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TECHNICAL SPECIFICATION

Speech and multimedia Transmission Quality (STQ);
Test Methods and Performance Requirements for
Active Noise Cancellation Headsets and other Earphones

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Speech and multimedia Transmission Quality (STQ).

Modal verbs terminology

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Introduction

Wired or wireless Active Noise Cancellation (ANC) headsets and earphones are a prevalent acoustic interface for communication systems. ANC aims to cancel ambient noise around the user by producing a sound pressure with opposite phase to the undesired noise. Applications of ANC can be found in noise-cancelling headsets, including over the ear and in ear form factors, reduction of noise in car and aircraft interiors, and control of noise in air conditioning ducts.

ANC in headsets and earphones can be realized with both analog and digital techniques, and ANC performance is dependent not only on the technique chosen, but also on the choice and integration of acoustic components into the device. Therefore, large variations in performance can be expected when comparing different devices, even for devices sharing a common ANC technique.

To get a holistic view of an ANC device performance, with a focus on the Quality of Experience delivered to the user, a range of test methods and performance metrics are summarized in the present document. The present document provides test methods that achieve repeatable and reproducible results in both inter-lab and intra-lab comparisons.

1 Scope

The present document specifies test methods and performance requirements for wireless and wired Active Noise Cancellation (ANC) devices such as headsets, earphones, headphones, hearables, and other ear worn devices (herein referred to as devices). The test methods and performance requirements cover ANC and other audio quality aspects related to the headset functionality as a communication and media consumption acoustic interface.

ANC performance metrics and requirements for handsets are out of scope.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference.

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The following referenced documents are necessary for the application of the present document.

[1] IEC 60268-4:2018: "Sound system equipment -- Part 4: Microphones".

[2] Recommendation ITU-T P.57: "Artificial Ears".

[3] Recommendation ITU-T P.58: "Head and torso simulator for telephonometry".

[4] Recommendation ITU-T P.64: "Determiniation of sensitivity/frequency characteristics of local telephone systems".

[5] Recommendation ITU-T P.381: "Technical requirements and test methods for the universal wired headset or headphone interface of digital mobile terminals".

[6] ETSI TS 103 224: "Speech and multimedia Transmission Quality (STQ); A sound field reproduction method for terminal testing including a background noise database".

[7] ETSI TS 126 132: "Universal Mobile Telecommunications System (UMTS); LTE; Speech and video telephony terminal acoustic test specification (3GPP TS 26.132)".

[8] Recommendation ITU-T P.501: "Test signals for use in telephony and other speech-based applications".

[9] Recommendation ITU-T P.56: "Objective measurement of active speech level".

[10] Recommendation ITU-T G.100.1: "The use of the decibel and of relative levels in speechband telecommunications".

[11] ETSI TS 103 737: "Speech and multimedia Transmission Quality (STQ); Transmission requirements for narrowband wireless terminals (handset and headset) from a QoS perspective as perceived by the user".

[12] ETSI TS 103 739: "Speech and multimedia Transmission Quality (STQ); Transmission requirements for wideband wireless terminals (handset and headset) from a QoS perspective as perceived by the user".

[13] ETSI TS 102 924: "Speech and multimedia Transmission Quality (STQ); Transmission requirements for Super-Wideband / Fullband handset and headset terminals from a QoS perspective as perceived by the user".

[14] ISO 532-1:2017: "Acoustics -- Methods for calculating loudness -- Part 1: Zwicker method".

[15] IEC 61672-1:2013: "Electroacoustics -- Sound level meters -- Part 1: Specifications".

[16] IEC 61260-1:2014: "Electroacoustics -- Octave-band and fractional-octave-band filters -- Part 1: Specifications".

[17] EN 50332-1:2013: "Sound system equipment: Headphones and earphones associated with personal music players - Maximum sound pressure level measurement methodology - Part 1: General method for "one package equipment"" (produced by CENELEC).

[18] Recommendation ITU-T P.700: "Calculation of loudness for speech communication".

[19] ETSI TS 103 558: "Speech and multimedia Transmission Quality (STQ); Methods for objective assessment of listening effort".

[20] Recommendation ITU-T P.863: "Perceptual objective listening quality prediction".

[21] ANSI/ASA S3.5-1997 (R2017): "American National Standard Methods for Calculation of the Speech Intelligibility Index".

[22] IEC 60565-1:2020: "Underwater acoustics -- Hydrophones -- Calibration of hydrophones -- Part 1: Procedures for free-field calibration of hydrophones".

2.2 Informative references

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] Recommendation ITU-T P.1150: "In-car communication audio specification".

[i.2] ANSI/ASA S12.2-2019: "Criteria For Evaluating Room Noise".

[i.3] Gordon, C.C., el al. (2014): "2012 Anthropometric Survey of U.S. Army Personnel: Methods and Summary Statistics". U.S. Army Natick Soldier Research Development & Engineering Center.

[i.4] Recommendation ITU-T P.76: "Determination of Loudness Ratings; Fundamental Principles".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

talk-through: functionality of an ANC device, which refers to an operational mode where ANC is applied selectively on certain (usually lower) frequencies with the intention to improve listening effort of perceived speech originated in the vicinity of the device

3.2 Symbols

For the purposes of the present document, the following symbols apply:

dB	decibel
dB_{Pa}	dB referenced to 1 Pascal
dB_V	dB referenced to 1 Volt
dB_{m0}	dB_V + 2,2 dB
dB_{SPL}	dB referenced to sound pressure level (2e-5 Pascal)
dB_{SPL}(A)	dB referenced to sound pressure level (2e-5 Pascal), A-weighted according to IEC 61672-1 [15]
N_A	Noise level in dB_{SPL} at the talker's ears

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ANC	Active Noise Cancelling
ASL	Active Speech Level
BGN	BackGround Noise
DF	Diffuse Field
DRP	Drum Reference Point
DUT	Device Under Test
EEP	Ear canal Entry Point
FB	FullBand
FFT	Fast Fourier Transform
HATS	Head And Torso Simulator
KPI	Key Performance Indicator
MOS	Mean Opinion Score
MOS-LEO	MOS - Listening Effort Objective
MOS-LQO	MOS - Listening Quality Objective
MRP	Mouth Reference Point
NB	NarrowBand
NC	Noise Criteria
NR	Noise Rating
PCM	Pulse Code Modulated
POI	Point Of Interconnection
RF	Radio Frequency
RLR	Receive Loudness Rating
SFR	Send Frequency Response
SNR	Signal to Noise Ratio
SPL	Sound Pressure Level
STMR	SideTone Masking Rating
SWB	Super-WideBand
TCL	Terminal Coupling Loss
TCL_W	Terminal Coupling Loss (weighted)
THD	Total Harmonic Distortion
TT	Talk-Through (mode)
WB	WideBand

4 Setup requirements

4.1 Test room requirements

4.1.1 Test room size

Tests for ANC devices require an acoustically isolated test room. The test room size should meet the recommendations of ETSI TS 103 224 [6]. In addition to the recommended size range for test rooms in ETSI TS 103 224 [6], smaller sound isolating booths or boxes are also allowed. For laboratories using a sound isolating booth or box, the following additional requirements apply:

1) The distance from any background noise generation loudspeaker to the acoustic test equipment shall be > 0,5 m

2) The diameter of any background noise generation loudspeaker diaphragm shall be such that the far-field approximation for sound wave propagation holds true for the frequency range of interest. The following two criteria (from IEC 60565-1 [22]) shall be met simultaneously:

   a) The distance from the listener to the speaker shall be at least 10 times larger than the radius of the speaker (frequency independent).

   b) The distance from the listener to the speaker (z) shall be greater than $4a^2/k$ where a is the radius of the speaker and k is the acoustic wavenumber (frequency dependent).

NOTE: The extra flexibility in using smaller sound isolating booths or boxes is cognizant of the substantial costs in producing a large test environment compliant to the end-to-end idle noise requirements in clause 4.2.4.

4.1.2 Test room acoustic requirements

The test room or sound isolating booth shall have a clarity index (C80) consistent with the requirements of ETSI TS 103 224 [6], i.e. suitable rooms shall have *C80 > 20 dB*. Furthermore, the test room should have a noise floor < 15 dB_{SPL}(A) and a Noise Criteria (NC) as defined in ANSI/ASA S12.2 2019 [i.2] of NC15 in order to meet the end-to-end test equipment idle noise requirements presented in clause 4.2.4.

NOTE: Frequency dependent test room recommendations, such as *Noise Criteria* (NC) defined in ANSI/ASA S12.2 2019 [i.2] provide helpful guidelines when designing an acoustic space for testing. However, ANSI/ASA S12.2-2019 [i.2] does not specify NC values below NC15. A truly acceptable NC recommendation to meet the end-to-end test equipment idle noise requirements presented in clause 4.2.4 falls within this undefined region. Therefore, NC15 is recommended as an absolute upper limit.

4.2 Test equipment requirements

4.2.1 Acoustic test equipment

4.2.1.1 Introduction

The acoustic test equipment setup includes two artificial ear simulators for headset mounting and signal recording and an artificial mouth simulator for speech reproduction.

An artificial mouth simulator is required for tests which incorporate speech reproduction. For such tests, a Recommendation ITU-T P.58 [3] HATS shall be used. However, an artificial mouth simulator is not required for those tests which exclude speech reproduction. Therefore, the acoustic equipment setup for such tests may consist of only a pair of ear simulators. The requirements for standalone ear simulators are provided in clause 4.2.1.2. For all tests, the end-to-end test equipment setup shall comply with the idle noise requirements described in clause 4.2.4.

4.2.1.2 Artificial ear simulators

Eardrum recordings shall be made using a Type 3.3 artificial ear defined in Recommendation ITU-T P.57 [2], clause 5.3.3. If not specified otherwise, Diffuse-Field (DF) equalization according to Recommendation ITU-T P.58 [3], clause 6.1.3 shall be applied for all recordings made during the testing procedure.

NOTE 1: In the analysis of some tests (e.g. in clauses 5.1, 5.2 or 5.3), measured spectra are referenced to another measured one and the DF-equalization cancels out. In such cases, DRP-measurements may be used directly for the calculation, without applying the DF-equalization first.

Low-noise artificial ear simulators with an inherent noise floor of < 7 dB_{SPL}(A) should be used in order to meet the end-to-end test equipment idle noise requirements presented in clause 4.2.4.

In the case that standalone artificial ear simulators are used without a mouth simulator, the ear simulators shall be mounted parallel to one-another such that both EEPs lie along the intersection of the test equipment's horizontal (reference) and transverse planes (as defined in Recommendation ITU-T P.58 [3]). Furthermore, the distance between the EEPs of the two ear simulators shall be between 130 mm and 150 mm. Lastly, the mounted ear simulators shall meet the sound leakage requirement (≥ 35 dB of attenuation) presented in clause 6.1.5 of Recommendation ITU-T P.58 [3].

NOTE 2: Recommendation ITU-T P.58 [3] requires an EEP-to-EEP distance of 130 mm to 133 mm. Although quantifiable differences in measuring over- and on-ear devices using a head breadth outside of this range are unkown, the current document allows for EEP-to-EEP distances of up to 150 mm. This is motivated by the data in Gordon el al. (2014) [i.3], which demonstrate that the Recommendation ITU-T P.58 requirement represents the 45th percentile and 5th percentile of Bizygomatic Breadths for female and male subjects, respectively [i.3]. Although this anotomical measure may slightly underestimate EEP-to-EEP distance, it provides a reasonable estimate. Thus, 130 mm to 133 mm demonstrates a short EEP-to-EEP distance compared to an average user. The extended requirement of 130 mm to 150 mm is adopted in the present document as a more representative head breadth, which may provide for more realistic device mounting.

4.2.1.3 Artificial mouth simulator

Speech playback shall be accomplished using a mouth simulator which meets the requirements established in Recommendation ITU-T P.58 [3], clause 6.2 and Recommendation ITU-T P.64 [4], clause 6. Furthermore, the mouth simulator shall meet the playback accuracy requirements in Table 4.2.1.3-1 (adapted from ETSI TS 126 132 [7], clause 5.3).

Table 4.2.1.3-1: Mouth simulator accuracy requirements

Item	Accuracy
Sound pressure	±0,7 dB
Sound pressure level at MRP in 1/3rd octave bands	±3 dB for 100 Hz to 200 Hz
	±1 dB for 200 Hz to 8 kHz
	±3 dB for 8 kHz to 20 kHz (see note)
Mouth simulator equalization	The flatness of the mouth simulator transfer characteristics after equalization, measured in 1/3rd octave bands with the signal used for equalization, shall be within ±1 dB from 100 Hz to 200 Hz and shall be within ±0,5 dB above 200 Hz (see note).
NOTE: Not all mouth simulators can be successfully equalized up to 20 kHz.	

The artificial mouth is equalized at the Mouth Reference Point (MRP) according to Recommendation ITU-T P.58 [3] and the upper equalization frequency shall be reported. The validity of the equalization, especially with respect to super-wideband and fullband, shall be checked.

4.2.3 Audio interface

Unless specified otherwise, the audio interface shall meet the requirements presented in Table 4.2.3-1 (adapted from ETSI TS 126 132 [7], clause 5.3).

Table 4.2.3-1: Audio interface requirements

Item	Requirement
Signal to noise ratio	> 110 dB(A)
Channel separation	> 110 dB
Measured maximum frequency	20kHz (see note 1)
Sampling rate	48 kHz
Electrical Signal Power	±0,2 dB for levels ≥ -50 dBm
	±0,4 dB for levels < -50 dBm
Time	±5 %
Frequency	±0,2 %
Electrical excitation levels	±0,4 dB (see note 2)
Frequency generation	±2 % (see note 3)
NOTE 1: The measured maximum frequency is due to limitations given by Recommendation ITU-T P.58 [3]. NOTE 2: Across the whole frequency range. NOTE 3: When measuring sampled systems, it is advisable to avoid measuring at sub-multiples of the sampling frequency. There is a tolerance of ±2 % on the generated frequencies, which may be used to avoid this problem, except for 4 kHz where only the -2 % tolerance may be used.	

4.2.4 Idle noise

The end-to-end test system shall provide a minimal noise floor. This requirement is due to the need of accurately measuring low noise levels, which are present after ANC reduction or as part of the ANC headset self-noise in quiet.

Since the idle noise captured at the artificial ears may depend on different sources (e.g. room, audio interface or ear simulator), the loudness level in phon of the whole test setup shall be evaluated in advance.

