National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Amendments for CNOSSOS-EU

Description of issues and proposed solutions

This report contains an erratum
d.d. 22 august 2019 on pages 101-107

RIVM Letter report 2019-0023
A. Kok | A. van Beek

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Colophon

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A. Kok (author), RIVM
A. van Beek (author), RIVM

Contact:
Arnaud Kok
Milieu en Veiligheid\Centrum Milieukwaliteit\Luchtkwaliteit, Klimaat en Geluid
Arnaud.kok@rivm.nl

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Synopsis

Amendments of Cnossos-EU:2015

In collaboration with a European working group, RIVM has formulated points for improvement regarding the new European calculation method for noise levels from road traffic, railway traffic and industry. According to the working group which consists of representatives from various member states, the proposals presented have greatly improved the calculation method. However, further research is still needed into the extent to which the soil has a noise dampening effect. This is one of the factors that determine how much of the noise produced at the source, eventually reaches residential units.

The objective of the calculation method is to ensure that a uniform method is used throughout Europe to calculate noise levels on the basis of which action plans are prepared for protecting the health of human beings from excessive noise levels. The method at hand focuses primarily on residential housing. As of 1 January 2019, all EU member states are required to use this method when preparing noise maps in response to the European Environmental Noise Guidelines. These noise maps must be prepared once every five years for large municipalities (agglomerations), busy secondary roads, motorways, and main railways. The points for improvement will be taken into account in the following round scheduled for 2022. In 2017, most countries prepared noise maps for the situation in 2016.

The working group started its work in 2018 with the approval of the European Commission. This was in response to previous research by RIVM, which made it clear that the European calculation method, called Cnossos-EU:2015, contains ambiguities and errors. Improvements were also possible. For each point in question, the working group explained why they considered it to be a problem and also prepared a motivated proposal for improvement. The working group also recommends preparing a guideline for calculating the amount of noise, from railway traffic for example, per country as uniformly as possible. After all, local situations and differences in the materials used can result in differences in the amount of noise produced by this source in different countries.

In addition to this report, RIVM prepared draft proposals for the texts of the new European calculation proposal. Both parts must be viewed in relation to the EU calculation proposal.

Keywords: noise, calculation methods, environmental noise directive

Publiekssamenvatting

Revisie van Cnossos-EU:2015

Het RIVM heeft met een Europese werkgroep verbeterpunten opgesteld voor de nieuwe Europese rekenmethode om geluidniveaus voor wegverkeer, railverkeer en industrie te berekenen. Volgens de werkgroep, waarin meerdere lidstaten vertegenwoordigd waren, is de rekenmethode met deze verbeterpunten flink verbeterd. Wel is nog onderzoek nodig naar de mate waarin de bodem een dempend effect heeft op geluid. Deze factor is mede bepalend voor hoeveel geluid van de bron uiteindelijk bij woningen komt.

Het doel van de rekenmethode is om in Europa op uniforme wijze de geluidniveaus te berekenen op basis waarvan actieplannen worden opgesteld om de gezondheid van mensen te beschermen tegen hoge geluidniveaus. Het gaat hierbij vooral om geluidniveaus bij woningen. Alle EU-lidstaten zijn vanaf 1 januari 2019 verplicht deze methode te gebruiken als ze geluidkaarten maken volgens de Europese richtlijn omgevingslawaai. Deze geluidkaart moeten zij elke vijf jaar maken voor grote gemeenten (agglomeraties), drukke provinciale wegen, rijkswegen en hoofdspoorwegen. De verbeterpunten zullen in de volgende ronde dat de kaarten worden gemaakt, in 2022, worden meegenomen.

De werkgroep is in 2018 met instemming van de Europese Commissie aan de slag gegaan. Aanleiding was eerder onderzoek van het RIVM waaruit bleek dat de Europese rekenmethode, Cnossos-EU:2015 geheten, onduidelijkheden en fouten bevat. Ook waren verbeteringen mogelijk. De werkgroep heeft per punt aangegeven waarom ze het als een probleem zien en een onderbouwd voorstel voor verbetering opgesteld. De werkgroep beveelt ook aan een handreiking op te stellen om de hoeveelheid geluid van bijvoorbeeld treinverkeer per land zo uniform mogelijk te berekenen. Lokale situaties en verschillen in treinmaterieel kunnen er namelijk voor zorgen dat de hoeveelheid geluid vanuit deze bron per land verschilt.

Naast dit rapport heeft het RIVM voorstellen opgesteld voor de letterlijke teksten voor het nieuwe Europese rekenvoorschrift. Beide onderdelen moeten in samenhang met het EU-rekenvoorschrift worden bezien.

Kernwoorden: geluid, rekenmethoden. Europese richtlijn omgevingslawaai

Contents

1 **Introduction — 11**

2 **Approach of the Working group — 13**

3 **Categorization of issues — 15**

4 **Classification of amendments — 17**

5 **Issues studied and proposed amendments — 19**
5.1 Introduction — 19
5.2 Include dwellings in text and define exposed area — 19
5.3 Specify façade points without reflections — 20
5.4 Rayleigh criterion should be specified — 20
5.5 15 degrees obstacles are not always out of scope — 22
5.6 In favourable conditions and diffraction by more than one edge, e is the length of the arcs between first and last diffraction edge — 22
5.7 If source or receiver are below the mean ground plane, do not use a null height for path length differences — 22
5.8 Diffraction around vertical edges must be specified — 23
5.9 Reflected rays are curved, depending on total length — 23
5.10 G-path is based on a 2D projection — 23
5.11 Specify unmodified heights for formula 2.5.20 — 24
5.12 Multiple Diffraction Problem — 25
5.13 Remove word local for velocity (traffic speed) — 27
5.14 New correction values for road surfaces — 27
5.15 Clarification of railway speed is required — 28
5.16 Error in French version of Table G-3 — 29
5.17 Table G-5, the values of the coefficients $L_{W0idling}$ for Diesel locomotive (c. 2 200 kW) at the 6350 Hz frequency seem wrong and centre frequencies are incorrect in a few Tables. — 29
5.18 Formula 2.4.1 is misleading/incorrect — 31
5.19 Reflections on vertical obstacles — 31
5.20 Vertical directivity railway noise — 32
5.21 Reflections between train and noise barrier — 32
5.22 Directivity of steel bridges for railway noise emissions — 33
5.23 Rail Squeal — 34
5.24 Rail pad stiffness — 35
5.25 Contact Filter and Rail roughness — 36
5.26 Wavelength — 38
5.27 Impact noise — 39
5.28 A-Weighting — 40
5.29 Ground attenuation — 40

6 **Possible improvements — 47**
6.1 Statistical method — 47
6.2 Attenuation from vegetation and industrial sites — 47
6.3 Heavy goods vehicles — 47
6.4 Addition of source heights — 47
6.5 Traction noise speed dependent — 47

7 Guidance — 49

8 Annex 1: Complete text for section 2.8 — 51

9 Annex 2: TNO report including PE calculations — 56

10 Annex 3: M+P report on emission values road surfaces — 57

11 Annex 4: dBvision report Bridge noise — 58

12 Annex 5: dBvision report on Rail squeal — 59

13 Annex 6: dBvision report on contact filter — 60

14 Annex 7: Research by Dirk van Maerke into an improved ground attenuation model — 61

15 Annex 8: Active members of the working group — 70

16 Annex 9: Amendments — 71
16.1 Include dwellings in text and specify how to calculate exposed area — 71
16.2 Specify façade points without reflections — 75
16.3 Rayleigh criterion — 75
16.4 Objects sloping more than 15 degrees are out of scope only for reflections — 77
16.5 With curved rays and multiple diffractions, e is the length of the sum of the arcs — 77
16.6 If source or receiver are below the mean ground plane, do not use a null height for path length differences — 77
16.7 Diffraction around vertical edges must be specified — 79
16.8 Reflected rays are curved depending on total length — 81
16.9 G_{path} is based on a 2D projection — 81
16.10 Specify unmodified heights for formula 2.5.20 — 81
16.11 Multiple diffractions in homogeneous condition — 81
16.12 Multiple diffractions in favourable conditions — 83
16.13 Remove the word local for velocity (traffic speed) — 84
16.14 Correct semi free field emission — 84
16.15 A weighting 2.1.1 vs 2.5.11 — 84
16.16 A unit is needs to be defined for the speed vehicle — 85
16.17 Error in French version of Table G-3 — 85
16.18 Table g-5 the values of the coefficients LW0idling for Diesel locomotive (c. 2 200 kW) at the 6350 Hz frequency seem wrong, and centre frequencies are incorrect in a few tables — 85
16.19 Reflections from vertical obstacles — 87
16.20 Equation 2.4.1 is incorrect — 87
16.21 Reflection between train and nearside noise barrier — 87
16.22 Steel bridges and railway noise — 92
16.23 Rail squeal — 93
16.24 Rail pad stiffness — 94
16.25 Contact filter and Rail Roughness — 94
16.26 Wavelength — 96
16.27 Impact noise — 96
16.28 Rail directivity — 97

16.29 Emission values road vehicles — 98
16.30 New correction values for road surfaces — 98

Erratum — 101-107

1 Introduction

During 2018, a working group consisting of representatives nominated by a number of EU member states has been working on refining the calculation method described within EU directive 2015/996 (Annex II of Directive 2002/49/EC) for road, rail and industrial noise (CNOSSOS-EU:2015).

A study performed in 2017 by RIVM using the CNOSSOS-EU:2015 method produced some unusual results which appeared to be caused by large errors in the method. As a result the Noise Regulatory Committee agreed, at a meeting on November 29 2017, that a working group would be established. Member states were invited to nominate experts to join the working group. In Annex 8 the active members of the working group are presented.

