TECHNICAL REPORT

ISO/TR 17534-3

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Acoustics — Software for the calculation of sound outdoors —

Part 3: Recommendations for quality assured implementation of ISO 9613-2 in software according to ISO 17534-1

Acoustique — Logiciels de prévision de bruit dans l'environnement — PartieParte 3: Recommandations pour l'assurance qualité mise en oeuvre de la norme ISO 9613-2 dans le logiciel selon 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 on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

ISO 17534 consists of the following parts, under the general title *Acoustics — Software for the calculation of sound outdoors*:

— *Part 1: Quality requirements and quality assurance*

— *Part 2: General recommendations for test cases and quality assurance interface* [Technical report]

— *Part 3: Recommendations for quality ensured implementation of* ISO 9613-2 *in software according to* ISO 17534-1 [Technical report]

Introduction

The general structure of the ISO 17534 series and the various Technical Reports are shown in Figure 1. The International Standard itself describes the measures necessary to ensure a high quality of calculation methods implemented in different software products with respect to correctness and precision. The requirements and specifications included are obviously independent from a specific calculation method, because they should be applied for all of them.

This Technical Report contains additional recommendations, test cases of both types according to ISO 17534-1:—, A.2 and A.3, and the forms to declare conformity by software manufacturers related to the quality ensured implementation of the calculation method ISO 9613-2. The test cases are based on the set of test cases and input parameters documented in Reference [1]. This Technical Report is a first step. Contents will be supplemented step by step and or even withdrawn if a standardization committee responsible for this specific calculation method decides about an alternative formulation that is in agreement with the requirements of ISO 17534.

