TECHNICAL REPORT

ISO/TR 17534-4

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Acoustics — Software for the calculation of sound outdoors —

Part 4: Recommendations for a quality assured implementation of the COMMISSION DIRECTIVE (EU) 2015/996 in software according to ISO 17534-1

Acoustique — Logiciels de prévision de bruit dans l'environnement — Partie 4: Recommandations pour l'assurance qualité de la mise en œuvre de la DIRECTIVE (UE) 2015/996 de la COMMISSION EUROPÉENNE dans les logiciels selon l'ISO 17534-1

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

A list of all parts in the ISO 17534 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The structure of the ISO 17534 series is shown in Figure 1. ISO 17534-1 describes the general approach of the ISO 17534 series, aiming to facilitate a standardized interpretation and a verifiably consistent software implementation of outdoor sound calculation methods. ISO/TR 17534-2 contains general recommendations for test cases and for a quality assurance interface. Further parts of the ISO 17534 series each address a specific outdoor sound calculation method for which they provide an agreed interpretation of ambiguous aspects, a set of illustrative test cases along with reference solutions, and an example of a template form for the declaration of conformity for software developers.

This document addresses the calculation method laid down in the COMMISSION DIRECTIVE (EU) 2015/996, hereafter referred to as CNOSSOS-EU:2015.

The European Commission developed Common NOise aSSessment methOdS (CNOSSOS-EU) for road, railway, aircraft and industrial noise for the purpose of strategic noise mapping. CNOSSOS-EU aims at improving the consistency and comparability of noise assessment results across the EU Member States which are performed on the basis of the data becoming available through the consecutive rounds of strategic noise mapping in Europe.

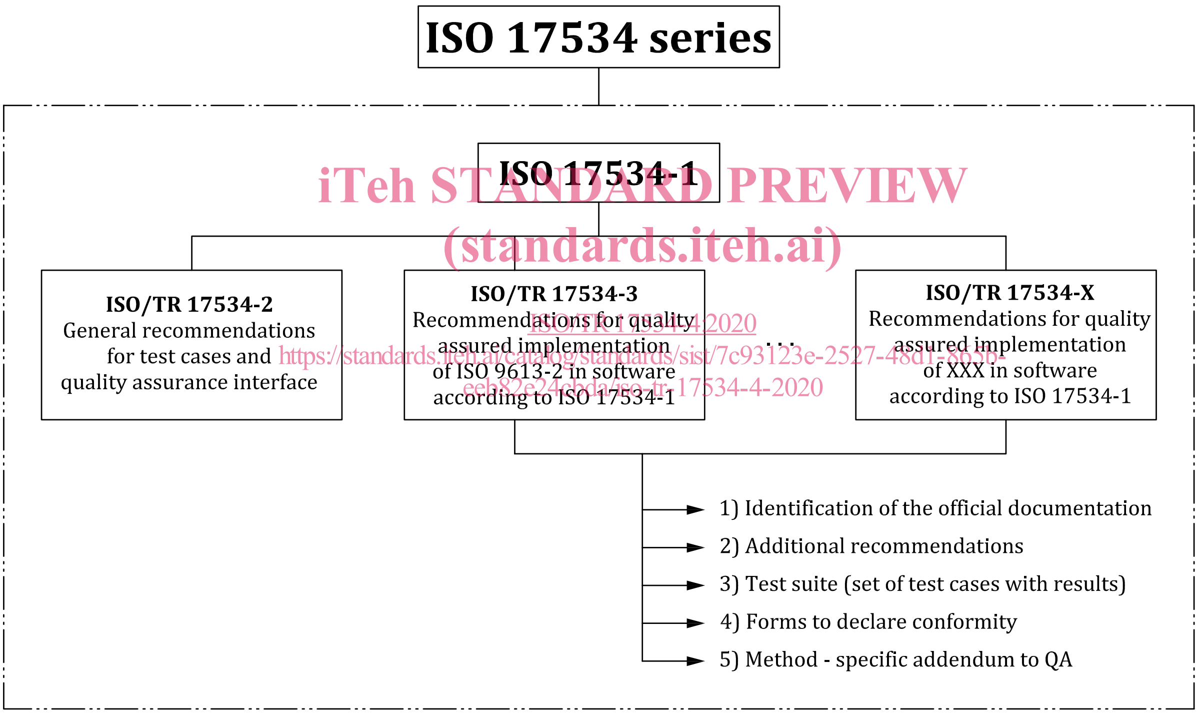

Figure 1 — Structure of the ISO 17534 series

Acoustics — Software for the calculation of sound outdoors —

Part 4: Recommendations for a quality assured implementation of the COMMISSION DIRECTIVE (EU) 2015/996 in software according to ISO 17534-1