The purpose of this working group was to propose refinements to the CNOSSOS-EU:2015 method. In this report, the results of the working group are presented. In a separate document, the exact texts for each of the recommended amendments are presented.

In this document, each of the identified issues are presented, the problem is set out and the rationale for the recommended solution has been described.

The working group has been working according the work plan which was agreed upon during the first meeting.

An important part of adopting each recommended revision Annex II is that the working group can be reasonably confident that the proposed solutions resolve the identified issues without introducing new problems.

2 Approach of the Working group

The working group approached research improvements of the Annex as follows. A total of three meetings were planned. During the first meeting, all the issues that would be taken on by the working group were identified. In the second meeting, the easy solutions were discussed and it was discussed how to proceed.

At the final meeting most issues were agreed upon and it was discussed how to present the results.

3 Categorization of issues

During the first meeting, issues were identified which represented a challenge to the successful implementation of CNOSSOS-EU:2015 which was assigned to one of the following three categories:

1. An error, unclear text or necessary improvement that needs to be corrected in Annex II;
2. An improvement that may lead to a better method but is not strictly necessary to correct Annex II (wish list); or
3. An issue that does not need to be addressed in Annex II but which should be addressed in a subsequent guidance document.

The working group has **only** addressed issues that fell under category **1**. The list of suggested improvements or issues for categories 2 and 3 are presented at the end of this report but no recommended amendment to Annex II has been provided.

4 Classification of amendments

During the second and third meeting, the working group addressed the list of issues established during the first meeting and the proposals for solutions. In some cases, it is simply fixing a small error in the text while in other cases the solution is more elaborate. The working group has decided in the third meeting to define three classes for the proposed amendments:

1. A clarification of text or fixing a clear error
2. An improvement to the method
3. An issue that was worked on but no final improvement has been decided upon.

The first class of amendments is necessary because it will prevent implausible results or different interpretations of the text. Different interpretations will lead to different results. Thereby, forgoing the purpose of introducing a method to enable improved comparison of noise maps between member states.

The second class of amendments, constitutes, mostly minor, changes to the method. By applying these changes, calculated results are considered to be more in line with reality.

The third class of amendments consists of amendments where there is a known issue but the solution is not straightforward. Different solutions have been studied. However, within the time frame of the working group, no definitive or satisfactory solution was confirmed.

5 Issues studied and proposed amendments

5.1 Introduction

In this section, we present each issue identified by the working group and categorized as "An error, unclear text or necessary improvement that needs to be fixed in Annex II". The structure of this chapter is that each issue is presented in a similar manner. First, the description of why this is an issue is presented. Next, the proposed amendment is discussed.

The specific text of the amendment is presented in Annex 9. In some cases, parts of the proposed amendments are included in the discussion. In other cases, only a description is shown. When the specific text is shown, the new text is presented in purple.

5.2 Include dwellings in text and define exposed area

5.2.1 Description of issue

Annex VI of the European Noise Directive specifies the data that needs to be sent to the Commission:

2.7. The total area (in km^2) exposed to values of L_{den} higher than 55, 65 and 75 dB, respectively. The estimated total number of dwellings (in hundreds) and the estimated total number of people (in hundreds) living in each of these areas must also be given. Those figures must include agglomerations.

The END sets out a requirement to report the area exposed to certain noise levels due to major sources. The exposed areas may be inside or outside designated agglomerations.
As the total number of dwellings and number of people living "in each of these areas" must also be given.
EU Directive 2015/996 currently sets out a methodology to determine the exposure of inhabitants (Page 92, section 2.8). However, it does not set out a common methodology to determine the exposure of area or number of dwellings to noise from major sources.

Because the methodology is not defined, there is a risk that different member states will use different methodology to calculate these values.

5.2.2 Proposed amendment

Our proposed amendment consists of two parts. The first is to simply include the word "dwellings" in section 2.8. An excerpt of the proposed amendment is shown below with the newly included text in purple. The entire amendment is shown in Annex 1.

For the assessment of the noise exposure of dwellings and the exposure of people living in dwellings, only residential buildings shall be considered. No dwellings or people shall be assigned to other buildings without residential use such as schools, hospitals, office buildings or factories. The assignment of the dwellings, and people living in dwellings, to the residential buildings shall be based on the latest official data (depending on the Member State's relevant regulations). This process can be extended to other noise sensitive buildings in the scope of the directive.

The second amendment is to define how to calculate the exposed area. One of the choices that needed to be made, was whether building footprints are part of the reported area and how to handle grid points that are inside buildings. After some discussion, it has been decided by a majority (not unanimous) vote to include building footprint when reporting the exposed area. The proposed text is as follows:

Determination of the Area Exposed to Noise

The assessment of the area exposed to noise is based on receiver point levels at 4 m above the terrain level calculated on a grid for individual sources.

Grid points that are located inside buildings shall be assigned a noise level result by interpolation based on nearby calculated grid noise level results outside buildings.

Depending on the grid resolution, the corresponding area is assigned to each calculation point in the grid. For example, with a 10 m x 10 m grid each assessment point represents an area of 100 square metres that is exposed to the calculated noise level.

5.2.3 *Type of amendment*

The amendment adding the words “dwellings” and “people living in dwellings” are classified as class 1: Clarification of text.

The amendment on how to determine area exposed is classified as class 2: Improvement of the method.

5.3 Specify façade points without reflections

5.3.1 *Description of issue*

In the current text, it is stated that noise levels in front of the building must be assigned to the building. It is not stated whether incident noise levels should be used or not. Most people will use incident noise levels.

5.3.2 *Proposed amendment*

An extra sentence is proposed.

The assessment of population exposure to noise is based on receiver point levels at 4 m above the terrain level in front of building façades of residential buildings. Reflections from the considered façade shall be excluded from the calculations.

5.3.3 *Type of amendment*

This amendment is classified as class 1: Clarification of text.

5.4 Rayleigh criterion should be specified

5.4.1 *Description of issue*

In the current text, the Rayleigh criterion is mentioned. However, it is not defined how this should be implemented. There may be different software implementations for applying the Rayleigh criterion. For example, it is unclear whether a criterion should be based on a single mean plane or on two mean planes (between source and diffraction point and between diffraction point and receiver). Also, the path length

difference is compared to −λ/20. At −λ/20 the attenuation of the direct ray due to diffraction is zero by definition.
However, including this criterion does have an effect.

Calculation of attenuation in case path difference is larger than λ/20

With −λ/20	Without −λ/20
$A_{dif} = \Delta_{ground(S,O)} + \Delta_{ground(O,R)}$	$A_{dif} = A_{ground(S,R)}$

If only the −λ/20 criterion is used, a 1 cm high bump will cause diffraction. That is why, a criterion should be indicating whether the ground can be considered to be flat (a flatness criterion).

5.4.2 *Proposed amendment*

Two possible approaches were discussed. Both include a test to see whether the ground is flat by comparing the path length difference from source to diffraction point to receiver, with that from image source to diffraction point to image receiver. If this difference is smaller than λ/4, the ground is considered to be flat.

This first criterion is:
The "Raleigh-criterion" is fulfilled. This is the case, if δ is larger than λ/4 – δ*, where δ* is the path length difference calculated with this same edge D but related to the mirror source S* calculated with the mean ground plane at the source side and the mirror receiver R* calculated with the mean ground plane at the receiver side. To calculate δ* only the points S*, D and R* are taken into account – other edges blocking the path S*->D->R* are neglected.

The calculation of δ^* is shown in the figure below:

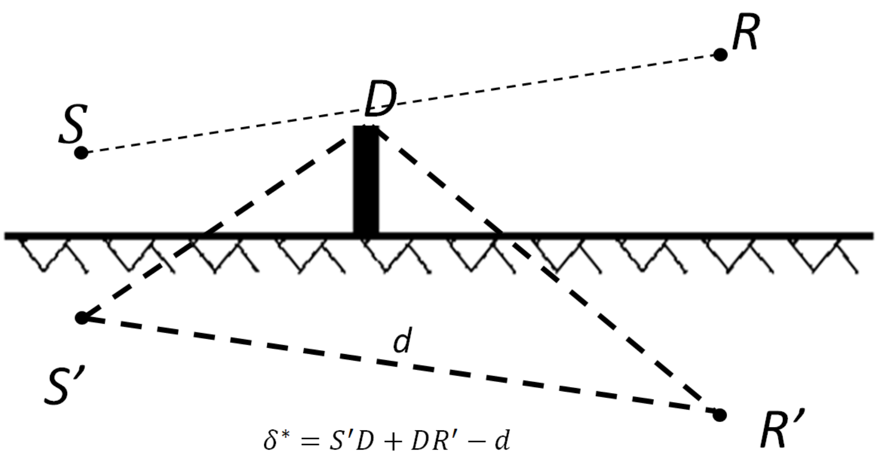


Figure 1: Calculation of path length difference for mirror source and mirror receiver.

There is some discussion whether the criterion above is sufficient or whether a second criterion needs to be included. This second criterion considers the path length difference and checks whether this is smaller than -λ/20. If that is the case, then the ground will also be considered to be flat.

5.4.3 Type of amendment
The amendment is classified as class 3: Worked on but no definitive agreement on solution is reached.

5.5 15 degrees obstacles are not always out of scope

5.5.1 Description of issue
In section 2.5.1 of the Annex, it is stated that "Partial covers and obstacles sloping, when modelled, more than 15° in relation to the vertical are out of the scope of this calculation method." This is not correct. It is clear this should only refer to reflections from such an obstacle. Diffraction should still be calculated.

