
**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 —
Partie 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

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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.

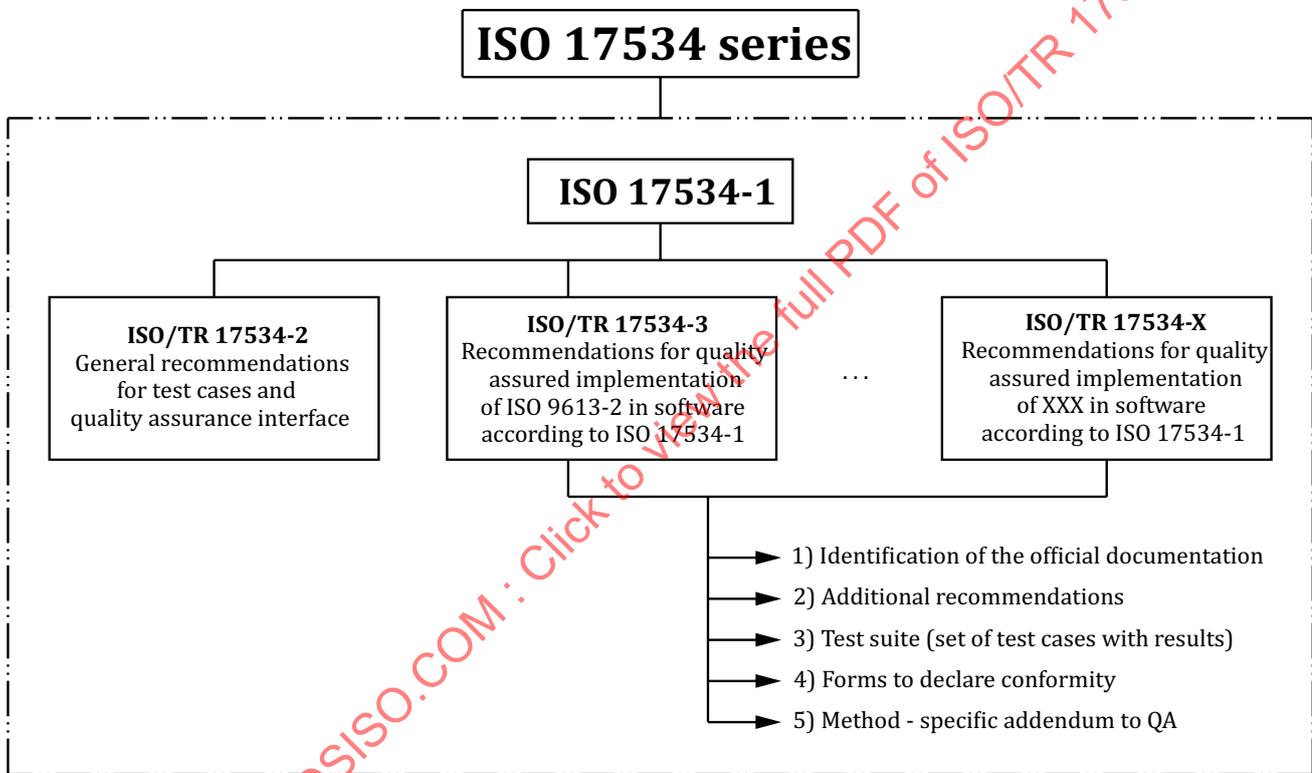


Figure 1 — Structure of ISO 17534 series consisting of the main Part 1 and subordinated Technical Reports

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:** Agreed solution for a problem incompletely or even not addressed in ISO 9613-2:1996
- **B:** Better and consistent solution for a problem inconsistently or unsatisfactorily treated in ISO 9613-2:1996
- **C:** Common 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.

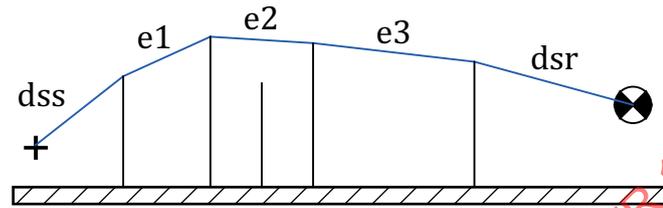
The ray path in plane EV connects source and receiver like a ribbon enveloping the diffracting edges as shown in [Figure 2](#).

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.

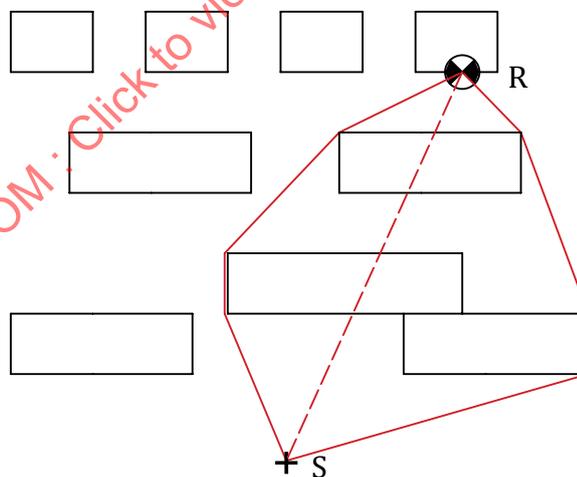
The path length difference, z , of each of these relevant contributions is the difference in length of the ribbon and the straight direct line from source to receiver. The length of the polygon-segments between the first and the last diffracting edge is the parameter e needed in ISO 9613-2:1996, Formula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

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

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

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 $A_{\text{bar,top}}$, $A_{\text{bar,side1}}$, and $A_{\text{bar,side2}}$ and an effective value

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

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 Sc_n is the image of the image source Sc_{n-1} . The construction of the real ray path of a second order reflection is shown in [Figure 4](#).

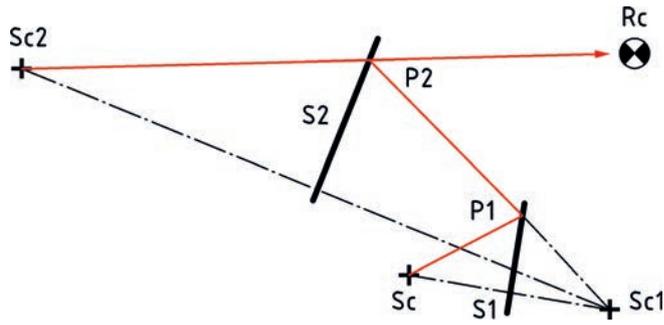


Figure 4 — Example to explain the construction of a 2nd order reflection with image sources Sc1 and Sc2

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



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

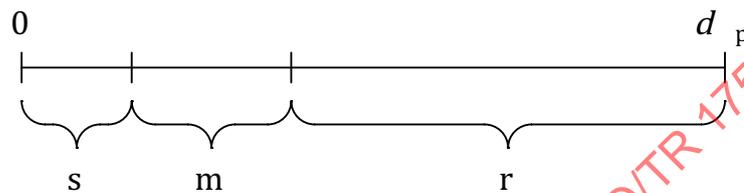
Table 2 — Octave-band sound power levels (linear) of the source

Quantity	Unit	Values							
		63	125	250	500	1 000	2 000	4 000	8 000
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 $T = 20^\circ\text{C}$ 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								
		63	125	250	500	1 000	2 000	4 000	8 000	
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 $\pm 0,05$ 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								
		63	125	250	500	1 000	2 000	4 000	8 000	
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 $\pm 0,05$ dB.

6.2.4 T03 – Porous ground ($G = 1$)

Input data:

Identical to above, but ground index $G = 1$.

Step by step results:

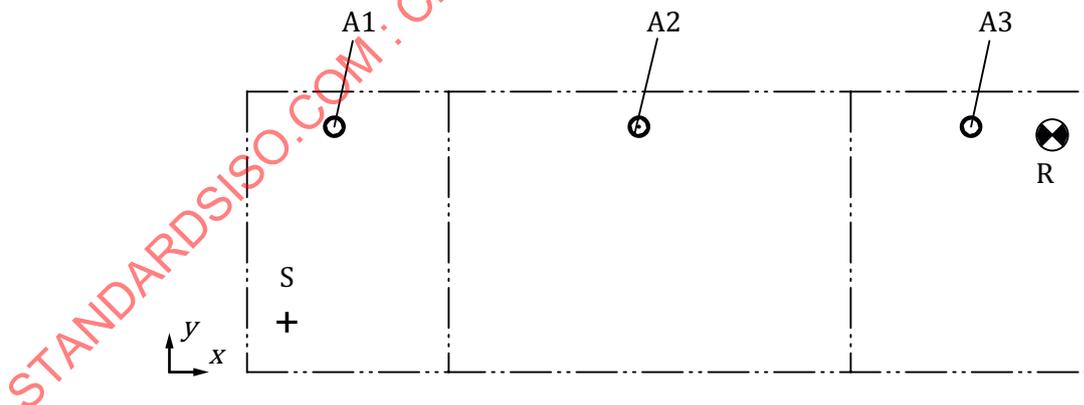
Single number step by step results see [Table 3](#).

Table 6 — Spectral step by step results

Quantity	Unit	Values								
		63	125	250	500	1 000	2 000	4 000	8 000	
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	
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 $\pm 0,05$ 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

Input data:

Identical to above, but ground factors G as shown in [Table 7](#).

Table 7 — Areas with different ground factors G

Area	G	Coordinates of areas							
		x_1 in m	y_1 in m	x_2 in m	y_2 in m	x_3 in m	y_3 in m	x_4 in m	y_4 in m
A1	0,2	0	60	50	60	50	-10	0	-10
A2	0,5	50	60	150	60	150	-10	50	-10
A3	0,9	150	60	210	60	210	-10	150	-10

Step by step results:

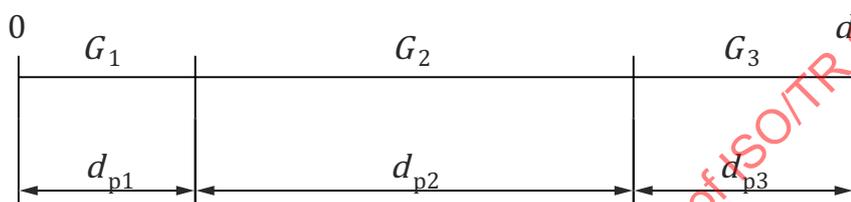


Figure 8 — Segments (ground projection) of propagation path with different ground indices G

Table 8 — Single number step by step results

Quantity	Unit	Value
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
d_{p1} (2d-length of path above ground with G_1)	m	40,88
d_{p2} (2d-length of path above ground with G_2)	m	102,19
d_{p3} (2d-length of path above ground with G_3)	m	51,10
G_s		0,20
G_r		0,67
G_m		0,43

Table 9 — Spectral step by step results

Quantity	Unit	Value								
		63	125	250	500	1 000	2 000	4 000	8 000	
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	-1,01	0,34	0,53	-0,80	-1,20	-1,20	-1,20	
A_{gr_r}	dB	-1,50	1,34	0,84	-0,49	-0,49	-0,49	-0,49	-0,49	
A_{gr_m}	dB	-0,68	-0,39	-0,39	-0,39	-0,39	-0,39	-0,39	-0,39	
A_{gr}	dB	-3,68	-0,06	0,79	-0,35	-1,69	-2,09	-2,09	-2,09	
A_{div}	dB	56,76	56,76	56,76	56,76	56,76	56,76	56,76	56,76	Total
L	dB	39,90	36,24	35,23	36,04	36,95	36,57	33,87	23,45	45,25
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	20,14	26,63	32,84	36,95	37,77	34,87	22,35	42,23

^a The result values in frequency bands and for the total level are considered to be correct if the deviation does not exceed $\pm 0,05$ dB.