1 Scope

This document facilitates a standardized interpretation and a verifiably consistent software implementation of the sound propagation part of the calculation method CNOSSOS-EU:2015 according to ISO 17534-1. Other parts of CNOSSOS-EU:2015, such as the source models or the calculation method for aircraft noise, are beyond the scope of this document. This document provides an agreed interpretation of ambiguous aspects of the sound propagation part of CNOSSOS-EU:2015, a set of illustrative test cases along with reference solutions, and an example of a template form for the declaration of conformity for software manufacturers.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 17534-1, *Acoustics — Software for the calculation of sound outdoors — Part 1: Quality requirements and quality assurance*

ISO/TR 17534-2, *Acoustics — Software for the calculation of sound outdoors — Part 2: General recommendations for test cases and quality assurance interface*

COMMISSION DIRECTIVE (EU) 2015/996 of 19 May 2015 establishing common noise assessment methods according to Directive 2002/49/EC of the European Parliament and of the Council, Official Journal of the European Union, L 168/1

3 Terms and definitions

For the purposes of this document, the terms and definitions given in CNOSSOS-EU:2015, ISO 17534-1, and ISO/TR 17534-2 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Identification of the official documentation

COMMISSION DIRECTIVE (EU) 2015/996 of 19 May 2015 establishing common noise assessment methods according to Directive 2002/49/EC of the European Parliament and of the Council, Official Journal of the European Union, L 168/1, herein referred to as CNOSSOS-EU:2015.

In its Chapter 2.5, "Calculation of noise propagation for road, railway, industrial sources", CNOSSOS-EU: 2015 describes a method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources.

5 Uniform and agreed interpretation of ambiguities

5.1 General

The propagation of sound outdoors in CNOSSOS-EU:2015 is calculated with a ray-based energetic model. Attenuations are calculated in eight octave bands, and separately for two idealized meteorological conditions labelled homogeneous and favourable. Finally, the A-weighted exposure level at a receiver position is given as the weighted energetic sum over all sources, paths, meteorological conditions, and octave bands.

Some aspects of the sound propagation model of CNOSSOS-EU:2015 are not described in sufficient detail to be unambiguous; in other aspects, in some part the official documentation is misleading. For each of these problematic topics, an agreed interpretation is given in 5.2 to 5.15 to allow for a standardized understanding of CNOSSOS-EU:2015.

The abbreviations are not explained when they are identical to those described in CNOSSOS-EU:2015.

Symbols are not defined when they are identical to those applied in CNOSSOS-EU:2015.

5.2 Sloping objects

Topic: CNOSSOS-EU:2015 states in subclause 2.5.1 that "obstacles sloping, when modelled, more than 15° in relation to the vertical are out of the scope of this calculation method". This restriction does not constitute a general restriction of the method. Rather, it applies only to reflectors: obstacles sloping more than 15° in relation to the vertical are not considered as reflectors.

Agreed interpretation:

Objects sloping more than 15° in relation to the vertical are not considered as reflectors, but are taken into account in all other aspects of propagation such as ground effects and diffraction.

5.3 Equivalent heights

Topic: CNOSSOS-EU:2015 states in subclause 2.5.3, under the headline "Significant heights above the ground", that "If the equivalent height of a point becomes negative, i.e. if the point is located below the mean ground plane, a null height is retained, and the equivalent point is then identical with its possible image." For points located below the mean ground plane, the equivalent height is set to zero in the calculation of A_{ground}. For the calculation of path length differences, it is irrelevant whether points lie above or below a mean ground plane, no points are shifted. For the calculation of $\Delta_{\text{ground(S,O)}}$ and $\Delta_{\text{ground(O,R)}}$ special care has to be taken in the case that one of the respective end points lies below the mean ground plane.

