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SERIES P: TELEPHONE TRANSMISSION QUALITY,
TELEPHONE INSTALLATIONS, LOCAL LINE
NETWORKS

Objective measuring apparatus

Artificial ears

ITU-T Recommendation P.57

ITU-T P-SERIES RECOMMENDATIONS

TELEPHONE TRANSMISSION QUALITY, TELEPHONE INSTALLATIONS, LOCAL LINE NETWORKS

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ITU-T Recommendation P.57

Artificial ears

Summary

This Recommendation specifies the electroacoustical characteristics of Artificial Ears to be used for telephonometric measurements. Three devices are specified: a telephone band type for measurements on traditional telephone sets, an insert type and a type faithfully reproducing the characteristics of the human ear.

The latter type (Type 3) is specified in four configurations. The requirements of the third one (Type 3.3 – Pinna simulator) have been slightly modified in this revision of ITU-T Rec. P.57 by specifying its construction by a softer elastomer.

Source

ITU-T Recommendation P.57 was revised by ITU-T Study Group 12 (2001-2004) and approved under the WTSA Resolution 1 procedure on 14 July 2002.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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ITU-T Recommendation P.57

Artificial ears

1 Scope

This Recommendation specifies the artificial ears for telephonometric use. Three types are recommended, covering the different transducers, types, sizes and technologies.

The methods of use of the artificial ears are outside the scope of this Recommendation, however, some general rules are provided about the application force and the positioning of transducers.

2 Object

Three types of artificial ears are defined:

- 1) a telephone band type for measurements on traditional telephone sets;
- 2) a type for measuring insert earphones;
- 3) a type which faithfully reproduces the characteristics of the median human ear.

3 Normative references

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [1] IEC 60318 (1970), *An IEC artificial ear, of the wideband type, for the calibration of earphones used in audiometry.*
- [2] IEC 60711 (1981), *Occluded-ear simulator for the measurement of earphones coupled to the ear by ear inserts.*
- [3] ITU-T Recommendation P.79 (1999), *Calculation of loudness ratings for telephone sets.*
- [4] ITU-T Recommendation P.38 (1993), *Transmission characteristics of operator telephone systems (OTS).*
- [5] IEC 61260 (1995), *Octave-band and fractional-octave-band filters*
- [6] IEC 60959 (1990), *Provisional head and torso simulator for acoustic measurements on air conduction hearing aids.*

4 Definitions

This Recommendation defines the following terms:

4.1 artificial ear: A device for the calibration of earphones incorporating an acoustic coupler and a calibration microphone for the measurement of the sound pressure and having an overall acoustic impedance similar to that of the average human ear over a given frequency band.

4.2 ear reference point (ERP): A virtual point for geometric reference located at the entrance to the listener's ear, traditionally used for calculating telephonometric loudness ratings.

4.3 ear canal entrance point (EEP): A point located at the centre of the ear canal opening.

4.4 ear-drum reference point (DRP): A point located at the end of the ear canal, corresponding to the ear-drum position.

4.5 ear canal extension: Cylindrical cavity extending the simulation of the ear canal provided by the occluded-ear simulator out of the concha cavity.

4.6 ear simulator: Device for measuring the output sound pressure 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 ear-drum.

4.7 occluded-ear simulator: Ear simulator which simulates the inner part of the ear canal, from the tip of an ear insert to the ear-drum.

4.8 pinna simulator: A device which has the approximate shape of dimensions of a median adult human pinna.

4.9 circum-aural earphones: Earphones which enclose the pinna and seat on the surrounding surface of the head. Contact to the head is normally maintained by compliant cushions. Circum-aural earphones may touch, but not significantly compress the pinna (see Figure 1).

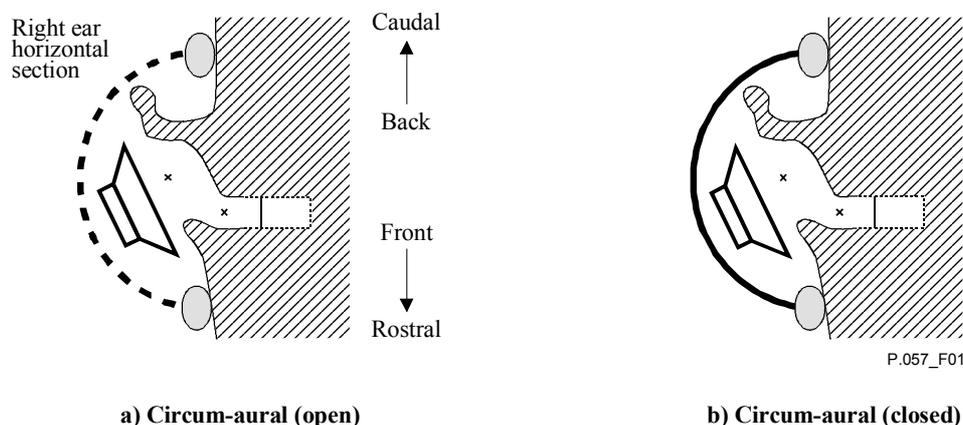


Figure 1/P.57 – Circum-aural earphones

4.10 supra-aural earphones: Earphones which rest upon the pinna and have an external diameter (or maximum dimension) of at least 45 mm (see Figure 2).

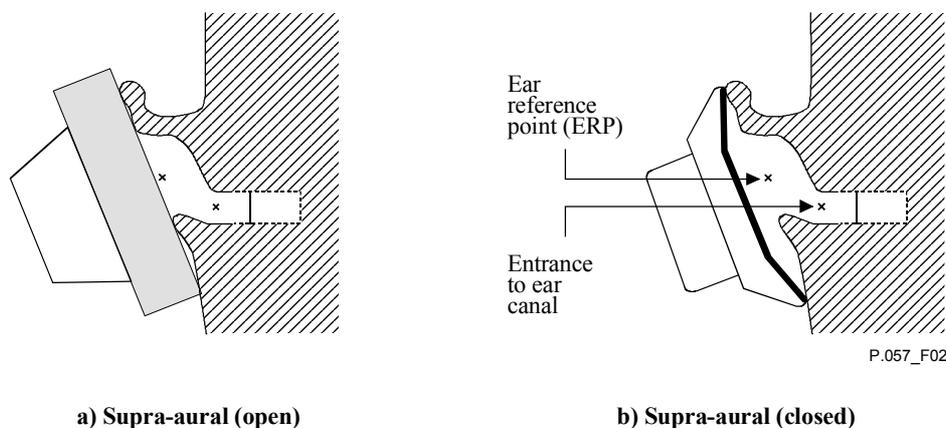


Figure 2/P.57 – Supra-aural earphones

4.11 supra-concha earphones: Earphones which are intended to rest upon the ridges of the concha cavity and have an external diameter (or maximum dimension) greater than 25 mm and less than 45 mm (see Figure 3).

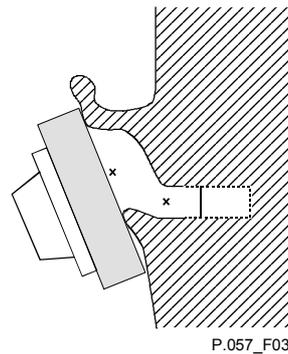


Figure 3/P.57 – Supra-concha (open) earphones

4.12 intra-concha earphones: Earphones which are intended to rest within the concha cavity of the ear. They have an external diameter (or maximum dimension) of less than 25 mm but are not made to enter the ear canal (see Figure 4).

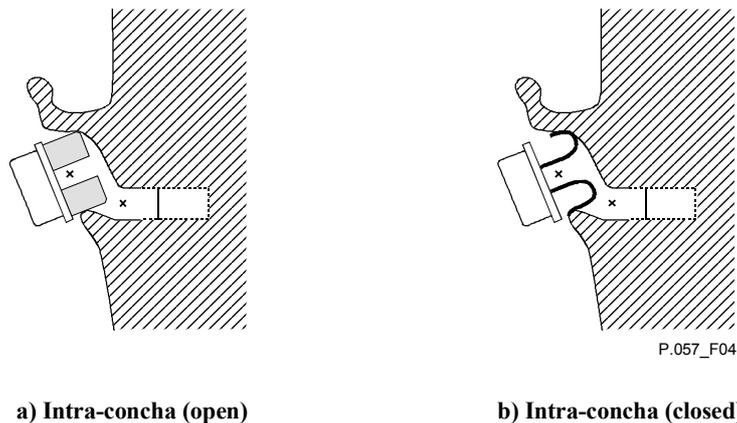


Figure 4/P.57 – Intra-concha earphones

4.13 insert earphones: Earphones which are intended to partially or completely enter the ear canal (see Figure 5).