6.2.6 T05 - Identical to T04, but calculation with the alternative method according to ISO 9613-2:1996, 7.3.2

Input data:

Identical to T04.

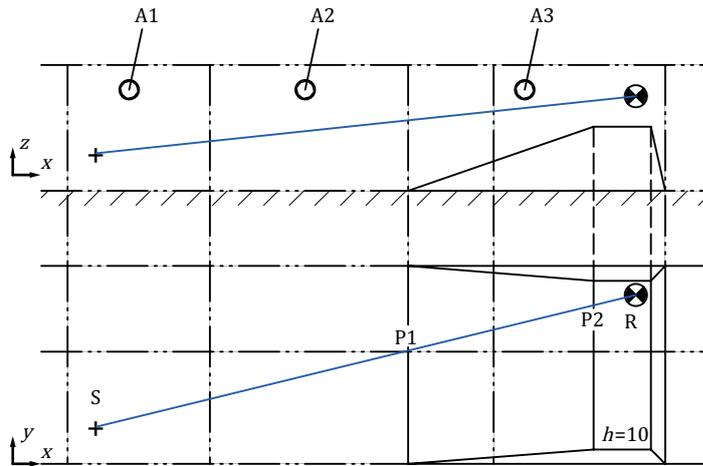
Step by step results:

Table 10 — Spectral step by step results

Quantity	Unit	Value								
		63	125	250	500	1 000	2 000	4 000	8 000	
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}	dB	4,32	4,32	4,32	4,32	4,32	4,32	4,32	4,32	
D_Ω	dB	3,01	3,01	3,01	3,01	3,01	3,01	3,01	3,01	
A_{div}	dB	56,76	56,76	56,76	56,76	56,76	56,76	56,76	56,76	Total
L	dB	34,90	34,86	34,71	34,38	33,95	33,17	30,48	20,05	42,46
A-weighting	dB	-26,2	-16,1	-8,6	-3,2	0,0	1,2	1,0	-1,1	
L_A^a	dB	8,70	18,76	26,11	31,18	33,95	34,37	31,48	18,95	39,30

^a The result values in frequency bands and for the total level are considered to be correct if the deviation does not exceed $\pm 0,05$ dB.

6.2.7 T06 – Ground with spatially varying heights and acoustic properties



Key

- S source
- R receiver
- P1 relevant point 1
- P2 relevant point 2
- A1 area with $G = 0,9$
- A2 area with $G = 0,5$
- A3 area with $G = 0,2$

Figure 9 — Ground with spatially varying heights and acoustic properties

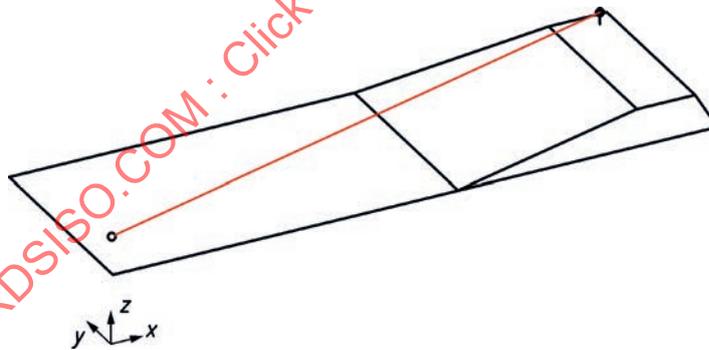


Figure 10 — 3D-presentation of scenario T06

Input data:

For source and receiver positions and emission spectrum see previous cases. Coordinates z for source and receiver are relative heights (height above ground).

Table 11 — Areas with different ground factors G

Area	Ground	Coordinates of areas							
		x_1 in m	y_1 in m	x_2 in m	y_2 in m	x_3 in m	y_3 in m	x_4 in m	y_4 in m
A1	0,9	0	60	50	60	50	-10	0	-10
A2	0,5	50	60	150	60	150	-10	50	-10
A3	0,2	150	60	210	60	210	-10	150	-10

Table 12 — Contour lines (rectangular areas)

z in m	x in m		y in m	
	min	max	min	max
0	0	120	-10	60
0	120	210	-10	60
10	185	205	-5	55

The band levels and the A-weighted sound pressure level at the receiver are calculated for $T = 20\text{ °C}$ and $F = 70\%$.

Step by step results:

Table 13 — Geometry of the ray path

Point	x in m	y in m	z_{abs} in m	z_{rel} in m
S	10,00	10,00	1,00	1,00
P1	120,00	33,16	8,53	8,53
P2	185,00	46,84	12,97	2,97
R	200,00	50,00	14,00	4,00

Table 14 — Single number step by step results

Quantity	Unit	Value
d_p (2-dimensional distance)	m	194,16
d_3 (3-dimensional distance)	m	194,60
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
d_{p1} (2d-length of path above ground with G1)	m	40,88
d_{p2} (2d-length of path above ground with G2)	m	102,19
d_{p3} (2d-length of path above ground with G3)	m	51,10
G_s		0,90
G_r		0,37
G_m		0,60

Table 15 — Spectral step by step results

Quantity	Unit	Value								
		63	125	250	500	1 000	2 000	4 000	8 000	
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	4,46	14,91	
a', b', c', d' for s		—	2,45	9,20	10,16	3,49	—	—	—	
A_{gr_s}	dB	-1,50	0,71	6,78	7,64	1,64	-0,15	-0,15	-0,15	
a', b', c', d' for r		—	4,24	3,50	1,51	1,50	—	—	—	
A_{gr_r}	dB	-1,50	0,08	-0,20	-0,94	-0,94	-0,94	-0,94	-0,94	
A_{gr_m}	dB	-0,68	-0,27	-0,27	-0,27	-0,27	-0,27	-0,27	-0,27	
A_{gr}	dB	-3,68	0,51	6,31	6,43	0,43	-1,37	-1,37	-1,37	
A_{div}	dB	56,78	56,78	56,78	56,78	56,78	56,78	56,78	56,78	Total
L	dB	39,88	35,65	29,70	29,24	34,82	35,83	33,13	22,68	43,85
A-weighting	dB	-26,2	-16,1	-8,6	-3,2	0,0	1,2	1,0	-1,1	
L_A^a	dB	13,68	19,55	21,10	26,04	34,82	37,03	34,13	21,58	40,59

NOTE Where a cell's value is not relevant, the input in the cell is "—".

^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.

6.2.8 T07 – Identical to T06, but calculation with the alternative method according to ISO 9613-2:1996, 7.3.2

Table 16 — Geometry of the ray path

Point	x in m	y in m	z_{abs} in m	z_{rel} in m
S	10,00	10,00	1,00	1,00
P1	120,00	33,16	8,53	8,53
P2	185,00	46,84	12,97	2,97
R	200,00	50,00	14,00	4,00

Table 17 — Single number results

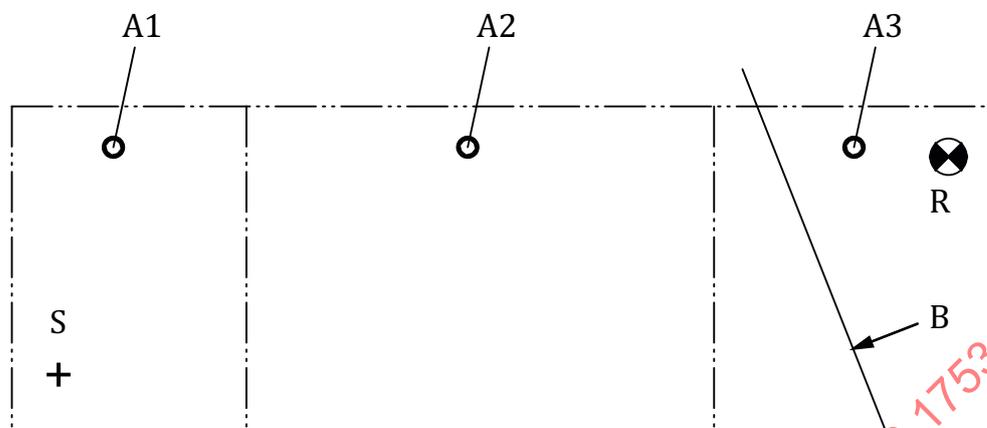
Quantity	Unit	Value
d_3	m	194,60
h_m	m	4,99

Table 18 — Spectral step by step results

Quantity	Unit	Values								
		63	125	250	500	1 000	2 000	4 000	8 000	
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	
$\alpha\text{-atm}(20^\circ, 70\%)$		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	4,46	14,91	
A_{gr}	dB	3,85	3,85	3,85	3,85	3,85	3,85	3,85	3,85	
D_Ω	dB	3,01	3,01	3,01	3,01	3,01	3,01	3,01	3,01	
A_{div}	dB	56,78	56,78	56,78	56,78	56,78	56,78	56,78	56,78	Total
L	dB	35,36	35,32	35,16	34,83	34,40	33,62	30,92	20,47	42,91
A-weighting	dB	-26,2	-16,1	-8,6	-3,2	0,0	1,2	1,0	-1,1	
L_A^a	dB	9,16	19,22	26,56	31,63	34,40	34,82	31,92	19,37	39,75

^a The result values in frequency bands and for the total level are considered to be correct if the deviation does not exceed $\pm 0,05$ dB.