Agreed interpretation:

The first major step in the algorithm is to decide whether A_{ground} or A_{dif} must be calculated. The step is based on real coordinates, not equivalent heights. If a point lies below the mean ground plane, its equivalent height is set to zero in the calculation of A_{ground}. Equations (2.5.31) and (2.5.32) of CNOSSOS -EU:2015 apply only in the most common case that both S and R lay above the mean ground plane. If either S or R lies below the mean ground plane, the following simplified Equations apply:

$\Delta_{\text{ground(S,O)}} = A_{\text{ground(S,O)}}$ (CNOSSOS-EU:2015, 2.5.31)

$\Delta_{\text{ground(O,R)}} = A_{\text{ground(O,R)}}$ (CNOSSOS-EU:2015, 2.5.32)

For the calculation of path length differences, the original coordinates are used and no points are shifted, i.e. in the calculation of $\Delta_{dif(S,R)}$ the original heights of S and R are used.

5.4 Alternative statistical approach

Topic: CNOSSOS-EU:2015 mentions in subclause 2.5.5, under the headline "Statistical approach inside urban areas for a path (S, R)", a statistical approach for calculations inside urban areas beyond the first line of buildings. This approach is not described in sufficient detail to be subjected to the quality assurance methodology of ISO 17534-1.

Agreed interpretation:

A statistical approach is not appropriate in the calculation of sound propagation beyond the first line of buildings.

5.5 Octave band centre frequency f_m

Topic: CNOSSOS-EU:2015 is somewhat ambiguous about whether nominal centre frequencies or exact centre frequencies should be used in the calculation of the atmospheric attenuation coefficient α_{atm}.

Agreed interpretation:

In the calculation of the atmospheric attenuation coefficient α_{atm}, ISO 9613-1 is followed, and exact centre frequencies are used. In all other calculations, the nominal centre frequency, denoted f_m, are used.

The tabulated values in ISO 9613-1 are based on the pressure at sea level.

5.6 Ground factor of the source area, G_S

Topic: CNOSSOS-EU:2015 introduces G_S in subclause 2.5.6 as the ground factor G of the source area. For industrial sources, it is left open how exactly G_S is to be calculated.

Agreed interpretation:

For industrial point sources, G_S is calculated as the average of the ground factor G over a distance of 1 m beginning at the vertical projection point below the source and proceeding along the direction source-receiver.

5.7 Distances in Figure 2.5.b of CNOSSOS-EU:2015

Topic: In CNOSSOS-EU:2015, it is unclear whether the distances d displayed in Figure 2.5.b are 3D-distances along the ground or 2D-projection onto a horizontal plane.

Agreed interpretation:

Figure 2.5.b displays a 2D-projection onto the horizontal plane. The distances d used in the calculation of G_{path} are measured in this horizontal plane.

5.8 Equivalent heights in Equation (2.5.20) of CNOSSOS-EU:2015

Topic: CNOSSOS-EU:2015 explains that modified equivalent heights should be used in the calculation of $A_{ground,F}$. But it is unclear whether these modified equivalent heights or unmodified equivalent heights should be used in the calculation of $A_{ground,F,min}$ according to Equation (2.5.20) of CNOSSOS-EU:2015.

Agreed interpretation:

Unmodified equivalent heights are used in the calculation of $A_{ground,F,min}$ according to Equation (2.5.20) of CNOSSOS-EU:2015.

5.9 Rayleigh's Criterion

Topic: CNOSSOS-EU:2015 states that no diffraction should be calculated if the ray path passes "high enough" over the diffraction edge. In this context, CNOSSOS-EU:2015 refers to Rayleigh's Criterion without providing details or formulae. The circumstances under which diffraction is calculated should be defined unambiguously.

Agreed interpretation:

In the unique vertical plane containing source and receiver, the line of sight from source to receiver is defined, under homogeneous conditions, as the straight line connecting source and receiver. Under favourable conditions, the line of sight is defined as the arc of radius Γ, given by Equation (2.5.24) of CNOSSOS-EU:2015, connecting source and receiver.

The decision whether diffraction must be calculated is made separately for homogeneous and favourable conditions respectively. If the line of sight is blocked, diffraction is always calculated. If the line of sight from source to receiver is unobstructed, Rayleigh's Criterion is employed as follows: first, that point D of the terrain profile including obstacles is identified, which gives the largest δ_D, i.e. the δ_D with the smallest absolute value. Then δ_D^* is calculated as the path length difference from S' to R' via D, where S' and R' are the respective images of source and receiver constructed with the appropriate mean ground planes containing source or receiver. Diffraction is calculated only if $\delta_D > -\lambda/20$ and $\delta_D > \lambda/4 - \delta_D^*$ (Rayleigh's Criterion), where λ is the wavelength at the nominal centre frequency and calculated with a speed of sound of 340 m/s.