5.5.2 Proposed amendment
We change the text slightly to read: "Objects sloping more than 15° in relation to the vertical are not considered as reflectors but taken into account in all other aspects of propagation such as ground effects and diffraction".

5.5.3 Type of amendment
This amendment is classified as class 1: Clarification of text.

5.6 In favourable conditions and diffraction by more than one edge, e is the length of the arcs between first and last diffraction edge

5.6.1 Description of issue
It is not clearly defined how to calculate the parameter e in favourable conditions (straight or curved lines as defined by the propagation path). The total effect is minor, however, every implementation should use the same method.
Here we state that the propagation path needs to be followed (curved rays). The influence may be small but it is better to clearly define which method to use.

5.6.2 Proposed amendment
We specify that the propagation path needs to be followed. That means that in favourable conditions, curved rays are used to determine e.

5.6.3 Type of amendment
This amendment is classified as class 1: Clarification of text.

5.7 If source or receiver are below the mean ground plane, do not use a null height for path length differences

5.7.1 Description of issue
When a source or receiver lies below the mean ground plane, a null height is retained. This could be misunderstood to imply that the points are shifted, which is not the case for diffraction. The null height is necessary to calculate the ground attenuation. However, it should be clear that no points are shifted for the calculation of diffraction because a strong overestimation of noise levels might occur.

5.7.2 Proposed amendment
This is clarified by adding a special condition in case the source or receiver are located below the mean ground plane.

In the special case the source lies below the mean ground plane $\Delta_{dif(S,R)}= \Delta_{dif(S',R)}$ and $\Delta_{ground(S,O)} = A_{ground(S,O)}$

In the special case the receiver lies below the mean ground plane $\Delta dif(S,R) = \Delta dif(S,R')$ and $\Delta_{ground(O,R)} = A_{ground(O,R)}$

5.7.3 *Type of amendment*
This amendment is classified as class 1: Clarification of text.

5.8 Diffraction around vertical edges must be specified

5.8.1 *Description of issue*
It is not clear how to handle diffraction along vertical edges and how to construct paths along vertical edges. When constructing ray paths, there are many methods and many different path types available. Keeping this unclear will lead to different methods to implement lateral diffraction.

5.8.2 *Proposed amendment*
For clarity, we now add the provision that a maximum of two lateral paths based on a convex path should be constructed.

Also, we have limited lateral diffraction to sources where lateral diffraction can be relevant (point sources).

Furthermore, it is clarified that the mean ground plane and the ground attenuation are calculated by following the actual diffracted path instead of the direct path.

5.8.3 *Type of amendment*
This amendment is classified as class 1: Clarification of text.

5.9 Reflected rays are curved, depending on total length

5.9.1 *Description of issue*
In case of reflections, it is not stated exactly how to determine the curvature. It could be based on the distance of the direct path or based on the path length including reflection.

5.9.2 *Proposed amendment*
We have added the clarification that the radius of the curvature is calculated by considering the total unfolded path length difference (in case of reflections).

5.9.3 *Type of amendment*
This amendment is classified as class 1: Clarification of text.

5.10 G-path is based on a 2D projection

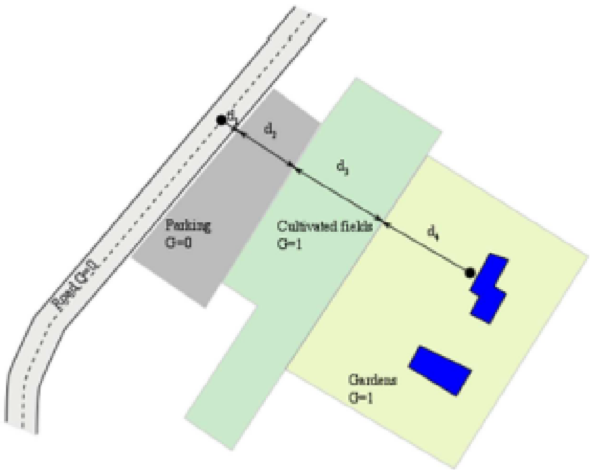
5.10.1 *Description of issue*
G_{path} can be calculated using a 3D or a 2D projection. In case of a 3D projection the total length in 3d on the ground is considered. In the example of a vertical object 1 meter wide and 6 meters high the 3D length is 6+1+6=13 meters (up, over the top and down) and the 2D projection is 1 meter. It should be clear that a 2D projection is to be used.

5.10.2 *Proposed amendment*

We have added a small sentence below the picture showing the determination of G_{path}:

Figure 2.5.b

Determination of the ground coefficient G_{path} over a propagation path



$$d_p = d_1 + d_2 + d_3 + d_4$$

$$G_{path} = {(0 \cdot d_1 + 0 \cdot d_2 + 1 \cdot d_3 + 1 \cdot d_4)}/{d_p} = {(d_3 + d_4)}/{d_p}$$

The distances d_n are determined by a 2D projection onto the horizontal plane.

5.10.3 *Type of amendment*

This amendment is classified as class 1: Clarification of text.

5.11 Specify unmodified heights for formula 2.5.20

5.11.1 *Description of issue*

There has been some discussion on whether or not to use modified height in formula 2.5.20:

(b) The lower bound of $A_{ground,F}$ depends on the geometry of the path:

$$A_{ground,F,\min} = \begin{cases} -3\left(1-\overline{G_m}\right) & \text{if } d_p \le 30(z_s + z_r) \\ -3\left(1-\overline{G_m}\right) \cdot \left(1 + 2\left(1 - {30(z_s+z_r)}/{dp}\right)\right) & \text{otherwise} \end{cases} \qquad (2.5.20)$$

It was agreed upon that no modified heights should be used. In the past, software applications have erroneously applied a modified height in formula 2.5.20. To avoid mistakes, we clarified that unmodified height must be used.

5.11.2 *Proposed amendment*

We specify exactly in which formula the modified heights must be used:

In equation 2.5.15 ($A_{ground,H}$) the heights …

We also specifically mention that modified heights should not be used in formula 2.5.20:

b) The lower bound of $A_{ground,F}$ (calculated with unmodified heights) depends on the geometry of the path:

$$A_{ground,F,\min} = \begin{cases} -3\left(1-\overline{G_m}\right) & \text{if } d_p \le 30\left(z_s+z_r\right) \\ -3\left(1-\overline{G_m}\right)\cdot\left(1+2\left(1-\dfrac{30\left(z_s+z_r\right)}{dp}\right)\right) & \text{otherwise} \end{cases} \quad (2.5.20)$$

5.11.3 *Type of amendment*

This amendment is classified as class 1: Clarification of text.

5.12 Multiple Diffraction Problem

5.12.1 *Description of issue*

In the current Annex, straight lines are used to determine which diffraction points are relevant. This leads to strange and clearly incorrect results where adding diffraction points leads to higher noise levels. The reason this error occurs is that in favourable conditions, propagation paths are curved. It is necessary to also use curved lines instead of straight lines for the diffracted path. The group has studied two possible solutions:

1. Curved ground solution
2. Curved ray solution

In the curved ground solution, the same method with straight lines as in the homogeneous situation is used but a coordinate transformation is applied before doing this. In the curved ray solutions, we use curved rays to determine diffraction points and calculate path length differences.

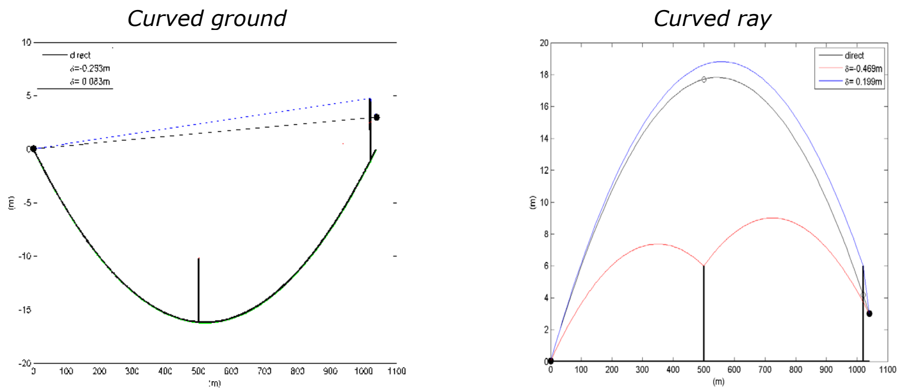


Figure 2: Difference between curved ground and curved ray approach.

It has been shown with PE calculations (see Annex 2) that there is no preference for either method. That is why, it has been decided to use the curved ray solution as it stays closer to the original method.

Also, an example of how to calculate diffraction under favourable condition with multiple diffractions and a similar example under homogeneous conditions is shown.

5.12.2 *Proposed amendment*

The proposed amendment consists of an updated figure and clear text (to replace the three points) on how to determine which diffraction points are taken into account in the calculation.

~~— determine the convex hull defined by the various potential diffraction edges;~~
~~— eliminate the diffraction edges which are not on the boundary of the convex hull;~~
~~— calculate *δF* based on the lengths of the curved sound ray, by breaking down the diffracted path into as many curved segments as necessary (see Figure 2.5.f)~~

$$\delta_F = \hat{S}O + \sum_{i=1}^{n-1} O_i\hat{O}_{i+1} - \hat{O}_n R - \hat{S}R$$

Under favourable conditions, the propagation path in the vertical propagation plane always consists of segments of a circle whose radius is given by the 3D-distance between source and receiver, 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 relevant propagation path is defined as the shortest combination of convex 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.