6.2.9 T08 – Flat ground with spatially varying acoustic properties and long barrier



Key

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

Figure 11 — Areas with different ground factors and long barrier

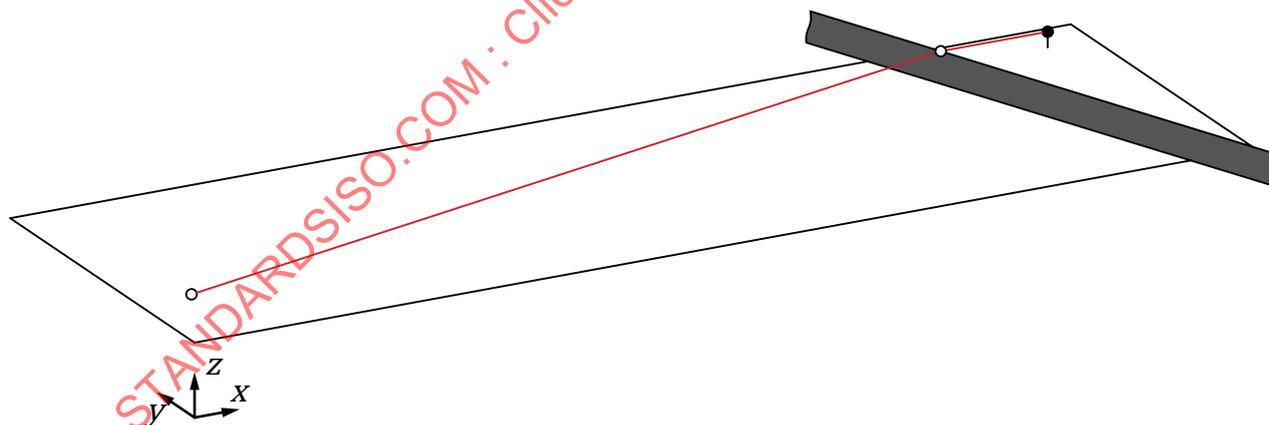


Figure 12 — 3D-presentation of scenario T08

Input data:

Source and receiver coordinates – [Table 1](#) (Test case T01).

Source emission frequency spectrum – [Table 2](#) (Test case T01).

Areas with different ground factors G – [Table 11](#) (Test case T06).

Table 19 — Barrier geometry

Upper edge	x in m	y in m	z in m
S1	100,0	240,0	6,0
S2	265,0	-180,0	6,0

Step by step results:

Table 20 — Single number step by step results

Quantity	Unit	Value
d_p (2-dimensional distance)	m	194,16
d_3 (3-dimensional distance)	m	194,19
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 1)		0,23
d_{p1} (2d-length of path above ground with G1)	m	40,88
d_{p2} (2d-length of path above ground with G2)	m	102,19
d_{p3} (2d-length of path above ground with G3)	m	51,10
G_s		0,90
G_r		0,37
G_m		0,60

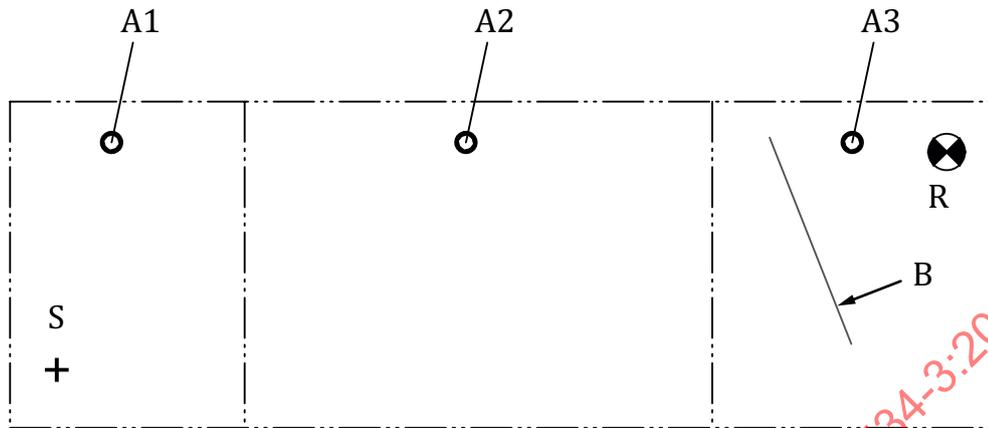
Table 21 — Spectral step by step results

Quantity	Unit	Values								
		63	125	250	500	1 000	2 000	4 000	8 000	
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', b', c', d' for s		—	2,45	9,20	10,16	3,49	—	—	—	
$A_{gr,s}$	dB	-1,50	0,71	6,78	7,64	1,64	-0,15	-0,15	-0,15	
a', b', c', d' for r		—	4,24	3,50	1,51	1,50	—	—	—	
$A_{gr,r}$	dB	-1,50	0,08	-0,20	-0,94	-0,94	-0,94	-0,94	-0,94	
$A_{gr,m}$	dB	-0,68	-0,27	-0,27	-0,27	-0,27	-0,27	-0,27	-0,27	
A_{gr}	dB	-3,68	0,51	6,31	6,43	0,43	-1,37	-1,37	-1,37	
D_z (top edge)	dB	5,06	5,33	5,83	6,68	8,01	9,84	12,12	14,71	
D_z (edge1)	dB	29,94	32,94	35,95	38,96	41,97	44,98	47,99	51,00	
D_z (edge2)	dB	31,26	34,27	37,27	40,28	43,29	46,30	49,31	52,32	
A_{bar} (top edge)	dB	5,06	4,82	0,00	0,26	7,58	9,84	12,12	14,71	
A_{bar} (edge1)	dB	29,94	32,94	35,95	38,96	41,97	44,98	47,99	51,00	
A_{bar} (edge2)	dB	31,26	34,27	37,27	40,28	43,29	46,30	49,31	52,32	
A_{bar}	dB	5,04	4,81	0,00	0,26	7,58	9,84	12,12	14,71	
A_{div}	dB	56,76	56,76	56,76	56,76	56,76	56,76	56,76	56,76	Total
L	dB	34,86	30,85	29,72	29,01	27,26	26,01	21,04	8,02	38,50
A-weighting	dB	-26,2	-16,1	-8,6	-3,2	0,0	1,2	1,0	-1,1	
L_A^a	dB	8,66	14,75	21,12	25,81	27,26	27,21	22,04	6,92	32,48

NOTE Where a cell's value is not relevant, the input in the cell is “—”.

^a The result values in frequency bands and for the total level are considered to be correct if the deviation does not exceed $\pm 0,05$ dB.

6.2.10 T09 – Flat ground with spatially varying acoustic properties and short barrier



Key

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

Figure 13 — Areas with different ground factors G and short barrier

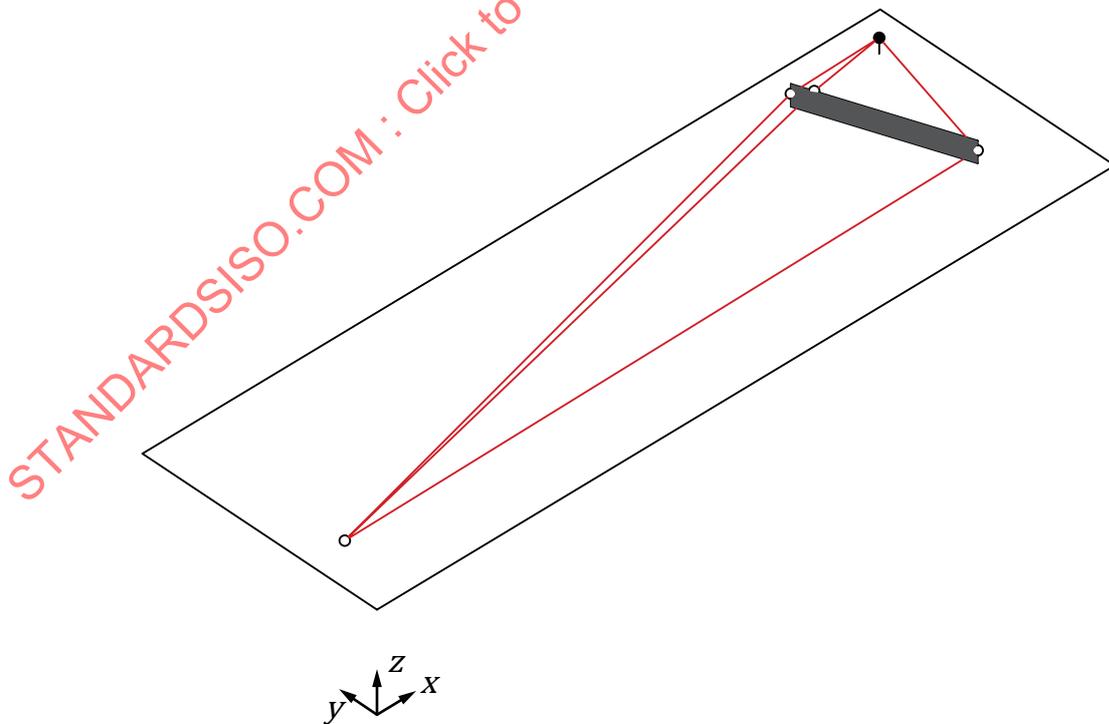


Figure 14 — 3D-presentation of scenario T09

Input data:

Source and receiver coordinates – [Table 1](#) (Test case T01).

Source emission frequency spectrum – [Table 2](#) (Test case T01).

Areas with different ground factors G – [Table 11](#) (Test case T06).

Table 22 — Barrier geometry

Upper edge	x in m	y in m	z in m
S1	175,0	50,0	6,0
S2	190,0	10,0	6,0

Step by step results:

Single number step by step results – [Table 20](#).