5.10 Parameter *e*

Topic: CNOSSOS-EU:2015 introduces the parameter *e* as the total distance along the path from the first to the last diffraction edge according to the "rubber band method". It is unclear how the parameter *e* is calculated for favourable propagation conditions.

Agreed interpretation:

The parameter *e* is defined as the total distance along the path from the first to the last diffraction edge. Under homogeneous conditions, straight lines are used as ray segments, while under favourable conditions, arcs of uniform radius are used as ray segments. Different diffraction edges may be relevant under homogeneous and favourable conditions respectively.

5.11 Diffraction under favourable conditions

Topic: CNOSSOS-EU:2015 explains diffraction under favourable propagation conditions. The text contains too little details to be unambiguous. In particular, the scale of Figure 2.5.f of CNOSSOS-EU: 2015 is chosen such that the ray segments appear to be straight lines while they should be arcs of radius Γ, given by Equation (2.5.24) of CNOSSOS-EU:2015.

Agreed interpretation:

Under favourable conditions, the propagation path in the vertical plane always consists of segments of a circle whose radius is given by the 3D-distance between source and receiver according to Equation (2.5.24) of CNOSSOS-EU:2015, i.e. all segments of a propagation path have the same radius of curvature. If the direct arc connecting source and receiver is blocked, the propagation path is defined as the shortest convex combination of arcs enveloping all obstacles. Convex in this context means that at each diffraction point, the outgoing ray segment is deflected downward with respect to the incoming ray segment (see ISO 9613-1).

To illustrate the principle of constructing the ray path with multiple diffractions under favourable conditions, Figure 2 is a slightly modified version of Figure 2.5.f of CNOSSOS-EU:2015, scaled such that the curvature of the rays is apparent.

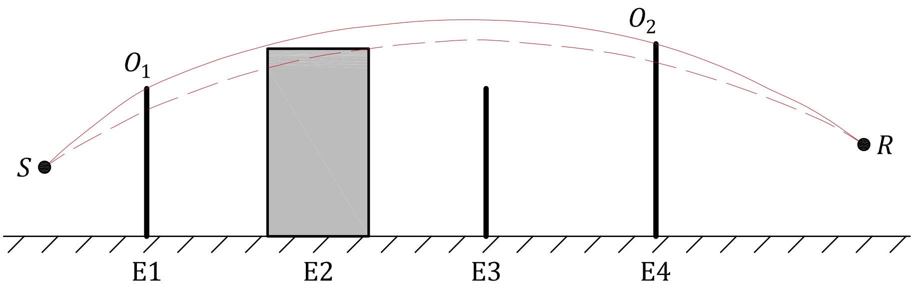

Figure 2 — Modified version of Figure 2.5.f of CNOSSOS-EU:2015 showing ray paths with easily visible curvature

5.12 Error in Figure 2.5.f and Equation (2.5.29) of CNOSSOS-EU:2015

Topic: Figure 2.5.f and Equation (2.5.29) of CNOSSOS-EU:2015 are erroneous.

Agreed interpretation:

Figure 2.5.f and Equation (2.5.29) of CNOSSOS-EU:2015 treat the point O_3 as a diffraction edge, even though it lies below the rubber band. This is incorrect. Given the geometry displayed in Figure 2.5.f of CNOSSOS-EU:2015, the right-hand edge of obstacle E2 cannot be treated as a diffraction edge. A corrected version of Figure 2.5.f of CNOSSOS-EU:2015 is displayed as Figure 3, with Equation (2.5.29) of CNOSSOS-EU:2015 reading: $\delta_F = \widehat{SO_1} + \widehat{O_1O_2} + \widehat{O_2O_3} + \widehat{O_3R} - \widehat{SR}$.

