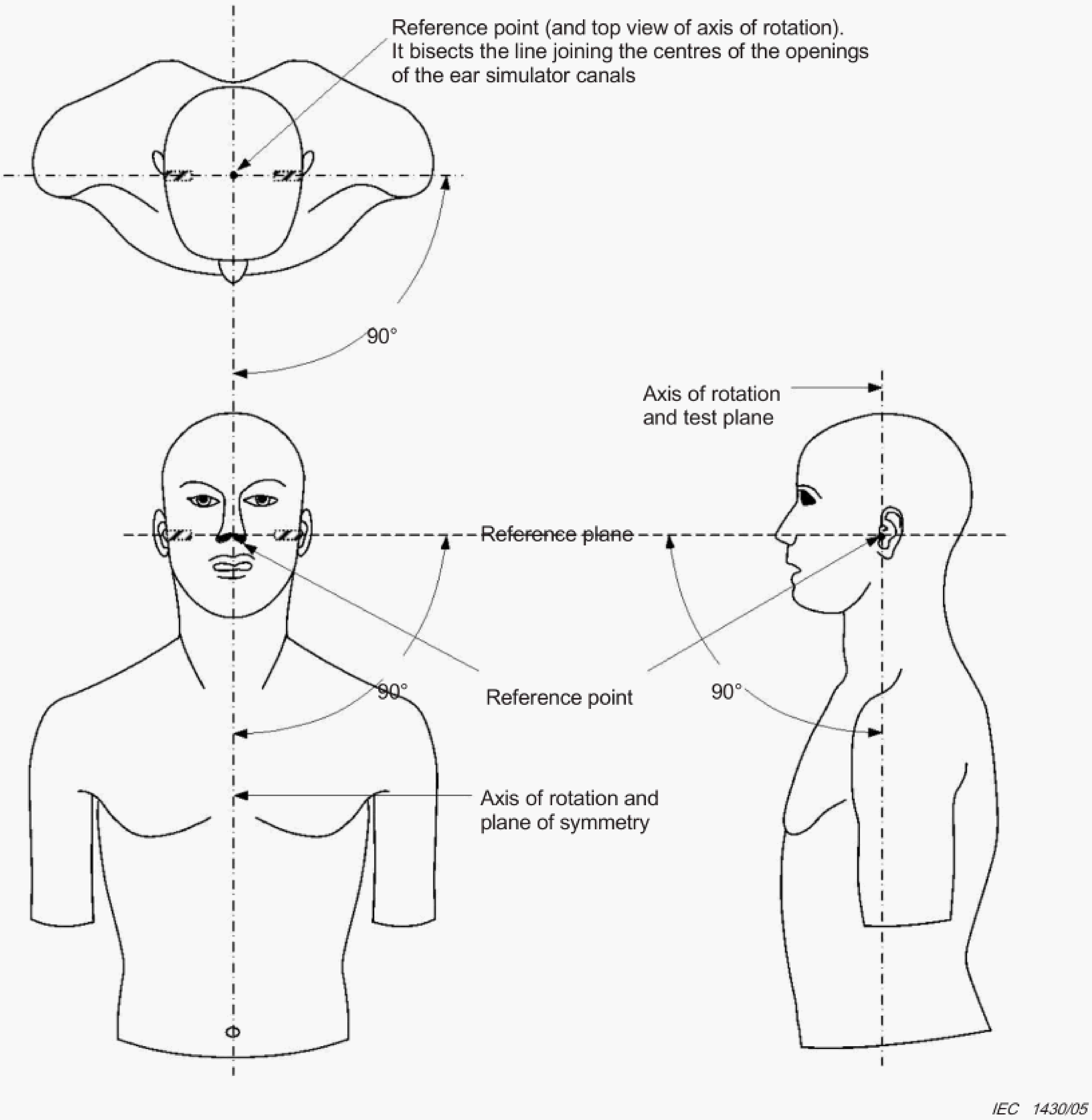

Figure C.1 – Manikin geometrical references

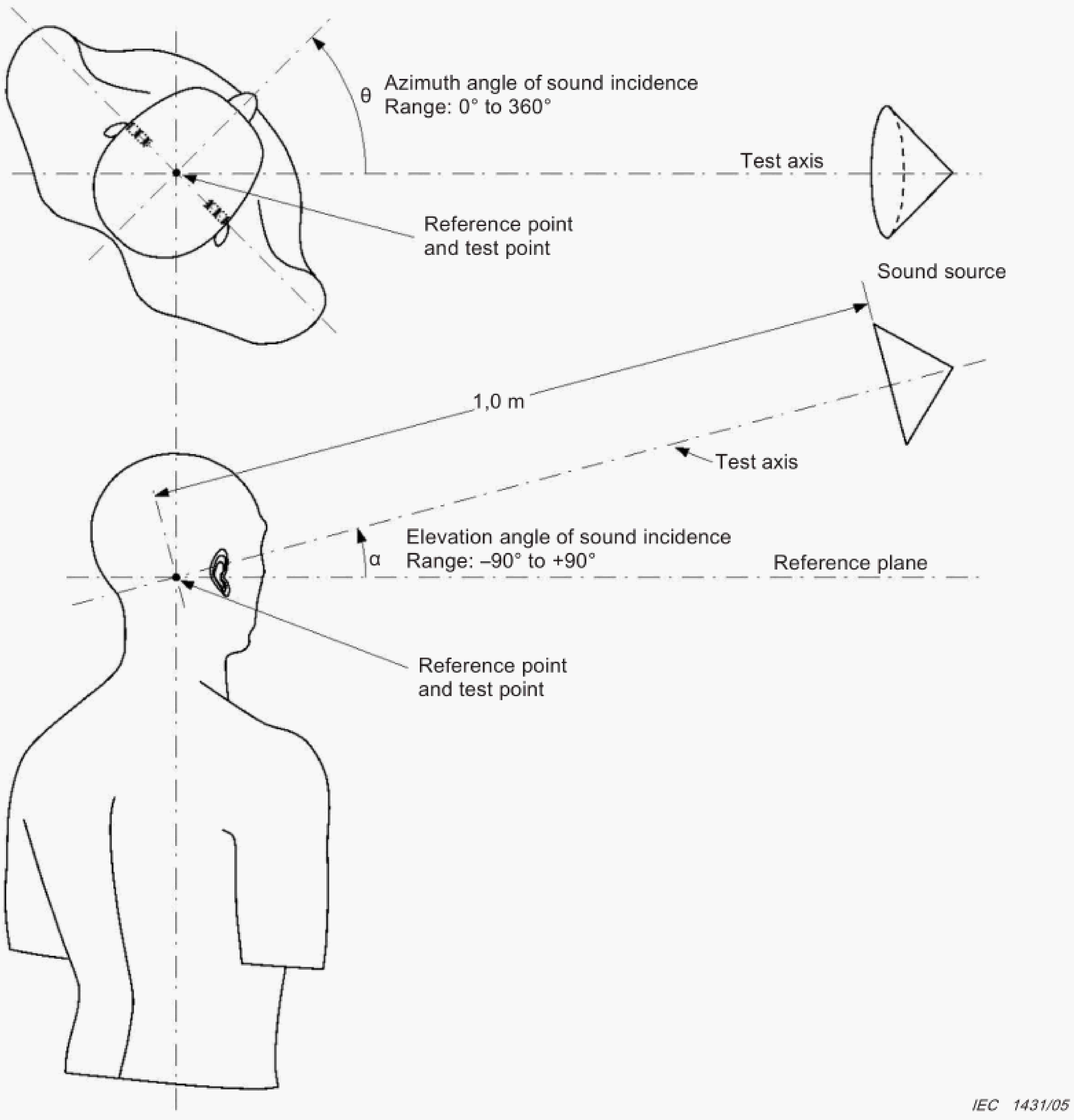

Figure C.2 – Co-ordinates for angles of azimuth and elevation

Bibliography

[1] IEC 60068, *Environmental testing*

NOTE Harmonized in the EN 60068 series (not modified).

[2] IEC 60118-7, *Hearing heads – Part 7: Measurement of the performance characteristics of hearing aids for production, supply and delivery quality assurance purposes*

NOTE Harmonized as EN 60118-7:2005 (not modified).

[3] ANSI S3.5:1997, *Methods for the calculation of the speech intelligibility index*

[4] *Manikin Measurements*. Mahlon D. Burkhard, Ed. Knowles Electronics, *1978*

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE Where an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60118-0	1983	Hearing aids Part 0: Measurement of electroacoustical characteristics	EN 60118-0	1993
IEC 60263	- [1]	Scales and sizes for plotting frequency characteristics and polar diagrams	-	-
IEC 60711	- [1]	Occluded-ear simulator for the measurement of earphones coupled to the ear by ear inserts	HD 443 S1	1983 [2]
IEC 60959	- [1]	Provisional head and torso simulator for acoustic measurements on air conduction hearing aids	-	-

1) Undated reference.

2) Valid edition at date of issue.

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