- The acoustic test equipment is placed into the measurement room and set into operational mode (in the absence of any DUT).
- An idle noise measurement of 10 s is conducted with the artificial ears. DF-equalization shall be applied.
- The specific loudness vs. time (in unit *sone*/*Bark*) and loudness vs. time (in unit *sone*) are calculated according to the time-varying Zwicker loudness model in ISO 532-1 [14] for the left and right channels using the diffuse soundfield calculation method.
- The overall specific loudness and overall loudness are calculated using the N5 statistical method, which returns the *sone* threshold (per Bark critical band in the case of specific loudness) surpassed by 5 % of analysis frames.
- The overall specific loudness and loudness are converted to unit *phon* according to the transformation described in clause 5.3 of ISO 532-1 [14] resulting in the overall specific loudness level and overall loudness level, respectively.

Test labs shall report their end-to-end test equipment idle noise overall loudness level and overall specific loudness level for both artificial ears. The idle noise overall loudness level at each ear shall be less than 5 phon and should be as close to 0 phon as possible. Furthermore, the overall specific loudness level shall be less than 5 phon for every Bark critical band.

4.2.5 Background noise generation system

A setup for simulating realistic background noises in a lab-type environment is described in ETSI TS 103 224 [6].

ETSI TS 103 224 [6] contains a description of the recording arrangement for realistic background noises, a description of the setup for a loudspeaker arrangement suitable to simulate a background noise field in a lab-type environment and a database of realistic background noises, which can be used for testing the terminal performance with a variety of different background noises.

The principle loudspeaker setup for the simulation arrangement is shown in Figure 4.2.5-1.

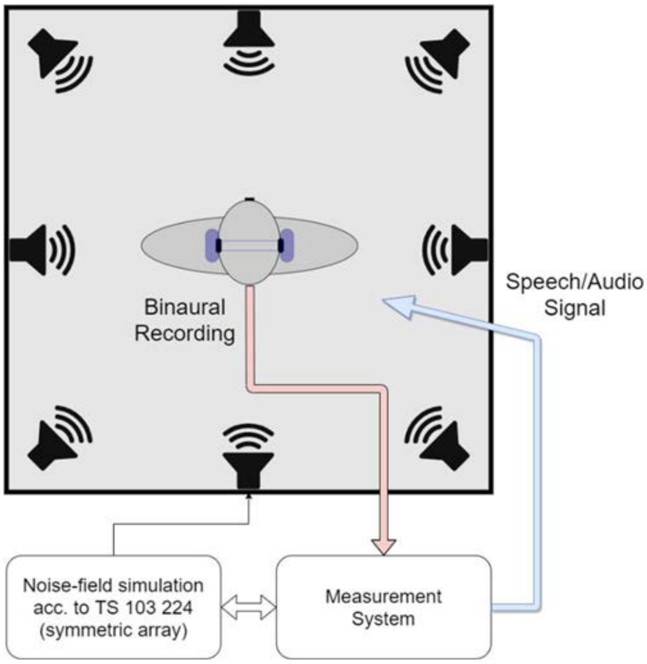

Figure 4.2.5-1: Loudspeaker arrangement for background noise simulation

The flexible equalization and calibration procedure described in clause 7 of ETSI TS 103 224 [6] shall be used in conjunction with the eight-channel symmetric microphone array for binaural applications (clause 5.4 of ETSI TS 103 224 [6]). Figure 4.2.5-2 illustrates the microphone positions used as equalization points around the acoustic test equipment.

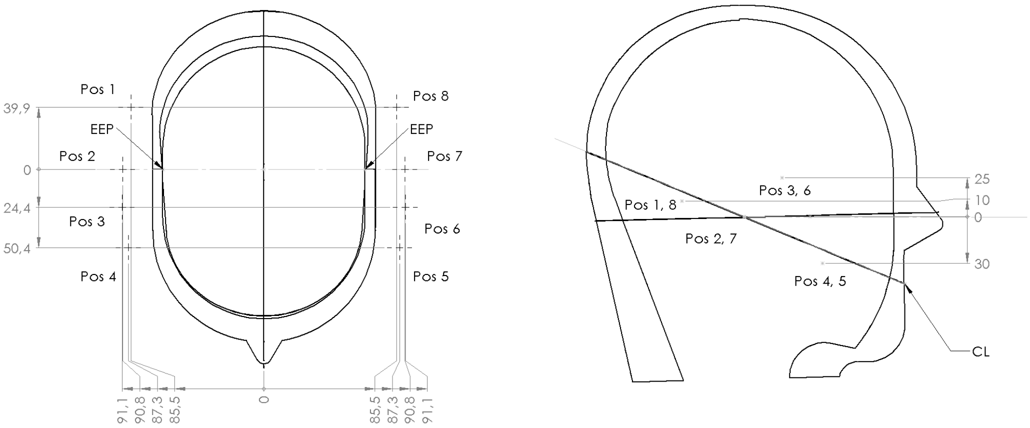

Figure 4.2.5-2: Positions of the recording microphones for binaural applications (vertical positions are related to the vertical position of the EEP)

If not stated otherwise this setup is used in all measurements where background noise playback is required. The noise types as specified in Table 4.2.5-1 shall be used for testing. The corresponding eight-channel sound files for the symmetric microphone array are provided in clause 8.3 of ETSI TS 103 224 [6]. The filename (in parentheses and italic font), length and levels per channel of the electronic attachments are provided in Table 4.2.5-1 for reference.

In addition, a time range for analysis is provided. In advance to each analysis range, a convergence time of at least 5 s shall be used, which allows the signal processing of the ANC device to adapt. If not stated otherwise, all measurements where background noise playback is required shall analyze the specified time range. In case the analysis time range exceeds the overall length of a noise, playback shall be repeated with a cross-fade of 20 ms.

Table 4.2.5-1: Noise types for ANC testing

Index	Noise Type	Description	Length (s)	Levels at microphones ($dB_{SPL}(A)$)	Analysis Start (s)	Analysis Duration (s)
1	Diffuse-Field Pink Noise (*PinkNoise*)	HATS and microphone array at centre of a sound sphere with 25 uncorrelated pink noise sources	20	1: 80,0 dB 2: 80,0 dB 3: 80,0 dB 4: 80,0 dB 5: 80,0 dB 6: 80,0 dB 7: 80,0 dB 8: 80,0 dB	5	10
2	Railway Platform (*RailwayPlatform*)	HATS and microphone array on a railway platform	35	1: 76,6 dB 2: 76,8 dB 3: 76,7 dB 4: 76,3 dB 5: 76,3 dB 6: 76,2 dB 7: 76,4 dB 8: 76,2 dB	5	10
3	Inside Bus (*Inside_Bus*)	HATS and microphone array in passenger cabin of a bus	35	1: 66,5 dB 2: 66,6 dB 3: 66,6 dB 4: 66,3 dB 5: 66,6 dB 6: 66,2 dB 7: 66,5 dB 8: 66,6 dB	5	10
4	Crossroadnoise (*Crossroadnoise*)	HATS and microphone array standing outside near a crossroad	35	1: 68,3 dB 2: 68,6 dB 3: 68,3 dB 4: 67,7 dB 5: 66,8 dB 6: 66,4 dB 7: 66,7 dB 8: 66,7 dB	5	10

NOTE 1: Convergence time may highly variate across different types of devices. For this reason, a common minimum duration of 5 s is used.
NOTE 2: The analysis start and range values include the required minimum convergence time.

4.3 DUT access interfaces

4.3.1 Access interface for analog devices

This clause refers specifically to analog wired devices. There is no discussion of analog wireless devices. A general test setup configuration and access interface for an analog wired ANC device is shown in Figure 4.3.1-1.

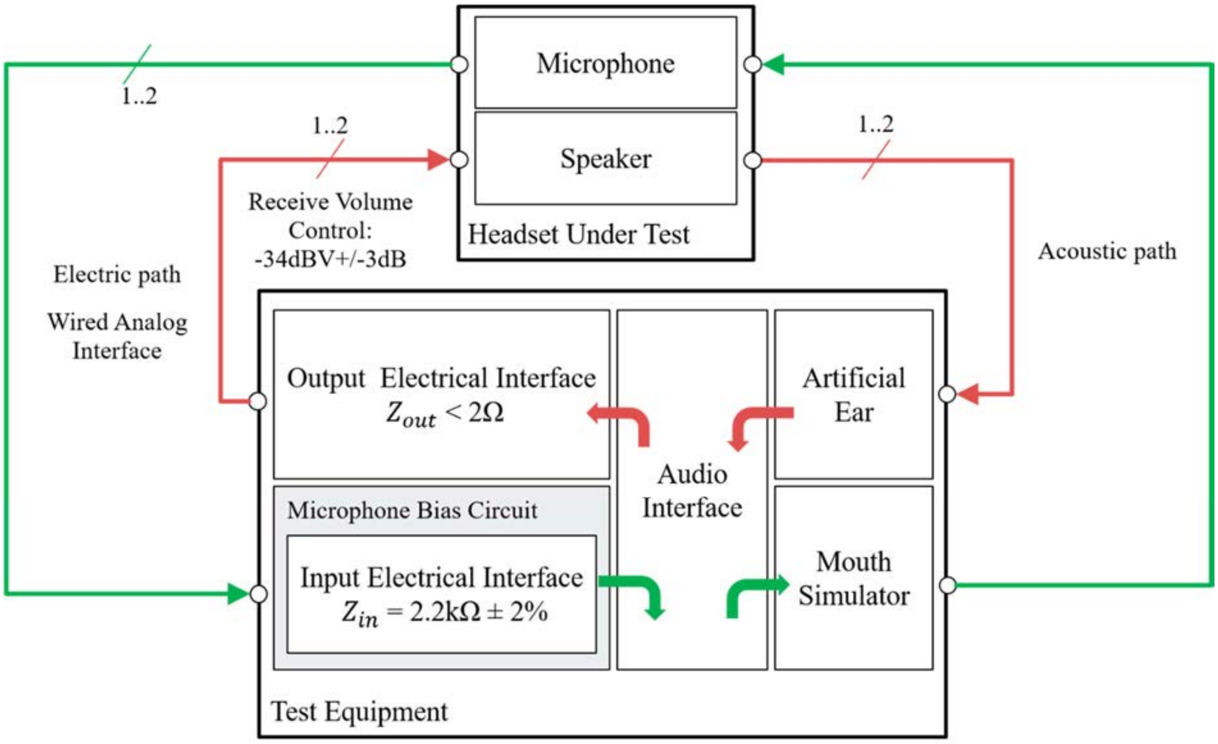

Figure 4.3.1-1: Test configuration for analog device

Specifications on input and output characteristics of the headset access interface are defined in Recommendation ITU-T P.381 [5], clause 8.1.1.1. Furthermore, details on the microphone bias circuit are provided in Figure 8-2 of the same recommendation.

4.3.2 Access interface for digital devices

The general setup configuration and access interface for a digital ANC device is described in Figure 4.3.2-1.

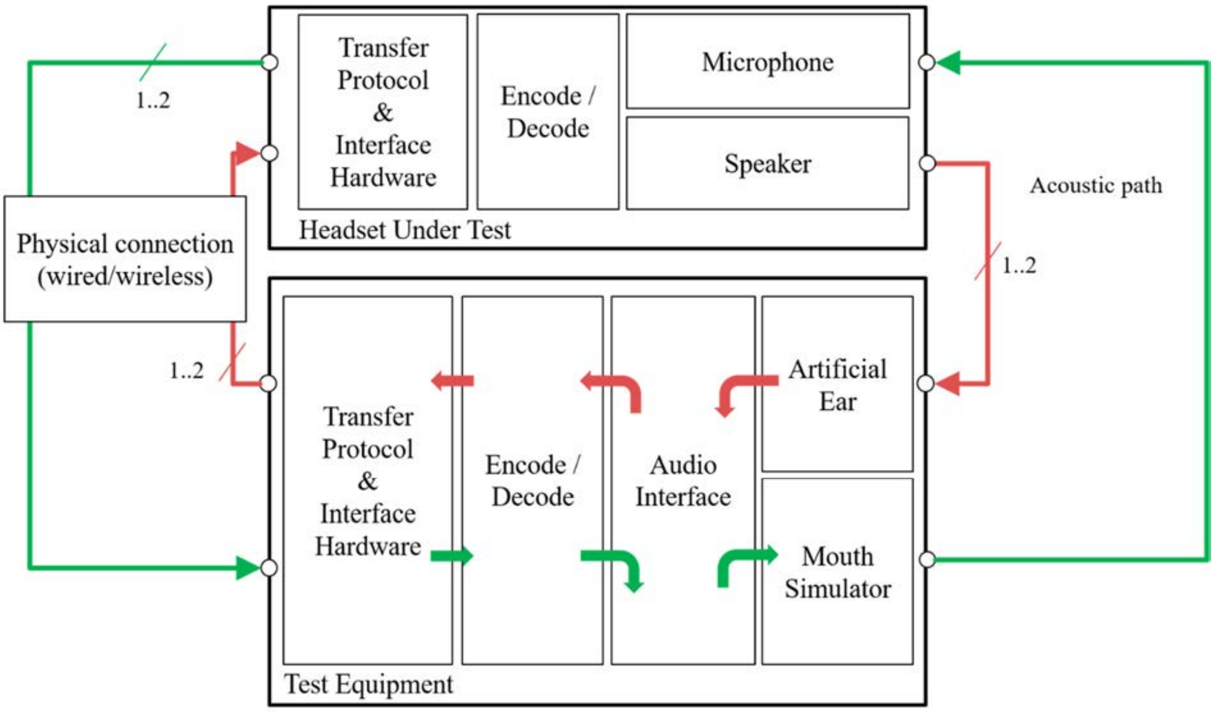

Figure 4.3.2-1: Test configuration for wireless digital device

For wireless digital devices, the short-range RF interface and wireless coding blocks are kept generic here to encompass any possible wireless connection between the access interface and the device. In some scenarios (e.g. if short-range RF interface transmits PCM audio), the signal sent and received by the test equipment and device under test may not require coding.

Voice call performance tests defined in clause 7 shall use the device access interfaces and test setups defined in the referenced recommendations.

4.4 Setup of ANC device and test equipment

The acoustic test equipment defined in clause 4.2.1 is positioned in the center of the measurement room. The equalization procedure of the background noise system described in clause 4.2.5 shall be conducted at this position.

The ANC device is positioned on the left and right artificial ears, in a manner corresponding to the most typical envisioned usage for the product.

If not specified otherwise, for measurements which are to be conducted with the ANC functionality *disabled*, the ANC device shall be in a switched on (active) state, with the ANC functionality purposely disabled.

If not specified otherwise, for measurements which are to be conducted with the ANC functionality *enabled*, the intensity of the ANC shall be set to the maximum (highest) available setting, if such an option is provided by the ANC device.

If not specified otherwise, for measurements which are to be conducted with the Talk-Through (TT) functionality *enabled*, the intensity of the Talk-through mode shall be set to the maximum (highest) available setting, if such an option is provided by the ANC device.

If not specified otherwise, all measurements shall be repeated five times by removing and replacing the headset on the artificial ears. The average and standard deviation across these repetitions are reported.