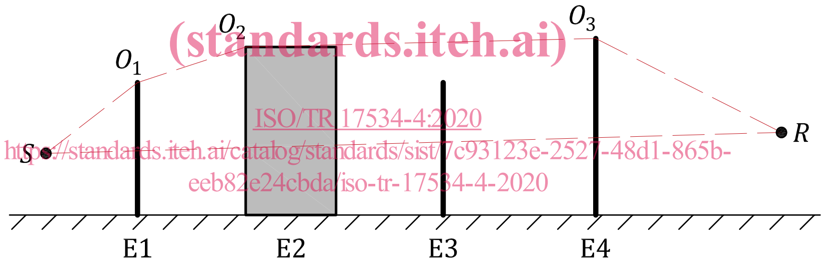

Figure 3 — Corrected version of Figure 2.5.f of CNOSSOS-EU:2015

5.13 Lateral diffraction

Topic: CNOSSOS-EU:2015 introduces lateral diffraction, i.e. diffraction on vertical edges. The description is too short to be unambiguous. In particular, it is left open exactly how laterally diffracted propagation paths are to be constructed.

Agreed interpretation:

As a general principle, lateral diffraction is considered only if the direct line of sight (see 5.9 above) between source and receiver is blocked and does not penetrate the terrain profile. In addition, the source must not be a mirror source due to reflection. This said, lateral diffraction edges are sought in the unique plane which contains both source and receiver, and which is also perpendicular to the vertical propagation plane. Obstacles are taken into account including adjoining obstacles. Obstacles which penetrate this plane form an area of intersection with that plane. An intersection area is only considered relevant if the corresponding obstacle is intersected by the direct line of sight. The diffraction edges of lateral paths are defined by a rubber band that stretches from source to receiver, left and right of the direct line of sight respectively, and encompasses all relevant intersection areas.

To calculate the ground attenuation for a laterally diffracted propagation path, a mean ground plane is calculated for the terrain profile vertically below the propagation path between source and receiver. This utilises a vertical X-Z auxiliary plane, whose Z coordinate corresponds to the absolute height, and whose X coordinate corresponds to the distance from the source point along the propagation path in the projection onto a horizontal plane. If a lateral propagation path in the projection onto a horizontal plane intersects the ground layout of a building, this building is taken into account in the calculation of G_{path} (usually with G=0) and in the calculation of the mean ground plane using its height. With respect to the calculation of the ground attenuation, a laterally diffracted propagation path is treated in the auxiliary X-Z plane as a propagation path with unblocked line of sight, and without diffraction.

5.14 Reflection on nearly vertical objects

Topic: CNOSSOS-EU:2015 explains reflection on (nearly) vertical objects. Further specifications are needed to formulate this aspect unambiguously.

Agreed interpretation:

Objects are considered as reflectors only if they slope less than 15° with respect to the vertical. For the calculation of reflected sound with a mirror image source propagation is only considered in a vertical propagation plane (i.e. not for laterally diffracted paths). The point of reflection, which lies on the reflecting object, is constructed assuming the reflecting surface is vertical. Ray paths are constructed for incident and reflected paths using straight lines under homogeneous conditions, and arcs under favourable conditions.

The height of the reflector, as viewed from the direction of the incident ray and measured through the point of reflection, is at least 0,5 m. The width of the reflector as viewed from the direction of the incident ray in a horizontal plane containing this reflection point is at least 0,5 m.

5.15 Retrodiffraction

Topic: CNOSSOS-EU:2015 describes the principle of retrodiffraction. It is unclear under which circumstances retrodiffraction is to be considered and how retrodiffraction is dealt with under favourable conditions.

Agreed interpretation:

Attenuation through retrodiffraction is calculated for every reflection.

The construction of the relevant path length difference δ' is shown in Figure 4 for homogeneous conditions. The upper edge of the reflector is used as fictitious diffraction edge and straight lines are used as ray segments. The resulting path length difference is $\delta'=\overline{S'O}-\overline{S'P}-\overline{PO}$.

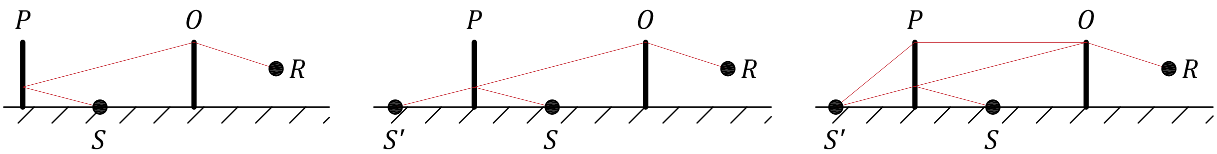

Figure 4 — Example for retrodiffraction under homogeneous conditions

Figure 5 depicts the same situation under favourable conditions. The construction is analogous to the homogeneous case but uses arcs for ray segments, instead of straight lines. In this example, the resulting path length difference becomes $\delta'=\overset{\frown}{S'O}+\overset{\frown}{OR}-\overset{\frown}{S'P}-\overset{\frown}{PR}$.