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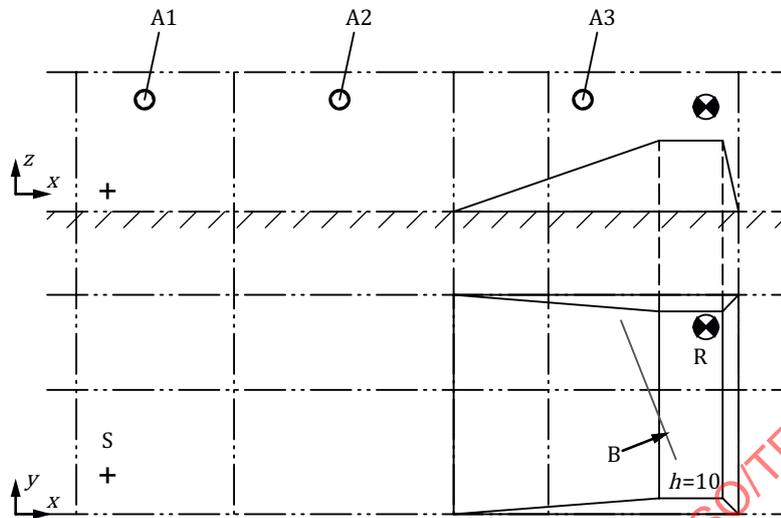
Table 23 — Spectral step by step results

Quantity	Unit	Values								
		63	125	250	500	1 000	2 000	4 000	8 000	
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', b', c', d' for s		—	2,45	9,20	10,16	3,49	—	—	—	
A_{gr_s}	dB	-1,50	0,71	6,78	7,64	1,64	-0,15	-0,15	-0,15	
a', b', c', d' for r		—	4,24	3,50	1,51	1,50	—	—	—	
A_{gr_r}	dB	-1,50	0,08	-0,20	-0,94	-0,94	-0,94	-0,94	-0,94	
A_{gr_m}	dB	-0,68	-0,27	-0,27	-0,27	-0,27	-0,27	-0,27	-0,27	
A_{gr}	dB	-3,68	0,51	6,31	6,43	0,43	-1,37	-1,37	-1,37	
D_z (top edge)	dB	5,07	5,34	5,84	6,70	8,04	9,88	12,16	14,76	
D_z (edge1)	dB	7,21	8,76	10,80	13,24	15,93	18,77	21,69	24,66	
D_z (edge2)	dB	20,11	23,05	26,03	29,03	32,03	35,03	38,04	41,05	
A_{bar} (top edge)	dB	5,07	4,83	0,00	0,28	7,61	9,88	12,16	14,76	
A_{bar} (edge1)	dB	7,21	8,76	10,80	13,24	15,93	18,77	21,69	24,66	
A_{bar} (edge2)	dB	20,11	23,05	26,03	29,03	32,03	35,03	38,04	41,05	
A_{bar}	dB	2,91	3,31	0,00	0,06	7,00	9,34	11,69	14,32	
A_{div}	dB	56,76	56,76	56,76	56,76	56,76	56,76	56,76	56,76	Total
L	dB	36,99	32,36	29,72	29,21	27,84	26,51	21,46	8,40	39,86
A-weighting	dB	-26,2	-16,1	-8,6	-3,2	0,0	1,2	1,0	-1,1	
L_A^a	dB	10,79	16,26	21,12	26,01	27,84	27,71	22,46	7,30	32,93

NOTE Where a cell's value is not relevant, the input in the cell is "—".

^a The result values in frequency bands and for the total level are considered to be correct if the deviation does not exceed $\pm 0,05$ dB.

6.2.11 T10 – Ground with spatially varying heights and acoustic properties and short barrier



Key

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

Figure 15 — Areas with different ground factors G , varying ground height and short barrier

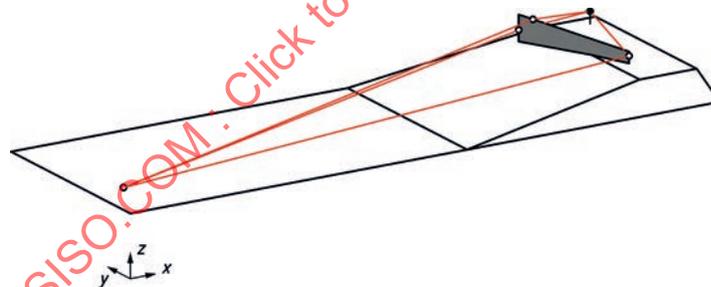


Figure 16 — 3D-presentation of scenario T10

Input data:

Table 24 — Coordinates of source S and receiver R

	x in m	y in m	z_{rel} in m
Source	10	10	1
Receiver	200	50	4

Source emission frequency spectrum – [Table 2](#) (Test case T01).

Areas with different ground factors G – [Table 12](#) (Test case T06).

Contour lines to describe different ground heights – [Table 13](#) (Test case T06).

Table 25 — Barrier geometry

Upper edge	x in m	y in m	z _{abs} in m
S1	175,0	50,0	17,0
S2	190,0	10,0	14,0

Step by step results:

Table 26 — Single number step by step results

Quantity	Unit	Value
d_p (2-dimensional distance)	m	194,16
d_3 (3-dimensional distance)	m	194,60
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
d_{p1} (2d-length of path above ground with G1)	m	40,88
d_{p2} (2d-length of path above ground with G2)	m	102,19
d_{p3} (2d-length of path above ground with G3)	m	51,10
G_s		0,90
G_r		0,37
G_m		0,60

Table 27 — Spectral step by step results

Quantity	Unit	Value							
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	4,46	14,91
a', b', c', d' for s		—	2,45	9,20	10,16	3,49	—	—	—
A_{gr_s}	dB	-1,50	0,71	6,78	7,64	1,64	-0,15	-0,15	-0,15

NOTE Where a cell's value is not relevant, the input in the cell is "—".

^a The result values in frequency bands and for the total level are considered to be correct if the deviation does not exceed $\pm 0,05$ dB.

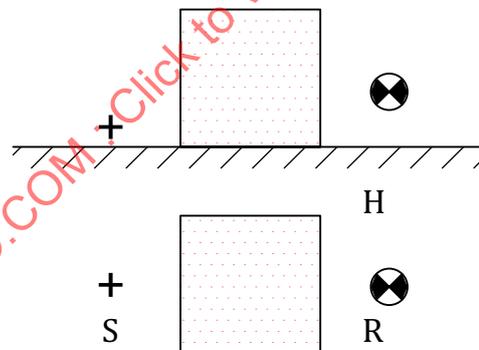
Table 27 (continued)

Quantity	Unit	Value								
a', b', c', d' for r		—	4,24	3,50	1,51	1,50	—	—	—	
$A_{gr,r}$	dB	-1,50	0,08	-0,20	-0,94	-0,94	-0,94	-0,94	-0,94	
$A_{gr,m}$	dB	-0,68	-0,27	-0,27	-0,27	-0,27	-0,27	-0,27	-0,27	
A_{gr}	dB	-3,68	0,51	6,31	6,43	0,43	-1,37	-1,37	-1,37	
D_z (top edge)	dB	5,99	6,93	8,37	10,31	12,67	15,31	18,13	20,00	
D_z (edge1)	dB	7,20	8,76	10,80	13,23	15,92	18,76	21,68	24,65	
D_z (edge2)	dB	—	—	—	—	—	—	—	—	
A_{bar} (top edge)	dB	5,99	6,42	2,07	3,89	12,24	15,31	18,13	20,00	
A_{bar} (edge1)	dB	7,20	8,76	10,80	13,23	15,92	18,76	21,68	24,65	
A_{bar} (edge2)	dB	—	—	—	—	—	—	—	—	
A_{bar}	dB	3,54	4,42	1,52	3,41	10,69	13,69	16,54	18,72	
A_{div}	dB	56,78	56,78	56,78	56,78	56,78	56,78	56,78	56,78	Total
L	dB	36,3	31,2	28,2	25,8	24,1	22,1	16,6	4,0	38,5
A-weighting	dB	-26,2	-16,1	-8,6	-3,2	0,0	1,2	1,0	-1,1	
L_A^a	dB	10,14	15,12	19,58	22,64	24,12	23,34	17,59	2,86	29,30

NOTE Where a cell's value is not relevant, the input in the cell is “—”.

^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.

6.2.12 T11 - Flat ground with homogeneous acoustic properties and cubic building - receiver at low height



Key

- S source
- R receiver
- H object

Figure 17 — Screening cubic building between source and receiver at low height

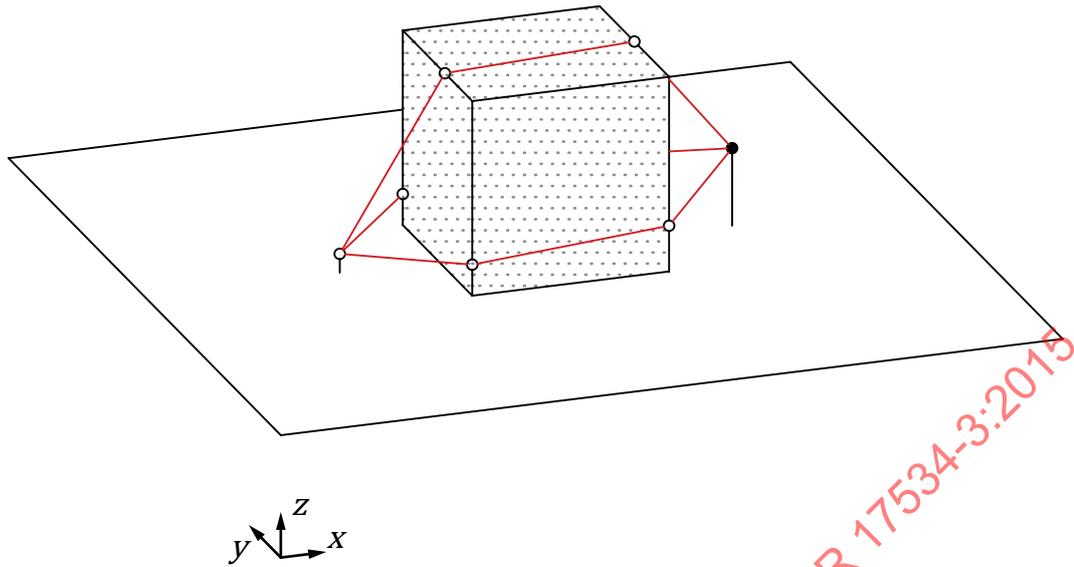


Figure 18 — 3D-presentation of scenario T11

Input data:

Table 28 — Coordinates of source S and receiver R (T11)

	x in m	y in m	z in m
Source	50	10	1
Receiver	70	10	4

Source emission frequency spectrum – [Table 2](#) (Test case T01).

Ground factor $G = 0,5$.