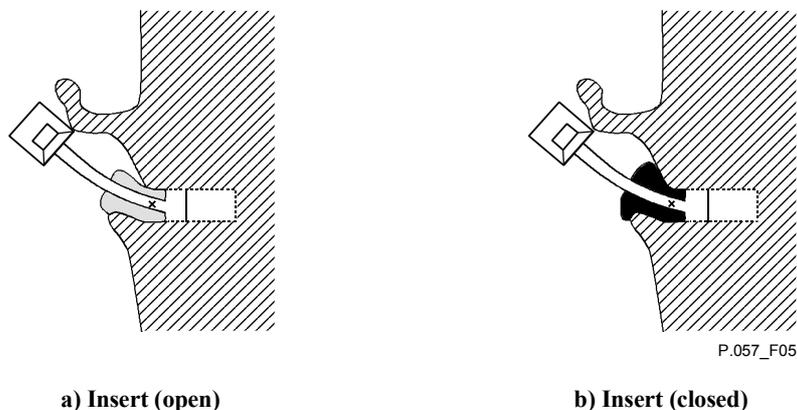


Figure 5/P.57 – Insert earphones

4.14 acoustically open earphones (nominally unsealed): Earphones which intentionally provide an acoustic path between the external environment and the ear canal.

4.15 acoustically closed earphones (nominally sealed): Earphones which are intended to prevent any acoustic coupling between the external environment and the ear canal.

5 Artificial ear types

5.1 Type 1 – IEC 60318

The Type 1 artificial ear is specified in IEC 60318 [1].

It is recommended that the Type 1 artificial ear should be used for measurements on supra-aural and supra-concha earphones, intended for telephone bandwidth (100 Hz to 4 kHz) applications.

The acoustic input impedance and the frequency sensitivity response of the Type 1 artificial ear are determined with reference to the ERP as specified in 5.4. The nominal modulus of the impedance curve and the corresponding tolerance limits are given in Table 1.

NOTE 1 – The Type 1 artificial ear is not suitable for measuring low acoustic impedance earphones.

NOTE 2 – The Type 1 artificial ear is defined for simulating the acoustic load of the human ear under no leakage conditions. For receive loudness rating calculations according to ITU-T Rec. P.79, it is recommended that measured data be corrected using the real ear loss correction L_E provided in Table 2/P.79.

NOTE 3 – It is recommended to use an application force between 5 N and 10 N for placing earcaps against Type 1 artificial ear. The force applied in measurements shall always be reported.

5.2 Type 2 – IEC 60711

The Type 2 artificial ear is specified in IEC 60711 [2].

It is recommended that the Type 2 artificial ear should be used for measurements on insert earphones, both sealed and unsealed.

The sound pressure measured by the Type 2 artificial ear is referred to the ear-drum reference point (DRP). The correction function given in Tables 2a (1/3 octave band measurements) and 2b (1/12 octave band and sine measurements) shall be used for converting data to the ear reference point (ERP) when it is required to calculate loudness ratings or check results against specifications based on measurements referred to the ERP.

NOTE – For receive loudness rating calculations according to ITU-T Rec. P.79, the real ear loss correction L_E should be as specified in ITU-T Rec. P.38.

Table 1/P.57 – Acoustical impedance (Type 1 – IEC 60318 artificial ear)

Frequency (Hz)	Acoustical imp. (dB re 1 Pa s/m ³)	Tolerance (± dB)	Frequency (Hz)	Acoustical imp. (dB re 1 Pa s/m ³)	Tolerance (± dB)
100	145.6	1	950	134.5	1
106	145.3	1	1000	134.0	1
112	145.0	1	1060	133.4	1
118	144.6	1	1120	132.8	1
125	144.3	1	1180	132.2	1
132	144.0	1	1250	131.7	1
140	143.7	1	1320	131.1	1
150	143.4	1	1400	130.6	1
160	143.2	1	1500	130.1	1
170	143.0	1	1600	129.6	1
180	143.0	1	1700	129.4	1
190	142.9	1	1800	129.2	1
200	142.8	1	1900	129.2	1
212	142.9	1	2000	129.3	1
224	142.9	1	2120	129.5	1
236	143.1	1	2240	129.7	1
250	143.2	1	2360	129.8	1
265	143.4	1	2500	129.8	1
280	143.5	1	2650	129.6	1
300	143.7	1	2800	129.2	1
315	143.6	1	3000	128.6	1
335	143.7	1	3150	127.9	1
355	143.6	1	3350	127.0	1
375	143.3	1	3550	125.9	1
400	143.0	1	3750	124.8	1
425	142.7	1	4000	123.2	1
450	142.2	1	4250	121.5	1
475	141.7	1	4500	119.5	1
500	141.3	1	4750	117.1	1
530	140.7	1	5000	114.2	1
560	140.1	1	5300	109.6	1
600	139.4	1	5600	104.7	1
630	138.9	1	6000	109.6	1
670	138.3	1	6300	113.6	1
710	137.6	1	6700	117.0	1
750	137.1	1	7100	119.5	1
800	136.4	1	7500	121.3	1
850	135.7	1	8000	123.2	1
900	135.1	1			

Table 2a/P.57 – S_{DE} – Third octave measurements

Frequency (Hz)	S_{DE} (dB)	Frequency (Hz)	S_{DE} (dB)
100	0.0	1000	-1.7
125	0.0	1250	-2.6
160	0.0	1600	-4.2
200	0.0	2000	-6.5
250	-0.3	2500	-9.4
315	-0.2	3150	-10.3
400	-0.5	4000	-6.6
500	-0.6	5000	-3.2
630	-0.7	6300	-3.3
800	-1.1	8000	-16.0
		(10 000)	(-14.4)

S_{DE} The transfer function DRP to ERP

$$S_{DE} = 20 \log_{10} (P_E/P_D)$$

where: P_E Sound pressure at the ERP
 P_D Sound pressure at the DRP

The values in this table apply to 1/3 octave band measurements only.

Table 2b/P.57 – S_{DE} – Twelfth octave measurements

Frequency (Hz)	S _{DE} (dB)						
92	0.1	290	-0.3	917	-1.3	2901	-11.0
97	0.0	307	-0.2	972	-1.4	3073	-10.5
103	0.0	325	-0.2	1029	-1.8	3255	-10.2
109	0.0	345	-0.2	1090	-2.0	3447	-9.1
115	0.0	365	-0.4	1155	-2.3	3652	-8.0
122	0.0	387	-0.5	1223	-2.4	3868	-6.9
130	0.0	410	-0.4	1296	-2.6	4097	-5.8
137	0.0	434	-0.6	1372	-3.1	4340	-5.0
145	0.0	460	-0.3	1454	-3.3	4597	-4.2
154	0.0	487	-0.7	1540	-3.9	4870	-3.3
163	0.0	516	-0.6	1631	-4.4	5158	-2.7
173	-0.1	546	-0.6	1728	-4.8	5464	-2.4
183	-0.1	579	-0.6	1830	-5.3	5788	-2.4
193	0.0	613	-0.6	1939	-6.0	6131	-2.5
205	0.1	649	-0.8	2053	-6.9	6494	-3.3
218	0.0	688	-0.8	2175	-7.5	6879	-4.5
230	-0.1	729	-1.0	2304	-8.1	7286	-5.9
244	-0.2	772	-1.1	2441	-9.1	7718	-9.0
259	-0.3	818	-1.1	2585	-9.5	8175	-14.2
274	-0.3	866	-1.2	2738	-10.4	8659	-20.7

The frequencies listed are the 1/12 octave centre frequencies specified in IEC 61260 [5]. The values apply to 1/12 octave band measurements as well as sine based measurements. S_{DE} may be determined for immediate frequencies by interpolation on a (log f) versus (ln dB) basis.

5.3 Type 3

The Type 3 artificial ear consists of the IEC 60711 occluded-ear simulator, to which is added an ear canal extension terminated with a pinna simulation device. Three pinna simulators are recommended, providing the suitable coupling arrangements for measuring different transducer types. The Type 3 artificial ear configurations are classified as follows:

- Type 3.1 Concha bottom simulator.
- Type 3.2 Simplified pinna simulator.
- Type 3.3 Pinna simulator (anatomically shaped).
- Type 3.4 Pinna simulator (simplified).