NOTE: The present document attempts to reduce fitting induced variability through the averaging of repeated measurements with multiple positioning attempts. To reduce inter-lab variability, test labs should be provided with a fitting strategy for a particular device.

4.5 Speech test signals

4.5.1 Introduction

Several tests described in the present document require the playback of a speech signal from the mouth simulator. The following clauses provide information on these signals.

Unless otherwise specified, all test signals shall be calibrated to an active speech level according to Recommendation ITU-T P.56 [9] of:

- -4,7 dB_{Pa} at the MRP for playback via mouth simulator.
- -16 dB_{m0} at the POI for playback via digital electrical interface (assuming an overload point of 3,14 dB_{m0} according to Recommendation ITU-T G.100.1 [10]).
- -37 dB_V at the POI for playback via analog electrical interface.

For measurements in the presence of background noise which include speech reproduction, the output level of the mouth simulator is increased to account for the *Lombard effect*. The Lombard effect refers to the change in speaking behaviour caused by acoustic noise as perceived by the talker. The level is increased by 3 dB for every 10 dB that the long-term A-weighted noise level N_A exceeds 50 dB_{SPL}(A). This relationship is shown equation 1:

$$I(N_A) = \begin{cases} 0 & \text{for} \quad N_A < 50 \\ 0{,}3 \cdot (N_A - 50) & \text{for} \quad N_A \geq 50 \geq 77 \\ 8{,}1 & \text{for} \quad N_A > 77 \end{cases} \quad (1)$$

Where:

I = The increase in dB of mouth output level due to noise level.

N_A = The long-term A-weighted noise level measured at the talker's ears.

As an example, if the background noise measures 70 dB_{SPL}(A), then the output of the mouth would be increased by 6 dB. No gain is applied for noise levels below 50 dB_{SPL}(A). The maximum amount of gain that can be applied is 8,1 dB.

4.5.2 Speech sequence with long pauses

For a speech sequence with long pauses, the four British English double-sentences provided in Annex C of Recommendation ITU-T P.501 [8] shall be concatenated and used. The sequence is 32 s in duration and includes eight unique sentences (two male speakers and two female speakers, each with two sentences).

This signal is typically used for the evaluation of e.g. speech quality or listening effort.

4.5.3 Short speech sequence

For a short speech sequence, the two-sentence, British English sequence defined in Annex D (clause D.2.2) of Recommendation ITU-T P.501 [8] shall be used. The sequence is 6,5 s in duration and includes two unique sentences (one male speaker and one female speaker).

This signal is typically used for the evaluation of e.g. sidetone or external speech transmission.

4.5.4 Long speech sequence

For a long speech sequence, the British English single-talk test sequence described in clause 7.3.2.1 of Recommendation ITU-T P.501 [8] shall be used. The sequence is 35,4 s in duration and includes twelve unique sentences (six male speakers and six female speakers).

This signal is typically used for the evaluation of e.g. sensitivity, loudness rating and frequency response in voice call scenarios.

5 ANC test methods and performance requirements

5.1 Insertion loss

5.1.1 Introduction

Insertion loss is a measurement (in dB) of the reduction in background noise caused by a DUT measured at the listener's eardrum. Insertion loss may be due to the physical occlusion of a device (*passive*), algorithmic noise reduction (*active*), or a combination of the two (*total*). Measurement methods for each of these three metrics are defined in this clause.

Each insertion loss metric is calculated as a difference spectrum between two measured spectra. Therefore, diffuse-field equalization is not required when conducting the acoustic measurements for insertion loss metrics.

For all insertion loss metrics, labs shall report results with 1/3rd octave frequency resolution from 20 Hz to 20 kHz. Labs may also report results with 4096-point FFT resolution for a more detailed representation.

Along with frequency dependent insertion loss metrics, labs should report the maximum insertion loss (with corresponding frequency), frequency range of insertion loss (e.g. where loss is ≥ 6 dB), and average insertion loss over all frequencies.

NOTE: Insertion loss metrics report positive numbers when the DUT reduces the measured background noise level at the listener's eardrum. As a convention, insertion loss metrics are often plotted with a flipped y-axis such that numerical increases in insertion loss are visualized as dips in the plotted response.

5.1.2 Total insertion loss

Definition:

The *Total Insertion Loss* (IL_{total}) is the difference between the equivalent continuous sound levels of:

1) the noise source measured at the listener's eardrum without wearing the ANC device (L_{OPEN}).

2) the noise source measured at the listener's eardrum when wearing the ANC device with ANC functionality *enabled* (L_{ON}).

The IL_{total} is expressed as a function of frequency, *f*, with 20 Hz $\leq f \leq$ 20 kHz, for each ear, *i*, and for each of the N noise types, *n*, as:

$$IL_{total}(f,i,n) = \left(L_{OPEN}(f,i,n) - L_{ON}(f,i,n)\right) \text{ in dB}, \forall i \in (l,r), \forall n \in (1:N) \quad (2)$$

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The device's ANC functionality is *enabled*.

3) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

4) The noise signal at the left and right artificial ears, with ANC *enabled*, is recorded to include analysis start and duration for noise *n* indicated in Table 4.2.5-1 with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

5) The FFT representation is used to calculate a 1/3rd octave resolution spectrum, $L_{ON}(f,i,n)$ in dB_{SPL}.

6) The ANC device is removed from the acoustic test equipment.

7) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

8) The noise signal at the left and right artificial ears, in the absence of the ANC device, is recorded to include analysis start and duration for noise *n* indicated in Table 4.2.5-1 with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

9) The FFT representation is used to calculate a 1/3rd octave resolution spectrum, $L_{OPEN}(f,i,n)$ in dB_{SPL}.

10) The IL_{total} as a function of frequency *f* is determined, for each ear *i*, and each noise type *n* from equation 2.

NOTE: If the test setup and environment has not changed, the $L_{OPEN}(f,i,n)$ measurement may be re-used from previous measurements since the measurement is independent from the ANC device under test.

5.1.3 Passive insertion loss

Definition:

The *Passive Insertion Loss* ($IL_{passive}$) is the difference between the equivalent continuous sound levels of:

1) the noise source measured at the listener's eardrum without wearing the ANC device (L_{OPEN}).

2) the noise source measured at the listener's eardrum when wearing the ANC device with ANC functionality *disabled* (L_{OFF})

The $IL_{passive}$ is expressed as a function of frequency, *f*, with $20 \text{ Hz} \leq f \leq 20$ kHz, for each ear *i*, and for each noise type *n* as:

$$IL_{passive}(f,i,n) = \left(L_{OPEN}(f,i,n) - L_{OFF}(f,i,n)\right) \text{ in dB}, \forall i \in (l,r), \forall n \in (1:N) \quad (3)$$

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The device's ANC functionality is *disabled*.

3) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

4) The noise signal at the left and right artificial ears, with ANC *disabled*, is recorded to include analysis start and duration for noise *n* indicated in Table 4.2.5-1 with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

5) The FFT representation is used to calculate a 1/3rd octave resolution spectrum $L_{OFF}(f,i,n)$ in dB_{SPL}.

6) The ANC device is removed from the acoustic test equipment.

7) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

8) The noise signal at the left and right artificial ears, in the absence of the ANC device, is recorded to include analysis start and duration for noise *n* indicated in Table 4.2.5-1 with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

9) The FFT representation is used to calculate a 1/3rd octave resolution spectrum $L_{OPEN}(f,i,n)$ in dB_{SPL}.

10) The $IL_{passive}$ as a function of frequency *f* is determined, for each ear *i*, and each noise type *n* from equation 3.

NOTE: If the test setup and environment has not changed, the $L_{OPEN}(f,i,n)$ measurement may be re-used from previous measurements since the measurement is independent from the ANC device under test.

5.1.4 Active insertion loss

Definition:

The *Active Insertion Loss* (IL_{active}) is the difference between the equivalent continuous sound levels of:

1) the noise source measured at the listener's eardrum when wearing the ANC device with ANC functionality *disabled* (L_{OFF}).

2) the noise source measured at the listener's eardrum when wearing the ANC device with ANC functionality *enabled* (L_{ON}).

The IL_{total} is expressed as a function of frequency, *f*, with $20 \text{ Hz} \leq f \leq 20$ kHz, for each ear, *i*, and for each noise type, *n*, from Table 4.2.5-1 as:

$$IL_{active} = \left(L_{OFF}(f, i, n) - L_{ON}(f, i, n)\right) \text{ in dB}, \forall i \in (l, r), \forall n \in (1{:}N) \quad (4)$$

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The device's ANC functionality is *enabled*.

3) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

4) The noise signal at the left and right artificial ears, with ANC *enabled*, is recorded to include analysis start and duration for noise *n* indicated in Table 4.2.5-1 with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

5) The FFT representation is used to calculate a 1/3rd octave resolution spectrum $L_{ON}(f, i, n)$ in dB_{SPL}.

6) The ANC device functionality is *disabled*.

7) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

8) The noise signal at the left and right artificial ears, with ANC *disabled*, is recorded to include analysis start and duration for noise *n* indicated in Table 4.2.5-1 with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

9) The FFT representation is used to calculate a 1/3rd octave resolution spectrum $L_{OFF}(f, i, n)$ in dB_{SPL}.

10) The IL_{active} as a function of frequency *f* is determined, for each ear *i*, and each noise type *n* from equation 4.

NOTE: If this test is run after the *Total* and *Passive Insertion Loss* tests for the same device, the $L_{OFF}(f, i, n)$ and $L_{ON}(f, i, j)$ measurements may be re-used from previous measurements.

5.2 Perceived noise loudness level reduction

5.2.1 Introduction

Perceived noise loudness level reduction is a single value perceptual measurement (in phon) of the attenuation of background noise at the listener's eardrum caused by a DUT. Perceived noise loudness level reduction may be due to the physical occlusion of a device (*passive*), algorithmic noise reduction (*active*), or a combination of the two (*total*). Measurement methods for each of these three metrics are defined in this clause.

Loudness level shall be calculated for each of the following perceived loudness level reduction metrics as follows (using a diffuse-field compensated binaural recording as input):

1) The loudness vs. time in unit *sone* is calculated according to the time-varying Zwicker loudness model in ISO 532-1 [14] for the left and right channels using the diffuse soundfield calculation method.

2) A single value loudness in *sone* for each ear is determined using the N5 statistical method, which returns the *sone* threshold surpassed by 5 % of analysis frames.

3) Because ISO 532-1 [14] assumes diotic sound presentation of each individual channel, the overall loudness in unit *sone* is determined as the average N5 loudness between the two ears.

4) The loudness level in *phon* is calculated with the overall loudness according to the transformation described in clause 5.3 of ISO 532-1 [14].

Test labs shall report the overall loudness level reduction for each of the following metrics. Additional, test labs should report loudness level reductions for the left and right ears individually.

NOTE: Prior to binaural summation of loudness in step 2 from above, test labs should verify that left and right ear loudness measurements are comparable. Substantial differences in loudness between ears may be due to DUT fit or measurement errors rather than DUT performance.

5.2.2 Total perceived noise loudness level reduction

Definition:

The *Total Perceived Noise Loudness Level Reduction* ($\Delta Loud_{Total}$) is the difference between:

1) the perceived loudness level - as measured according to the ISO 532-1 [14] - of the ambient noise in the absence of the ANC device ($Loud_{OPEN}$); and

2) the ambient noise loudness level with the device ANC functionality *enabled* ($Loud_{ON}$).

The $\Delta Loud_{Total}$ is expressed for each noise type *n* as:

$$\Delta Loud_{Total}\,(n) = (Loud_{OPEN}(n) - Loud_{ON}(n)) \text{ in phon}, \forall n \in (1{:}\,N) \quad (5)$$

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The device's ANC functionality is *enabled*.

3) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

4) The noise signal at the left and right artificial ears, with ANC *enabled*, is recorded to include analysis start and duration for noise *n* indicated in Table 4.2.5-1 with a 48 kHz sampling rate.

5) The recorded noise signal is diffuse-field corrected and processed with a Zwicker Loudness calculator, conforming to ISO 532-1 [14] to determine $Loud_{ON}$ as described in clause 5.2.1.

6) The ANC device is removed from the acoustic test equipment.

7) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

8) The noise signal at the left and right artificial ears, in the absence of the ANC device, is recorded for the duration of noise n indicated in Table 4.2.5-1 with a 48 kHz sampling rate.

9) The recorded noise signal is diffuse-field corrected and processed with a Zwicker Loudness calculator, conforming to ISO 532-1 [14], to determine $Loud_{OPEN}$ as described in clause 5.2.1.

10) The $\Delta Loud_{Total}$ is determined each noise type *n*, by equation 5.

5.2.3 Passive perceived noise loudness level reduction

Definition:

The *Passive Perceived Noise Loudness Level Reduction* $\left(\Delta Loud_{passive}\right)$ is the difference between:

1) the perceived loudness level - as measured according to the ISO 532-1 [14] - of the ambient noise in the absence of the ANC device ($Loud_{OPEN}$) and;

2) the ambient noise loudness level with the device ANC functionality *disabled* ($Loud_{OFF}$).

The $\Delta Loud_{passive}$ is expressed for each noise type *n* as:

$$\Delta Loud_{passive}\ (n) = (Loud_{OPEN}(n) - Loud_{OFF}(n)) \text{ in phon}, \forall n \in (1: N) \quad (6)$$

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The device's ANC functionality is *disabled*.

3) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

4) The noise signal at the left and right artificial ears, with ANC disabled, is recorded for the duration of noise *n* indicated in Table 4.2.5-1 with a 48 kHz sampling rate.

5) The recorded noise signal is diffuse-field corrected and processed with a Zwicker Loudness calculator, conforming to ISO 532-1 [14] to determine $Loud_{OFF}$ as described in clause 5.2.1.

6) The ANC device is removed from the acoustic test equipment.

7) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

8) The noise signal at the left and right artificial ears, in the absence of the ANC device, is recorded for the duration of noise *n* indicated in Table 4.2.5-1 with a 48 kHz sampling rate.

9) The recorded noise signal is diffuse-field corrected and processed with a Zwicker Loudness calculator, conforming to ISO 532-1 [14], to determine $Loud_{OPEN}$ as described in clause 5.2.1.

10) The $\Delta Loud_{passive}$ is determined for each noise type *n*, by equation 6.

5.2.4 Active perceived noise loudness level reduction

Definition:

The *Active Perceived Noise Loudness Level Reduction* ($\Delta Loud_{active}$) is the difference between:

1) the perceived loudness level - as measured according to the ISO 532-1 [14] - of the ambient noise with the device ANC functionality *enabled* ($Loud_{ON}$); and

2) the perceived loudness level - as measured according to the ISO 532-1 [14] - of the ambient noise with the device ANC functionality *disabled* ($Loud_{OFF}$).