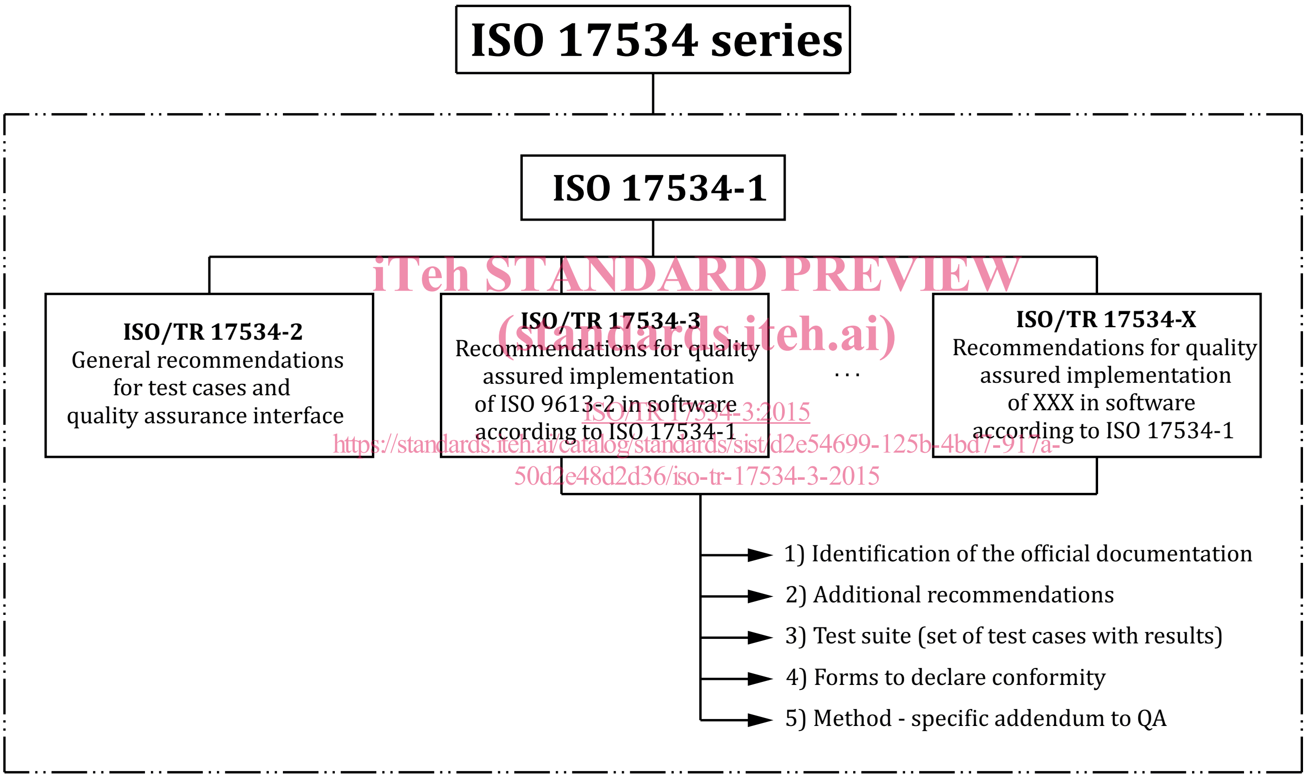


Figure 1 — Structure of ISO 17534 series consisting of the main Part 1 and subordinated Technical Reports

Acoustics — Software for the calculation of sound outdoors —

Part 3: Recommendations for quality assured implementation of ISO 9613-2 in software according to ISO 17534-1

1 Scope

This Technical Report contains additional recommendations for the calculation method of ISO 9613-2 that are agreed on to be implemented in software quality ensured test cases with detailed results that allow checking the correct implementation and forms to declare conformity with these requirements by a specified software product.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9613-2:1996, *Acoustics — Attenuation of sound during propagation outdoors — Part 2: General method of calculation*

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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9613-2, ISO 17534-1, and ISO/TR 17534-2 apply.

4 Identification of the official documentation

ISO 9613-2:1996, *Acoustics — Attenuation of sound during propagation outdoors — Part 2: General method of calculation*.

NOTE ISO 9613-2 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. The method predicts the equivalent continuous A-weighted sound pressure level (as described in ISO 1996) under meteorological conditions.

5 Additional recommendations

5.1 General

The calculation of sound propagation with the engineering method specified in ISO 9613-2 is an approximation where the sound wave propagating over a structured terrain with any complexity is replaced by some few ray paths. In many cases, there are more alternatives to define these paths and for each of these alternatives examples can be constructed where the method fails. It is important to keep the method as transparent as possible to be able to avoid the resulting traps in modelling. Therefore, the additional rules defined herein are kept to a minimum, to ensure a common interpretation of ISO 9613-2 to reduce uncertainty in the calculations. These rules are based on experience with various software implementations, and have been agreed upon to maintain consistency in results.

The obviousness of additional recommendations is explained in the following by introductory notes in 5.2 up to 5.9. Furthermore, each of these additional recommendations is classified.

— **A: A**greed solution for a problem incompletely or even not addressed in ISO 9613-2:1996

— **B: B**etter and consistent solution for a problem inconsistently or unsatisfactorily treated in ISO 9613-2:1996

— **C: C**ommon interpretation of an unclear content of ISO 9613-2:1996.

5.2 Screening

NOTE The calculation of screening (A_{bar}), as described in ISO 9613-2, takes into account diffraction over the top edge(s) and lateral diffraction around the vertical edge(s). The calculation is based on the difference of the path length of the ray over or around the barrier edges and the shortest distance source–receiver neglecting the blocking objects (direct ray).

The ray over the upper edge can be constructed as the shortest possible polygon line source – edge – receiver in a vertical plane containing source and receiver similar to a rubber band connecting these two points. In the same way, the rays around the two vertical edges can be constructed as the shortest polygon lines around these edges in a further plane perpendicular to the vertical plane and also containing source and receiver positions.

This construction of the relevant ray paths in two perpendicular planes is equivalent to Formula (16) in ISO 9613-2, in the case of a right angle between the line source – receiver and the screen.