NOTE – Acoustically open earphones equipped with soft cushions should be positioned against the Type 3 artificial ear with the same force as applied in normal use. The force applied in measurements shall always be reported.

5.3.1 Type 3.1 – Concha bottom simulator

The concha bottom simulation is realized in Type 3.1 artificial ear by a flat plate termination of the 10.0 mm ear canal extension.

It is recommended that the Type 3.1 artificial ear should be used for measurements on intra-concha earphones, designed for sitting on the bottom of the concha cavity.

Table 3a/P.57 – Leakage simulation – realized using a slit (Type 3.2 artificial ear)

Leakage grade	Use	Slit depth (mm)	Slit height (mm)	Opening angle (degrees)
Low	LRGP/HATS	2.8 ± 0.2	0.26 ± 0.01	84 ± 1
High	HATS	1.9 ± 0.2	$0.50 + 0.01 - 0.03$	240 ± 1

Table 3b/P.57 – Leakage simulation – realized using cylindrical holes (Type 3.2 artificial ear)

Leakage grade	Use	Number of holes	Diameter (mm)	Depth (mm)
High	LRGP	33	1.7	8.5 ± 0.2
		6	1.8	8.5 ± 0.2

It is recommended that the Type 3.2 artificial ear should be used for measurements on supra-aural and supra-concha earphones, both sealed and unsealed, intended for wideband telephony applications (100 Hz to 8 kHz). It is also recommended for measurements on low acoustic impedance earphones.

The acoustic input impedance and the frequency sensitivity response of the Type 3.2 artificial ear are determined with reference to the ERP as specified in 5.4. The nominal modulus of the impedance curve and the corresponding tolerance limits are given in Table 4.

NOTE 1 – The leakage grade ("high" or "low") adopted in measurements shall be reported.

NOTE 2 – The Type 3.2 artificial ear emulates the human ear canal, with the microphone diaphragm at the eardrum position. Hence, in addition to the particular microphone characteristics, the frequency sensitivity response of the artificial ear includes an individual ERP to DRP transfer function. It is essential, therefore, that measurement values are corrected for the frequency sensitivity response calibration data (open ear condition) provided with the particular artificial ear used.

NOTE 3 – For receive loudness rating calculations according to ITU-T Rec. P.79, the real ear loss correction L_E should be set to zero.

NOTE 4 – The ERP to DRP transfer function depends significantly on the acoustic loading of the ear. For diagnostic purposes (e.g. to interpret differences to measurements made using the Type 1 artificial ear), the Type 3.2 artificial ear may be supplied with calibration data recorded under closed ear condition or other well-defined acoustical terminations.

NOTE 5 – The flat plate termination of the ear canal extension provided by the Type 3.2 artificial ear is a possible implementation of Type 3.1 artificial ear.

NOTE 6 – The Type 3.2 artificial ear is only intended for use with earphones designed to operate in close contact with the real pinna.

NOTE 7 – All dimensions determining the acoustic leak are for guidance only. They may be modified slightly for different commercial designs in order to obtain the nominal acoustic input impedance.

NOTE 8 – It is recommended to use an application force between 5 N and 10 N for placing hard earcaps against Type 3.2 artificial ear. The force applied in the measurements shall always be reported.

All leakage related dimensions are for guidance only – see also Figure 6. Practical implementation must always be optimized with respect to the acoustical specifications.

**Table 4a/P.57 – Acoustical impedance, resonance, and Q-factors
(Type 3.2 – low and high leak)**

	Q-factor	Resonance (Hz)	Magnitude (dB)
Low leak	1.81	713.8	140.4
Tolerance (\pm)	0.18	25	1.0
High leak	3.5	1570	138.8
Tolerance (\pm)	0.35	50	1.5

Table 4b/P.57 – Acoustical impedance (Type 3.2 – low leak)

Frequency (Hz)	Acoustical imp. (dB re 1 Pa s/m³)	Tolerance (± dB)	Frequency (Hz)	Acoustical imp. (dB re 1 Pa s/m³)	Tolerance (± dB)
100	125.77	4.00	950	137.18	1.00
106	126.07	4.00	1000	136.33	1.00
112	126.18	4.00	1060	135.34	1.00
118	126.28	4.00	1120	134.40	1.00
125	126.44	4.00	1180	133.48	1.00
132	126.60	4.00	1250	132.46	1.00
140	126.74	4.00	1320	131.48	1.00
150	127.26	4.00	1400	130.40	1.00
160	127.27	4.00	1500	129.10	1.00
170	127.42	3.73	1600	127.85	1.00
180	127.79	3.47	1700	126.69	1.00
190	127.89	3.23	1800	125.58	1.00
200	128.10	3.00	1900	124.46	1.00
212	128.44	3.00	2000	123.45	1.00
224	128.71	3.00	2120	122.38	1.26
236	129.01	3.00	2240	121.22	1.51
250	129.31	3.00	2360	119.99	1.74
265	129.66	2.75	2500	118.69	2.00
280	130.08	2.51	2650	117.60	2.00
300	130.46	2.21	2800	116.99	2.00
315	130.92	2.00	3000	117.47	2.00
335	131.50	2.00	3150	117.91	2.00
355	132.02	2.00	3350	118.74	2.00
375	132.52	2.00	3550	119.23	2.00
400	133.23	2.00	3750	118.77	2.00
425	133.95	1.73	4000	116.22	2.00
450	134.72	1.47	4250	111.62	2.27
475	135.32	1.23	4500	108.19	2.53
500	136.08	1.00	4750	111.36	2.77
530	136.97	1.00	5000	114.89	3.00
560	137.78	1.00	5300	117.80	3.00
600	138.75	1.00	5600	119.87	3.00
630	139.45	1.00	6000	121.93	3.00
670	140.13	1.00	6300	123.19	3.00
710	140.32	1.00	6700	124.61	3.00
750	140.30	1.00	7100	125.81	3.00
800	139.76	1.00	7500	126.90	3.00
850	138.99	1.00	8000	128.12	3.00
900	138.09	1.00			

Table 4c/P.57 – Acoustical impedance (Type 3.2 – high leak)

Frequency (Hz)	Acoustical imp. (dB re 1 Pa s/m³)	Tolerance (± dB)	Frequency (Hz)	Acoustical imp. (dB re 1 Pa s/m³)	Tolerance (± dB)
100	105.4	4.0	950	127.7	1.5
106	105.9	4.0	1000	128.4	1.5
112	106.2	4.0	1060	129.4	1.5
118	106.7	4.0	1120	130.5	1.5
125	107.3	4.0	1180	131.7	1.5
132	107.7	4.0	1250	133.3	1.5
140	108.3	4.0	1320	134.9	1.5
150	108.9	4.0	1400	137.2	1.5
160	109.6	4.0	1500	138.1	1.5
170	110.1	3.7	1600	138.1	1.5
180	110.6	3.5	1700	137.1	1.5
190	111.1	3.2	1800	135.8	1.5
200	111.5	3.0	1900	134.0	1.5
212	112.1	3.0	2000	133.0	1.5
224	112.4	3.0	2120	130.7	2.0
236	113.0	3.0	2240	128.3	2.0
250	113.4	3.0	2360	126.3	2.0
265	114.0	2.8	2500	124.2	2.0
280	114.5	2.5	2650	122.6	2.0
300	115.0	2.2	2800	121.5	2.0
315	115.5	2.0	3000	121.7	2.0
335	116.1	2.0	3150	121.9	2.0
355	116.6	2.0	3350	122.6	2.0
375	117.1	2.0	3550	123.3	2.0
400	117.7	2.0	3750	123.4	2.0
425	118.4	1.5	4000	121.7	2.0
450	118.8	1.5	4250	118.2	2.3
475	119.3	1.5	4500	113.8	2.5
500	120.0	1.5	4750	110.9	2.8
530	120.6	1.5	5000	113.6	3.0
560	121.1	1.5	5300	116.6	3.0
600	121.9	1.5	5600	118.9	3.0
630	122.3	1.5	6000	121.3	3.0
670	123.0	1.5	6300	122.7	3.0
710	123.6	1.5	6700	124.3	3.0
750	124.4	1.5	7100	125.7	3.0
800	125.2	1.5	7500	126.9	3.0
850	126.1	1.5	8000	128.3	3.0
900	126.9	1.5			