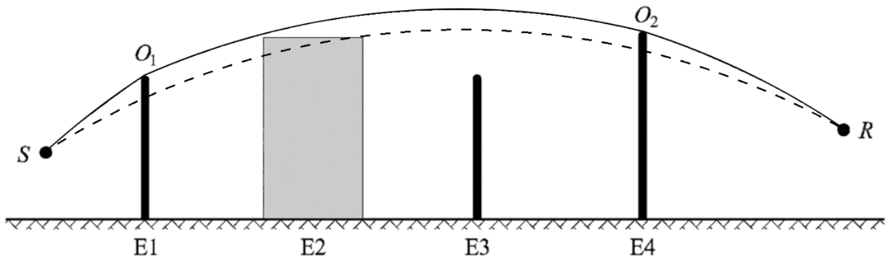
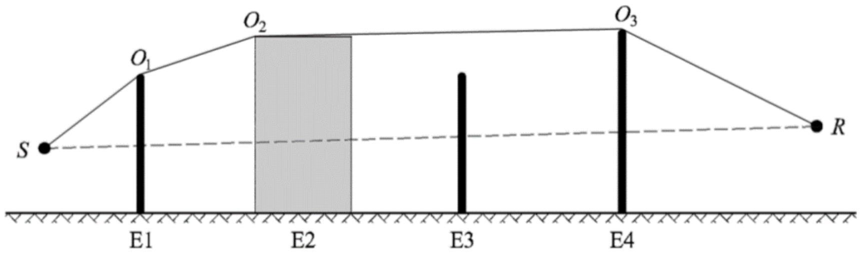


Figure 2.5.f Example of calculation of the path difference in favourable conditions, in the case of multiple diffractions

$$\delta_F = \hat{S}O_1 + O_1\hat{O}_2 + \hat{O}_2R - \hat{S}R \quad (2.5.29)$$

We have included the same example but with straight lines under the section on homogeneous conditions.



$$\delta = SO_1 + O_1O_2 + O_2O_3 + O_3R - SR$$

Figure 2.d

5.12.3 Type of amendment

This amendment is classified as class 1: Fix of error (favourable) and clarification of text (homogeneous)

5.13 Remove word local for velocity (traffic speed)

5.13.1 Description of issue

In the Annex it is stated: "*If local measurement data is unavailable, the maximum legal speed for the vehicle category shall be used*."

It is not clear what is meant with "local"; Must it be of a specific road, even between certain intersections or can it be based on measurement of road types?

5.13.2 Proposed amendment

We propose to remove the word "local" allowing member states a choice on how and when to deviate from maximum legal speeds.

5.13.3 Type of amendment

This amendment is classified as class 1: Clarification of text.

5.14 New correction values for road surfaces

5.14.1 Description of issue

Each country is permitted to use their own emission values. Some default values for road surface corrections are presented in Table F-4. These values are a direct copy of values used in the Netherlands. These

values work within the framework of the Dutch national method. There are some differences between the CNOSSOS-EU:2015 method and the Dutch national method which result in incorrect values and an incorrect Table.
There are two differences:

1. The reference speed for light vehicles is 80 km/h in the Netherlands and 70 km/h in CNOSSOS-EU:2015.
2. In the Netherlands, the corrections are always applied on the total emission (no separation between rolling and propulsion noise). In CNOSSOS-EU:2015, corrections that lead to higher emissions are not applied on propulsion noise. Using the current values in the Annex therefore leads to an underestimation of emission values.

To fix part 1 of this issue (reference speed), we simply change the values for light vehicles to take the different reference speed into account.

For part 2 of this issue, two solutions were considered. The first was to change the values in the Table and the second was to apply the correction for road surfaces on both the rolling and propulsion noise components. The second solution seems viable because the emission heights are 0.05m for both components and when determining correction values, rolling noise is always measured together with propulsion noise, so it is difficult to separate the components. The difficulty with the second solution is that it seems counterintuitive.

After some discussion, it was decided to only change the emission values in the Table. In the future, this may be reconsidered. In Annex 3, we present a report that described how the new values were derived.

5.14.2 Proposed amendment
A completely new Table with corrections for road surfaces is presented.

5.14.3 Type of amendment
This amendment is classified as class 1: Fix of error.

5.15 Clarification of railway speed is required

5.15.1 Description of issue
In formula 2.3.2 on railway noise, the correction on emission as a function of number of vehicles and speed of vehicles is presented:

$$L_{W',eq,line,i}(\psi,\varphi) = L_{W,0,dir,i}(\psi,\varphi) + 10 \times \lg\left(\frac{Q}{1\,000v}\right) \text{ (for } c = 1) \quad (2.3.2)$$

The parameters Q, v and $L_{W,0,dir}$ are described below this formula. In the description for the parameter v (speed), a unit is missing. It might be unclear whether speed is in m/s of km/h.

5.15.2 Proposed amendment
The unit km/h was added.

v is their speed [km/h] in the j-th for

5.15.3 *Type of amendment*
This is a class 1 amendment: clarification of text.

5.16 Error in French version of Table G-3

5.16.1 *Description of issue*
In the second part of the Table G-3, the coefficient indicated at the top is $L_{r,VEH,i}$. This is incorrect and should be (as in other languages) $L_{H,VEH,i}$ This error occurs both in the text and in the corrigendum.

5.16.2 *Proposed amendment*
We propose to change the coefficient at the top of the second part of the Table G-3 to $L_{H,VEH,i}$. This change is only relevant for the French version of Annex II and the corrigendum.

5.16.3 *Type of amendment*
This is a class 1 amendment: Fix of error

5.17 Table G-5, the values of the coefficients $L_{W0idling}$ for Diesel locomotive (c. 2 200 kW) at the 6350 Hz frequency seem wrong and centre frequencies are incorrect in a few Tables.

5.17.1 *Description of issue*
In Table G-5, coefficients for idling trains are given. In the case of diesel locomotives (c 2200kW), the values at 6350 Hz differ greatly from all other values. It seems that a conversion error has occurred where an 8 has accidentally been changed into a 3.

Also, a few frequencies seem to differ slightly from the centre frequency for their octave band. This occurs in Tables G-3, G5 and G6

5.17.2 *Proposed amendment*
We propose to change the values for diesel-locomotive from 31.4 to 81.4 and 30.7 to 80.7. We also propose to change the frequencies:
316 Hz to 315 Hz
3160 Hz to 3150 Hz
6350 Hz to 6300 Hz

The numbers that need to be changed are shown in the next picture. Only half of the second part of Table G5 is shown.

Frequentie	$L_{W,0,idling}$				
	Voe				
	d		d		
	Diesel-locomotief (c. 800 kW)		Diesel-locomotief (c. 2 200 kW)		Dies
	bron A	bron B	bron A	bron B	bron A
800 Hz	95,2	92,7	101,7	99,2	90,9
1 000 Hz	95,1	93,0	101,6	99,5	91,8
1 250 Hz	95,1	92,9	99,3	97,1	92,8
1 600 Hz	94,1	93,1	96,0	95,0	92,8
2 000 Hz	94,1	93,2	93,7	92,8	90,8
2 500 Hz	99,4	98,3	101,9	100,8	88,1
3 160 Hz	92,5	91,5	89,5	88,5	85,2
4 000 Hz	89,5	88,7	87,1	86,3	83,2
5 000 Hz	87,0	86,0	90,5	89,5	81,7
6 350 Hz	84,1	83,4	31,4	30,7	78,8
8 000 Hz	81,5	80,9	81,2	80,6	76,2
10 000 Hz	79,2	78,7	79,6	79,1	73,9

5.17.3 *Type of amendment*

This is a class 1 amendment: Fix of error

5.18 Formula 2.4.1 is misleading/incorrect

5.18.1 Description of issue

Formula 2.4.1 states how to calculate emission values (per meter) for moving industrial vehicles (represented as line sources). Formula 2.4.1 states the correction for working hours. It is:

$$C_W = -10\lg\left(\frac{l \times n}{1\,000 \times V \times T_0}\right) \quad 2.4.1$$

Where n is the number of passages per period, v the speed of the vehicles, T_0 the number of hours per period and l the length of the source. This implies that C_w is a correction to determine the total emission of the line source per period. However, the text above formula 2.4.1 talks about emission per meter. This implies that the length of the line source should not be added in C_w but 1 meter as the reference length.

5.18.2 Proposed amendment

A solution could be to change formula 2.4.1. However, the formula that needs to be used, is the same as for road traffic noise. That is why, it is proposed to simply state:

Source lines representing moving vehicles are calculated according to formula 2.2.1

For reference, this formula is:

$$L_{W',eq,line,i,m} = L_{W,i,m} + 10 \times \lg\left(\frac{Q_m}{1\,000 \times v_m}\right) \quad (2.2.1)$$

where $L_{W,i,m}$ is the directional sound power of a single vehicle. $L_{W',m}$ is expressed in dB (re. 10^{-12} W/m). These sound power levels are calculated for each octave band i from 125 Hz to 4 kHz.

5.18.3 Type of amendment

This is a class 1 amendment: Fix of error.

5.19 Reflections on vertical obstacles

5.19.1 Description of issue

When an object has a slope of less than 15 degrees, it is considered to be vertical. There is no description of how to derive paths in favorable or homogeneous conditions. Because this is not described, different ways to implement the method can occur. To avoid this, a clarifying text in proposed.

5.19.2 Proposed amendment

We propose the following text to express in detail how to handle sloped objects:

Surfaces of objects are only considered as reflectors when their slope is less than 15° with respect to the vertical. Reflections are considered for paths in the vertical propagation plane only, i.e., not for laterally diffracted paths. For the incident and reflected path (assuming that the reflecting surface is vertical), the point of reflection (which lays on the reflecting object), is constructed using straight lines under homogeneous and curved lines under favourable propagation conditions. The height of the reflector shall be at least 0.5 m when measured through the point of reflection and viewed from the direction of the incident ray. After projection onto a horizontal plane, the width of the reflector shall be at least 0.5 m when measured through the point of reflection and viewed from the direction of the incident ray.