However, according to ISO 9613-2:1996, the calculation of the path-length difference z over the upper edge(s) shall generally and with any orientation of the line source – receiver relative to the screen be performed with ISO 9613-2:1996, Formula (16) for single diffraction and ISO 9613-2:1996, Formula (17) for double diffraction, where a component distance “a” parallel to the barrier edge between source and receiver is one of the input parameters. But with double diffraction, the method fails and is even not applicable in general cases where the two diffracting edges are not parallel, because a single component distance parallel to the barrier edge between source and receiver cannot be defined. For more diffracting edges, the two most effective barriers are taken to reduce the problem to the case of double diffraction; therefore, the general case of more than two diffractions is also not applicable.

However, the described rubber band construction of the relevant ray paths in two planes identical with the method of ISO 9613-2, in case of a single diffraction and with a right angle between the line source - receiver and the screen, can consistently be extended to the most general case of any number and orientation of diffracting edges. This is the recommended alternative method to overcome the described problem as long as it is not solved generally in a revised version of ISO 9613-2.

Lateral diffraction for more than one screening object blocking the direct ray source – receiver is not explicitly mentioned in ISO 9613-2. The recommended method to solve this frequently occurring problem is a consistent extension of the lateral diffraction with one barrier as long as it is not solved generally in a revised version of ISO 9613-2.

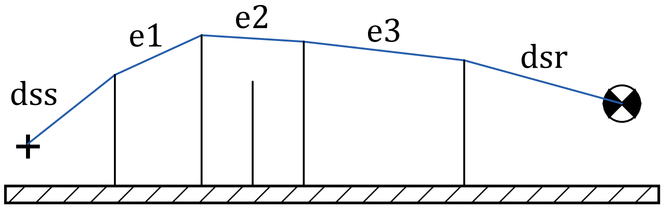
If acoustically impervious objects like barriers or buildings are blocking the direct straight line from source to receiver, three contributing ray paths should be taken into account in the most general case; one over top and two laterally diffracted around the objects. The ray over top is constructed in a vertical plane EV, the lateral diffracted rays in a plane EL. Both planes contain source and receiver, plane EV is perpendicular to the reference plane x-y and plane EL is perpendicular to plane EV.

The ray path in plane EV connects source and receiver like a ribbon enveloping the diffracting edges as shown in Figure 2.

It is obvious that in plane EL, the two ray paths transmitting most sound energy to the receiver should be taken into account. In many cases, these are the shortest possible ray paths left and right from the direct path S-R. Figure 3 shows such a clear example without ambiguity. However, it should be mentioned that there are more complex cases where the shortest paths form a zig-zag-line or even where not the shortest paths are the most important ones. A common strategy will be developed and included in further revisions.

Lateral diffraction paths are neglected if the maximal distance of one or more diffracting edges contributing to the ribbon from the straight line source – receiver exceeds this maximal distance in the plane EV by a factor more than 8.

The path length difference, *z*, of each of these relevant contributions is the difference in length of the ribbon and the straight direct line from source to receiver. The length of the polygon-segments between the first and the last diffracting edge is the parameter *e* needed in ISO 9613-2:1996, Formula (15).



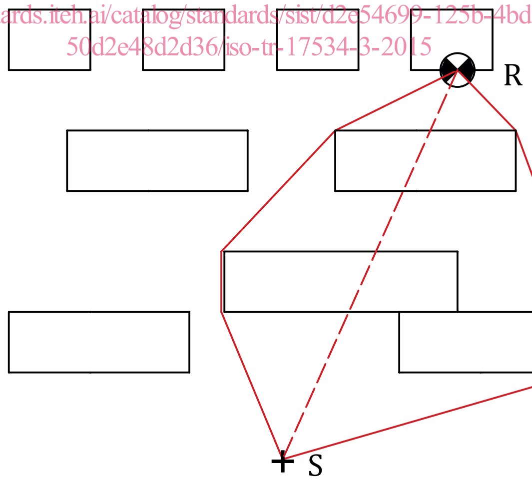
Key

dss polygon-segment from source to the first active diffraction edge

dsr polygon-segment from the last active diffraction edge to the receiver

e1…*en* polygon-segment between two following active diffraction edges

Figure 2 — The calculation ray in plane EV



Key

R receiver

S source

Figure 3 — The two calculation rays in plane EL

Classification of this additional recommendation: A, B.