5.3.3 Type 3.3 – Pinna simulator

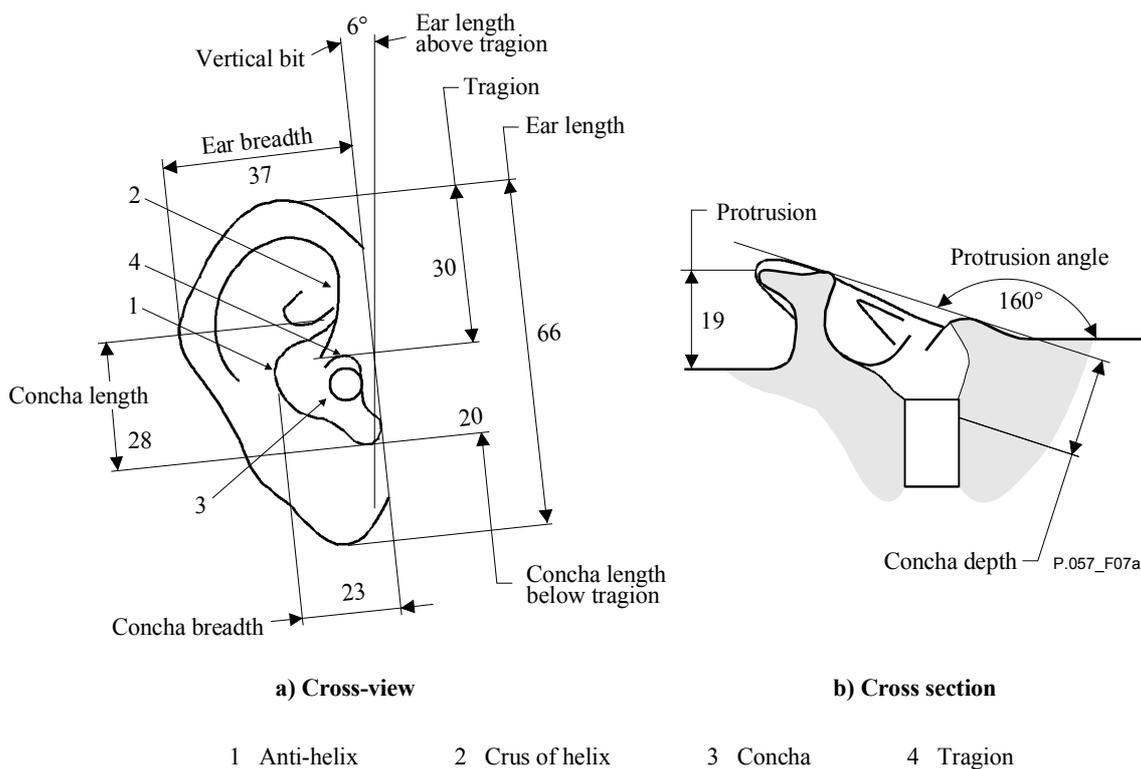
The Type 3.3 artificial ear is realized by terminating the real ear canal extension with the pinna simulator described in IEC 60959 [6] (see Figure 7). The dots in Figure 7b are located on a vertical axis through the ear canal entrance point. The pinna simulator shall be made from a high-quality elastomer, the shore-A hardness of which, measured at the surface 15 mm forward to the ear canal opening should be $55 \pm 10^\circ$ Shore-00 (reference ASTM D2240 / DIN53505).

It is recommended that the Type 3.3 artificial ear be used for measurements on supra-concha earphones which, due to their peculiar shape, do not fit the circular rims of Type 1 or Type 3.2 artificial ears, whichever is applicable. Type 3.3 artificial ear should also be used for measuring intra-concha earphones not intended for sitting on the bottom of the concha cavity.

The sound pressure measured by the Type 3.3 artificial ear is referred to the ear-drum reference point (DRP). The correction function given in Tables 2a (1/3 octave band measurements) and 2b (1/12 octave band and sine measurements) shall be used for converting data to the ear reference point (ERP) when it is required to calculate loudness ratings or check results against specifications based on measurements referred to the ERP.

NOTE 1 – For receive loudness rating calculations according to ITU-T Rec. P.79, the real ear loss correction L_E should be set to zero.

NOTE 2 – The application force of hard earcaps against the Type 3.3 pinna simulator should preferably be within the range of 13 Newton. The force applied in the measurements shall always be reported.