The $\Delta Loud_{active}$ is expressed, for each noise type *n* as:

$$\Delta Loud_{active}(n) = (Loud_{OFF}(n) - Loud_{ON}(n)) \text{ in phon}, \forall n \in (1: N) \quad (7)$$

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The device's ANC functionality is *enabled*.

3) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

4) The noise signal at the left and right artificial ears, with ANC enabled, is recorded for the duration of noise *n* indicated in Table 4.2.5-1 with a 48 kHz sampling rate.

5) The recorded noise signal is diffuse-field corrected and processed with a Zwicker Loudness calculator, conforming to ISO 532-1 [14] to determine $Loud_{ON}$ as described in clause 5.2.1.

6) The device's ANC functionality is *disabled*.

7) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

8) The noise signal at the left and right artificial ears, with ANC *disabled*, is recorded to include analysis start and duration for noise *n* indicated in Table 4.2.5-1 with a 48 kHz sampling rate.

9) The recorded noise signal is diffuse-field corrected and processed with a Zwicker Loudness calculator, conforming to ISO 532-1 [14], to determine $Loud_{OFF}$ as described in clause 5.2.1.

10) The $\Delta Loud_{active}$ is determined for each noise type *n*, by equation 7.

5.3 Self-noise

5.3.1 Introduction

The self-noise of an ANC-enabled device is caused by amplification of the electrical system noise floor resulting from ANC processing, which becomes audible in quiet environments. DUT self-noise is characteristically low level (nearing the threshold of audibility) and therefore requires minimal idle noise in the test environment and equipment. Test setup idle noise requirements are defined in clause 4.2.4.

Test labs shall report the *Self-Noise Spectrum* with 1/3rd octave frequency resolution from 20 Hz to 20 kHz. Labs may also report results with 4096-point FFT resolution for a more detailed representation.

Along with the frequency dependent *Self-Noise Spectrum*, labs should report the maximum self-noise and its corresponding frequency bin.

NOTE: DUT self-noise may approach or fall below the test equipment idle noise floor. In such cases, the test equipment idle noise will impact the reported self-noise spectrum or loudness level of a DUT. However, the impact may not be perceptually relevant if both spectra are below the threshold of audibility. Test labs should report DUT self-noise spectra alongside the test equipment idle noise spectra to demonstrate where such saturation may take place.

5.3.2 Self-noise spectrum

Definition:

The *Self-Noise Spectrum*, N_{self}, is the diffuse-field corrected equivalent continuous A-weighted sound level of the self-noise generated by the ANC device, measured at the listener's eardrum when wearing the ANC device with the ANC functionality enabled.

N_{self} is expressed as a function of frequency, *f*, with $20\text{ Hz} \leq f \leq 20\text{ kHz}$, for each ear *i as*:

$$N_{self}(f,i) = L_{ON,A}(f,i) \text{ in } \mathrm{dB_{SPL}}, \forall \mathrm{i} \in (l,r) \tag{8}$$

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The background noise generation system is *disabled*.

3) The device's ANC functionality is *enabled*.

4) The noise signal at the left and right artificial ears, with ANC *enabled* and diffuse-field correction *enabled*, is recorded for 10 s with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

5) The FFT representation is used to calculate a 1/3rd octave resolution spectrum $L_{ON}(f,i,n)$ in $\mathrm{dB_{SPL}}$.

6) A-weighting according to IEC 61672-1 [15] shall be applied to $L_{ON}(f,i,n)$, resulting in the spectrum $L_{ON,A}(f,i)$.

7) $N_{self}(f,i)$ is determined, for each ear *i*, by equation 8.

5.3.3 Self-noise loudness level

Definition:

The *Self-Noise Loudness Level*, ($Loud_{self}$), is the perceived loudness level - as measured according to ISO 532-1 [14] - of the *Self-Noise*.

The loudness level $Loud_{self}$ is expressed as:

$$Loud_{self} = Loud_{ON} \text{ in phon} \quad (9)$$

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.
2) The background noise generation system is *disabled*.
3) The device's ANC functionality is *enabled*.
4) The noise signal at the left and right artificial ears, with ANC *enabled* and diffuse-field correction *enabled*, is recorded for 10 s with a 48 kHz sampling rate.
5) The recorded noise signal is processed with a Zwicker Loudness calculator, conforming to ISO 532-1 [14], to determine $Loud_{ON}$ as described in clause 5.2.1.
6) $Loud_{self}$ is determined by equation 9.

5.4 Wind noise gain

Definition:

The *Wind Noise Gain*, G, is the difference between the equivalent continuous sound levels generated by:

1) A laminar wind flow measured at the listener's eardrum when wearing the ANC device with the ANC functionality *enabled* (L_{ON}).
2) A laminar wind flow measured at the listener's eardrum when wearing the ANC device with the ANC functionality *disabled* (L_{OFF}).

The *Wind Noise Gain* is expressed as a function of the azimuthal angle θ of the wind direction (demonstrated in Figure 5.4-1) and frequency *f*, with $20 \text{ Hz} \leq f \leq 20 \text{ kHz}$, for a given wind speed *v* (e.g. *v* = 3 m/s):

$$G(\theta, f, i) = \left(L_{ON}(\theta, f, i) - L_{OFF}(\theta, f, i)\right) \text{ in dB}, \forall \text{i} \in (l, r), \forall \theta \in -180°: 30°: 180° \quad (10)$$

NOTE: General guidance for the measurement of Wind Noise in microphones is given in IEC 60268-4 [1].

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.
2) A low noise radial or axial fan is positioned at ear height and oriented such that the direction of the air flow forms an angle θ with the look direction of the acoustic test equipment.
3) The fan is adjusted such that the wind speed, when measured near the ANC device noise microphone, is v = 3 m/s.
4) The device's ANC functionality is *enabled*.
5) The noise signal at the left and right artificial ears, with ANC *enabled*, is recorded for 10 s with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).
6) The FFT representation is used to calculate a 1/3rd octave resolution spectrum, $L_{ON}(f, i, n)$ in dB_{SPL}.
7) The device's ANC functionality is *disabled*.

8) The noise signal at the left and right artificial ears, with ANC *disabled*, is recorded for 10 s with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

9) The FFT representation is used to calculate a 1/3rd octave resolution spectrum, $L_{OFF}(f, i, n)$ in dB_{SPL}.

10) G is determined, for each ear i, and each angle of wind incidence θ by equation 10.

NOTE: The use of an automated turntable is recommended for changing the relative angle θ between the acoustic test equipment and the angle of incidence of the wind.

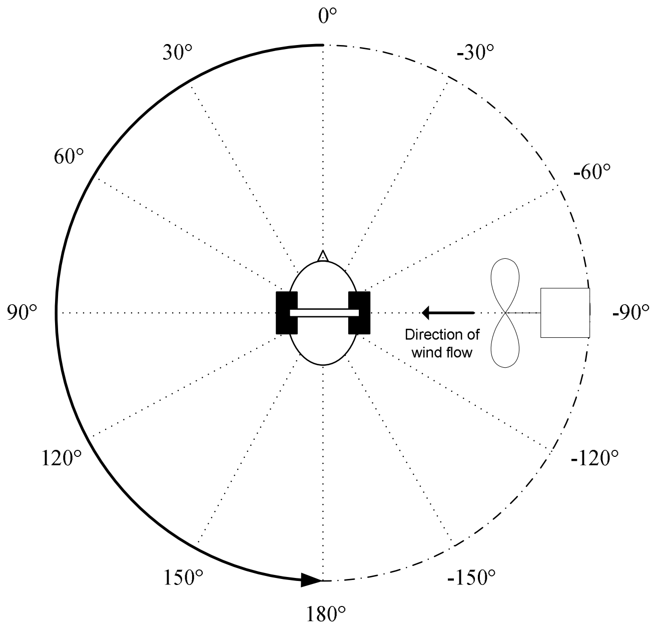

Figure 5.4-1: Example wind flow direction

5.5 ANC Activation

5.5.1 Activation threshold level

Definition:

The *Activation Threshold Level*, L_{thresh}, is the equivalent continuous sound level which causes the mean *Active Insertion Loss* to be > 0,5 dB in the frequency range 125 Hz $\leq f \leq$ 1 kHz.

NOTE: This test is only relevant for devices where automatic ANC enabling/disabling as a function of background noise level is implemented.

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) An override gain, *G*, for the background noise generation system is initially set to a value of -60 dB.

3) The ANC functionality is *enabled*.

4) Pink Noise (first row of Table 4.2.5-1) is played back through the background noise generation system, with its level adjusted by *G* dB.

5) The noise signal at the left and right artificial ears, with ANC *enabled*, is recorded for 10 s with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

6) The FFT representation is used to calculate a 1/3rd octave resolution spectrum $L_{ON}(f, i, 1)$ in dB_{SPL}.

7) The ANC functionality is *disabled*.

8) Pink Noise (first row of Table 4.2.5-1) is played back through the background noise generation system, with its level adjusted by *G* dB.

9) The noise signal at the left and right artificial ears, with ANC *disabled*, is recorded for 10 s with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

10) The FFT representation is used to calculate a 1/3rd octave resolution spectrum $L_{OFF}(f, i, 1)$ in dB_{SPL}.

11) The IL_{active} as a function of frequency *f* is determined for each ear *i*, from equation 4 based on $L_{ON}(f, i, 1)$ and $L_{OFF}(f, i, 1)$.

12) While $\left(\frac{1}{20}\sum_{f,i} IL_{active}(f, i, 1)\right) \leq 0{,}5$ dB for $125\text{ Hz} \leq f \leq 1$ kHz and $i \in (\text{l}, \text{r})$, i.e. the ANC functionality is not *enabled*, the override gain *G* is increased by 5 dB and steps 3 to 11 are repeated.

13) If $\left(\frac{1}{20}\sum_{f,i} IL_{active}(f, i, 1)\right) > 0{,}5$ dB for $125\text{ Hz} \leq f \leq 1$ kHz and $i \in (\text{l}, \text{r})$, the measurement is stopped, and L_{thresh} is reported. L_{thresh} is the level of the Pink Noise from Table 4.2.5-1 plus the gain G.

5.5.2 Activation time

Definition:

The *Activation Time*, $t_{activation}$, is the time in ms required for the automatic ANC functionality to activate, following the incidence of a noise event at a level $> L_{thresh}$ as calculated in clause 5.5.1.

NOTE 1: This test is only relevant for devices where automatic ANC enabling/disabling as a function of background noise level is implemented.

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The *Activation Threshold Level*, L_{thresh}, is determined according to clause 5.5.1.

3) The ANC functionality is *enabled*.

4) Pink Noise (first row of Table 4.2.5-1) is played back through the background noise generation system, at a level $L_{thresh} - 10$ dB for 10 s, immediately followed by playback at a level $L_{thresh} + 10$ dB for another 10 s. The level transition point is denoated as t_{10} in ms.

5) The noise signals at the left artificial ear, with ANC *enabled*, synchronously recorded with the noise playback for 20 s with a 48 kHz sampling rate.

6) The equivalent continuous sound level over time at the left ear, $L_{ON}(t)$, is calculated using an integration time of 35 ms according to IEC 61672-1 [15].

7) The acoustic transmission delay from the background noise system to the left ear microphone is removed from the recording, such that $L_{ON}(0)$ is time aligned to the initial incidence of the Pink Noise test signal.

8) The *Activation Time*, $t_{activation}$, in ms is determined as the time elapsed between t_{10} and $t_{activated}$, where $t_{activated} > t_{10}$ is the time in ms at which point $L_{ON}(t)$ has reached its steady state of ANC activation. See Figure 5.5.2-1 for more detail.

NOTE 2: The *Activation Time* should be tested for the right side of the DUT to ensure symmetry in the device performance.

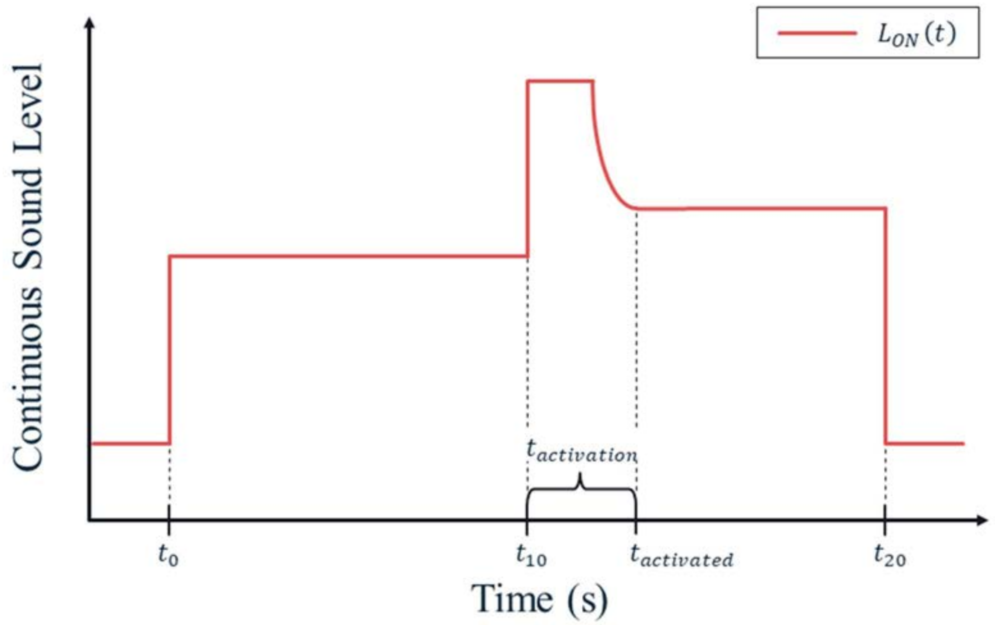

Figure 5.5.2-1: Illustration of Activation Time measurement

5.6 Acoustic overload point

Definition:

The *Acoustic Overload Point* (expressed in dB_{SPL}), is the equivalent continuous sound level at the ANC noise microphone port entry that causes the Total Harmonic Distortion Plus Noise (THD+N) of the signal at the listener's eardrum to reach 10 %. The *Acoustic Overload Point* is assessed for discrete frequencies *f*, with 100 Hz $\leq f \leq$ 8 kHz.

For this measurement, an extra loudspeaker with THD < 0,5 % in frequency range 100 Hz to 10 kHz at 90 dB_{SPL} at 1 m shall be used. Furthermore, a reference microphone with dynamic range upper limit of > 130 dB_{SPL} shall be used.

NOTE 1: Physical access to the ANC microphones is generally not available in commercial ANC devices.

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The ANC functionality is *enabled*.

3) The extra loudspeaker shall be positioned 0,25 m from the acoustic test equipment at a 90º angle of incidence (directly to the left). The acoustic center of the loudspeaker shall be facing the left ear simulator at the same height as the EEP.