Table 29 — Edge coordinates of cubic building with height 10 m (T11)

Edge no.	x in m	y in m
1	55	5
2	65	5
3	65	15
4	55	15

Step by step results:

Table 30 — Single number step by step results

Quantity	Unit	Value
d_p (2-dimensional distance)	m	20,00
d_3 (3-dimensional distance)	m	20,22
length of s-region	m	20,00
length of r-region	m	20,00
length of m-region	m	0,00
q (ISO 9613-2:1996, Table 3 Footnote 2)		0,00
d_{p1} (2d-length of path above ground with G1)	m	20,00
G_s		0,50
G_r		0,50

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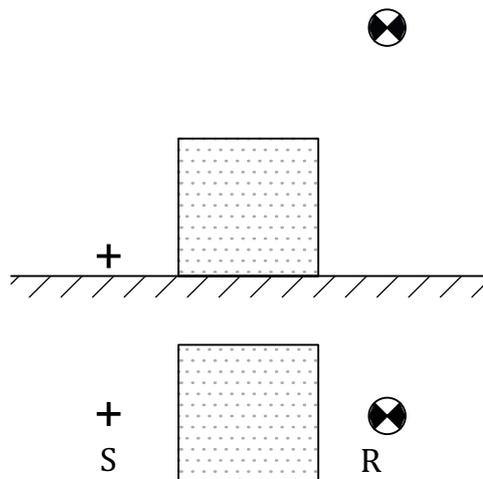
Table 31 — Spectral step by step results

Quantity	Unit	Values								
		63	125	250	500	1 000	2 000	4 000	8 000	
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	0,00	0,01	0,02	0,06	0,10	0,18	0,46	1,55	
a', b', c', d' for s		—	1,65	4,09	4,41	2,17	—	—	—	
A_{gr_s}	dB	-1,50	-0,67	0,55	0,71	-0,41	-0,75	-0,75	-0,75	
a', b', c', d' for r		—	2,38	2,17	1,50	1,50	—	—	—	
A_{gr_r}	dB	-1,50	-0,31	-0,41	-0,75	-0,75	-0,75	-0,75	-0,75	
A_{gr_m}	dB	15,36	18,94	23,32	25,00	25,00	25,00	25,00	25,00	
A_{gr}	dB	-3,00	-0,99	0,13	-0,04	-1,16	-1,50	-1,50	-1,50	
C_3 - top		1,09	1,31	1,84	2,49	2,84	2,96	2,99	3,00	
D_z - top	dB	15,36	18,94	23,32	25,00	25,00	25,00	25,00	25,00	
A_{bar} - top	dB	15,36	18,94	23,19	25,00	25,00	25,00	25,00	25,00	
C_3 - left		1,09	1,31	1,85	2,49	2,84	2,96	2,99	3,00	
D_z - left	dB	12,89	16,30	20,60	24,83	28,39	31,56	34,61	37,63	
A_{bar} - left	dB	12,89	16,30	20,60	24,83	28,39	31,56	34,61	37,63	
C_3 - right		1,09	1,31	1,85	2,49	2,84	2,96	2,99	3,00	
D_z - right	dB	12,89	16,30	20,60	24,83	28,39	31,56	34,61	37,63	
A_{bar} - right	dB	12,89	16,30	20,60	24,83	28,39	31,56	34,61	37,63	
A_{bar}	dB	8,79	12,24	16,53	20,12	22,18	23,41	24,14	24,55	
A_{div}	dB	37,12	37,12	37,12	37,12	37,12	37,12	37,12	37,12	Total
L	dB	50,09	44,62	39,20	35,75	34,77	33,79	32,78	31,28	51,81
A-weighting	dB	-26,2	-16,1	-8,6	-3,2	0,0	1,2	1,0	-1,1	
L_A^a	dB	23,89	28,52	30,60	32,55	34,77	34,99	33,78	30,18	41,30

NOTE Where a cell's value is not relevant, the input in the cell is "—".

^a The result values in frequency bands and for the total level are considered to be correct if the deviation does not exceed $\pm 0,05$ dB.

6.2.13 T12 – Flat ground with homogeneous acoustic properties and cubic building – receiver at large height



Key

S source

R receiver

Figure 19 — Screening cubic building between source and receiver at large height

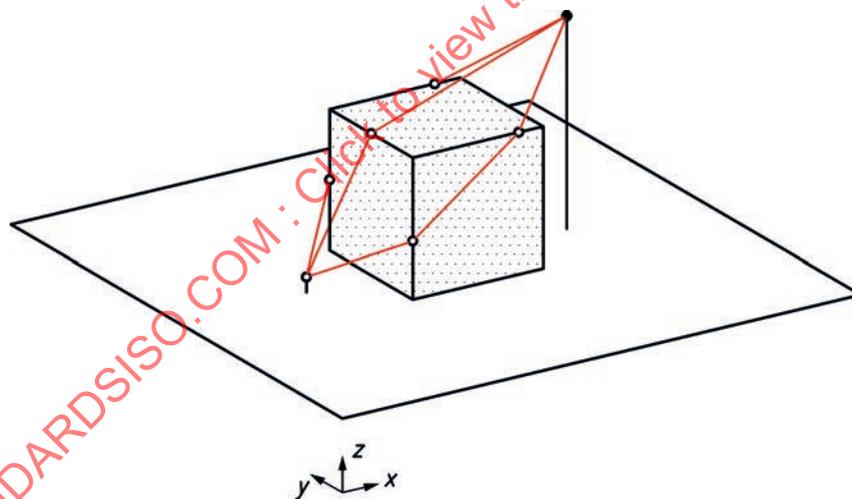


Figure 20 — 3D-presentation of scenario T12

Input data:**Table 32 — Coordinates of source S and receiver R**

	<i>x</i> in m	<i>y</i> in m	<i>z</i> in m
Source	50	10	1
Receiver	70	10	15

Source emission frequency spectrum – [Table 2](#) (Test case T01).

Ground factor $G = 0,5$.

Edge coordinates (m) of building H with height 10 m, see [Table 29](#) (previous).

Step by step results:**Table 33 — Single number step by step results**

Quantity	Unit	Value
d_p (2-dimensional distance)	m	20,00
d_3 (3-dimensional distance)	m	24,41
length of s-region	m	20,00
length of r-region	m	20,00
length of m-region	m	0,00
q (ISO 9613-2:1996, Table 3 Footnote 2)		0,00
G_s		0,50
G_r		0,50

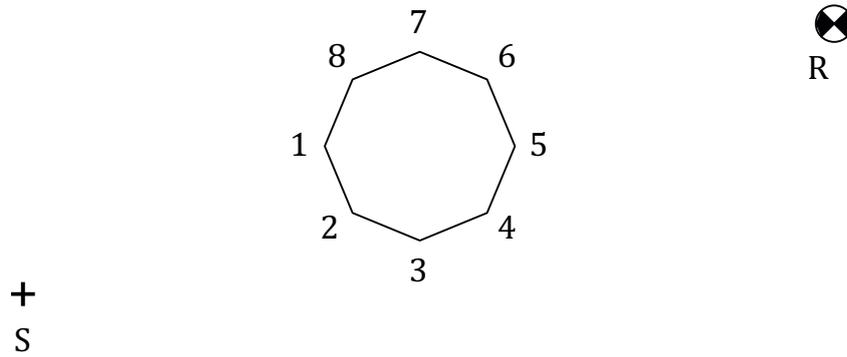
Table 34 — Spectral step by step results

Quantity	Unit	Values								
		63	125	250	500	1 000	2 000	4 000	8 000	
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	0,00	0,01	0,03	0,07	0,12	0,22	0,56	1,87	
a', b', c', d' for s		—	1,65	4,09	4,41	2,17	—	—	—	
A_{gr_s}	dB	-1,50	-0,67	0,55	0,71	-0,41	-0,75	-0,75	-0,75	
a', b', c', d' for r		—	1,50	1,50	1,50	1,50	—	—	—	
A_{gr_r}	dB	-1,50	-0,75	-0,75	-0,75	-0,75	-0,75	-0,75	-0,75	
A_{gr_m}	dB	9,60	11,83	14,39	17,16	20,00	20,00	20,00	20,00	
A_{gr}	dB	-3,00	-1,42	-0,20	-0,04	-1,16	-1,50	-1,50	-1,50	
C_3 - top		1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	
D_z - top	dB	9,60	11,83	14,39	17,16	20,00	20,00	20,00	20,00	
A_{bar} - top	dB	9,60	11,83	14,39	17,16	20,00	20,00	20,00	20,00	
C_3 - left		1,08	1,28	1,80	2,45	2,83	2,95	2,99	3,00	
D_z - left	dB	11,87	15,11	19,32	23,58	27,17	30,36	33,42	36,44	
A_{bar} - left		11,87	15,11	19,32	23,58	27,17	30,36	33,42	36,44	
C_3 - right		1,08	1,28	1,80	2,45	2,83	2,95	2,99	3,00	
D_z - right	dB	11,87	15,11	19,32	23,58	27,17	30,36	33,42	36,44	
A_{bar} - right	dB	11,87	15,11	19,32	23,58	27,17	30,36	33,42	36,44	
A_{bar}	dB	6,20	8,95	12,23	15,53	18,59	19,27	19,62	19,81	
A_{div}	dB	38,75	38,75	38,75	38,75	38,75	38,75	38,75	38,75	Total
L	dB	51,04	46,71	42,19	38,70	36,70	36,26	35,57	34,07	53,28
A-weighting	dB	-26,2	-16,1	-8,6	-3,2	0,0	1,2	1,0	-1,1	
L_A^a in	dB	24,84	30,61	33,59	35,50	36,70	37,46	36,57	32,97	43,81

NOTE Where a cell's value is not relevant, the input in the cell is "—".

^a The result values in frequency bands and for the total level are considered to be correct if the deviation does not exceed $\pm 0,05$ dB.

6.2.14 T13 - Flat ground with homogeneous acoustic properties and polygonal building - receiver at low height



Key

- S source
- R receiver

Figure 21 — Screening polygonal building between source and receiver at low height

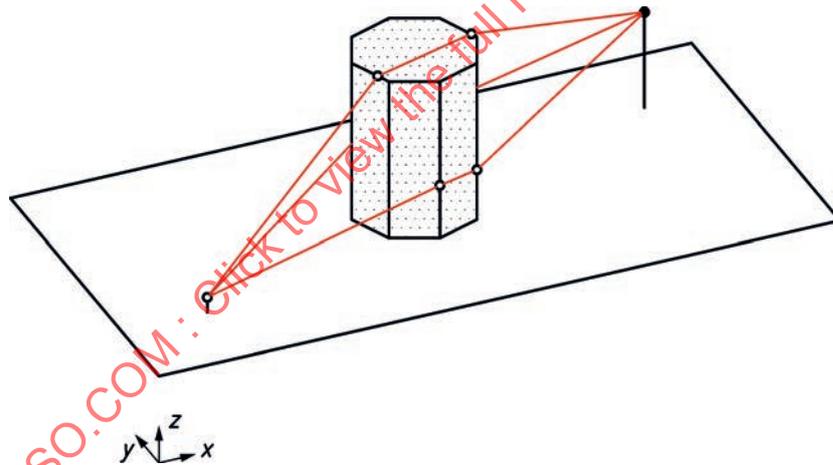


Figure 22 — 3D-presentation of scenario T13

Input data:

Table 35 — Coordinates of source S and receiver R

	<i>x</i> in m	<i>y</i> in m	<i>z</i> _{rel} in m
Source	0	10	1
Receiver	30	20	6

Source emission frequency spectrum – [Table 2](#) (Test case T01).

Ground factor *G* = 0,6.