**Figure 7a/P.57 – Anatomically shaped pinna simulator
(not to scale, units in mm)**

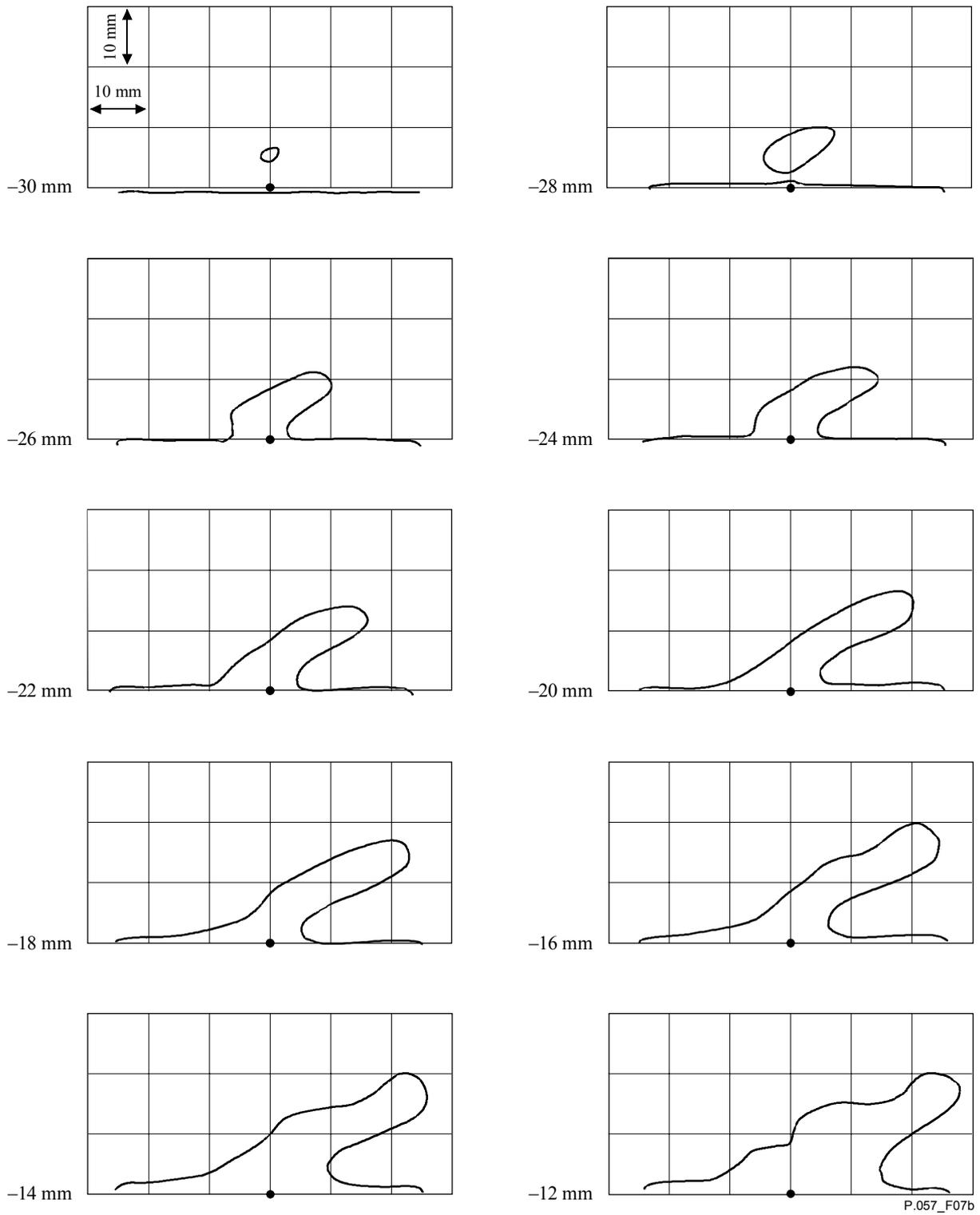
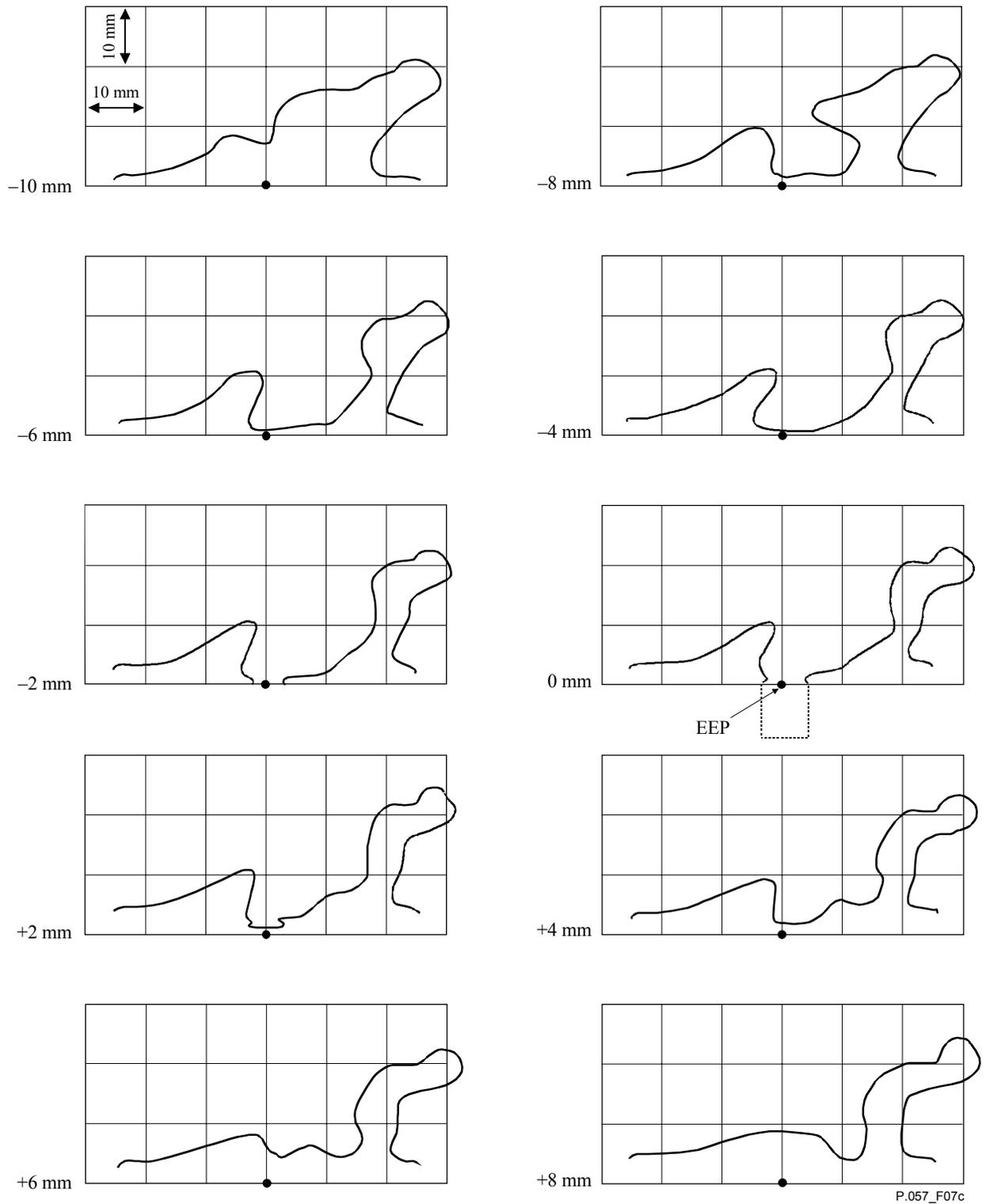
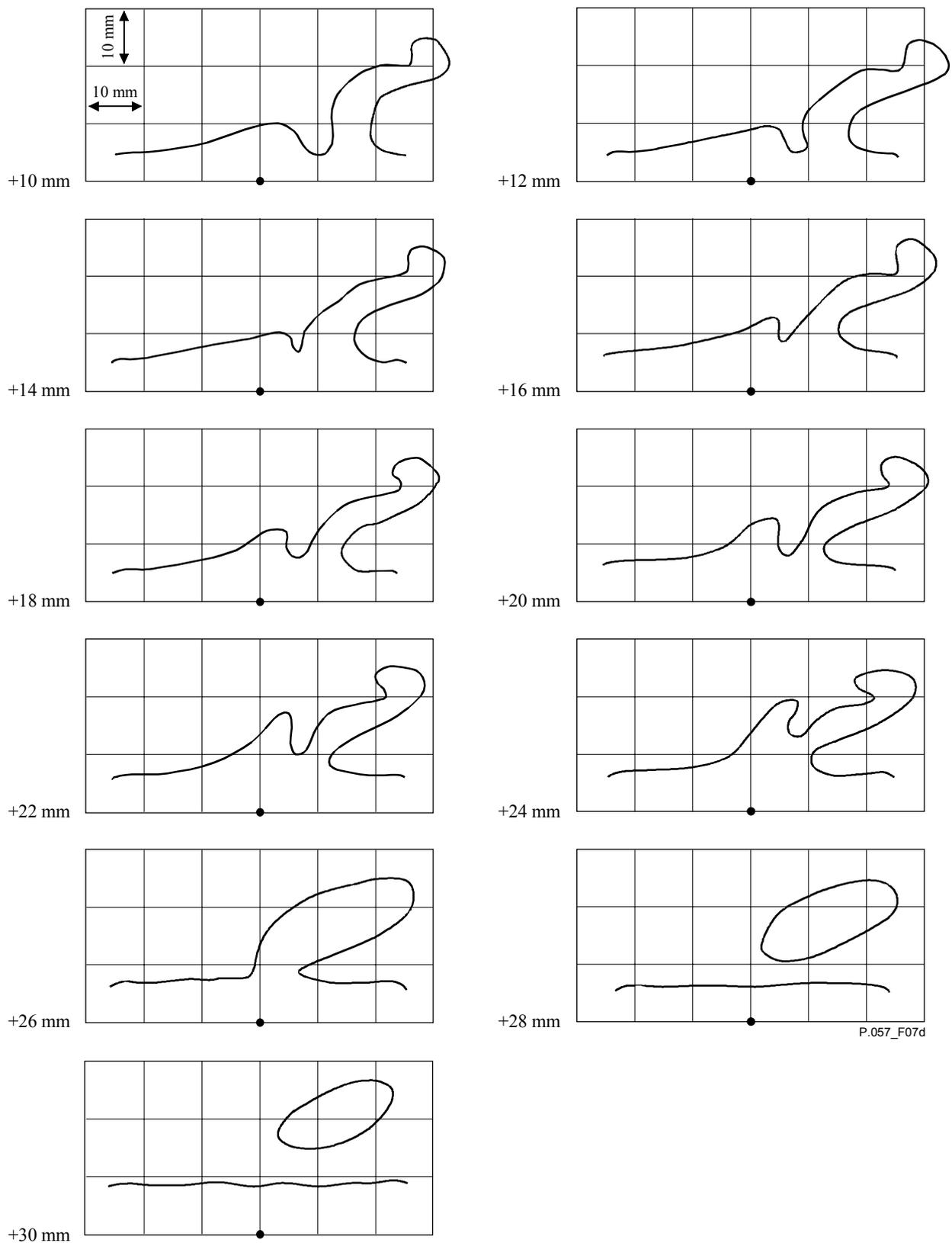


Figure 7b/P.57 – Pinna simulator cross sections



P.057_F07c

Figure 7c/P.57 – Pinna simulator cross sections



P.057_F07d

Figure 7d/P.57 – Pinna simulator cross sections

5.3.4 Type 3.4 – Pinna simulator (simplified)

The pinna simulation is realized in Type 3.4 artificial ear by terminating the drum reference plane of the Type 2 artificial ear with an ear canal extension and a simplified pinna (see Figure 8). The pinna shall be made by an elastomer with a shore-A hardness of 25 ± 2 at $20^\circ\text{C} \pm 2^\circ\text{C}$.

It is recommended that Type 3.4 artificial ear be used as an alternative to Type 3.3 for measurements on supra-concha earphones and for measurements on supra-aural receivers in applications where the pressure dependent characterization of receiving electroacoustic performances is needed. The Type 3.4 artificial ear is intended to reproduce the typical leakage occurring in real use for pressure forces in the range between 1 N and 13 N.