5.3 Limitation of the maximal possible attenuation by barriers

According to ISO 9613-2:1996 “the barrier attenuation D_z, in any octave band, should not be taken to be greater than 20 dB in the case of single diffraction and 25 dB in the case of double diffraction”. The reason for this limitation is that the level behind screens and other objects can be determined by other ray paths caused for instance by reflections. However, it was obviously overseen that D_z is not only calculated for the diffraction over the upper edge, but also for the lateral diffraction around the vertical edges. A limitation of all three contributions will result in an effective limitation of the barrier attenuation of 15 dB with a single screen. On the other side, the contribution of a lateral diffraction should vanish if an object like a barrier is long and the vertical edges are far away from the receiver. Therefore, it should be the recommended interpretation of ISO 9613-2 to apply this limitation of D_z only for the diffraction over the top edge.

The restriction of D_z, not to be taken greater than 20 dB in the case of single diffraction and 25 dB in the case of double diffraction in any octave band, should only be applied for diffraction over the upper edges.

Classification of this additional recommendation: C.

5.4 Calculation of the path-length difference, *z*

NOTE D_z is calculated in ISO 9613-2:1996, Formula (14) as 10 times the logarithm of an expression that depends on the path-length difference z, where z is given a negative sign if the ray source – receiver passes above the top edge. Therefore, increasing the height of source and/or receiver will result in a reduced barrier attenuation and with a certain height of the ray above the top edge this barrier, attenuation will be 0. Increasing the height more will result in an argument of the logarithm that falls even below 1; the resulting D_z will be negative producing an apparent increase of the level behind a barrier over the value without the barrier. As this was obviously overseen when this equation was designed and due to the very simple improvement solving this problem, the calculation of D_z according to ISO 9613-2:1996, Formula (14) is recommended in two steps.

Formula (14) of ISO 9613-2:1996 should be applied stepwise.

a) $$z_{\min} = \frac{-2\lambda}{(C_2 C_3 K_{\text{met}})}$$

b) $$D_z = \begin{cases} 10 \lg \left[3 + \left(\frac{C_2}{\lambda} \right) C_3 z K_{\text{met}} \right] \text{dB} & \text{for } z > z_{\min} \\ 0 & \text{for } z \le z_{\min} \end{cases}$$

Classification of this additional recommendation: B.

5.5 Diffraction with barrier on reflecting ground

The diffraction over the top edge is calculated with ISO 9613-2:1996, Formula (12) with $A_{\text{bar}} = D_z - A_{\text{gr}} > 0$. The method should take into account that the height of the effective ray path will be increased by the barrier and therefore the influence of the ground will be reduced. But with reflecting ground A_{gr} is negative (−3 dB) and therefore the installation of a barrier with even very low height will remove the ground effect and dupe a barrier attenuation of 3 dB.

Formula (12) of ISO 9613-2:1996 should not be applied with $A_{\text{gr}} < 0$.

Classification of this additional recommendation: B.

5.6 No level increase caused by barriers due to lateral diffraction

NOTE In software realizations, the combination of ground simulated by contour lines or grids of height points with objects can, in rare cases, cause a level increase behind elevated ground if a screening object is inserted due to lateral diffraction. This can easily be avoided by a simple strategy.