5.19.3 *Type of amendment*
This amendment is classified as class 1: Clarification of text.

5.20 Vertical directivity railway noise

5.20.1 *Description of issue*
Vertical directivity is calculated in CNOSSOS-EU:2015 by:

$$\Delta L_{W,dir,ver,i} = \left(\left|\frac{40}{3} * \left[\frac{2}{3} * \sin(2 * \psi) - \sin(\psi)\right] * \lg\left[\frac{f_{c,i} + 600}{200}\right]\right|\right)$$

For angles $-\pi/2 < \psi < \pi/2$.

In NMPB, this formula is almost exactly the same but for angles $0 < \psi < \pi/2$

$$\Delta L_{W,dir,ver,i} = \left(\frac{40}{3} * \left[\frac{2}{3} * \sin(2 * \psi) - \sin(\psi)\right] * \lg\left[\frac{f_{c,i} + 600}{200}\right]\right)$$

The difference is that in the CNOSSOS-EU:2015 adaptation the vertical directivity is always positive due to the position of the absolute symbols.

The maximum difference between the two equations is at an angle of 90 degrees ($\pi/2$), when the correction at 63Hz is -6.94 in NMPB and 6.94 in CNOSSOS-EU:2015, a difference of 13.88 dB occurs.

5.20.2 *Proposed amendment*
We propose to change the location of the absolute symbol so that the results in NMPB and CNOSSOS-EU:2015 are the same:

$$\Delta L_{W,dir,ver,i} = \left(\frac{40}{3} * \left[\frac{2}{3} * \sin(|2 * \psi|) - \sin(|\psi|)\right] * \lg\left[\frac{f_{c,i} + 600}{200}\right]\right)$$

5.20.3 *Type of amendment*
This amendment is classified as class 1: Fix of error

5.21 Reflections between train and noise barrier

5.21.1 *Description of issue*
It is known that barrier-train interaction can lead to reduced barrier attenuation. There is currently no provision to take this into account. Therefore, the effectiveness of a reflecting noise barrier will be overestimated. Depending on the situation, this overestimation can be as high 10 dB.

5.21.2 Proposed amendment

We propose to include a method based on the French standard NF S31-133:2011-02. The method uses retro-diffraction to calculate the effect of barrier-train interaction. The method that we propose is currently widely used in France.

The method uses retro diffraction formula's, in a simplified manner, to calculate an equivalent source sound power. For each source/receiver configuration, a correction on source sound power is used.

Once the equivalent source sound power is known, the noise levels are calculated based on all the normal formulas of Annex II.

5.21.3 Type of amendment

This is a class 2 amendment: Improvement of method.

5.22 Directivity of steel bridges for railway noise emissions

5.22.1 Description of issue

Currently, noise emitted by steel railway bridges is modelled by applying a correction to the rolling noise. This correction is a single overall dB value (not frequency dependent) and noise emitted by the bridge has the same directivity as train noise (dipole). It is well known that noise emitted by the bridge does not have dipole directivity.

An example of the use of a dipole or a monopole for the bridge emission is shown below.

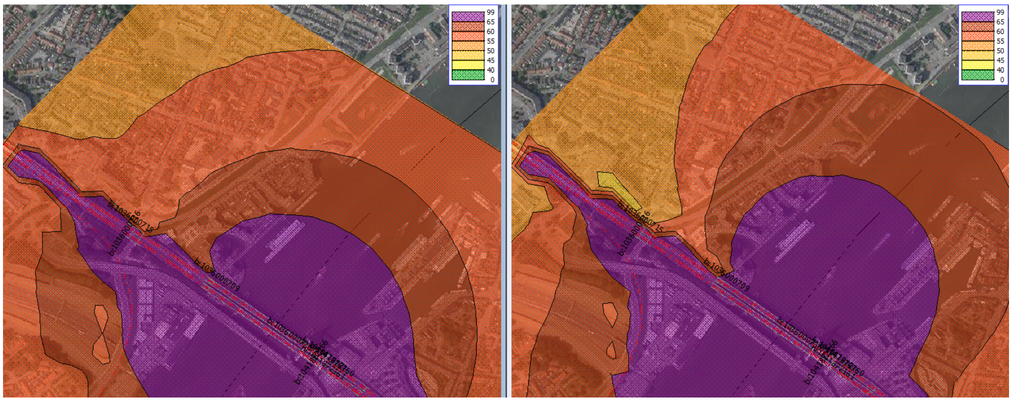


Figure 3: Use of monopole (left) and dipole (right) for bridge structure emitted noise.

In the above example, noise levels are much lower close to the track due to the presence of a noise barrier on the north side of the rail track; The bridge emits with a dipole directivity.

5.22.2 Proposed amendment

We introduce the possibility to use frequency dependent correction terms. Secondly, we change the directivity of bridges such that noise is emitted uniformly by bridges (but trains remain as dipole). In Annex 4, a detailed report is presented on this subject.

5.22.3 Type of amendment

This is a class 2 amendment: Improvement of method.

5.23 Rail Squeal

5.23.1 Description of issue

Annex II incorporates a description of curve squeal noise that needs clarification and refinement on a few aspects. Firstly, there is a potentially ambiguous formulation, as it features both an "appropriate description" and a "simple approach" for curve squeal. The text needs to clarify which of these formulations has to be used in a specific case. Secondly, the curve radius that is generally associated with squeal noise of tram systems is much smaller than the two curvature classes declared in Annex II. Trams do not tend to squeal in curves with radii over 200 meters.

Thirdly, the track length restriction, stating that squeal in sections shorter than 50 m can be ignored, implies that short turnouts (of switches[1]) as well as tight tramway curves, both of which are likely to cause severe squeal, would be excluded. Finally, the expression 'branch-outs of points' needs to become more descriptive.

In Annex 5 we present an article with background of the proposal.

5.23.2 Proposed amendment

In Section 2.3.2 the contents of subsection "Squeal" should be replaced by:

Curve squeal is a special source that is only relevant for curves and is therefore localised. Curve squeal is generally dependent on curvature, friction conditions, train speed, track-wheel geometry and dynamics. As it can be significant, an appropriate description is required. At locations where curve squeal occurs, generally in curves and turnouts of railroad switches, suitable excess noise power spectra need to be added to the source power. The excess noise may be specific to each type of rolling stock and certain wheel and bogie types may be significantly less prone to squeal than other types. If measurements of the excess noise are available that take sufficiently the stochastic nature of squeal into account, these may be used.

If no appropriate measurements are available, a simple approach can be taken. In this approach, squeal noise shall be considered by adding the following excess values to the rolling noise sound power spectra for all frequencies.

[1] Not all languages have a short and easy expression for a switch turnout that can be understood. Translators can use Figure 3 and the (English) wikipedia lemma "Railroad switch" to find proper descriptions for other languages. In German Gleisabzweigung can be used, in Dutch afbuiging van een wissel. The RailLexic of UIC (subscription required) may also contain good translations for a switch turnout.

Train	5 dB for curves with 300 m < R ≤ 500 m and l_{track} ≥ 50 m; 8 dB for curves with R ≤ 300 m and l_{track} ≥ 50 m; 8 dB for switch turnouts with R ≤ 300 m
Train	5 dB for curves and switch turnouts with R ≤ 200 m

where l_{track} is the length of track along the curve and R is the curve radius.

The applicability of these sound power spectra or excess values shall normally be verified on-site, especially for trams and for locations where curves or turnouts are treated with measures against squeal.

5.23.3 *Type of amendment*

This amendment is classified as class 1: textual clarification

5.24 Rail pad stiffness

5.24.1 *Description of issue*

The description of track stiffness may benefit from a clarification. At several sections in the Directive the term stiffness is used, as 'acoustic' stiffness, of just stiffness. It needs to be clarified whether this refers to dynamic stiffness or static stiffness.

The pad stiffness value that is relevant for acoustics needs to refer to the dynamic stiffness (at small strains). Its value can be quite different from static stiffness over large strains which is relevant for track engineering. Chapter 3.8 from Thompson's book gives a thorough treatment on pad stiffness for noise prediction. The relevant frequency range for the dynamic stiffness is 100-5000 Hz. When measuring the dynamic stiffness of a rail pad in a laboratory set-up, a pre-load within the range 20-60 kN needs to be applied to it. It would be helpful to know the value of the pad stiffness belonging to the classification 'soft', 'medium' and 'hard' in Table G-3 of Annex II.

The source of these track transfer functions is the IMAGINE project (2004-2006). Modifications to the tabulated functions were necessary in Annex II, probably due to the different definition of the transfer function in IMAGINE. Unfortunately, the pad stiffness values are not listed in IMAGINE and neither are most of the other settings in the TWINS model that produced these transfer functions. Elsewhere in Annex II, in Table 2.3.b, another classification is given for the pad stiffness: 'soft', 'medium' and 'stiff'. This classification contains certain stiffness ranges in MN/m. It probably originates from the STAIRRS project (2000-2002). It is unlikely that these ranges for the ('acoustic') stiffness correspond to the classification in Table G-3 as they are from a different source with a different goal.