The sound pressure measured by the Type 3.4 artificial ear is referred to the ear-drum reference point (DRP). The correction function given in Tables 2a (1/3 octave band measurements) and 2b (1/12 octave bands and sine measurements) shall be used for converting data to the ear reference point (ERP) when it is required to calculate loudness ratings or check results against specifications based on measurements at the ERP.

NOTE – For receive loudness rating calculations according to ITU-T Rec. P.79, the real ear loss correction L_E shall be set to zero.

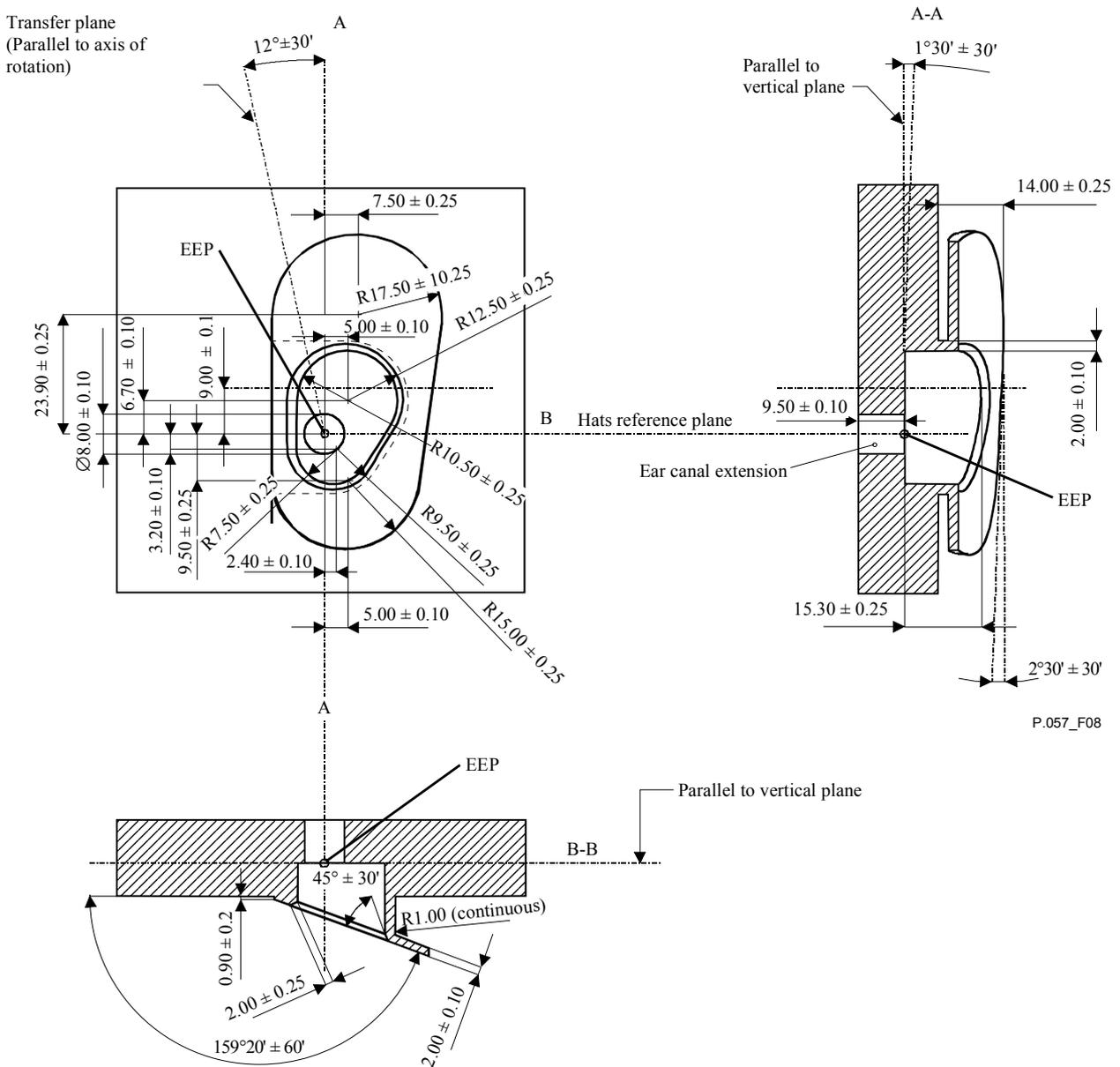


Figure 8/P.57 – Type 3.4 artificial ear

5.4 Calibration of the artificial ears Type 1 and Type 3.2

5.4.1 Performance testing of the IEC 60711 occluded-ear simulator (Type 3.2 only)

The proper performance of the IEC 60711 occluded-ear simulator which is an integral part of the Type 3.2 artificial ear is essential to the performance of the complete artificial ear.

NOTE – Performance testing and calibration of the occluded-ear simulator are specified in IEC 60711.

5.4.2 Frequency sensitivity response

The artificial ear to be calibrated is mounted in a large plane baffle. The sound pressure is measured immediately in front of the ERP using a probe microphone with its probe tip (diameter less than 1.5 mm) positioned at the ear reference plane as indicated in Figure 9.

The frequency sensitivity response (open ear condition) is then defined as the ratio between the output of the artificial ear and the corresponding sound pressure at the ERP recorded by the probe microphone when subjected to a plane incident wave perpendicular to the baffle.

NOTE 1 – The frequency sensitivity response has a very low sensitivity to the positioning of the sound source. In practice, therefore, more compact calibration setups may be realized with or without correction of the results, depending on the required calibration accuracy.

NOTE 2 – The frequency sensitivity response under closed ear conditions may be measured using the calibration setup for acoustic input impedance described in 5.4.3. It is determined as the ratio between the output of the artificial ear and the sound pressure recorded by the probe microphone at the ERP.

NOTE 3 – The frequency sensitivity response shall normally be determined within the range of atmospheric reference conditions given in 5.6 at the frequencies listed in Table 2b. The actual atmospheric conditions shall be reported. When the artificial ear operating conditions are significantly different from the reference conditions, the calibration of the frequency sensitivity response should, if possible, be performed under these conditions.

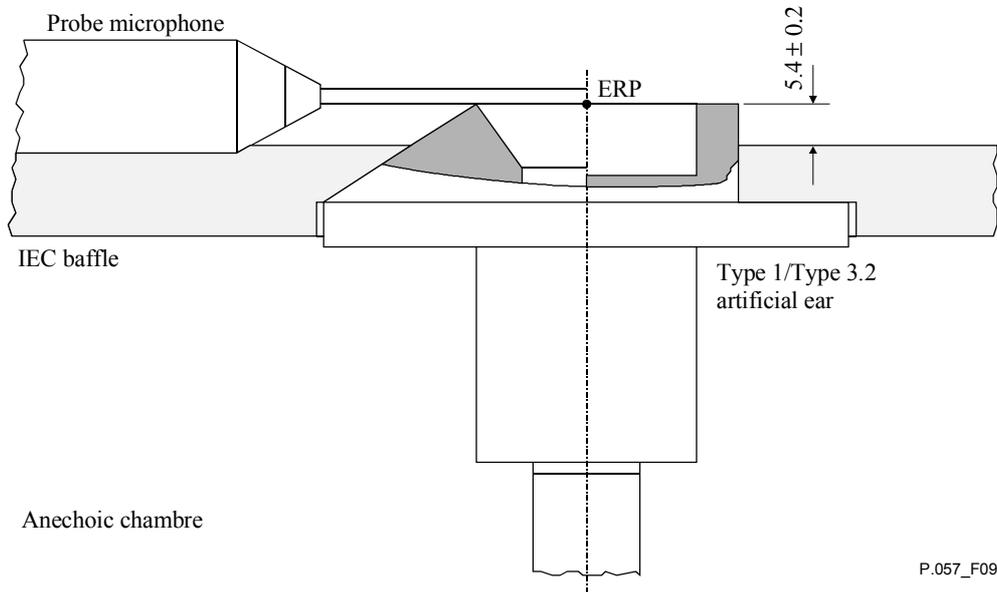


Figure 9/P.57 – Setup for measuring the frequency sensitivity response (open ear conditions) of Type 1 and Type 3.2 artificial ears

5.4.3 Acoustic input impedance

A 1/2" working standard pressure microphone (IEC WS2P) with its protection grid mounted is placed in a flat surface and concentrically applied and sealed to the artificial ear for use as a constant volume velocity source, driving the artificial ear at the ERP. The corresponding sound pressure at the ERP shall be measured using a probe microphone with its probe tip (diameter less

than 1.5 mm) positioned at the ERP. The distance between the microphone grid and the pickup point of the ear simulator shall be less than 1 mm. A practical implementation of a calibration device is shown in Figure 10.