4) The reference microphone is placed along the axis running through the two ear simulators' EEPs 1 cm from the left ear DUT.

5) A 1 second sine wave with a test frequency of 125 Hz is selected as the test signal, which is played back via the loudspeaker.

6) The test signal playback level is calibrated to an initial level, *L*, of 80 dB_{SPL} at the reference microphone.

7) The test signal is played back at the level *L* and recorded at the left ear simulator at 48 kHz sampling rate.

8) The THD+N of the recording is computed. If the THD+N is less than 10 %, *L* is increased by 5 dB. Otherwise, the level *L* is stored as $AOP(f) = L$, where *f* is the test frequency.

9) Steps 6-8 are repeated with test frequencies 250, 500, 1 000, 2 000, 4 000 and 8 000 Hz.

NOTE 2: The *Acoustic Overload Point* should be tested for the right side of the DUT to ensure symmetry in the device performance.

5.7 Self-speech

5.7.1 Introduction

The measurements described in clause 5.7 assess the performance of the ANC device in terms of transmission of speech sounds generated by the user of the device. The transmission of self-speech to a user's own ears is characterized by multiple paths. Recommendation ITU-T P.76 [i.4] defines four such paths, three of which are relevant to the transmission of self-speech for ANC devices:

- The bone conduction path through mechanical transmission within a user's head.
- The direct air path through acoustic transmission between a user's mouth and ear.
- The electrical path through a device's circuitry from the microphone(s) to the driver(s).

Due to the limitations of existing test equipment (e.g. HATS as defined in Recommendation ITU-T P.58 [3]), the bone conduction path of self-speech may not be reliably reproduced. Therefore, the subjective accuracy of tests described in clause 5.7 may be limited to the direct air and electrical paths of self-speech.

5.7.2 Self-speech insertion loss

Definition:

The *Self-speech Insertion Loss* (IL_{SS}), divided in *Passive Self-speech Insertion Loss* ($IL_{SS,passive}$), *Total Self-speech Insertion Loss* ($IL_{SS,total}$) and *Talk-through Self-speech Insertion Loss* ($IL_{SS,TT}$), is the difference between the continuous sound level measured at the listener's eardrum without wearing the device, $L_{SS,OPEN}$, and the equivalent continuous sound levels measured at the listener's eardrum while wearing the ANC device with:

1) ANC functionality *disabled*, $L_{SS,OFF}$
2) ANC functionality *enabled*, $L_{SS,ON}$
3) Talk-through functionality *enabled* (if applicable), $L_{SS,TT}$

respectively, for a test signal generated by the listener's mouth (e.g. the artificial mouth of the HATS wearing the ANC device).

The multiple IL_{SS} conditions are expressed as a function of frequency f, with $20\text{ Hz} \leq f \leq 20\text{ kHz}$, for each ear i as:

$$IL_{SS,passive}(f,i) = \left(L_{SS,OPEN}(f,i) - L_{SS,OFF}(f,i)\right) \text{ in dB}, \forall i \in (l,r) \quad (11)$$

$$IL_{SS,total}(f,i) = \left(L_{SS,OPEN}(f,i) - L_{SS,ON}(f,i)\right) \text{ in dB}, \forall i \in (l,r) \quad (12)$$

$$IL_{SS,TT}(f,i) = \left(L_{SS,OPEN}(f,i) - L_{SS,TT}(f,i)\right) \text{ in dB}, \forall i \in (l,r) \quad (13)$$

Measurement:

1) The test signal used for the measurements shall be the short speech sequence described in clause 4.5.3.
2) The test equipment shall be set up according to clause 4.4.
3) The background noise generation system is *disabled*.
4) The device's ANC functionality is *disabled.*
5) The test signal at the left and right artificial ears, with ANC *disabled*, is recorded with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).
6) The FFT representation is used to calculate a 1/3rd octave resolution spectrum $L_{SS,OFF}(f,i)$ in dB_{SPL}.
7) The device's ANC functionality is *enabled*.

8) The test signal at the left and right artificial ears, with ANC *disabled*, is recorded with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

9) The FFT representation is used to calculate a 1/3rd octave resolution spectrum $L_{SS,ON}(f,i)$ in dB_{SPL}.

10) The device's Talk-through functionality is *enabled* (if applicable).

11) The test signal at the left and right artificial ears, with Talker through *enabled*, is recorded with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

12) The FFT representation is used to calculate a 1/3rd octave resolution spectrum $L_{SS,TT}(f,i)$ in dB_{SPL}.

13) The ANC device is removed from the acoustic test equipment.

14) The test signal at the left and right artificial ears, in the absence of the ANC device, is recorded with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

15) The FFT representation is used to calculate a 1/3rd octave resolution spectrum $L_{SS,OPEN}(f,i)$ in dB_{SPL}.

16) The *Passive Self-speech Insertion Loss* ($IL_{SS,passive}$), *Total Self-speech Insertion Loss* ($IL_{SS,total}(f,i)$) and *Talk-through Self-speech Insertion Loss* ($IL_{SS,TT}(f,i)$) are determined as functions of frequency f for each ear i from equations 11, 12 and 13, respectively.

5.7.3 Self-speech loudness level reduction

Definition:

The *Self-speech Loudness Level Reduction* ($\Delta Loud_{SS}$), divided in *Passive Self-speechLoudness Level Reduction* ($\Delta Loud_{SS,passive}$), *Total Self-speechLoudness Level Reduction* ($\Delta Loud_{SS,total}$) and *Talk-through Self-speechLoudness Level Reduction* ($\Delta Loud_{SS,TT}$), is the difference between the loudness level measured at the listener's eardrum without wearing the device ($Loud_{SS,OPEN}$), and the loudness levels measured at the listener's eardrum while wearing the ANC device with:

1) ANC functionality *disabled*, $Loud_{SS,OFF}$

2) ANC functionality *enabled*, $Loud_{SS,ON}$

3) Talk-through functionality *enabled* (if applicable), $Loud_{SS,TT}$

respectively, for a test signal generated by the listener's mouth (e.g. the artificial mouth of the HATS wearing the ANC device). The loudness level is measured according to Recommendation ITU-T P.700 [18].

The multiple $\Delta Loud_{SS}$ conditions are expressed as:

$$\Delta Loud_{SS,passive} = \left(Loud_{SS,OPEN} - Loud_{SS,OFF}\right) \text{ in phon} \quad (14)$$

$$\Delta Loud_{SS,total} = \left(Loud_{SS,OPEN} - Loud_{SS,ON}\right) \text{ in phon} \quad (15)$$

$$\Delta Loud_{SS,TT} = \left(Loud_{SS,OPEN} - Loud_{SS,TT}\right) \text{ in phon} \quad (16)$$

Measurement:

1) The test signal used for the measurements shall be the short speech sequence described in clause 4.5.3.

2) The test equipment shall be set up according to clause 4.4.

3) The background noise generation system is *disabled*.

4) The device's ANC functionality is *disabled.*

5) The test signal at the left and right artificial ears, with ANC *disabled*, is recorded with a 48 kHz sampling rate and the loudness level is calculated according to Recommendation ITU-T P.700 [18] to determine $Loud_{SS,OFF}$ in phon.

6) The device's ANC functionality is *enabled*.

7) The test signal at the left and right artificial ears, with ANC *enabled*, is recorded with a 48 kHz sampling rate and the loudness level is calculated according to Recommendation ITU-T P.700 [18] to determine $Loud_{SS,ON}$ in phon.

8) The device's Talk-through functionality is *enabled* (if applicable).

9) The test signal at the left and right artificial ears, with Talk-trough *enabled*, is recorded with a 48 kHz sampling rate and the loudness level is calculated according to Recommendation ITU-T P.700 [18] to determine $Loud_{SS,TT}$ in phon.

10) The ANC device is removed from the acoustic test equipment.

11) The test signal at the left and right artificial ears, in the absence of the ANC device, is recorded with a 48 kHz sampling rate and the loudness is calculated according to Recommendation ITU-T P.700 [18] to determine $Loud_{ST,OPEN}$ in phon.

12) The *Passive Self-speech Loudness Reduction* ($\Delta Loud_{SS,passive}$), *Total Self-speech Loudness Reduction* ($\Delta Loud_{SS,total}$) and, if applicable, *Talk-through Self-speech Loudness Reduction* ($\Delta Loud_{SS,TT}$), are determined from equations 14, 15 and 16, respectively.

5.8 External speech

5.8.1 Introduction

The measurements described in clause 5.8 assess the performance of the ANC device in terms of transmission of speech sounds generated in the near end of the device.

As source of the external speech signals, one of the two following options may be realized:

1) A secondary mouth simulator (standalone or included in a HATS) is placed in the vicinity of the primary test equipment. The HATS/mouth simulator shall fulfill the requirements as described in clause 4.2.1.3. For the generation of external speech signals, the secondary HATS/mouth simulator shall be positioned in front of the primary test equipment, with the mouth simulator directed towards the front of the primary test equipment. The secondary mouth simulator MRP shall be at the same height as the primary test equipment reference plane. The distance between the secondary mouth simulator MRP and the transverse plane of the primary test equipment shall be 75 cm.

2) A loudspeaker in the vicinity of the test equipment. The spectrum of acoustic signal produced by the loudspeaker shall be equalized under free field conditions with a measurement microphone positioned on the main loudspeaker axis at a distance of d_{eq} = 50 cm from the loudspeaker membrane. For the generation of external speech signals, the loudspeaker shall be positioned in front of the primary test equipment, with the center of the loudspeaker membrane at a horizontal distance of d_h = 40 cm from the primary test equipment's transverse plane and a vertical distance of d_v = 30 cm above the primary test equipment's reference plane. The diagonal distance between the center of the loudspeaker membrane and the center of the primary test equipments EEP-to-EEP axis is d = 50 cm. The loudspeaker shall be inclined downwards so that the main loudspeaker axis intersects the center of the EEP-to-EEP axis.

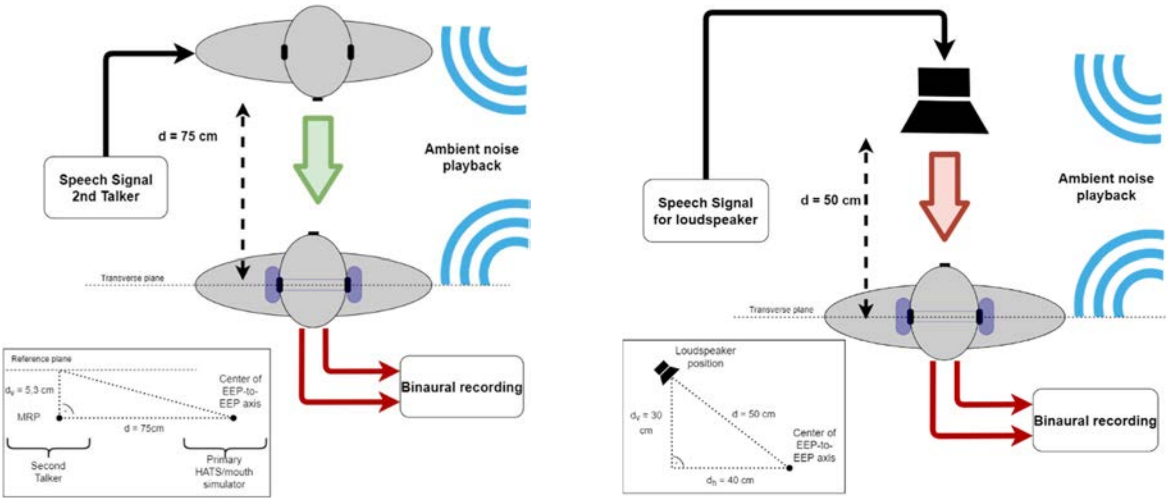

Figure 5.10-1: Setups for external speech signals

In the case of external speech generation by means of a secondary HATS/mouth simulator, the level of the test signal shall be calibrated as described in clause 4.5.1 at the MRP of the secondary HATS/mouth simulator. For measurements in the presence of BGN, the speech level is adjusted at the MRP to take into account the Lombard effect (see level adjustment calculation according to clause 4.5.1).

In the case of external speech generation by means of a loudspeaker, the level of the test signal for measurements in silence shall be calibrated to an Active Speech Level (ASL) of 65 dB_{SPL}, calculated according to Recommendation ITU-T P.56 [9], at a distance of 50 cm from the loudspeaker membrane on the main loudspeaker axis. For measurements in the presence of background noise, the level of the test signal is additionally increased in order to provide an acceptable SNR as determined by equation 17 (inferred from clause 9.7.1 of Recommendation ITU-T P.1150 [i.1]). Similar as in clause 4.5.1, the A-weighted noise level N_A is used as an input variable here.

$$ASL(N_A) = \max(65\,; \min(46{,}183 + 0{,}404 \cdot N_A; 85)) \text{ in } \mathrm{dB_{SPL}} \quad (17)$$

5.8.2 External speech insertion loss

Definition:

The *External Speech Insertion Loss* (IL_{ES}), divided in *Passive External Speech Insertion Loss* ($IL_{ES,passive}$), *Total External Speech Insertion Loss* ($IL_{ES,total}$), and *Talk-through External Speech Insertion Loss* ($IL_{ES,TT}$), is the difference between the continuous sound level measured at the listener's eardrum without wearing the device, $L_{ES,OPEN}$, equivalent continuous sound levels measured at the listener's eardrum while wearing the ANC device with:

1) ANC functionality *disabled*, $L_{ES,OFF}$
2) ANC functionality *enabled*, $L_{ES,ON}$
3) Talk-through functionality *enabled* (if applicable), $L_{ES,TT}$

respectively, for a test signal generated by an external speech sound source as described in clause 5.8.1.

The multiple ESR conditions are expressed as a function of frequency f, with 20 Hz $\leq f \leq$ 20 kHz, for each ear i as:

$$IL_{ES,passive}(f,i) = \left(L_{ES,OPEN}(f,i) - L_{ES,OFF}(f,i)\right) \text{ in dB}, \forall i \in (l,r) \quad (18)$$

$$IL_{ES,total}(f,i) = \left(L_{ES,OPEN}(f,i) - L_{ES,ON}(f,i)\right) \text{ in dB}, \forall i \in (l,r) \quad (19)$$

$$IL_{ES,TT}(f,i) = \left(L_{ES,OPEN}(f,i) - L_{ES,TT}(f,i)\right) \text{ in dB}, \forall i \in (l,r) \quad (20)$$

Measurement:

1) The test signal used for the measurements shall be the short speech sequence described in clause 4.5.3.

2) The test equipment shall be set up according to clause 4.4.

3) The background noise generation system is *disabled*.

4) The device's ANC functionality is *disabled*.