5.24.2 *Proposed amendment*

On page 14, in Table [2.3.b], fourth column, third row:

Represents an indication of the ~~'acoustic'~~ 'dynamic' stiffness

On page 14, in Table [2.3.b], Fourth column, sixth row:

~~Stiff~~ Hard
(800-1 000 MN/m)

5.24.3 Type of amendment
This amendment is classified as class 1: textual clarification.

5.25 Contact Filter and Rail roughness

5.25.1 Description of issue
In the rail source model for railway and tramway noise, a contact filter (denoted A3,i) takes part in all rolling noise calculations, see equation (2.3.7). It has been reported in 2014 that the CNOSSOS-EU:2015 method includes values for contact filters that are outdated. A set of contact filters is needed to convert data acquired from direct measurement of rail and wheel roughness into combined effective roughness. This filter simulates the low-pass frequency filtering effect of the contact patch.

The main purpose of correcting the set of contact filters in CNOSSOS-EU:2015, is to avoid large errors when directly measured rail and wheel roughness is used for computations.

The proposal consists of changes in the default values in appendix G. These default values are not mandatory to use.

Therefore, it is suggested that a correction to the outdated contact filters should be accompanied by a compensating correction of other default parameters in CNOSSOS-EU:2015.

In Annex 6, we present an article with background of the proposal.

The default spectrum for rail roughness in CNOSSOS-EU:2015, titled 'Average network (Normally maintained smooth)', is a copy of the spectrum in the Dutch computation method RMR. The Dutch spectrum is a stylised version of an average spectrum from rail roughness measurements on 30 track sites in the Netherlands in the 1990s. This means that the computed average of the measurement data was manipulated by hand to make it smoother which was probably done to make it easier for the user to copy the values. The spectral fine-structure was removed from the data resulting in a straight line (slope 1 dB per one-third octave).

The problem is mainly that the shorter wavelengths of the stylised version have a roughness level that is too high, not only if it is compared to the original data but also to more recent data measured at different wavelengths.

At the time, simplification was considered not significant because the spectrum was an average of a dataset with a considerable statistical spread. However, there is no reason to assume that a standard spectrum for rail roughness should be a straight line. We propose to repair the unnecessary stylisation. We propose to use a realistic rail roughness default spectrum based on measurement data.

5.25.2 *Proposed amendment*

Table G-1 Coefficients Lr,TR,i and Lr,VEH,i for rail and wheel roughness

$L_{r,TR,i}$		
Wavelength	Rail Roughness	
	E	M
	EN ISO 3095:2013 (Well maintained and very smooth)	Average network (Normally maintained smooth)
2 000 mm	17,1	35,0
1 600 mm	17,1	31,0
1 250 mm	17,1	28,0
1 000 mm	17,1	25,0
800 mm	17,1	23,0
630 mm	17,1	20,0
500 mm	17,1	17,0
400 mm	17,1	13,5
315 mm	15,0	10,5
250 mm	13,0	9,0
200 mm	11,0	6,5
160 mm	9,0	5,5
125 mm	7,0	5,0
100 mm	4,9	3,5
80 mm	2,9	2,0
63 mm	0,9	0,1
50 mm	−1,1	-0,2
40 mm	−3,2	-0,3
31,5 mm	−5,0	-0,8
25 mm	−5,6	-3,0
20 mm	−6,2	-5,0
16 mm	−6,8	-7,0
12,5 mm	−7,4	-8,0
10 mm	−8,0	-9,0
8 mm	−8,6	-10,0
6,3 mm	−9,2	-12,0
5 mm	−9,8	-13,0
4 mm	−10,4	-14,0
3,15 mm	−11,0	-15,0
2,5 mm	−11,6	-16,0
2 mm	−12,2	-17,0
1,6 mm	−12,8	-18,0
1,25 mm	−13,4	-19,0
1 mm	−14,0	-19,0
0,8 mm	−14,0	-19,0

Table G-2 Coefficients A3,i for the contact filter

	$A_{3,i}$				
Wavelength	Wheel load 50 kN - wheel diameter 360 mm	Wheel load 50 kN - wheel diameter 680 mm	Wheel load 50 kN - wheel diameter 920 mm	Wheel load 25 kN - wheel diameter 920 mm	Wheel load 100 kN - wheel diameter 920 mm
2 000 mm	0,0	0,0	0,0	0,0	0,0
1 600 mm	0,0	0,0	0,0	0,0	0,0
1 250 mm	0,0	0,0	0,0	0,0	0,0
1 000 mm	0,0	0,0	0,0	0,0	0,0
800 mm	0,0	0,0	0,0	0,0	0,0
630 mm	0,0	0,0	0,0	0,0	0,0
500 mm	0,0	0,0	0,0	0,0	0,0
400 mm	0,0	0,0	0,0	0,0	0,0
315 mm	0,0	0,0	0,0	0,0	0,0
250 mm	0,0	0,0	0,0	0,0	0,0
200 mm	0,0	0,0	0,0	0,0	0,0
160 mm	0,0	0,0	0,0	0,0	-0,1
125 mm	0,0	0,0	-0,1	0,0	-0,2
100 mm	0,0	-0,1	-0,1	0,0	-0,3
80 mm	-0,1	-0,2	-0,3	-0,1	-0,6
63 mm	-0,2	-0,3	-0,6	-0,3	-1,0
50 mm	-0,3	-0,7	-1,1	-0,5	-1,8
40 mm	-0,6	-1,2	-1,3	-1,1	-3,2
31,5 mm	-1,0	-2,0	-3,5	-1,8	-5,4
25 mm	-1,8	-4,1	-5,3	-3,3	-8,7
20 mm	-3,2	-6,0	-8,0	-5,3	-12,2
16 mm	-5,4	-9,2	-12,0	-7,9	-16,7
12,5 mm	-8,7	-13,8	-16,8	-12,8	-17,7
10 mm	-12,2	-17,2	-17,7	-16,8	-17,8
8 mm	-16,7	-17,7	-18,0	-17,7	-20,7
6,3 mm	-17,7	-18,6	-21,5	-18,2	-22,1
5 mm	-17,8	-21,5	-21,8	-20,5	-22,8
4 mm	-20,7	-22,3	-22,8	-22,0	-24,0
3,15 mm	-22,1	-23,1	-24,0	-22,8	-24,5
2,5 mm	-22,8	-24,4	-24,5	-24,2	-24,7
2 mm	-24,0	-24,5	-25,0	-24,5	-27,0
1,6 mm	-24,5	-25,0	-27,3	-25,0	-27,8
1,25 mm	-24,7	-28,0	-28,1	-27,4	-28,6
1 mm	-27,0	-28,8	-28,9	-28,2	-29,4
0.8 mm	-27,8	-29,6	-29,7	-29,0	-30,2

5.26.1 *Type of amendment*

Class 2 improvement of the method. The main purpose of a correction to the set of contact filters in appendix G of Annex II, is to avoid large errors when directly measured rail and wheel roughness are used for calculations.

In Annex 6 we present an article with background of the proposal.

If the proposed amendment of wheel roughness is followed, the calculated emission with all default values will change.

In Annex 6 a proposal of wheel roughness can be found which leaves the calculated rolling noise emissions with that set of default values unchanged compared to the present Annex.

However, default values are not mandatory and countries are recommended to validate the rolling noise emission model with measurements.

5.27 Impact noise

5.27.1 Description of issue

The impact noise in CNOSSOS-EU:2015 is calculated by (energetically) adding a so-called 'impact roughness spectrum' to the total effective roughness (formula 2.3.11). In a comparison study commissioned by RIVM in 2017, it was found that the CNOSSOS-EU:2015 impact roughness corresponds to a noise emission that is more than 15 dB(A) higher than a continuously welded track. Clearly, this is not realistic. This high value may be related to the definition of 'joint density' in IMAGINE (number of joints per unit of track length).

Without going into details of the approach given in IMAGINE, we recall that in CNOSSOS-EU:2015, the definition of the joint density is given in the text below equation (2.3.12). It states that 1 joint per 100 m of track is represented by setting nl = 0,01. A detailed description of the issue and solution is presented in Annex 6.

5.27.2 Proposed amendment

We propose to amend this issue by changing Table G-5 with the coefficients for impact noise.

Table G-4 Coefficients $L_{R,IMPACT,i}$ for impact noise

$L_{R,IMPACT,i}$	
Wavelength	Single switch/joint/crossing/100 m
2 000 mm	22,0
1 600 mm	22,0
1 250 mm	22,0
1 000 mm	22,0
800 mm	22,0
630 mm	20,0
500 mm	16,0
400 mm	15,0
315 mm	14,0
250 mm	15,0
200 mm	14,0
160 mm	12,0
125 mm	11,0
100 mm	10,0
80 mm	9,0
63 mm	8,0
50 mm	6,0
40 mm	3,0

$L_{R,IMPACT,i}$	
Wavelength	Single switch/joint/crossing/100 m
31,5 mm	2,0
25 mm	-3,0
20 mm	-8,0
16 mm	-13,0
12,5 mm	-17,0
10 mm	-19,0
8 mm	-22,0
6,3 mm	-25,0
5 mm	-26,0
4 mm	-32,0
3,15 mm	-35,0
2,5 mm	-40,0
2 mm	-43,0
1,6 mm	-45,0
1,25 mm	-47,0
1 mm	-49,0
0,8 mm	-50,0

5.27.3 *Type of amendment*
This amendment is classified as class 1

5.28 A-Weighting

5.28.1 *Description of issue*
The use of A-weighting is mentioned in two parts of the Annex. The first one is in the part defining common indicators (formula 2.1.1) and the second one is defined in the section on propagation (formula 2.5.11). It is unclear why the A-weighting is defined twice. Both formulas refer to IEC31672-1 for the frequency weighting. However, in IEC31672-1 only values for 1/3 octave bands are presented.