Table 36 — Edge coordinates of screening polygonal building with height 10 m

Edge no.	<i>x</i> in m	<i>y</i> in m
1	10,96	15,50
2	12,00	13,00
3	14,50	11,96
4	17,00	13,00
5	18,04	15,50
6	17,00	18,00
7	14,50	19,04
8	12,00	18,00

Step by step results:

Table 37 — Single number step by step results – ground properties

Quantity	Unit	Value
<i>d</i> _p (2-dimensional distance)	m	31,62
<i>d</i> ₃ (3-dimensional distance)	m	32,02
length of s-region	m	30,00
length of r-region	m	31,62
length of m-region	m	0,00
<i>q</i> (ISO 9613-2:1996, Table 3, footnote 2)		0,00

Table 38 — Single number step by step results – ray geometry

Quantity	Unit	top	left	right	direct
Length	m	35,18	33,04	32,49	32,02
<i>d</i> _{ss}	m	15,21	14,59	14,81	
<i>d</i> _{sr}	m	13,41	15,71	14,94	
<i>e</i>	m	6,55	2,74	2,74	
<i>z</i>	m	3,17	1,02	0,48	
<i>K</i> _{met}	dB	0,98	1,00	1,00	

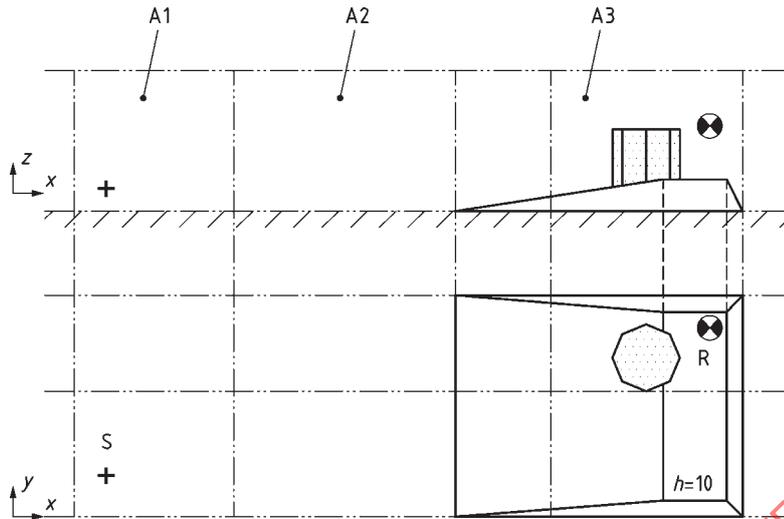
Table 39 — Spectral step by step results

Quantity	Unit	Values								
		63	125	250	500	1 000	2 000	4 000	8 000	
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	0,00	0,01	0,04	0,09	0,16	0,29	0,73	2,45	
a', b', c', d' for s		—	1,72	5,18	5,64	2,45	—	—	—	
A_{gr_s}	dB	-1,50	-0,47	1,61	1,89	-0,03	-0,60	-0,60	-0,60	
a', b', c', d' for r		—	2,75	1,66	1,50	1,50	—	—	—	
A_{gr_r}	dB	-1,50	0,15	-0,51	-0,60	-0,60	-0,60	-0,60	-0,60	
A_{gr_m}	dB	11,73	14,65	18,48	22,92	25,00	25,00	25,00	25,00	
A_{gr}	dB	-3,00	-0,32	1,11	1,29	-0,63	-1,20	-1,20	-1,20	
C_3 - top		1,04	1,14	1,47	2,11	2,66	2,90	2,98	2,99	
D_z - top	dB	11,73	14,65	18,48	22,92	25,00	25,00	25,00	25,00	
A_{bar} - top	dB	11,73	14,65	17,37	21,64	25,00	25,00	25,00	25,00	
C_3 - left		1,01	1,03	1,10	1,36	1,93	2,55	2,87	2,96	
D_z - left	dB	8,32	10,31	12,93	16,42	20,76	24,92	28,41	31,56	
A_{bar} - left	dB	8,32	10,31	12,93	16,42	20,76	24,92	28,41	31,56	
C_3 - right		1,01	1,03	1,10	1,36	1,93	2,55	2,87	2,96	
D_z - right	dB	6,78	8,19	10,30	13,42	17,56	21,64	25,10	28,24	
A_{bar} - right	dB	6,78	8,19	10,30	13,42	17,56	21,64	25,10	28,24	
A_{bar}	dB	3,72	5,54	7,89	11,24	15,36	18,78	21,14	22,71	
A_{div}	dB	41,11	41,11	41,11	41,11	41,11	41,11	41,11	41,11	Total
L in	dB	51,17	46,66	42,86	39,28	37,00	34,02	31,22	27,93	53,31
A-weighting	dB	-26,2	-16,1	-8,6	-3,2	0,0	1,2	1,0	-1,1	
L_A^a	dB	24,97	30,56	34,26	36,08	37,00	35,22	32,22	26,83	42,71

NOTE Where a cell's value is not relevant, the input in the cell is "—".

^a The result values in frequency bands and for the total level are considered to be correct if the deviation does not exceed $\pm 0,05$ dB.

6.2.15 T14 – Ground with spatially varying heights and acoustic properties and polygonal building



Key

- S source
- R receiver
- P1 relevant point 1
- P2 relevant point 2
- A1 area with $G = 0,5$
- A2 area with $G = 0,9$
- A3 area with $G = 0,2$

Figure 23 — Ground with spatially varying heights and acoustic properties and polygonal building

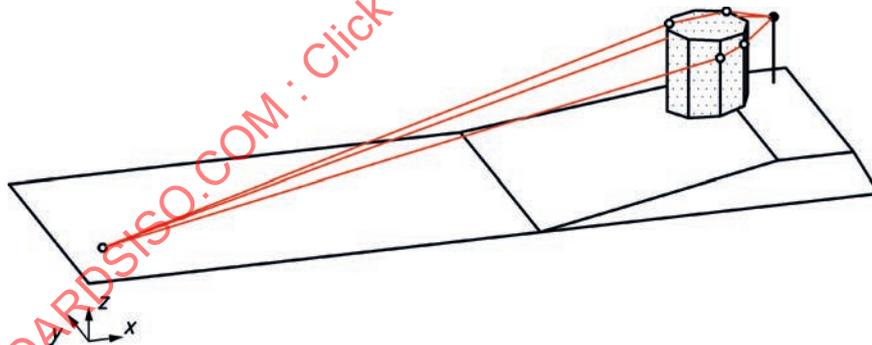


Figure 24 — 3D-presentation of scenario T14

Input data:

Table 40 — Coordinates of source S and receiver R

	x in m	y in m	z in m
Source	10	10	1
Receiver	200	50	28,5

Source emission frequency spectrum – [Table 2](#) (Test case T01).

Contour lines defining the areas with different ground heights, see [Table 13](#) (Test case T06).

Table 41 — Areas with different ground factor G

Area	Ground	Coordinates of areas							
		x_1 in m	y_1 in m	x_2 in m	y_2 in m	x_3 in m	y_3 in m	x_4 in m	y_4 in m
A1	0,5	0	60	50	60	50	-10	0	-10
A2	0,9	50	60	150	60	150	-10	50	-10
A3	0,2	150	60	210	60	210	-10	150	-10

Table 42 — Edge coordinates of screening polygonal building with height 30 m

Edge no.	x in m	y in m
1	169,39	41,00
2	172,50	33,50
3	180,00	30,39
4	187,50	33,50
5	190,61	41,00
6	187,50	48,50
7	180,00	51,61
8	172,50	48,50

Step by step results:

Table 43 — Single number step by step results – ground properties

Quantity	Unit	Values
d_p (2-dimensional distance)	m	194,16
d_3 (3-dimensional distance)	m	196,10
length of s-region	m	30,00
length of r-region	m	194,16
length of m-region	m	0,00
q (ISO 9613-2:1996, Table 3 footnote 2)		0,00
d_{p1} (2d-length of path above ground with G1)	m	40,88
d_{p2} (2d-length of path above ground with G2)	m	102,19
d_{p3} (2d-length of path above ground with G3)	m	51,10
G_s		0,50
G_r		0,63
G_m		0,00

Table 44 — Single number step by step results – ray geometry

Quantity	Unit	top	left	right	direct
Length	m	196,80	197,01	201,93	196,10
d_{ss}	m	166,61	176,76	172,91	
d_{sr}	m	12,42	20,25	20,82	
e	m	17,76	0,00	8,20	
z	m	0,70	0,91	5,83	
K_{met}	dB	0,76	1,00	1,00	

Table 45 — Spectral step by step results

Quantity	Unit	Values								
		63	125	250	500	1 000	2 000	4 000	8 000	
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	0,22	0,55	0,98	1,76	4,49	15,02	
a', b', c', d' for s		—	2,45	9,20	10,16	3,49	—	—	—	
$A_{gr,s}$	dB	-1,50	-0,27	3,10	3,58	0,25	-0,75	-0,75	-0,75	
a', b', c', d' for r		—	1,50	1,50	1,50	1,50	—	—	—	
$A_{gr,r}$	dB	-1,50	-0,55	-0,55	-0,55	-0,55	-0,55	-0,55	-0,55	
$A_{gr,m}$	dB	4,85	7,38	10,85	14,19	17,27	20,27	22,49	22,49	
$A_{gr, in}$	dB	-3,00	-0,83	2,55	3,03	-0,31	-1,30	-1,30	-1,30	
C_3 – top		1,25	1,72	2,39	2,80	2,95	2,99	3,00	3,00	
D_z – top	dB	7,36	9,89	13,36	16,70	19,78	22,78	25,00	25,00	
A_{bar} – top	dB	7,36	9,89	10,81	13,68	19,78	22,78	25,00	25,00	
C_3 – left		1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	
D_z – left	dB	8,02	9,86	12,14	14,73	17,52	20,41	23,36	26,34	
A_{bar} – left	dB	8,02	9,86	12,14	14,73	17,52	20,41	23,36	26,34	
C_3 – right		1,06	1,22	1,65	2,32	2,77	2,94	2,98	3,00	
D_z – right	dB	14,10	17,41	21,60	26,03	29,79	33,05	36,12	39,15	
A_{bar} – right	dB	14,10	17,41	21,60	26,03	29,79	33,05	36,12	39,15	
A_{bar}	dB	4,20	6,50	8,21	11,02	15,34	18,28	20,96	22,51	
A_{div}	dB	56,85	56,85	56,85	56,85	56,85	56,85	56,85	56,85	Total
L	dB	34,93	30,42	25,18	21,55	20,14	17,41	12,00	-0,08	36,87
A-weighting	dB	-26,2	-16,1	-8,6	-3,2	0,0	1,2	1,0	-1,1	
L_A^a	dB	8,73	14,32	16,58	18,35	20,14	18,61	13,00	-1,18	25,38

NOTE Where a cell's value is not relevant, the input in the cell is “—”.