5) The test signal at the left and right artificial ears, with ANC *disabled*, is recorded with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

6) The FFT representation is used to calculate a 1/3rd octave resolution spectrum $L_{ES,OFF}(f,i)$ in dB_{SPL}.

7) The device's ANC functionality is *enabled*.

8) The test signal at the left and right artificial ears, with ANC *disabled*, is recorded with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

9) The FFT representation is used to calculate a 1/3rd octave resolution spectrum $L_{ES,ON}(f,i)$ in dB_{SPL}.

10) The device's Talk-through functionality is *enabled* (if applicable).

11) The test signal at the left and right artificial ears, with Talk-through *enabled*, is recorded with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

12) The FFT representation is used to calculate a 1/3rd octave resolution spectrum $L_{ES,TT}(f,i)$ in dB_{SPL}.

13) The ANC device is removed from the acoustic test equipment.

14) The test signal at the left and right artificial ears, in the absence of the ANC device, is recorded with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

15) The FFT representation is used to calculate a 1/3rd octave resolution spectrum $L_{ES,OPEN}(f,i)$ in dB_{SPL}.

16) The *Passive External Speech Insertion Loss* ($IL_{ES,passive}$), *Total External Speech Insertion Loss* ($IL_{ES,total}(f,i)$) and *Talk-through External Speech Insertion Loss* ($IL_{ES,TT}(f,i)$) are determined as functions of frequency f for each ear i from equations 18, 19 and 20, respectively.

5.8.3 External speech loudness level reduction

Definition:

The *External Speech Loudness Level Reduction* ($\Delta Loud_{ES}$), divided in *Passive External Speech Loudness Level Reduction* ($\Delta Loud_{ES,passive}$), *Total External Speech Loudness Level Reduction* ($\Delta Loud_{ES,total}$) and *Talk-through External Speech Loudness Level Reduction* ($\Delta Loud_{ES,TT}$) is the difference between the loudness level measured at the listener's eardrum without wearing the device ($Loud_{ES,OPEN}$), and the loudness level measured at the listener's eardrum while wearing the ANC device with:

1) ANC functionality *disabled*, $Loud_{ES,OFF}$

2) ANC functionality *enabled*, $Loud_{ES,ON}$

3) Talk-through functionality *enabled* (if applicable), $Loud_{ES,TT}$

respectively, for a test signal generated by an external speech sound source as described in clause 5.8.1. The loudness level is measured according to Recommendation ITU-T P.700 [18].

The multiple $\Delta Loud_{ES}$ conditions are expressed for each ear i as:

$$\Delta Loud_{ES,passive} = \left(Loud_{ES,OPEN} - Loud_{ES,OFF}\right) \text{ in phon} \tag{21}$$

$$\Delta Loud_{ES,total} = \left(Loud_{ES,OPEN} - Loud_{ES,ON}\right) \text{ in phon} \tag{22}$$

$$\Delta Loud_{ES,TT} = \left(Loud_{ES,OPEN} - Loud_{ES,TT}\right) \text{ in phon} \tag{23}$$

Measurement:

1) The test signal used for the measurements shall be the short speech sequence described in clause 4.5.3.

2) The test equipment shall be set up according to clause 4.4.

3) The background noise generation system is *disabled*.

4) The device's ANC functionality is *disabled*.

5) The test signal at the left and right artificial ears, with ANC *disabled*, is recorded with a 48 kHz sampling rate and the loudness level is calculated according to Recommendation ITU-T P.700 [18] to determine $Loud_{ES,OFF}$ in phon.

6) The device's ANC functionality is *enabled*.

7) The test signal at the left and right artificial ears, with ANC *enabled*, is recorded with a 48 kHz sampling rate and the loudness level is calculated according to Recommendation ITU-T P.700 [18] to determine $Loud_{ES,ON}$ in phon.

8) The device's Talk-through functionality is *enabled* (if applicable).

9) The test signal at the left and right artificial ears, with Talk-through *enabled*, is recorded with a 48 kHz sampling rate and the loudness level is calculated according to Recommendation ITU-T P.700 [18] to determine $Loud_{ES,TT}$ in phon.

10) The ANC device is removed from the acoustic test equipment.

11) The test signal at the left and right artificial ears, in the absence of the ANC device, is recorded with a 48 kHz sampling rate and the loudness level is calculated according to Recommendation ITU-T P.700 [18] to determine $Loud_{ES,OPEN}$ in phon.

12) The *Passive External Speech Loudness Level Reduction* ($\Delta Loud_{ES,passive}$), *Total External Speech Loudness Level Reduction* ($\Delta Loud_{ES,total}$) and, if applicable, *Talk-through External Speech Loudness Level Reduction* ($\Delta Loud_{ES,TT}$), are determined for each ear i from equations 21, 22 and 23, respectively.

5.8.4 External speech listening effort

Definition:

The *External Speech Listening Effort Improvement* (ΔLE_{ES}), divided in *Passive External Speech Listening Effort Improvement* ($\Delta LE_{ES,passive}$), *Total External Speech Listening Effort Improvement* ($\Delta LE_{ES,total}$) and *Talk-through External Speech Listening Effort Improvement* ($\Delta LE_{ES,TT}$), is the difference between the listening effort measured at the listener's eardrum without wearing the device ($MOS\text{-}LEO_{ES,OPEN}$) and the listening effort measured while wearing the ANC device with:

1) ANC functionality *disabled*, $MOS\text{-}LEO_{ES,OFF}$

2) ANC functionality *enabled*, $MOS\text{-}LEO_{ES,ON}$

3) Talk-through functionality *enabled* (if applicable), $MOS\text{-}LEO_{ES,TT}$

respectively, for a test signal generated by an external speech sound source as described in clause 5.8.1. The listening effort mean opinion score, *MOS-LEO*, is calculated as described in ETSI TS 103 558 [19] without a noise-only reference signal.

The multiple ΔLE_{ES} conditions are expressed for each noise type, *n*, from Table 4.2.5-1 as:

$$\Delta LE_{ES,passive}(n) = \left(MOS\text{-}LEO_{ES,OFF}(n) - MOS\text{-}LEO_{ES,OPEN}(n)\right), \forall n \in (1:N) \quad (24)$$

$$\Delta LE_{ES,total}(n) = \left(MOS\text{-}LEO_{ES,ON}(n) - MOS\text{-}LEO_{ES,OPEN}(n)\right), \forall n \in (1:N) \quad (25)$$

$$\Delta LE_{ES,TT}(n) = \left(MOS\text{-}LEO_{ES,TT}(n) - MOS\text{-}LEO_{ES,OPEN}(n)\right), \forall n \in (1:N) \quad (26)$$

Measurement:

1) The test signal used for the measurements shall be the long speech sequence described in clause 4.5.4.

2) The test equipment shall be set up according to clause 4.4.

3) The device's ANC functionality is *disabled.*

4) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

5) The test signal at the left and right artificial ears, with ANC *disabled*, is recorded for the duration of the test signal with a 48 kHz sampling rate and the listening effort score according to ETSI TS 103 558 [19] is calculated to determine *MOS-LEO*$_{ES,OFF}(n)$.

6) The device's ANC functionality is *enabled*.

7) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

8) The test signal at the left and right artificial ears, with ANC *enabled*, is recorded for the duration of the test signal with a 48 kHz sampling rate and the listening effort score according to ETSI TS 103 558 [19] is calculated to determine *MOS-LEO*$_{ES,ON}(n)$.

9) The device's Talk-through functionality is *enabled* (if applicable).

10) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

11) The test signal at the left and right artificial ears, with Talk-through *enabled*, is recorded for the duration of the test signal with a 48 kHz sampling rate and the listening effort score according to ETSI TS 103 558 [19] is calculated to determine *MOS-LEO*$_{ES,TT}(n)$.

12) The ANC device is removed from the acoustic test equipment.

13) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

14) The test signal at the left and right artificial ears, in the absence of the ANC device, is recorded for the duration of noise *n* indicated in Table 4.2.5-1 with a 48 kHz sampling rate and the listening effort score according to ETSI TS 103 558 [19] is calculated to determine *MOS-LEO*$_{ES,OPEN}(n)$.

15) The *Passive External Speech Listening Effort Improvement* ($\Delta LE_{ES,passive}$), *Total External Speech Listening Effort Improvement* ($\Delta LE_{ES,total}$) and, if applicable, *Talk-through External Speech Listening Effort Improvement* ($\Delta LE_{ES,TT}$), are determined for each noise type *n* from equations 24, 25 and 26, respectively.

NOTE: Test labs should consider the limitations of prediction accuracy when interpreting the results of perceptual models. The current *MOS-LEO* prediction accuracy for ANC device use cases is provided in clause D.5.2 of ETSI TS 103 558 [19].

5.9 Downlink speech intelligibility index improvement

Definition:

The *Downlink Speech Intelligibility Index Improvement* (ΔSII) is the difference between the Speech Intelligibility Index - as measured according to ANSI/ASA S3.5-1997 [21] - of a simulated downlink speech signal, when measured with the ANC algorithm enabled and disabled.

The ΔSII is expressed for each noise type *n* as:

$$\Delta SII(i,n) = \left(SII_{ON}(i,n) - SII_{OFF}(i,n)\right), \forall i \in (l,r), \forall n \in (1:N) \quad (27)$$

NOTE 1: This KPI is typically only relevant for handset ANC where the SNR with ANC disabled may be low enough to impact intelligibility. It may also be applicable for certain non-occluded ANC device designs.

NOTE 2: The Speech Intelligibility Index is calculated according to ANSI/ASA S3.5-1997 [21]. More information, as well as MATLAB and C code is available at http://sii.to/programs.html.

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The ANC functionality is *enabled*.

3) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

4) The noise signal at the left and right artificial ears, with ANC *enabled*, is recorded to include analysis start and duration for noise *n* indicated in Table 4.2.5-1 with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

5) The FFT representation is used to calculate a 1/3rd octave resolution spectrum, $L_{ON}(f)$.

6) The *Speech Intelligibility Index* with ANC *enabled*, SII_{ON}, is calculated according to ANSI/ASA S3.5-1997 [21] considering: (1) A long-term average speech spectrum (at normal level) according to Table 3 of ANSI/ASA S3.5-1997 [21], and (2) The noise spectrum given by $L_{ON}(f)$.

7) The ANC functionality is *disabled*.

8) Noise *n* from Table 4.2.5-1 is played back through the background noise generation system.

9) The noise signal at the left and right artificial ears, with ANC *enabled*, is recorded to include analysis start and duration for noise *n* indicated in Table 4.2.5-1 with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

10) The FFT representation is used to calculate a 1/3rd octave resolution spectrum, $L_{OFF}(f)$.

11) The *Speech Intelligibility Index* with ANC *disabled*, SII_{OFF}, is calculated according to ANSI/ASA S3.5-1997 [21] considering: (1) A long-term average speech spectrum (at normal level) according to Table 3 of ANSI/ASA S3.5-1997 [21], and (2) The noise spectrum given by $L_{OFF}(f)$.

12) The *Speech Intelligibility Index Improvement* is determined by for each noise type *n*, by equation 27.

5.10 Informative measurements

5.10.1 Acoustic leak robustness

Definition:

The *Acoustic Leak Robustness* measurement may provide useful information about the performance of the ANC device, for scenarios in which the acoustic leak is increased compared to the one which can be typically achieved. This impairment may be caused by physical objects located between the ANC device and the ears, such as hair/facial hair or eyeglasses/sunglasses.

NOTE 1: The impact of an introduced leak depends on the geometry of the ANC device. For example, an ANC device with circumaural earphone design would most likely be more affected from this impairment than a device with supra-aural or in-ear earphones.

The *Acoustic Leak Robustness* (ALR_x) is the result difference of a measured attribute x (e.g. total insertion loss, passive insertion loss, active insertion loss, total perceived noise loudness reduction, etc.) between:

1) A measurement with the ANC device set up according to clause 4.4.

2) A measurement with the ANC device set up according to clause 4.4, which is additionally and intentionally impaired by an acoustic leak.

The multiple ALR_x conditions should be calculated for the various measured attributes or quantities x described in clauses 5.1 to 5.9, and are expressed as a difference (Δx) according to:

$$ALR_x = \left(x_{impaired} - x_{normal}\right) \quad (28)$$

where the various attributes or quantities x may or may not be functions of the form $x(f,i,n)$, $x(f,i)$, $x(i,n)$, or $x(i)$, for each frequency f, with $20Hz \leq f \leq 20kHz$, each ear $i \in (l,r)$ and each noise type, n, from Table 4.2.5-1.

The resulting measurement unit of ALR_x is the measurement unit of the attribute or quantity x under test.

Measurement:

1) The ANC device is set up according to clause 4.4.

2) A given measurement is conducted as described in clause 5.1 to 5.9 and the result is reported as x_{normal}.

3) the ANC device is mounted on the ear simulators with an intentional impairment on the earphones' leak.

4) The measurement is repeated one more time with the acoustic leak impairment and the result is reported as $x_{impaired}$.

5) The Acoustic Leak Robustness ALR_x of the given measured attribute or quantity x is determined from equation 28.

NOTE 2: At the time of publication of the present document, no ear simulator with a defined earphone leak control was available for this test. As long as such equipment is under study, a pair of eyeglasses/sunglasses mounted between the artificial ears and the ANC device may be used for this measurement. Similarly, the acoustic seal of in-ear devices may be impaired through purposeful placement of the device in a non-occluded fashion.

6 Test methods for audio playback

6.1 Level range

Definition:

The *Audio Playback Level Range* ($APLR$) is the difference between the equivalent continuous sound levels over the frequency range of 20 Hz to 20 kHz, measured at the listener's eardrum while wearing the ANC device with:

1) the playback volume of the ANC device set to the maximum (highest) volume setting, APL_{max};

2) the playback volume of the ANC device set to the minimum (lowest) volume setting, APL_{min};

for a test signal played back via the ANC device. $APLR$ is determined with ANC functionality enabled ($APLR_{ON}$), and disabled ($APLR_{OFF}$) as the average of left and right ear:

$$APLR_{OFF,AVG}(f) = \frac{1}{2}\left(APLR_{OFF}(f,l) + APLR_{OFF}(f,r)\right) \text{ in dB} \tag{29}$$

$$APLR_{ON,AVG}(f) = \frac{1}{2}\left(APLR_{ON}(f,l) + APLR_{ON}(f,r)\right) \text{ in dB} \tag{30}$$

The multiple $APLR$ conditions are expressed for each ear i as:

$$APLR_{OFF}(f,i) = \left(APL_{max,OFF}(f,i) - APL_{min,OFF}(f,i)\right) \text{ in dB}, \forall i \in (l,r) \tag{31}$$

$$APLR_{ON}(f,i) = \left(APL_{max,ON}(f,i) - APL_{min,ON}(f,i)\right) \text{ in dB}, \forall i \in (l,r) \tag{32}$$

Measurement:

1) The test signal used for the measurements shall be programme simulation noise as defined in EN 50332-1 [17].