The acoustic input impedance is then defined as the ratio between the sound pressure recorded by the probe microphone and the volume velocity generated by the 1/2" microphone.

NOTE – The acoustic input impedance shall be determined within the range of atmospheric reference conditions given in 5.6. The actual conditions shall be reported.

Annex A contains a practical description of a procedure which allows complete calibration based on a calibrated reference microphone and a calibrated volume.

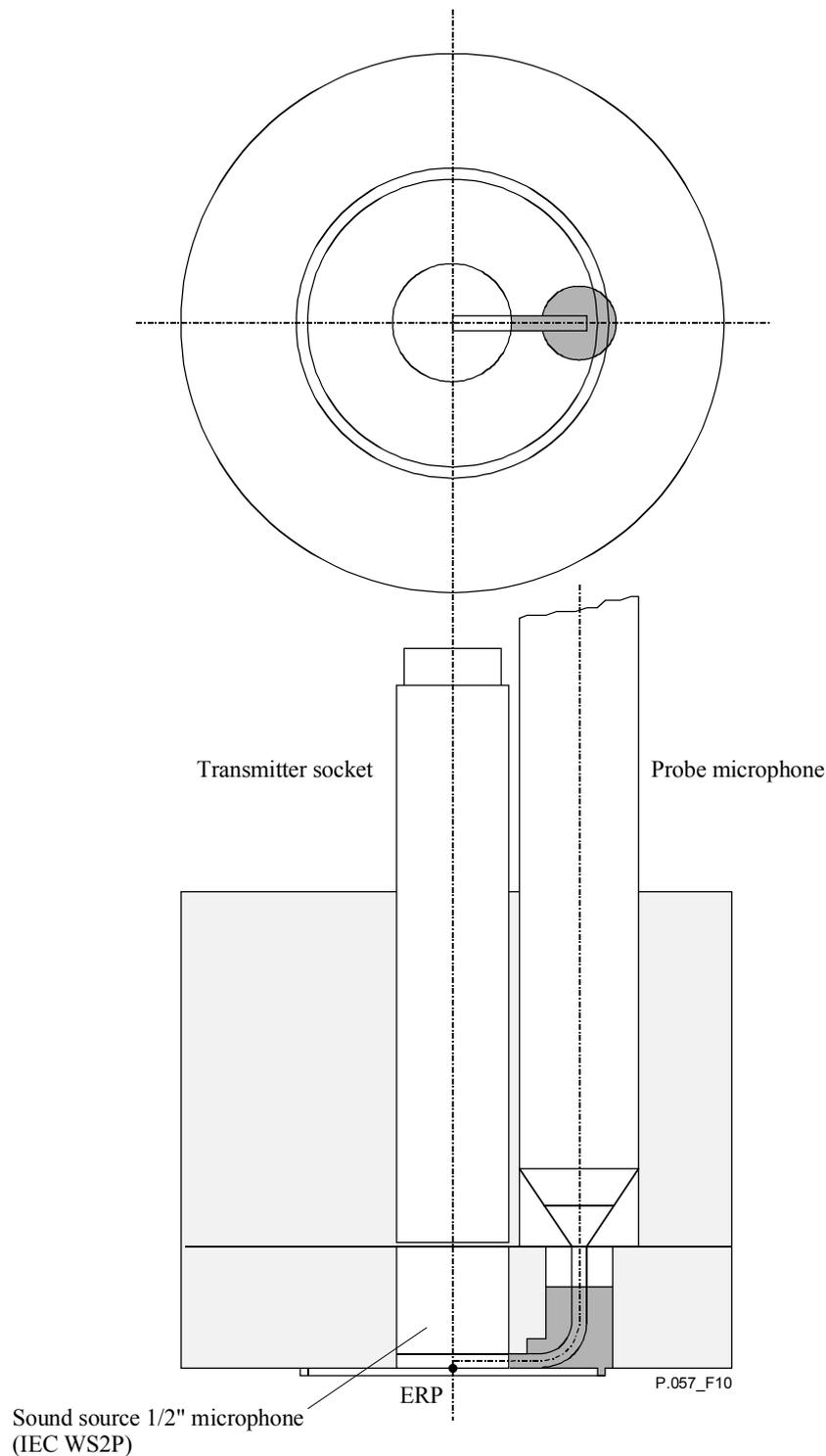


Figure 10/P.57 – Practical implementation of a calibration device (impedance probe) for measuring acoustical input impedance of Type 1 and Type 3.2 artificial ears

5.5 Performance verification of the artificial ears Type 2, Type 3.1, Type 3.3 and Type 3.4

These types of artificial ears do not provide a well-defined ERP, as they either do not simulate the pinna or features a flexible pinna which may cause the frequency sensitivity response and acoustical input impedance to change as a function of application pressure. Thus an actual calibration with respect to frequency sensitivity response as well as acoustic input impedance is not relevant.

The performance verification of these artificial ears, therefore, relies exclusively on the performance testing and calibration of the occluded ear simulator as specified in IEC 60711 in combination with a verification of the mechanical properties of the pinna simulator (Types 3.3 and 3.4 only).

5.6 Atmospheric reference conditions

It is recommended that measurements using artificial ears are performed under the following reference conditions:

Static pressure: 101.3 ± 3.0 kPa

Temperature: 23 ± 3 °C

Humidity: 60 ± 20 %

NOTE – When it is required to perform measurements under other atmospheric conditions, the actual conditions shall be reported.

5.7 General requirements

The metallic parts composing the artificial ears shall be made of non-magnetic material.

NOTE – The IEC WS2P microphones used in the artificial ears may contain magnetic material.

5.8 DRP to ERP correction

While Types 2, 3.3 and 3.4 artificial ears are calibrated by applying a known acoustic pressure to the DRP, Types 1 and 3.2 are calibrated by applying a known acoustic pressure to the ERP. As a consequence, the acoustic pressure measured by means of Types 2, 3.3 and 3.4 shall be referred to the ERP by means of the standardized correction functions reported in Tables 2a and 2b, while the pressure measured by Types 1 and 3.2 is directly referred to the ERP.

NOTE – The individual calibration of Types 1 and 3.2 can either be provided by the manufacturer in terms of the overall electroacoustic sensitivity from the ERP to the electric output of the measurement microphone built into the artificial ear, or in terms of the level correction between the acoustic pressure measured by the built in microphone and the pressure at the ERP. The latter approach is preferable as it allows for an easier routine check of the artificial ears calibration.

Annex A

A practical procedure for determination of the acoustic input impedance of artificial ears

A.1 Introduction

The procedure described in this annex allows accurate and traceable calibration of the acoustic input impedance of artificial ears Type 1 and Type 3.2 as required in 5.4.3. Additionally, the calibration setup allows determination of the closed condition frequency sensitivity response of the artificial ears.

The procedure relies on the availability of a laboratory standard 1/2" pressure microphone (IEC LS2P) calibrated with respect to its frequency sensitivity response and a calibrated reference volume.

The setup required to perform the measurements is shown in Figure A.1. It is based upon an audio frequency response analyser and an impedance probe consisting of an 1/2" working standard

pressure microphone (IEC WS2P) used as transmitter, and a probe microphone used as receiver (see Figure 10).

The reference microphone and the reference volume are used to determine the relative frequency sensitivity responses of the transmitter and probe microphones in the impedance probe prior to the calibration of the artificial ear itself. For this purpose the reference microphone is mounted in a calibration unit, positioning it as closely as possible to the probe tip integrated in the impedance probe.