^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.

6.2.16 T15 – Flat ground with homogeneous acoustic properties and polygonal building – receiver at large height

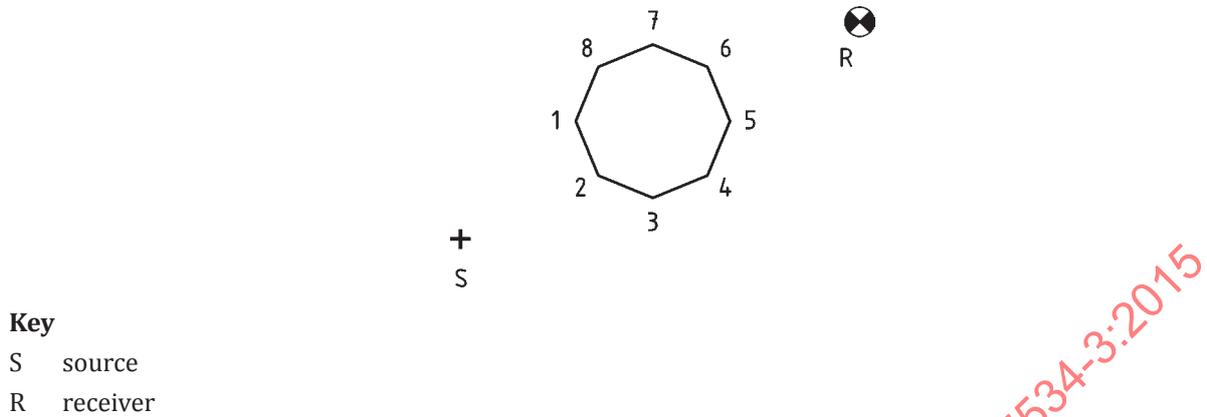


Figure 25 — Screening polygonal building between source and receiver

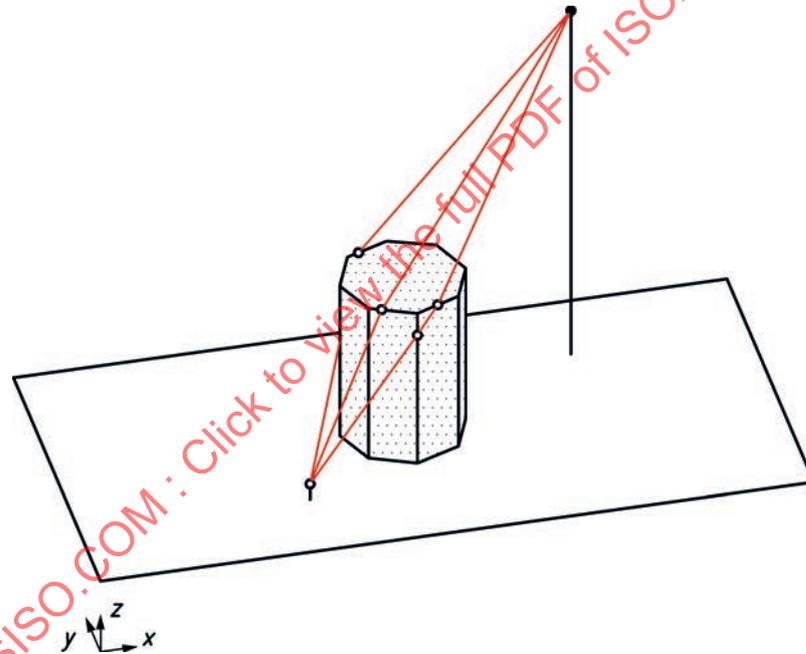


Figure 26 — 3D-presentation of scenario T15

Input data:

Table 46 — Coordinates of source S and receiver R

	x in m	y in m	z in m
Source	8	10	1
Receiver	25	20	23

Source emission frequency spectrum – [Table 2](#) (Test case T01).

Ground factor $G = 0,2$.

Edge coordinates (m) of building H with height 10 m see [Table 36](#) (Test case T13).

Step by step results:

Table 47 — Single number step by step results – ground properties

Quantity	Unit	Value
d_p (2-dimensional distance)	m	19,72
d_3 (3-dimensional distance)	m	29,55
length of s-region	m	19,72
length of r-region	m	19,72
length of m-region	m	0,00
q (ISO 9613-2:1996, Table 3 Footnote 2)		0,00
G_s		0,20
G_r		0,20
G_m		0,00

Table 48 — Single number step by step results – ray geometry

Quantity	Unit	top	left	right	direct
Length	m	29,84	31,20	29,78	29,55
d_{ss}	m	10,49	12,25	10,01	
d_{sr}	m	19,35	18,10	17,55	
e	m	0,00	0,85	2,21	
z	m	0,29	1,66	0,23	
K_{met}	dB	0,95	1,00	1,00	

Table 49 — Spectral step by step results

Quantity	Unit	Values							
		63	125	250	500	1 000	2 000	4 000	8 000
f		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	0,00	0,01	0,03	0,08	0,15	0,27	0,68	2,26
a', b', c', d' for s		—	1,65	4,06	4,38	2,16	—	—	—
A_{gr_s}	dB	-1,50	-1,17	-0,69	-0,62	-1,07	-1,20	-1,20	-1,20
a', b', c', d' for r		—	1,50	1,50	1,50	1,50	—	—	—
A_{gr_r}	dB	-1,50	-1,20	-1,20	-1,20	-1,20	-1,20	-1,20	-1,20
A_{gr_m}	dB	6,05	7,04	8,53	10,51	12,90	15,56	18,39	20,00
A_{gr}	dB	-3,00	-2,37	-1,89	-1,82	-2,27	-2,40	-2,40	-2,40
C_3 – top		1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

NOTE Where a cell's value is not relevant, the input in the cell is “—”.

^a The result values in frequency bands and for the total level are considered to be correct if the deviation does not exceed $\pm 0,05$ dB.

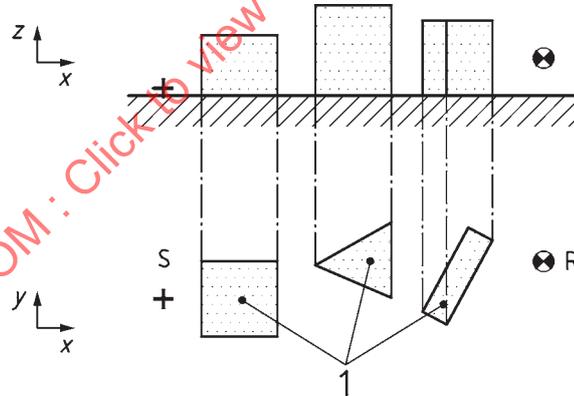
Table 49 (continued)

Quantity	Unit	Values								
		63	125	250	500	1 000	2 000	4 000	8 000	
f		63	125	250	500	1 000	2 000	4 000	8 000	
D_z - top	dB	6,05	7,04	8,53	10,51	12,90	15,56	18,39	20,00	
A_{bar} - top	dB	6,05	7,04	8,53	10,51	12,90	15,56	18,39	20,00	
C_3 - left		1,00	1,00	1,01	1,04	1,15	1,50	2,14	2,68	
D_z - left	dB	9,59	11,82	14,41	17,30	20,62	24,70	29,23	33,21	
A_{bar} - left	dB	9,59	11,82	14,41	17,30	20,62	24,70	29,23	33,21	
C_3 - right		1,00	1,02	1,07	1,25	1,72	2,39	2,80	2,95	
D_z - right	dB	5,86	6,76	8,23	10,62	14,24	18,35	21,94	25,13	
A_{bar} - right	dB	5,86	6,76	8,23	10,62	14,24	18,35	21,94	25,13	
A_{bar}	dB	2,10	3,24	4,86	7,12	10,11	13,39	16,56	18,68	
A_{div}	dB	40,41	40,41	40,41	40,41	40,41	40,41	40,41	40,41	Total
L	dB	53,49	51,71	49,59	47,21	44,60	41,33	37,76	34,05	57,53
A-weighting	dB	-26,2	-16,1	-8,6	-3,2	0,0	1,2	1,0	-1,1	
L_A^a	dB	27,29	35,61	40,99	44,01	44,60	42,53	38,76	32,95	49,92

NOTE Where a cell's value is not relevant, the input in the cell is “—”.

^a The result values in frequency bands and for the total level are considered to be correct if the deviation does not exceed $\pm 0,05$ dB.

6.2.17 T16 - Flat ground with homogeneous acoustic properties and three buildings



Key

- 1 buildings H1, H2, and H3
- S source
- R receiver

Figure 27 — Three screening buildings (H1, H2, H3) between source and receiver

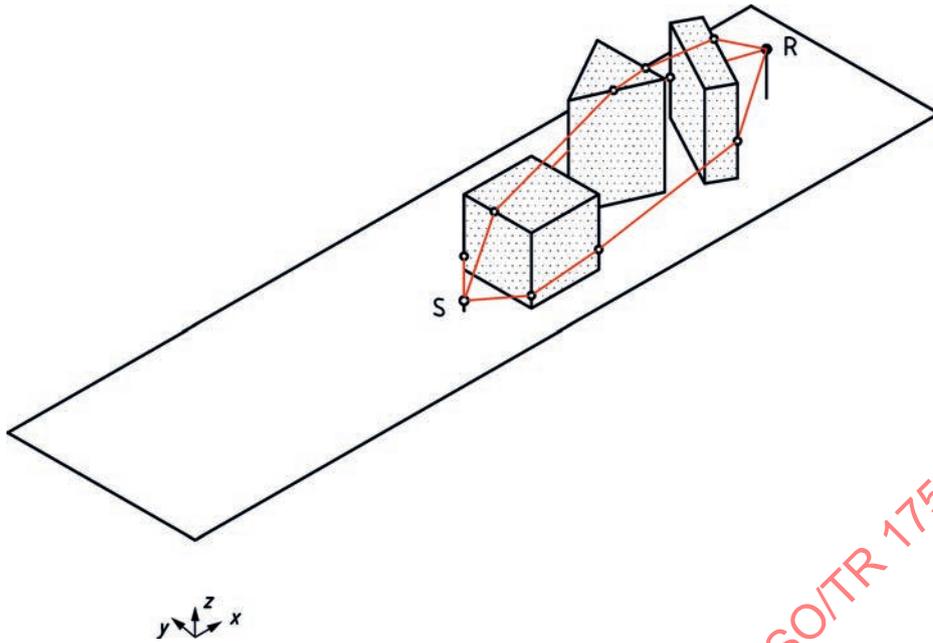


Figure 28 — 3D-presentation of scenario T16

Input data:

Table 50 — Coordinates of source S and receiver R

	x in m	y in m	z in m
Source	50	10	1
Receiver	100	15	5

Source emission frequency spectrum - [Table 2](#) (Test case T16).