2) The ANC device is set up according to clause 4.4.

3) The background noise generation system is *disabled*.

4) The device's ANC functionality is *disabled.*

5) The device's playback volume is set to the minimal (lowest) setting.

6) The test signal at the left and right artificial ears, with ANC *disabled*, is recorded with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

7) This FFT representation is used to calculate a 1/3rd octave resolution spectrum in $APL_{min,OFF}(f,i)$.

8) The device's playback volume is set to the maximal (highest) setting.

9) The test signal at the left and right artificial ears, with ANC *disabled*, is recorded with a 48 kHz sampling rate and analyzed with a 4096-point FFT resolution (Hann window with 50 % overlap).

10) This FFT representation is used to calculate a 1/3rd octave resolution spectrum in $APL_{max,OFF}(f,i)$.

11) The *Audio Playback Level Range* $APLR_{OFF}(f,i)$ is determined from equation 31.

12) The device's ANC functionality is *enabled.*

13) Steps 5 to 9 are repeated with ANC functionality *enabled* in order to determine the corresponding playback levels $APL_{min,ON}(f,i)$ and $APL_{max,ON}(f,i)$, as well as the *Audio Playback Level Range* $APLR_{ON}(f,i)$ as given by equations 31 and 32.

14) The left and right ear average results are calculated for each of the *Audio Playback Level Range* conditions as $APLR_{OFF,AVG}(f)$ and $APLR_{ON,AVG}(f)$ as given by equations 29 and 30.

6.2 Frequency response deviation

Definition:

The *Audio Playback Frequency Response Deviation* (ΔFR_{AP}) is the difference (if any) between the audio playback frequency response measured while wearing the ANC device with:

1) the ANC functionality *enabled* ($FR_{AP,ON}$);

2) the ANC functionality *disabled* ($FR_{AP,OFF}$);

for a test signal played back via the ANC device at the same playback volume setting.

Each frequency response $FR_{AP,ON}$ and $FR_{AP,OFF}$ is determined separately for each earphone for frequencies from 20 Hz to 20 kHz, inclusive, by measuring the equivalent continuous sound level at the listener's eardrum and referring it to the equivalent continuous sound level of the test signal, averaged over the complete test sequence length.

The *Audio Playback Frequency Response Deviation*, ΔFR_{AP}, is expressed as a function of frequency *f*, with 20 Hz $\leq f \leq$ 20 kHz, for each ear i, as:

$$\Delta FR_{AP}(f,i) = \left(FR_{AP,ON}(f,i) - FR_{AP,OFF}(f,i)\right) \text{ in dB}, \forall \text{i} \in (l,r) \qquad (33)$$

Measurement:

1) The test signal used for the measurements shall be programme simulation noise as defined in EN 50332-1 [17].

2) The ANC device and test equipment shall be set up according to clause 4.4.

3) The background noise generation system is *disabled*.

4) The device's ANC functionality is *enabled*.

5) The test signal is recorded with ANC functionality *enabled* at the left and right ears of the acoustic test equipment with a 48 kHz sample rate and the audio playback frequency response, $FR_{AP,ON}(f,i)$, is determined separately for each ear i as a function of frequency f.

6) The device's ANC functionality is *disabled*.

7) The test signal is recorded with ANC functionality *disabled* at the left and right ears of the acoustic test equipment with a 48 kHz sample rate and the audio playback frequency response, $FR_{AP,OFF}(f,i)$, is determined separately for each ear i as a function of frequency f.

8) The *Audio Playback Frequency Response Deviation*, $\Delta FR_{AP}(f, i)$, is determined as a function of frequency f, for each ear i, by equation 33.

6.3 Loudness level deviation

Definition:

The *Audio Playback Loudness Deviation* ($\Delta Loud_{AP}$) is the change (if any) in the perceived loudness level measured at the listener's eardrum while wearing the ANC device with:

1) ANC functionality *enabled*, $Loud_{AP,ON}$

2) ANC functionality *disabled*, $Loud_{AP,OFF}$

for a test signal played back via the ANC device at the same playback volume setting. The loudness level is calculated according to ISO 532-1 [14].

The *Audio Playback Loudness Deviation*, $\Delta Loud_{AP}$, is expressed as:

$$\Delta Loud_{AP} = \left(Loud_{AP,ON} - Loud_{AP,OFF}\right) \text{ in phon} \quad (34)$$

Measurement:

1) The test signal used for the measurements shall be programme simulation noise as defined in EN 50332-1 [17].

2) The ANC device and test equipment shall be set up according to clause 4.4.

3) The background noise generation system is *disabled*.

4) The device's ANC functionality is *enabled*.

5) The test signal is recorded with ANC functionality *enabled* at the left and right ears of the acoustic test equipment with a 48 kHz sampling rate. The recorded noise signal is diffuse-field corrected and processed with a Zwicker Loudness calculator, conforming to ISO 532-1 [14] to determine $Loud_{AP,ON}$ as described in clause 5.2.1.

6) The device's ANC functionality is *disabled*.

7) The test signal is recorded with ANC functionality *disabled* at the left and right ears of the acoustic test equipment with a 48 kHz sampling rate. The recorded noise signal is diffuse-field corrected and processed with a Zwicker Loudness calculator, conforming to ISO 532-1 [14] to determine $Loud_{AP,OFF}$ as described in clause 5.2.1.

8) The *Audio Playback Loudness Deviation*, $\Delta Loud_{AP}$, is determined by equation 34.

9) The left and right ear average result is calculated as $\Delta Loud_{AP_{AVG}}$.

6.4 Listening effort improvement

Definition:

The *Audio Playback Listening Effort Improvement* (ΔLE_{AP}), divided in *Passive Audio Playback Listening Effort Improvement* ($\Delta LE_{AP,active}$) and *Talk-through Audio Playback Listening Effort Improvement* ($\Delta LE_{AP,TT}$), is the change (if any) in listening effort measured at the listener's eardrum while wearing the ANC device with

1) ANC functionality *enabled*, MOS-LEO$_{AP,ON}$

2) ANC functionality *disabled*, MOS-LEO$_{AP,OFF}$

3) ANC functionality talk-through *enabled* (if applicable), MOS-LEO$_{AP,TT}$

for a test signal played back via the ANC device at the same playback volume setting. The listening effort mean opinion score, *MOS-LEO*, is calculated as described in ETSI TS 103 558 [19] without a noise-only reference signal.

The multiple *Audio Playback Listening Effort Improvement* conditions are expressed for each noise type, n, as:

$$\Delta LE_{AP,active}(n) = \left(MOS\text{-}LEO_{AP,ON}(n) - MOS\text{-}LEO_{AP,OFF}(n)\right), \forall n \in (1:N) \quad (35)$$

$$\Delta LE_{AP,TT}(n) = \left(MOS\text{-}LEO_{AP,TT}(n) - MOS\text{-}LEO_{AP,OFF}(n)\right), \forall n \in (1:N) \quad (36)$$

Measurement:

1) The test signal used for the measurements shall be the long speech sequence described in clause 4.5.4.

2) The test equipment shall be set up according to clause 4.4.

3) The device's ANC functionality is *disabled.*

4) Noise n from Table 4.2.5-1 is played back through the background noise generation system.

5) The test signal at the left and right artificial ears, with ANC *disabled*, is recorded for the duration of the test signal with a 48 kHz sampling rate and the listening effort score according to ETSI TS 103 558 [19] is calculated to determine $MOS - LEO_{AP,OFF}(n)$.

6) The device's ANC functionality is *enabled*.

7) Noise n from Table 4.2.5-1 is played back through the background noise generation system.

8) The test signal at the left and right artificial ears, with ANC *enabled*, is recorded for the duration of the test signal with a 48 kHz sampling rate and the listening effort score according to ETSI TS 103 558 [19] is calculated to determine$MOS - LEO_{AP,ON}(n)$.

9) The device's Talk-through functionality is *enabled* (if applicable).

10) Noise n from Table 4.2.5-1 is played back through the background noise generation system.

11) The test signal at the left and right artificial ears, with ANC *enabled*, is recorded for the duration of the test signal with a 48 kHz sampling rate and the listening effort score according to ETSI TS 103 558 [19] is calculated to determine $MOS - LEO_{AP,TT}(n)$.

12) The *Passive Audio Playback Listening Effort Improvement* ($\Delta LE_{AP,active}$) and *Talk-through Audio Playback Listening Effort Improvement* ($\Delta LE_{AP,TT}$, if applicable) are determined for each noise type n from equations 35 and 36 respectively.

NOTE: Test labs should consider the limitations of prediction accuracy when interpreting the results of perceptual models. The current *MOS-LEO* prediction accuracy for ANC device use cases is provided in clause D.5.2 of ETSI TS 103 558 [19].

7 Test methods and performance requirements for voice call

7.1 Introduction

In addition to noise cancelation and media playback, ANC devices also often provide voice call functionality (typically realized via analog or digital connection to another communication device). Clause 7 describes the test methods and performance requirements for voice call functionality with an ANC device, many of which are available in other ETSI specifications or Recommendation ITU-Ts. Beyond the cited methods and requirements, there are additional requirements on the voice call behavior with both ANC functionality enabled and disabled.

If not specified otherwise, all tests described herein shall be conducted with the device's ANC functionality *enabled*.

7.2 Tests only for analog interface

7.2.1 Sensitivity

7.2.1.1 Sensitivity in send

Definition:

The sensitivity in send direction is defined according to clause 8.1.2 of Recommendation ITU-T P.381 [5], and is measured from the MRP to the sending input of the device access interface.

Measurement:

The sensitivity in send measurements are relevant only for analog (wired) devices, connected to the test equipment as described in clause 4.3.1:

1) The ANC device and test equipment shall be set up according to clause 4.4.
2) The background noise generation system is *disabled*.
3) The test shall be carried out according to the measurement method described in clause 8.1.3 of Recommendation ITU-T P.381 [5].

Requirement:

The limits for the sensitivity in send direction shall comply with the requirements according to clause 8.1.3 of Recommendation ITU-T P.381 [5].

7.2.1.2 Sensitivity in receive

Definition:

The sensitivity in receive direction is defined according to clause 8.1.3 of Recommendation ITU-T P.381 [5] as the diffuse field equalized sound pressure at the listener's ear drum, and is measured from the receiving output of the device access interface to the to the drum reference position (DRP) with diffuse-field correction.

Measurement:

The sensitivity in receive measurements are relevant only for analog (wired) devices, connected to the test equipment as described in clause 4.3.1. For testing ANC devices, the sensitivity in receive direction is divided further into S_{ON}, measured with the device's ANC functionality enabled, and S_{OFF}, measured with the device's ANC functionality disabled:

1) The ANC device and test equipment shall be set up according to clause 4.4.
2) The background noise generation system is *disabled*.
3) The device's ANC functionality is *enabled.*
4) The test shall be carried out according to the measurement method described in clause 8.1.2 of Recommendation ITU-T P.381 [5], in order to obtain the sensitivity in receive, S_{ON}.
5) The device's ANC functionality is *disabled.*
6) The test is repeated according to the measurement method as described in step 4, but with the ANC functionality disabled, in order to obtain the *Sensitivity in Receive*, S_{OFF}.

Requirement:

The limits for the sensitivity in receive direction for the analog ANC device with ANC functionality both enabled and disabled shall comply with the requirements according to clause 8.1.3 of Recommendation ITU-T P.381 [5].

7.3 Tests only for digital interface

7.3.1 Loudness rating

7.3.1.1 Send loudness rating

Definition:

The *Send Loudness Rating* (SLR) is defined, depending on the provided bandwidth of the ANC device, in the corresponding specification listed in Table 7.3.1.1-1.

Table 7.3.1.1-1: References to send loudness rating measurements

Transmission Bandwidth	Specification	Clause
NB	ETSI TS 103 737 [11]	6.2.1
WB	ETSI TS 103 739 [12]	6.2.1
SWB	ETSI TS 102 924 [13]	6.3.2

Measurement:

The *Send Loudness Rating* measurements are relevant only for digital (wired and wireless) devices, connected to the test equipment as described in clauses 4.3.2 and 4.3.3 respectively.

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The background noise generation system is *disabled*.

3) The test shall be carried out according to the corresponding specification listed in Table 7.3.1.1-1, depending on the provided bandwidth of the ANC device.

Requirement:

The SLR limits shall comply with the requirements according to the corresponding specification from Table 7.3.1.1-1, depending on the provided bandwidth of the ANC device.

7.3.1.2 Receive loudness rating

Definition:

The *Receive Loudness Rating* (RLR) is defined, depending on the provided bandwidth of the ANC device, in the corresponding specification listed in Table 7.3.1.2-1.

Table 7.3.1.2-1: References to receive loudness rating measurements

Transmission Bandwidth	Specification	Clause
NB	ETSI TS 103 737 [11]	6.2.3 binaural Headset
WB	ETSI TS 103 739 [12]	6.2.3 binaural Headset
SWB	ETSI TS 102 924 [13]	6.4.4

Measurement:

The *RLR* measurements are relevant only for digital (wired and wireless) ANC devices, connected to the test equipment as described in clauses 4.3.2 and 4.3.3 respectively. The *RLR* is adjustable via the volume control of the ANC device. For testing ANC devices, the RLR is divided further into RLR_{ON}, measured with the device's ANC functionality enabled, and RLR_{OFF}, measured with the device's ANC functionality disabled.

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The background noise generation system is *disabled*.

3) The device's ANC functionality is *enabled.*

4) The test shall be carried out according to the measurement method described in the corresponding specification listed in Table 7.3.1.2-1, depending on the provided bandwidth of the ANC device. The volume setting of the ANC device is adjusted in order to achieve a Receive Loudness Rating, RLR_{ON}, within the limits of the nominal RLR value.

5) The device's ANC functionality is *disabled.*

6) The test is repeated according to the measurement method described in the corresponding specification listed in Table 7.3.1.2-1 depending on the provided bandwidth of the ANC device, at the same volume setting of the ANC device as adjusted in step 4, in order to obtain the *Receive Loudness Rating*, RLR_{OFF}.

Requirement:

The limits for the nominal *Receive Loudness Rating* shall comply with the requirements according to the corresponding specification from Table 7.3.1.2-1 depending on the provided bandwidth of the ANC device, for both measured values of *Receive Loudness Rating*, RLR_{ON} and RLR_{OFF}, with ANC functionality enabled and disabled, respectively.

7.3.2 Sidetone performance

7.3.2.1 Sidetone masking rating (STMR)

Definition:

The *Sidetone Masking Rating* ($STMR$) is defined, depending on the provided bandwidth of the ANC device, in the corresponding specification listed in Table 7.3.2.1-1.