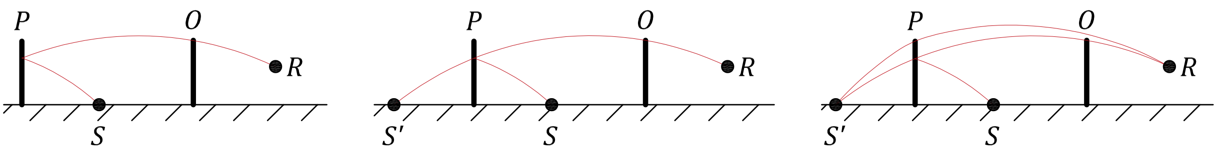

Figure 5 — Example for retrodiffraction under favourable conditions

6 Test cases

6.1 General

The test cases are based on the series proposed with ISO/TR 17534-2, but extended to address special aspects of CNOSSOS-EU:2015. As mentioned in 5.13, diffraction on vertical edges is not described in sufficient detail to be unambiguous in the official documentation. The sentence "Equation (2.5.21) may be used to calculate the diffractions on vertical edges (lateral diffractions) in case of industrial noise" opens many possibilities to treat this issue. According to the general requirements of Quality Assurance in ISO 17534-1 it was necessary to provide a detailed specification – this is given in 5.13 above. Lateral diffraction is restricted to industrial sources and ensures a continuous transition from the screened to the unscreened position when the receiver moves horizontally behind the objects blocking the direct line of sight. Unfortunately, lateral diffraction requires a lot of additional calculation steps.

Independent from the different national specifications (in which cases lateral diffraction is taken into account) lateral diffraction is included in all test cases where it influences the result if the point source is assumed to be an industrial facility, thus allowing for the certification of a correct implementation in all cases. The test cases are complete in the sense that all data necessary to perform the calculations are given.

Intermediate and final results are shown separately for the propagation in the vertical plane and for the propagation around vertical edges – when only road-traffic and railway are of concern, the validation of a quality assured implementation in accordance with ISO 17534-1 can be restricted to the propagation in the vertical plane.

When testing a software implementation, the calculated A-weighted long-term sound pressure levels, referred to as final results, are compared with the reference results given in 6.3 in Table 362 and Table 363. A software implementation of CNOSSOS-EU:2015 is considered quality assured in accordance with ISO 17534-1 if – for all test cases – the deviation of the calculated final results from the reference results does not exceed ±0,1 dB in any octave band. If some of the final results differ too much from the reference results, the implementation is considered flawed. Intermediate results are provided – mostly to two decimal places – to facilitate the necessary search for the deficiency of the implementation. Test results and tolerances are based on experience with calculations made with different software platforms.

Unless stated otherwise, the input parameters shown in Tables 1 and 2 apply to all test cases.

Table 1 — Input parameters identical for all test cases

p %	50
Relative humidity %	70
T °C	10

Table 2 — Linear octave-band sound power levels and A-weighting correction values

Value	Octave-band centre frequency in Hz							
	63	125	250	500	1 000	2 000	4 000	8 000
Sound power level L_W in dB	93	93	93	93	93	93	93	93
A-weighting correction value in dB	−26,2	−16,1	−8,6	−3,2	0,0	1,2	1,0	−1,1

In the Tables containing the parameters of the mean ground plane (MGP) and the heights *z* above this MGP, the two abbreviations z_1 and z_2 are used. Their correspondence to the notation in CNOSSOS-EU: 2015 is shown in Table 3.

Table 3 — Correspondence between z_1 and z_2, used in some Tables such as Table 18, and z_s, $z_{o,s}$, $z_{o,r}$, z_r

	S -> R	S -> O_1	O_n -> R
z_1	z_s	z_s	$z_{o,r}$
z_2	z_r	$z_{o,s}$	z_r

6.2 Test cases with intermediate and final results

6.2.1 TC01-TC03 — Flat ground with homogeneous acoustic properties

The test cases to check free sound propagation with different conditions are shown in Figure 6.