Ground factor $G = 0,5$.

Table 51 — Edge coordinates of three buildings with heights z

Edge no.	object 1			object 2			object 3		
	x in m	y in m	z in m	x in m	y in m	z in m	x in m	y in m	z in m
1	55,00	5,00	8,00	70,00	14,50	12,00	90,11	19,48	10,00
2	65,00	5,00	8,00	80,00	10,17	12,00	93,27	17,78	10,00
3	65,00	15,00	8,00	80,00	20,17	12,00	87,27	6,61	10,00
4	55,00	15,00	8,00				84,11	8,31	10,00

Step by step results:

Table 52 — Single number step by step results – ground properties

Quantity	Unit	Value
d_p (2-dimensional distance)	m	50,25
d_3 (3-dimensional distance)	m	50,41
length of s-region	m	30,00
length of r-region	m	50,25
length of m-region	m	0,00
q (ISO 9613-2:1996, Table 3 Footnote 2)		0,00
G_s		0,50
G_r		0,50
G_m		0,00

Table 53 — Single number step by step results – ray geometry

Quantity	Unit	top	left	right	direct
Length	m	55,75	53,74	54,79	50,41
d_{ss}	m	8,62	7,08	7,08	
d_{sr}	m	10,06	10,88	15,28	
e	m	37,07	35,77	32,43	
z	m	5,34	3,33	4,39	
K_{met}	dB	0,99	1,00	1,00	

Table 54 — Spectral step by step results (T16)

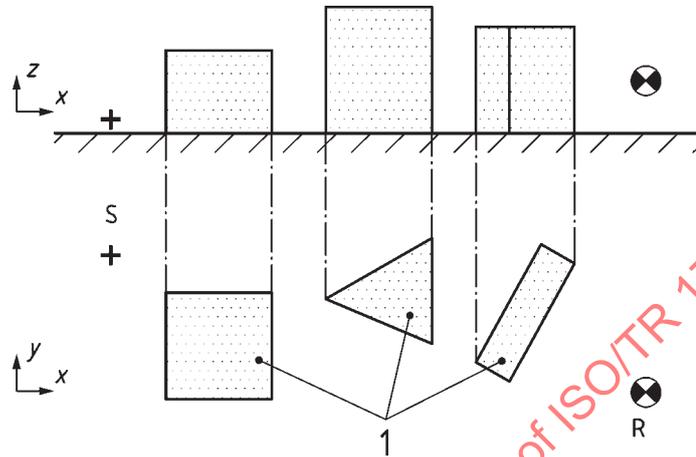
Quantity	Unit	Values								
		63	125	250	500	1 000	2 000	4 000	8 000	
f	Hz	63	125	250	500	1 000	2 000	4 000	8 000	
L_W	dB	93	93	93	93	93	93	93	93	
α -atm(20°,70 %)		0,1	0,3	1,1	2,8	5,0	9,0	22,9	76,6	
A_{atm}	dB	0,01	0,02	0,06	0,14	0,25	0,45	1,15	3,86	
a', b', c', d' for s		—	1,82	6,48	7,10	2,79	—	—	—	
A_{gr_s}	dB	-1,50	-0,59	1,74	2,05	-0,11	-0,75	-0,75	-0,75	
a', b', c', d' for r		—	3,41	2,07	1,50	1,50	—	—	—	
A_{gr_r}	dB	-1,50	0,20	-0,46	-0,75	-0,75	-0,75	-0,75	-0,75	
A_{gr_m}	dB	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
A_{gr}	dB	-3,00	-0,39	1,28	1,30	-0,86	-1,50	-1,50	-1,50	
C_3 - top		1,76	2,42	2,82	2,95	2,99	3,00	3,00	3,00	
D_z - top	dB	15,71	19,88	23,46	25,00	25,00	25,00	25,00	25,00	
A_{bar} - top	dB	15,71	19,88	22,18	23,70	25,00	25,00	25,00	25,00	
C_3 - left		1,73	2,40	2,80	2,95	2,99	3,00	3,00	3,00	
D_z - left	dB	13,84	17,90	21,48	24,65	27,70	30,71	33,72	36,73	
A_{bar} - left	dB	13,84	17,90	21,48	24,65	27,70	30,71	33,72	36,73	
C_3 - right		1,64	2,31	2,77	2,94	2,98	3,00	3,00	3,00	
D_z - right	dB	14,70	18,89	22,59	25,82	28,88	31,90	34,91	37,92	
A_{bar} - right	dB	14,70	18,89	22,59	25,82	28,88	31,90	34,91	37,92	
A_{bar}	dB	9,91	14,04	17,29	19,87	22,11	23,32	24,08	24,51	
A_{div}	dB	45,05	45,05	45,05	45,05	45,05	45,05	45,05	45,05	Total
L	dB	41,03	34,28	29,33	26,64	26,45	25,68	24,22	21,07	42,52
A-weighting	dB	-26,2	-16,1	-8,6	-3,2	0,0	1,2	1,0	-1,1	
L_A^a	dB	14,83	18,18	20,73	23,44	26,45	26,88	25,22	19,97	32,54

NOTE Where a cell's value is not relevant, the input in the cell is "—".

^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.

6.2.18 T17 – Flat ground with homogeneous acoustic properties and three buildings – alternative position of source and receiver

Geometric and acoustic properties of ground and screening objects are identical to T16. Only the position of source and receiver are different.



Key

- 1 buildings H1, H2, and H3
- S source
- R receiver

Figure 29 — Three screening buildings (H1, H2, H3) between source and receiver

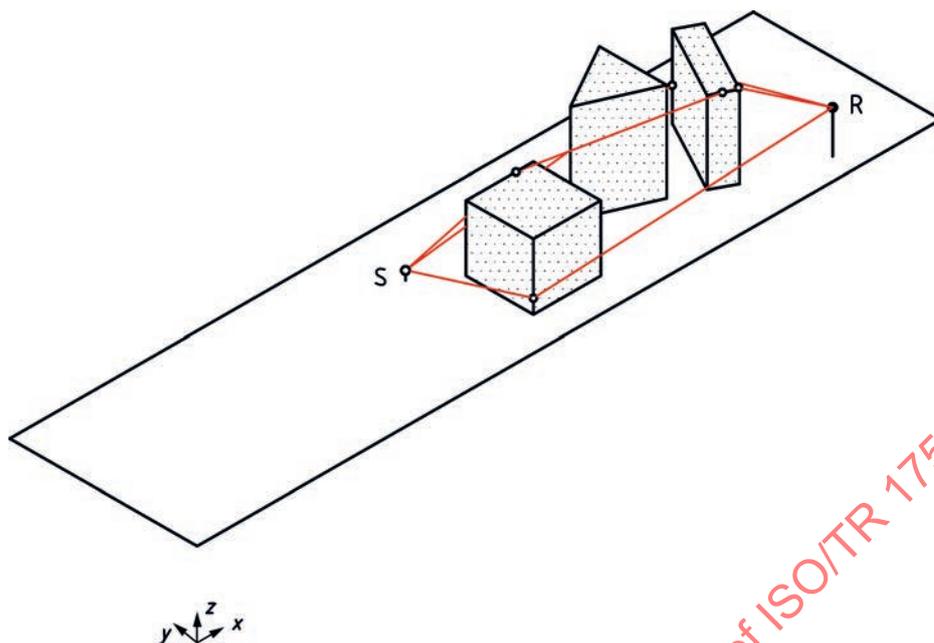


Figure 30 — 3D-presentation of scenario T17

Input data:

Table 55 — Coordinates of source, S, and receiver, R

Point	x in m	y in m	z in m
Source	50	19	1
Receiver	98	3,5	5

Table 56 — Single number step by step results - ray geometry

Quantity	Unit	top	left	right	direct
Length	m	53,36	58,93	58,03	50,60
d_{ss}	m	14,78	30,11	14,88	
d_{sr}	m	12,18	15,06	43,15	
e	m	26,40	13,76	0,00	
z	m	2,76	8,33	7,44	
K_{met}	dB	0,980	1,00	1,00	

Table 57 — 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	0,01	0,02	0,06	0,14	0,25	0,46	1,16	3,88	
a', b', c', d' for s		—	1,82	6,49	7,12	2,79	—	—	—	
A_{gr_s}	dB	-1,50	-0,59	1,75	2,06	-0,10	-0,75	-0,75	-0,75	
a', b', c', d' for r		—	3,41	2,08	1,50	1,50	—	—	—	
A_{gr_r}	dB	-1,50	0,21	-0,46	-0,75	-0,75	-0,75	-0,75	-0,75	
A_{gr_m}	dB	10,39	14,44	18,29	21,60	22,91	22,91	22,91	22,91	
A_{gr}	dB	-3,00	-0,39	1,28	1,31	-0,85	-1,50	-1,50	-1,50	
C_3 - top		1,48	2,11	2,67	2,91	2,98	2,99	3,00	3,00	
D_z - top	dB	12,48	16,53	20,38	23,69	25,00	25,00	25,00	25,00	
A_{bar} - top	dB	12,48	16,53	19,09	22,39	25,00	25,00	25,00	25,00	
C_3 - left		1,16	1,51	2,15	2,69	2,91	2,98	2,99	3,00	
D_z - left	dB	15,85	19,80	24,26	28,21	31,55	34,65	37,69	40,70	
A_{bar} - left	dB	15,85	19,80	24,26	28,21	31,55	34,65	37,69	40,70	
C_3 - right		1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	
D_z - right	dB	14,82	17,61	20,51	23,46	26,44	29,43	32,44	35,44	
A_{bar} - right	dB	14,82	17,61	20,51	23,46	26,44	29,43	32,44	35,44	
A_{bar}	dB	9,37	13,01	16,03	19,28	22,12	23,33	24,09	24,52	
A_{div}	dB	45,08	45,08	45,08	45,08	45,08	45,08	45,08	45,08	Total
L	dB	41,54	35,28	30,55	27,18	26,39	25,63	24,17	21,02	43,11
A-weighting	dB	-26,2	-16,1	-8,6	-3,2	0,0	1,2	1,0	-1,1	
L_A^a	dB	15,34	19,18	21,95	23,98	26,39	26,83	25,17	19,92	32,72

NOTE Where a cell's value is not relevant the input in the cell is "—".

^a The result values in frequency bands and for the total level are considered to be correct if the deviation does not exceed $\pm 0,05$ dB.