Table 7.3.2.1-1: References to sidetone masking rating measurements

Transmission Bandwidth	Specification	Clause
NB	ETSI TS 103 737 [11]	6.3.1
WB	ETSI TS 103 739 [12]	6.3.2
SWB	ETSI TS 102 924 [13]	6.3.7

Measurement:

For testing ANC devices, the $STMR$ is divided further into $STMR_{ON}$, measured with the device's ANC functionality enabled, and $STMR_{OFF}$, measured with the device's ANC functionality disabled.

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The background noise generation system is *disabled*.

3) The device's ANC functionality is *enabled.*

4) The test shall be carried out according to the measurement method described in the corresponding specification listed in Table 7.3.2.1-1, depending on the provided bandwidth of the ANC device, in order to obtain the *Sidetone Masking Rating*, $STMR_{ON}$.

5) The device's ANC functionality is *disabled.*

6) The test is repeated according to the measurement method described in the corresponding specification listed in Table 7.3.2.1-1 depending on the provided bandwidth of the ANC device, in order to obtain the *Sidetone Masking Rating*, $STMR_{OFF}$.

Requirement:

The limits for the *Sidetone Masking Rating* shall comply with the requirements according to the corresponding specification from Table 7.3.2.1-1 depending on the provided bandwidth of the ANC device, for both measured values of *Sidetone Masking Rating*, $STMR_{ON}$ and $STMR_{OFF}$, with ANC functionality enabled and disabled, respectively.

7.3.3 Quality of echo cancellation

7.3.3.1 Terminal coupling loss

Definition:

The *Terminal Coupling Loss* (*TCL*) and weighted *TCL* (TCL_w, for NB transmission only) are defined, depending on the provided bandwidth of the ANC device, in the corresponding specification listed in Table 7.3.3.1-1.

Table 7.3.3.1-1: References to terminal coupling loss measurements

Transmission Bandwidth	Specification	Clause
NB	ETSI TS 103 737 [11]	6.6.2
WB	ETSI TS 103 739 [12]	6.6.2
SWB	ETSI TS 102 924 [13]	6.3.9

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The background noise generation system is disabled.

3) The test shall be carried out according to the measurement method described in the corresponding specification listed in Table 7.3.3.1-1, depending on the provided bandwidth of the ANC device, in order to obtain the *Terminal Coupling Loss*.

Requirement:

TCL and TCL_w shall fulfil the requirements according to the corresponding specification from Table 7.3.3.1-1 depending on the provided bandwidth of the ANC device.

7.3.4 Double talk performance

7.3.4.1 Attenuation range in send direction during double talk

Definition:

The attenuation range in send direction during double talk ($A_{H,S,dt}$) is defined, depending on the provided bandwidth of the ANC device, in the corresponding specification listed in Table 7.3.4.1-1.

Table 7.3.4.1-1: References to sidetone masking rating measurements

Transmission Bandwidth	Specification	Clause
NB	ETSI TS 103 737 [11]	6.7.1
WB	ETSI TS 103 739 [12]	6.8.2
SWB	ETSI TS 102 924 [13]	6.4.10.2

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The background noise generation system is *disabled*.

3) The test shall be carried out according to the measurement method described in the corresponding specification listed in Table 7.3.4.1-1, depending on the provided bandwidth of the ANC device, in order to obtain the attenuation range in send direction during double talk, $A_{H,S,dt}$.

Requirement:

The attenuation range in send direction during double talk shall fulfil the requirements according to the corresponding specification from Table 7.3.4.1-1 depending on the provided bandwidth of the ANC device.

7.3.5 Background noise performance

7.3.5.1 Speech quality in presence of background noise

Definition:

The speech quality in the presence of background noise is defined, depending on the provided bandwidth of the ANC device, in the corresponding specification listed in Table 7.3.5.1-1.

Table 7.3.5.1-1: References to Speech quality in the presence of background noise measurements

Transmission Bandwidth	Specification	Clause
NB	ETSI TS 103 737 [11]	6.9.2
WB	ETSI TS 103 739 [12]	6.10.2
SWB	ETSI TS 102 924 [13]	6.4.12.2

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) Noise 4 from Table 4.2.5-1 is played back through the background noise generation system.

3) The test shall be carried out according to the measurement method described in the corresponding specification listed in Table 7.3.5.1-1, depending on the provided bandwidth of the ANC device, but only for the background noise scenario as described in step 2.

Requirement:

The speech quality in the presence of background noise shall fulfil the requirements according to the corresponding specification from Table 7.3.5.1-1 depending on the provided bandwidth of the ANC device.

7.4 Tests for analog and digital interface

7.4.1 Frequency response

7.4.1.1 Send Frequency Response (SFR)

Definition:

The Send Frequency Response (SFR) is defined, depending on the type of access interface and the provided bandwidth of the ANC device, in the corresponding specification listed in Table 7.4.1.1-1.

Table 7.4.1.1-1: References to send frequency response measurements

Access Interface	Transmission Bandwidth	Specification	Clause
Digital (wired/wireless)	NB	ETSI TS 103 737 [11]	6.1.1
	WB	ETSI TS 103 739 [12]	6.1.1
	SWB	ETSI TS 102 924 [13]	6.3.1
Analog	NB	-	-
	WB, SWB	Recommendation ITU-T P.381 [5]	8.1.4

In the NB voice call scenario for analog (wired) devices, connected to the test equipment as described in clause 4.3.1, the *SFR* is measured from the MRP to the sending input of the device access interface.

Measurement:

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The background noise generation system is *disabled*.

3) The test shall be carried out according to the measurement method described in the corresponding specification listed in Table 7.4.1.1-1, depending on the type of access interface and the provided bandwidth of the ANC device, in order to obtain the *Send Frequency Response*, *SFR*.

   In the NB voice call scenario for analog (wired) devices, the test signal used for the measurements shall be the long speech sequence as described in clause 4.5.4. The measured power density spectrum at the MRP is used as the reference power density spectrum for determining the sending sensitivity. The send sensitivity is determined in third octave intervals as given by IEC 61260-1 [16] for frequencies between 100 Hz and 4 kHz inclusive. In each third octave band, the level of the measured signal is referred to the level of the reference signal, averaged over the complete test sequence length. The sensitivity is determined in dBV/Pa.

Requirement:

The measured frequency response shall be within the limits as defined in the corresponding specification from Table 7.4.1.1-1 depending on the type of access interface and the provided bandwidth of the ANC device.

In the case of NarrowBand (NB) voice call scenario for analog (wired) devices, connected to the test equipment as described in clause 4.3.1, the measured frequency response shall be within the limits as defined in Table 7.4.1.1-2.

Table 7.4.1.1-2: Tolerance mask for the narrowband send frequency response

Frequency (Hz)	Upper limit	Lower limit
200	4	−∞
300	-	−4
1 000	-	−4
3 000	4	-
4 000	-	−12
5 000	2	−∞
NOTE: All sensitivity values are expressed in dB on an arbitrary scale. The limits for intermediate frequencies lie on straight lines drawn between the given values on a linear (dB) - logarithmic (Hz) scale.		

7.4.1.2 Receive frequency response

Definition:

The *Receive Frequency Response* (*RFR*) is defined, depending on the type of access interface and the provided bandwidth of the ANC device, in the corresponding specification listed in Table 7.4.1.2-1.

Table 7.4.1.2-1: References to receive frequency response measurements

Access Interface	Transmission Bandwidth	Specification	Clause
Digital (wired/wireless)	NB	ETSI TS 103 737 [11]	6.1.2
	WB	ETSI TS 103 739 [12]	6.1.2
	SWB	ETSI TS 102 924 [13]	6.4.2
Analog	NB	-	-
	WB, SWB	Recommendation ITU-T P.381 [5]	8.1.5

In the NB voice call scenario for analog (wired) devices, connected to the test equipment as described in clause 4.3.1, the *Receive Frequency Response* is defined as the diffuse field equalized sound pressure at the listener's ear drum, measured with narrowband speech from the receiving output of the device access interface to the DRP with diffuse-field correction.

Measurement:

For testing ANC devices, the RFR is divided further into RFR_{ON}, measured with the device's ANC functionality enabled, and RFR_{OFF}, measured with the device's ANC functionality disabled.

1) The ANC device and test equipment shall be set up according to clause 4.4.

2) The background noise generation system is *disabled*.

3) The device's ANC functionality is *enabled.*

4) The test shall be carried out according to the measurement method described in the corresponding specification listed in Table 7.4.1.2-1, depending on the type of access interface and the provided bandwidth of the ANC device, in order to obtain the Receive Frequency Response, RFR_{ON}.

   In the case of narrowband voice call scenario for analog (wired) devices, connected to the test equipment as described in clause 4.3.1, the test signal used for the measurements in receive shall be the long speech sequence as described in clause 4.5.4, band-limited in the narrowband frequency range. The band limitation is achieved by bandpass filtering in the frequency range between 100 Hz and 4 kHz using a bandpass filter providing ≥ 24 dB/octave. The test signal level applied to the access interface shall be -16 dBm0, measured according to Recommendation ITU-T P.56 [9]. The receive sensitivity is determined in third octave intervals as given by IEC 61260-1 [16] for frequencies between 100 Hz and 4 kHz inclusive. In each third octave band, the level of the measured signal is referred to the level of the reference signal, averaged over the complete test sequence length. The sensitivity is determined in $dB_{Pa/V}$.

5) The device's ANC functionality is *disabled.*

6) The test is repeated according to the measurement method as described in step 4, but with the ANC functionality disabled, in order to obtain the *Receive Frequency Response*, RFR_{OFF}.

Requirement:

The measured frequency response shall be within the limits as defined in the corresponding specification from Table 7.4.1.2-1 depending on the type of access interface and the provided bandwidth of the ANC device, for both measured frequency responses, RFR_{ON} and RFR_{OFF}, with ANC functionality enabled and disabled, respectively.

In the NB voice call scenario for analog (wired) devices, connected to the test equipment as described in clause 4.3.1, the measured frequency response shall be within the limits as defined in Table 7.4.1.2-2.

Table 7.4.1.2-2: Tolerance mask for the narrowband receive frequency response

Frequency (Hz)	Upper limit	Lower limit
200	10	−∞
300	9	−10
400	-	−6
1 000	6	−6
2 000	8	−6
3 000	8	−6
4 000	8	−12
5 000	8	−∞
NOTE: All sensitivity values are expressed in dB on an arbitrary scale. The limits for intermediate frequencies lie on straight lines drawn between the given values on a linear (dB) - logarithmic (Hz) scale.		

7.4.2 One-way speech quality in receive

Definition:

The *Speech Quality Delta in Receive* (ΔSQ_{VC}) is the difference (if any) between the objective Mean Opinion Score of the listening quality (*MOS-LQO*) measured at the listener's eardrum while wearing the ANC device with ANC functionality *enabled*, $MOS\text{-}LQO_{VC,ON}$, and ANC functionality *disabled*, $MOS\text{-}LQO_{VC,OFF}$, during a voice call.

The listening speech quality $MOS\text{-}LQO_f$ is calculated according to Recommendation ITU-T P.863 [20] in fullband mode for voice call transmissions in WB, SWB and FB. For NB transmissions, $MOS\text{-}LQO_n$ is calculated according to Appendix III of Recommendation ITU-T P.863 [20].

The *Speech Quality Delta in Receive*, ΔSQ_{VC} is expressed for each ear i as:

$$\Delta SQ_{VC}(i) = MOS\text{-}LQO_{VC,ON}(i) - MOS\text{-}LQO_{VC,OFF}(i), \forall \mathrm{i} \in (l, r) \qquad (37)$$

Measurement:

1) The test signal used for the measurements shall be the long speech sequence described in clause 4.5.4.

2) The test equipment shall be set up according to clause 4.4. The background noise generation system is *disabled*.

3) The device's ANC functionality is *disabled.*

4) The test signal at the left and right artificial ears is recorded with 48 kHz sampling rate and calibrated to an active speech level of 73 dB_{SPL} according to Recommendation ITU-T P.56 [9]. The listening quality is calculated according to the aforementioned definitions to determine $\text{MOS-LQO}_{VC,OFF}(i)$.

5) The device's ANC functionality is *enabled.*

6) The test signal at the left and right artificial ears is recorded with 48 kHz sampling rate and calibrated to an active speech level of 73 dB_{SPL} according to Recommendation ITU-T P.56 [9]. The listening quality is calculated according to the aforementioned definitions to determine $\text{MOS-LQO}_{VC,ON}(i)$.

7) The *Speech Quality Delta in Receive*, $\Delta SQ_{VC}(i)$ is determined from equation 37 for each ear i.

Requirement:

For each ear i, $\Delta SQ_{VC}(i)$ shall be greater or equal to -0.1 MOS.

7.4.3 Listening effort in the presence of background noise

Definition:

The *Voice Call Listening Effort Improvement* (ΔLE_{VC}) is the difference between the listening effort (*MOS-LEO*) measured at the listener's eardrum while wearing the ANC device with ANC functionality *enabled*, $MOS\text{-}LEO_{VC,ON}$, and ANC functionality *disabled*, $MOS\text{-}LEO_{VC,OFF}$, during a voice call in the presence of background noise.

The listening effort mean opinion score, *MOS-LEO*, is calculated according to ETSI TS 103 558 [19].

The *Voice Call Listening Effort Improvement*, ΔLE_{VC}, is expressed for each noise type, n, from Table 4.2.5-1 as:

$$\Delta LE_{VC}(n) = MOS\text{-}LEO_{VC,ON}(n) - MOS\text{-}LEO_{VC,OFF}(n), \forall n \in (1{:}\,N) \qquad (38)$$

Measurement:

1) The test signal used for the measurements shall be the long speech sequence described in clause 4.5.4.

2) The test equipment shall be set up according to clause 4.4.

3) The device's ANC functionality is *disabled.*

4) Noise 4 from Table 4.2.5-1 is played back through the background noise generation system.

5) The test signal at the left and right artificial ears, with ANC *disabled*, is recorded with a 48 kHz sampling rate and the listening effort according to ETSI TS 103 558 [19] is calculated to determine $MOS\text{-}LEO_{VC,OFF}(4)$.

6) The device's ANC functionality is *enabled*.

7) Noise 4 from Table 4.2.5-1 is played back through the background noise generation system.

8) The test signal at the left and right artificial ears, with ANC *enabled*, is recorded with a 48 kHz sampling rate and the listening effort according to ETSI TS 103 558 [19] is calculated to determine $MOS\text{-}LEO_{VC,ON}(4)$.

9) The *Voice Call Listening Effort Improvement*, ΔLE_{VC}, is determined from equation 38.

NOTE: Test labs should consider the limitations of prediction accuracy when interpreting the results of perceptual models. The current *MOS-LEO* prediction accuracy for ANC device use cases is provided in clause D.5.2 of ETSI TS 103 558 [19].

History

Document history		
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