5.28.2 *Proposed amendment*
It is proposed to skip formula 2.1.1 and only refer to the method described in sections 2.2, 2.3, 2.4 and 2.5. Also, we propose to include the following table to define the A-weighting for octave band centre frequencies:

Frequency [Hz]	63	125	250	500	1000	2000	4000	8000
$AWC_{f,I}$ [dB]	-26.2	-16.1	-8.6	-3.2	0	1.2	1.0	-1.1

5.28.3 *Type of amendment*
This amendment is classified as class 1

5.29 Ground attenuation

5.29.1 *Description of issue*
A number of issues were found concerning ground attenuation. The main issues were:

1. Formula’s not suitable for high sources
2. Discontinuity between the situations where G_{path}=0 and G_{path}>0
3. Much less attenuation at larger distances (in favourable conditions)

5.29.1.1 Formula's not suitable for high sources
The ground attenuation is calculated by assuming a ground factor at the source and the average between source and receiver. From a fundamental point of view, this is incorrect as the propagation path should be reciprocal, i.e., the propagation path from source to receiver is the same as from receiver to source. However, in the case of low sources, using the method in Annex II is a fair approximation as the first reflection occurs very near the source.

In the case of high sources and low(er) receivers, this approximation is no longer valid. The first reflection could even occur closer to the receiver than to the source, making the ground type near the receiver more relevant.

The consequence of this issue is that results are not plausible.

5.29.1.2 Discontinuity between situation where $G_{path}=0$ and $G_{path}>0$
There is an exception for the special case $G_{path}=0$. It is unknown what the reason is for this exception. It does lead to a discontinuity which is illustrated in the figure below (excerpt from the report in Annex 2)

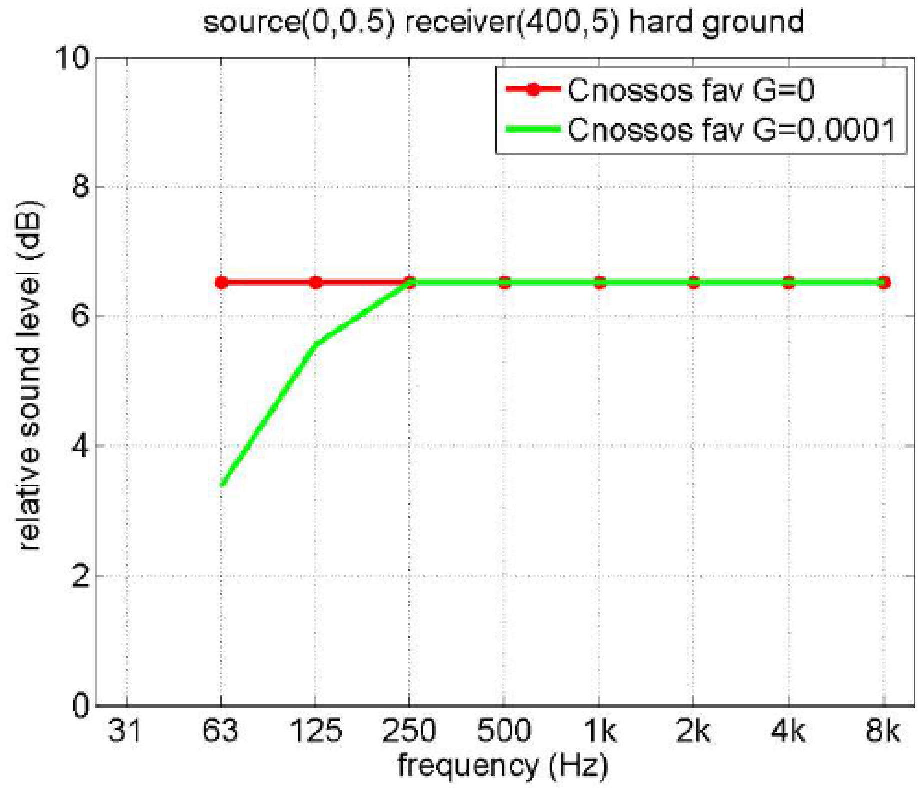
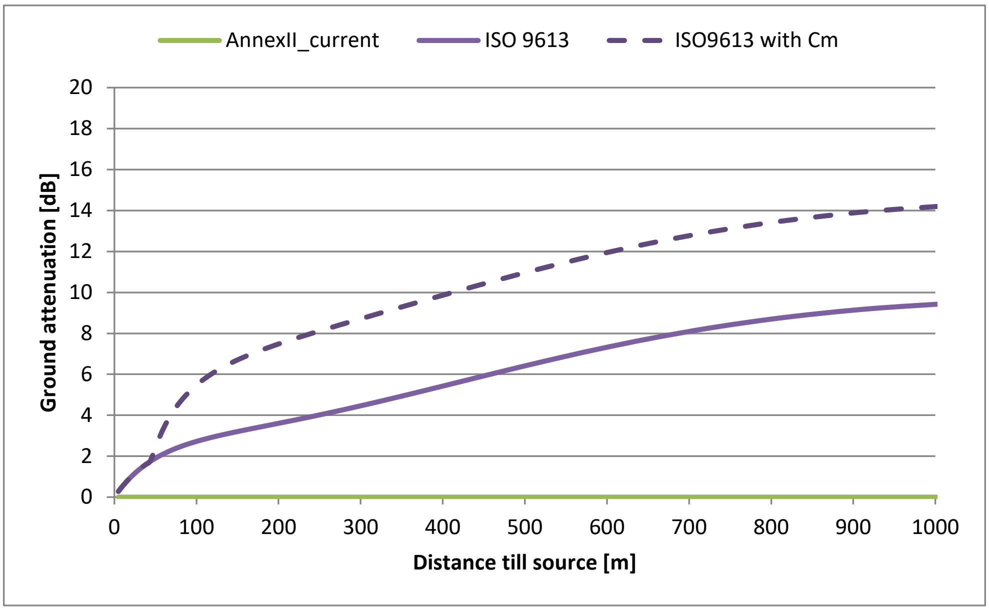


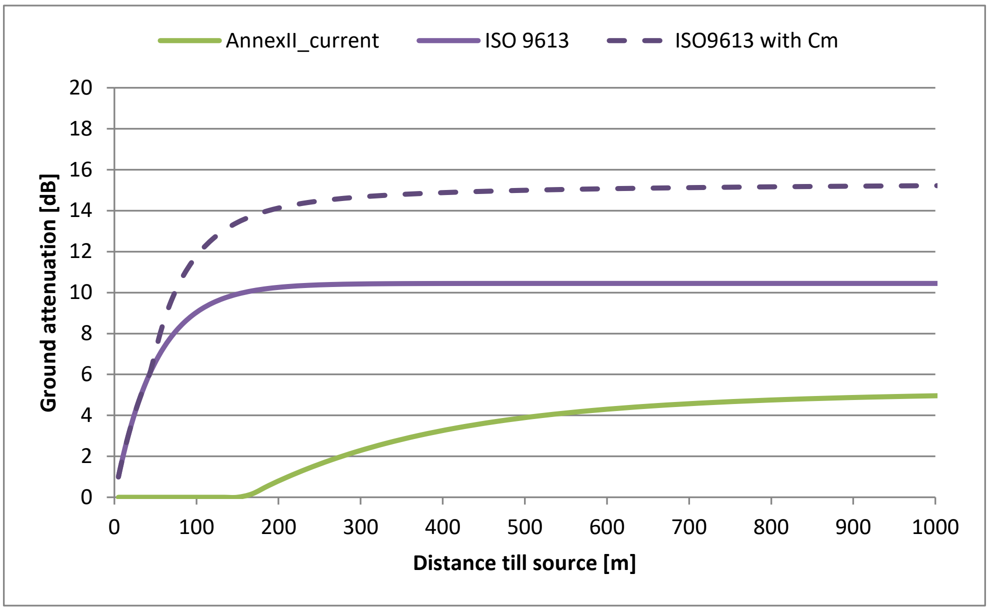
Figure 4: Comparison between relative sound levels for $G_{path}=0$ and G_{path} slightly above 0.

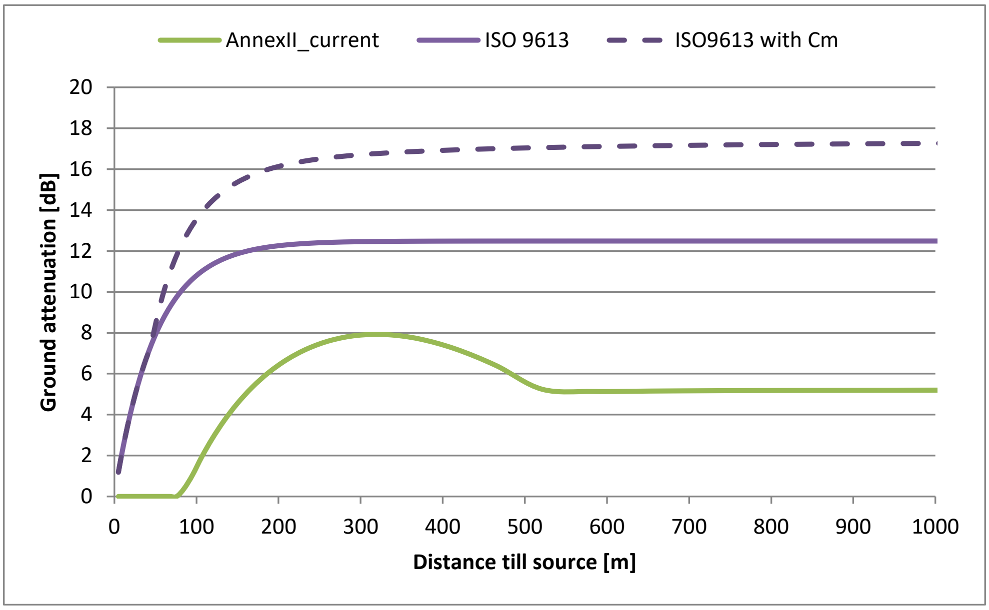
There are a few options. The first is to simply keep the current ground attenuation formula's but remove the discontinuity when $G_{path}=0$ and define how to calculate G_s for industrial noise sources (for example as the average over a distance of 30 times the height of the source).