If the direct ray is screened, the three barrier attenuations $A_{bar,top}$, $A_{bar,side1}$, and $A_{bar,side2}$ and an effective value

$$A_{bar} = -10 \lg \left(10^{-0,1 A_{bar,top}} + 10^{-0,1 A_{bar,side1}} + 10^{-0,1 A_{bar,side2}} \right) \text{ dB}$$

should be calculated. If the result of this equation is negative, the effective A_{bar} is 0.

Classification of this additional recommendation: B.

5.7 No ground effect calculated with rays laterally diffracted

NOTE In ISO 9613-2, the determination of the ground effect A_{gr} and of the barrier attenuation A_{bar} are independent parts carried out consecutively. The lateral diffraction is not equivalent to the calculation of additional contributions with their own ground influence, but produces a modification of the barrier attenuation between source and receiver. This is not unambiguously expressed in ISO 9613-2 and can, therefore, in some cases, cause different interpretations. This can be avoided by a simple clarification.

The ground effect A_{gr} in ISO 9613-2:1996, 7.3 is determined for each pair of source-receiver from the path in the vertical plane EV; the paths of lateral diffracted sound in plane EL are not considered.

Classification of this additional recommendation: C.

5.8 No lateral diffraction with elevated ground screening the direct ray

The screening by elevated ground is not explicitly mentioned in ISO 9613-2 but can be solved by treating a contour line or a triangulation line forming the ground surface like the top edge of a barrier. However, lateral diffraction around hills or other elevated parts of the ground is not covered by the method described for barriers. Taking into account that the profile of such formations is generally not bounded by vertical edges, lateral diffraction should not be taken into account in such cases. This should be clarified unambiguously to avoid different interpretations.

If at least one contour line of the ground is relevant for the screening and influences the shape of the rubber band from source to receiver, lateral diffraction is not calculated.

Classification of this additional recommendation: C.

5.9 Multi-reflection – the extension to reflections of higher orders

ISO 9613-2 describes the calculation of specular reflections based on the method of mirror image sources. The application of the method to calculate the contribution of even higher order reflections is not explicitly mentioned, but a trivial extension by repeating the procedure with these mirror images. Taking into account the broad application of ISO 9613-2 with industrial noise and in other fields of noise prediction, this extension should be integrated explicitly.

The n^{th} order image source Scn is the image of the image source Scn-1. The construction of the real ray path of a second order reflection is shown in Figure 4.

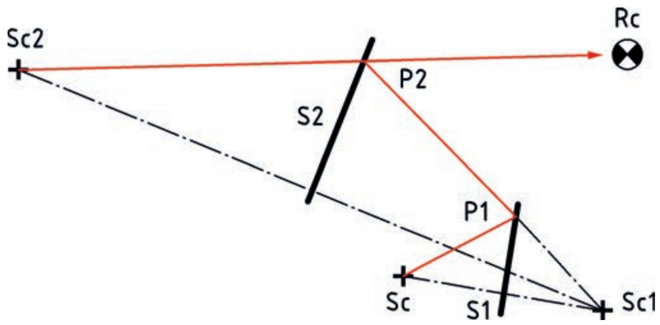


Figure 4 — Example to explain the construction of a 2nd order reflection with image sources Sc1 and Sc2

Classification of this additional recommendation: A.

6 Test cases

6.1 General

The test cases are complete in the sense that all data necessary to perform the calculation are given.

For the precisely defined test cases, the step-by-step results are shown with precision 2 according to ISO 17534-1:—, A.2.

Test cases T01 up to T07 can be solved by applying ISO 9613-2 exclusively. Test cases T08 up to T19 are based on ISO 9613-2 and the application of additional recommendations according to 5.2 up to 5.9.