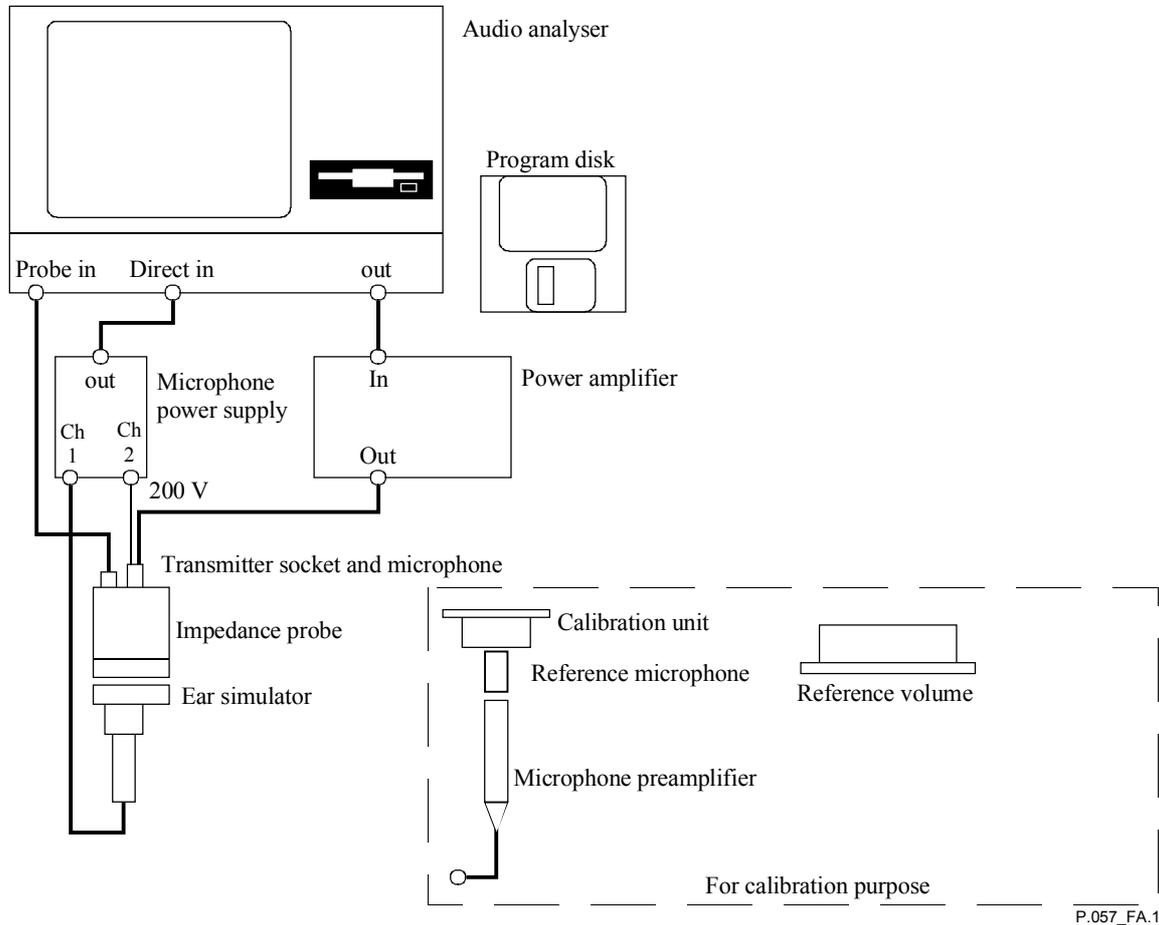


Figure A.1/P.57 – Measurement setup

A.2 Calibration of the impedance probe

A.2.1 Frequency response of the probe microphone

The reference microphone (Figure A.1) is mounted in the calibration unit and the calibration unit is placed in a suitable test bench. The impedance probe is attached to the calibration unit and the reference microphone is now used to calibrate the probe microphone. This is done by measuring the frequency response of the probe microphone relative to the frequency response of the reference microphone. The signal is delivered by the transmitter microphone of the impedance probe. The absolute frequency response of the probe microphone in [V / Pa] is then obtained as follows:

$$H_{\text{Prb.Abs}}(f) = \left[\frac{V_{\text{O,Prb}}(f)}{V_{\text{O,Ref}}(f)} \right] \cdot H_{\text{RefCal}}(f)$$

where:

- $H_{Prb.Abs}(f)$ = Absolute frequency response of the probe microphone.
 $V_{O,Prb}(f)$ = Probe microphone output voltage in calibration unit.
 $V_{O,Ref}(f)$ = Reference microphone output voltage in calibration unit.
 $H_{RefCal}(f)$ = Absolute calibrated reference microphone response.

A.2.2 Relative frequency response of the transmitter microphone

Apart from a constant factor, the transmitter microphone capsule in the impedance probe has the same frequency sensitivity when used as a volume source, as for its normal use as a receiver. Hence, the same method and setup as for the probe microphone calibration is used to calibrate the transmitter microphone of the impedance probe. The only difference is that now the reference microphone delivers the signal, and the calibrated probe microphone is used to calibrate the transmitter microphone which, in this case, is used as a receiver:

$$H_{Tr.Abs.Mic}(f) = \left[\frac{V_{O,Tr}(f)}{V_{O,Prb}(f)} \right] \cdot H_{Prb.Abs}(f)$$

where:

- $H_{Tr.Abs.Mic}(f)$ = Absolute microphone frequency response of the transmitter microphone.
 $V_{O,Prb}(f)$ = Probe microphone output voltage in calibration unit.
 $V_{O,Tr}(f)$ = Transmitter microphone output voltage in calibration unit.
 $H_{Prb.Abs}(f)$ = Absolute frequency response of the probe microphone (as measured above).

The frequency response of the transmitter microphone, relative to the sensitivity at a reference frequency (f_0), when used as a volume velocity source is then:

$$H_{Tr.Rel.Src}(f) = \frac{H_{Tr.Abs.Mic}(f)}{H_{Tr.Abs.Mic}(f_0)} \cdot (f/f_0)$$

where the term (f/f_0) relates to the fact that the transmit sensitivity is expressed in terms of volume velocity rather than volume.

A.2.3 Absolute sensitivity of the transmitter microphone as a volume velocity source

The additional factor describing the absolute sensitivity of the transmitter microphone, when used as a volume velocity source remains to be determined. This factor is found by measuring the sound pressure level produced by the transmitter microphone in the reference volume. The reference volume is placed in the test bench and the impedance probe is attached to the reference volume. The nominal acoustical impedance in [Pa s/m^3] equals one divided by the acoustic compliance (C_a) of the reference volume:

$$Z_{a,Ref.Vol} = \frac{1}{j\omega_a} = \frac{\rho c^2}{j\omega V}$$

It is recommended that the reference volume has a size comparable to the volume of the artificial ears. For a known excitation voltage, $V_{i,Tr.Mic}$, the sound pressure, $p_{Pr.Mic}$, is measured at a low frequency (f_0) where the frequency response of the transmitter microphone is frequency independent and the reference volume behaves as an ideal compliance. The absolute sensitivity factor of the transmitter microphone in [m^3 / Vs] is calculated as follows:

$$S_{Tr.Src} = \left[\frac{p_{Pr.Mic}(f_0)}{Z_{a,Ref.Vol}(f_0) \cdot V_{i,Tr.Mic}(f_0)} \right]$$

Thus the absolute sensitivity of the transmitter microphone, when used as a volume velocity source is:

$$H_{Tr.Abs.Src}(f) = H_{Tr.Rel.Src}(f) \cdot s_{Tr.Src}$$

A.3 Artificial ear calibration

A.3.1 Determination of acoustical impedance

During the measurements the artificial ear is placed in a suitable test bench (not shown in Figure A.1). Referring to Figure A.1 the impedance probe is attached to the artificial ear. With the transmitter microphone providing the volume velocity $q(f)$, the sound pressure $p_{ERP}(f)$ at the ERP is measured by the probe microphone of the impedance probe:

$$Z_{Ear,ERP}(f) = \frac{p_{ERP}(f)}{q(f)} = \frac{\left[\frac{V_{O,PrbMic}(f)}{H_{Prb.Abs}(f)} \right]}{\left[\frac{V_{i,Tr.Src}(f)}{H_{Tr.Abs.Src}(f)} \right]}$$

where:

$V_{i,Tr.Src}(f)$ = Input voltage to the transmitter mic. used as a volume velocity source.

$V_{O,PrbMic}(f)$ = Output voltage of the probe microphone.

A.3.2 Determination of closed condition sound pressure sensitivity

The same setup is used as for determination of acoustic input impedance, but the output voltage of the artificial ear relative to the sound pressure at the ERP is measured:

$$H_{Ear,Closed Cond.}(f) = \frac{V_{O,Ear}(f)}{\left[\frac{V_{O,PrMic}(f)}{H_{Prb.Abs}(f)} \right]}$$

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