Key

S source

R receiver

Figure 6 — Test cases TC01-TC03 to check free sound propagation with different conditions

With the first three test cases, the correct consideration of the ground factor G is checked. The terrain is flat. Table 4 shows the coordinates of source and receiver which is identical for all three test cases.

Table 4 — Coordinates of source S and receiver R

Point	x (m)	y (m)	z (m)
S	10	10	1
R	200	50	4

6.2.2 TC01 — Reflecting ground (G = 0)

Tables 5 and 6 contain the intermediate and the final results.

Table 5 — Ground attenuation (in frequency bands where no diffraction is relevant)

f in Hz	63	125	250	500	1 000	2 000	4 000	8 000
w (H)[a]	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
C_f (H)	194,16	194,16	194,16	194,16	194,16	194,16	194,16	194,16
$A_{ground,H}$ in dB	-3,00	-3,00	-3,00	-3,00	-3,00	-3,00	-3,00	-3,00
w (F)[b]	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
C_f (F)	194,16	194,16	194,16	194,16	194,16	194,16	194,16	194,16
$A_{ground,F}$ in dB	-4,36	-4,36	-4,36	-4,36	-4,36	-4,36	-4,36	-4,36

[a] (H) – homogeneous

[b] (F) – favourable

Table 6 — Step by step and final results related to the propagation in the vertical plane

f in Hz	**63**	**125**	**250**	**500**	**1 000**	**2 000**	**4 000**	**8 000**	
L_W in dB	93	93	93	93	93	93	93	93	
α_{atm}	0,12	0,41	1,04	1,93	3,66	9,66	32,77	116,88	
A_{atm} in dB	0,02	0,08	0,20	0,37	0,71	1,88	6,36	22,70	
A_{div} in dB	56,76	56,76	56,76	56,76	56,76	56,76	56,76	56,76	
$A_{boundary,H}$ in dB	-3,00	-3,00	-3,00	-3,00	-3,00	-3,00	-3,00	-3,00	
$A_{boundary,F}$ in dB	-4,36	-4,36	-4,36	-4,36	-4,36	-4,36	-4,36	-4,36	**Total**
L_H in dB	39,21	39,16	39,03	38,86	38,53	37,36	32,87	16,54	46,70
L_F in dB	40,58	40,52	40,40	40,23	39,89	38,72	34,24	17,90	48,07
L in dB	39,95	39,89	39,77	39,60	39,26	38,09	33,61	17,27	47,44
A-weighting in dB	-26,2	-16,1	-8,6	-3,2	0,0	1,2	1,0	-1,1	
L_A in dB	13,75	23,79	31,17	36,40	39,26	39,29	34,61	16,17	44,12

6.2.3 TC02 — Mixed ground (G = 0,5)

Tables 7 and 8 contain the intermediate and the final results.

Table 7 — Ground attenuation (in frequency bands where no diffraction is relevant)

f in Hz	**63**	**125**	**250**	**500**	**1 000**	**2 000**	**4 000**	**8 000**
w (H)	8,2E-05	4,5E-04	2,5E-03	0,01	0,08	0,41	2,10	10,13
C_f (H)	199,17	213,44	225,43	134,05	23,76	2,49	0,47	0,10
$A_{ground,H}$ in dB	-1,50	-1,50	-1,50	0,85	5,71	-1,50	-1,50	-1,50
w (F)	0,00	0,00	0,00	0,01	0,08	0,41	2,10	10,13
C_f (F)	199,17	213,44	225,43	134,05	23,76	2,49	0,47	0,10
$A_{ground,F}$ in dB	-2,18	-2,18	-2,18	-2,18	-0,93	-2,18	-2,18	-2,18

Table 8 — Step by step and final results related to the propagation in the vertical plane

f in Hz	**63**	**125**	**250**	**500**	**1 000**	**2 000**	**4 000**	**8 000**
L_W in dB	93	93	93	93	93	93	93	93
α_{atm}	0,12	0,41	1,04	1,93	3,66	9,66	32,77	116,88
A_{atm} in dB	0,02	0,08	0,20	0,37	0,71	1,88	6,36	22,70
A_{div} in dB	56,76	56,76	56,76	56,76	56,76	56,76	56,76	56,76
$A_{boundary,H}$ in dB	-1,50	-1,50	-1,50	0,85	5,71	-1,50	-1,50	-1,50