6.2 Test cases with step by step results and final result interval

6.2.1 T01-T03 – Flat ground with homogeneous acoustic properties

Key

S source

R receiver

Figure 5 — Test case to check free sound propagation with different conditions

Input data:

Table 1 — Coordinates of source, S, and receiver, R

	x in m	*y* in m	*z* in m
S	10	10	1
R	200	50	4

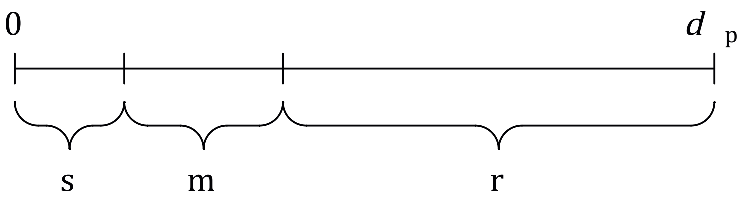
Table 2 — Octave-band sound power levels (linear) of the source

Quantity	Unit	Values							
f	Hz	63	125	250	500	1 000	2 000	4 000	8 000
L_W	dB	93	93	93	93	93	93	93	93

The band levels and the A-weighted sound pressure level at the receiver should be calculated for $T = 20°C$ and $F = 70$ %.

6.2.2 T01 – Reflecting ground ($G = 0$)

Step by step results:



Key

s source region

m middle region

r receiver region

d_p 2-dimensional distance

Figure 6 — Regions according to Figure 1 in ISO 9613-2

Table 3 — Single number step by step results

Quantity	Unit	Values
d_p (2-dimensional distance)	m	194,16
d_3 (3-dimensional distance)	m	194,19
A_{div}	dB	56,76
length of s-region	m	30,00
length of r-region	m	120,00
length of m-region	m	44,16
q (ISO 9613-2:1996, Table 3 footnote 2)		0,23

Table 4 — Spectral step by step results

Quantity	Unit	Values								
f	Hz	63	125	250	500	1 000	2 000	4 000	8 000	
L_W	dB	93	93	93	93	93	93	93	93	
α-atm(20°,70 %)		0,1	0,3	1,1	2,8	5,0	9,0	22,9	76,6	
A_{atm}	dB	0,02	0,06	0,21	0,54	0,97	1,75	4,45	14,87	
A_{gr_s}	dB	−1,50	−1,50	−1,50	−1,50	−1,50	−1,50	−1,50	−1,50	
A_{gr_r}	dB	−1,50	−1,50	−1,50	−1,50	−1,50	−1,50	−1,50	−1,50	
A_{gr_m}	dB	−0,68	−0,68	−0,68	−0,68	−0,68	−0,68	−0,68	−0,68	
A_{gr}	dB	−3,68	−3,68	−3,68	−3,68	−3,68	−3,68	−3,68	−3,68	
A_{div}	dB	56,76	56,76	56,76	56,76	56,76	56,76	56,76	56,76	**Total**
L	dB	39,90	39,86	39,70	39,37	38,95	38,17	35,47	25,04	47,46
A-weighting	dB	−26,2	−16,1	−8,6	−3,2	0,0	1,2	1,0	−1,1	
L_A[a]	dB	**13,70**	**23,76**	**31,10**	**36,17**	**38,95**	**39,37**	**36,47**	**23,94**	**44,29**

[a] The result values in frequency bands and for the total level are considered to be correct if the deviation does not exceed ±0,05 dB.

6.2.3 T02 – Mixed ground (G = 0,5)

Input data:

Identical to above, but ground index G = 0,5.

Step by step results:

Single number step by step results see Table 3.

Table 5 — Spectral step by step results

Quantity	Unit	Values								
f	Hz	63	125	250	500	1 000	2 000	4 000	8 000	
L_W	dB	93	93	93	93	93	93	93	93	
α-atm (20°,70 %)		0,1	0,3	1,1	2,8	5,0	9,0	22,9	76,6	
A_{atm}	dB	0,02	0,06	0,21	0,54	0,97	1,75	4,45	14,87	
A_{gr_s}	dB	−1,50	−0,27	3,10	3,58	0,25	−0,75	−0,75	−0,75	
A_{gr_r}	dB	−1,50	0,62	0,25	−0,75	−0,75	−0,75	−0,75	−0,75	
A_{gr_m}	dB	−0,68	−0,34	−0,34	−0,34	−0,34	−0,34	−0,34	−0,34	
A_{gr}	dB	−3,68	0,01	3,01	2,49	−0,85	−1,84	−1,84	−1,84	
A_{div}	dB	56,76	56,76	56,76	56,76	56,76	56,76	56,76	56,76	**Total**
L	dB	39,90	36,17	33,02	33,20	36,11	36,33	33,63	23,20	44,61
A-weighting	dB	−26,2	−16,1	−8,6	−3,2	0,0	1,2	1,0	−1,1	
L_A[a]	dB	**13,70**	**20,07**	**24,42**	**30,00**	**36,11**	**37,53**	**34,63**	**22,10**	**41,53**

[a] The result values in frequency bands and for the total level are considered to be correct if the deviation does not exceed ±0,05 dB.

6.2.4 T03 – Porous ground (G = 1)

Input data:

Identical to above, but ground index G = 1.

Step by step results:

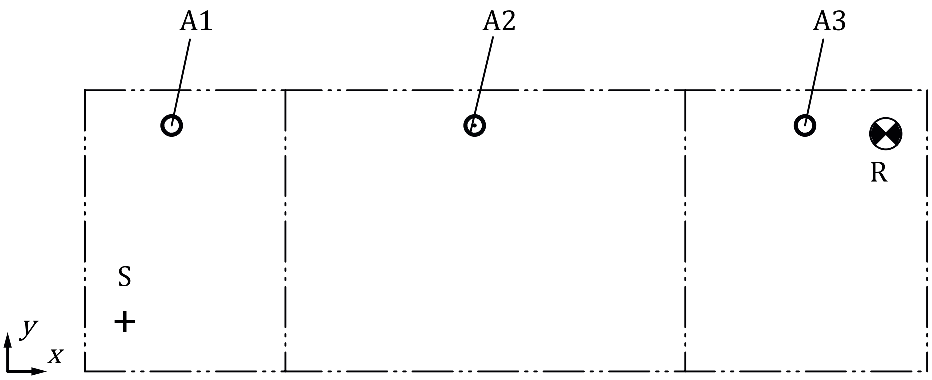
Single number step by step results see Table 3.

Table 6 — Spectral step by step results

Quantity	Unit	Values								
f	Hz	63	125	250	500	1 000	2 000	4 000	8 000	
L_W	dB	93	93	93	93	93	93	93	93	
α-atm (20°,70 %)		0,1	0,3	1,1	2,8	5,0	9,0	22,9	76,6	
A_{atm}	dB	0,02	0,06	0,21	0,54	0,97	1,75	4,45	14,87	
A_{gr_s}	dB	−1,50	0,95	7,70	8,66	1,99	0,00	0,00	0,00	
A_{gr_r}	dB	−1,50	2,74	2,00	0,01	0,00	0,00	0,00	0,00	
A_{gr_m}	dB	−0,68	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
A_{gr}	dB	−3,68	3,69	9,69	8,66	1,99	0,00	0,00	0,00	
A_{div}	dB	56,76	56,76	56,76	56,76	56,76	56,76	56,76	56,76	**Total**
L	dB	39,90	32,48	26,33	27,03	33,27	34,49	31,79	21,36	42,80
A-weighting	dB	−26,2	−16,1	−8,6	−3,2	0,0	1,2	1,0	−1,1	
$\boldsymbol{L_A}$[a]	dB	**13,70**	**16,38**	**17,73**	**23,83**	**33,27**	**35,69**	**32,79**	**20,26**	**39,14**

[a] The result values in frequency bands and for the total level are considered to be correct if the deviation does not exceed ±0,05 dB.

6.2.5 T04 – Flat ground with spatially varying acoustic properties



Key

S source
R receiver
A1 area with G = 0,2
A2 area with G = 0,5
A3 area with G = 0,9

Figure 7 — Flat ground with different ground factors G