5.29.1.3 Much less attenuation than other methods at larger distances
We noticed that in favourable conditions over relatively large distances, the ground attenuation leads to dramatically different (higher) results compared to other standard calculation methods. These higher levels are mainly visible for rail traffic and industrial noise. In the figure below the attenuation according to ISO 9613-2 is compared to CNOSSOS-EU:2015.

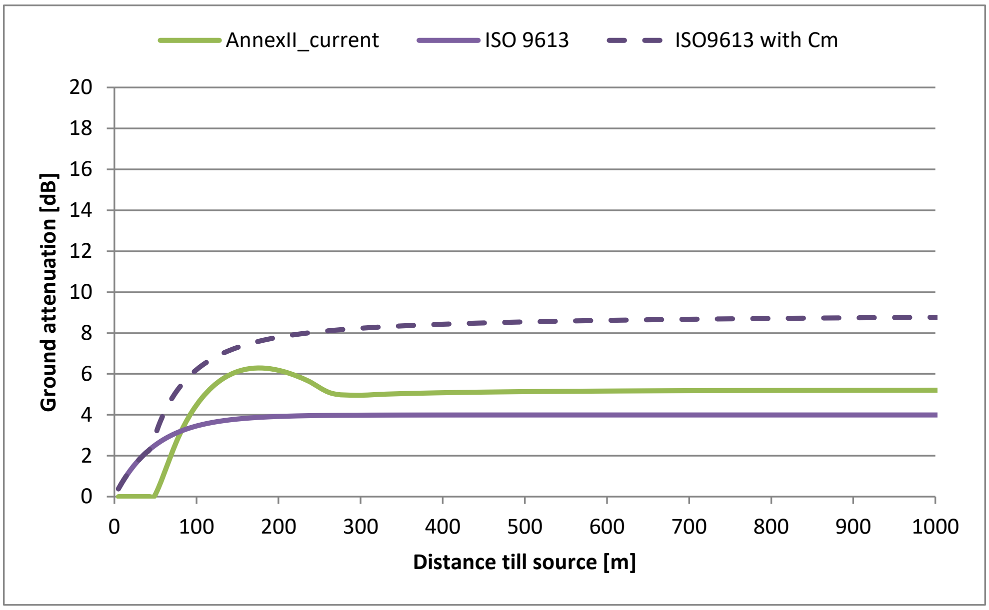
An example is shown below where the percentage of favourable propagation was assumed to be 30%, the ground factor is 1 (absorbing ground), source height is 0.5 meters and receiver height is 4 meters. We compare the results of Annex II with the results from ISO that includes the meteorological correction (dashed lines).



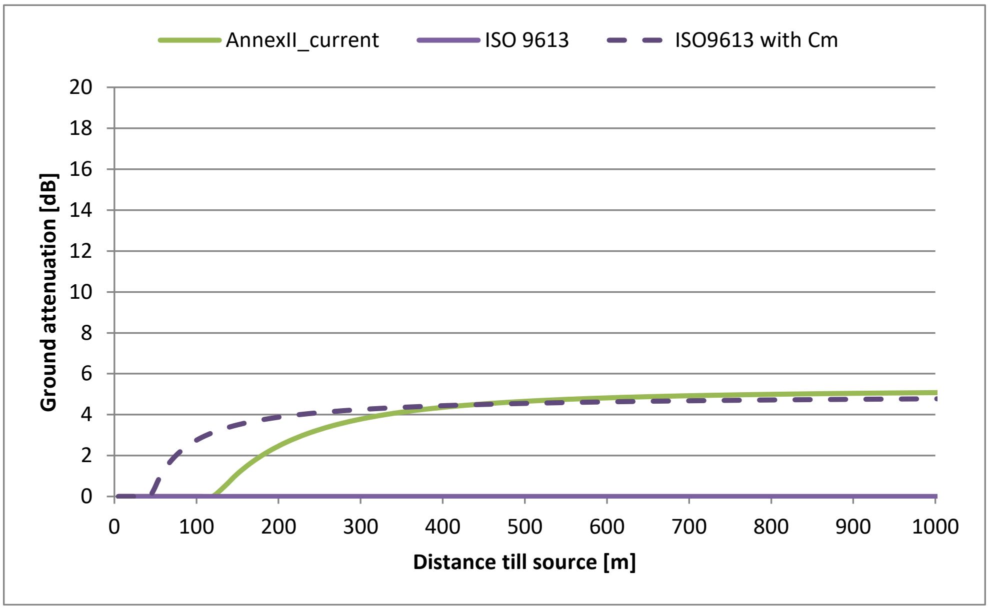


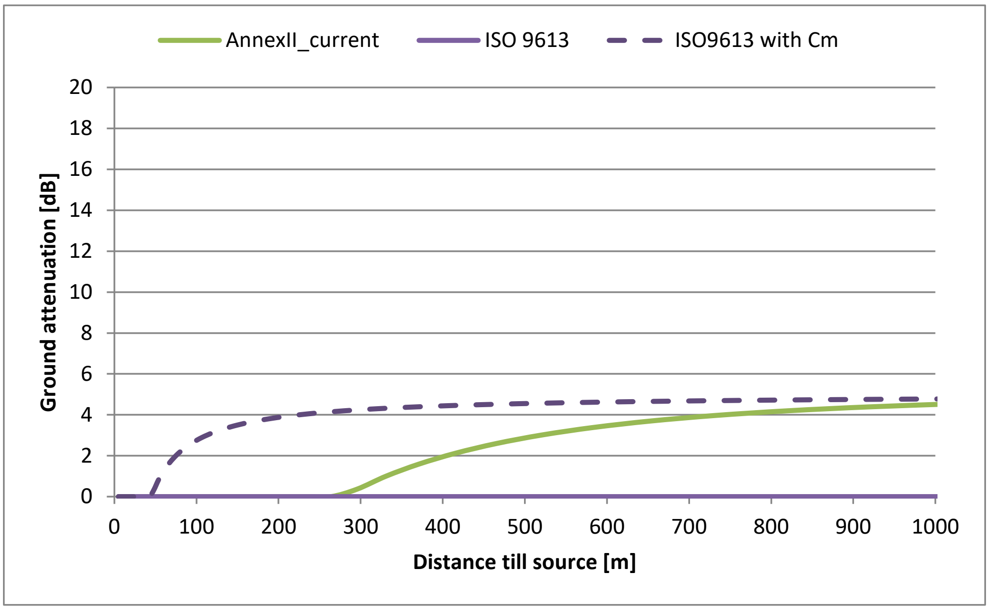


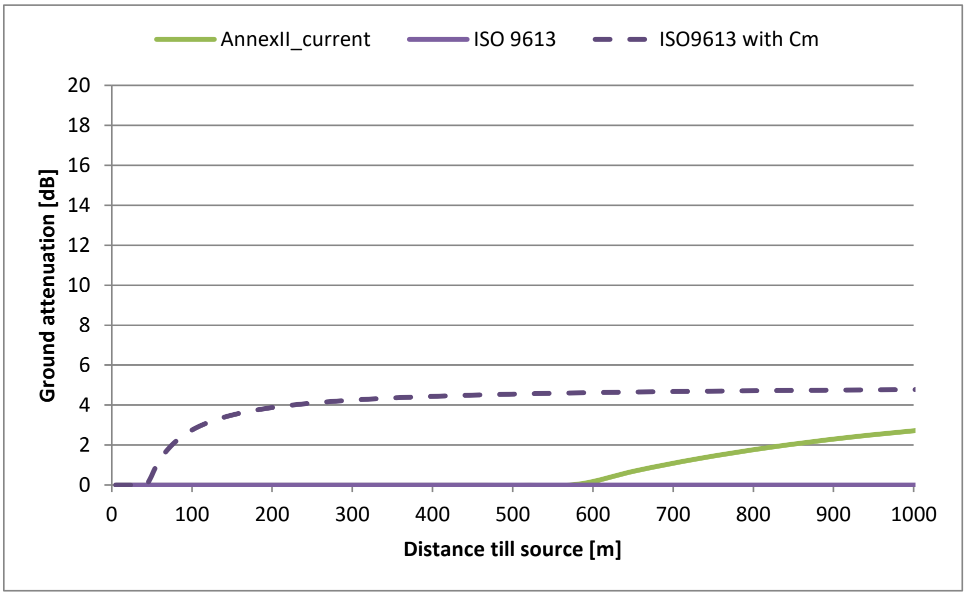
AnnexII_current
ISO 9613
ISO9613 with Cm
Ground attenuation [dB]
0
2
4
6
8
10
12
14
16
18
20
0
100
200
300
400
500
600
700
800
900
1000
Distance till source [m]



AnnexII_current
ISO 9613
ISO9613 with Cm
Ground attenuation [dB]
0
2
4
6
8
10
12
14
16
18
20
0
100
200
300
400
500
600
700
800
900
1000
Distance till source [m]


AnnexII_current
ISO 9613
ISO9613 with Cm
Ground attenuation [dB]
20
18
16
14
12
10
8
6
4
2
0
0
100
200
300
400
500
600
700
800
900
1000
Distance till source [m]


AnnexII_current
ISO 9613
ISO9613 with Cm
Ground attenuation [dB]
20
18
16
14
12
10
8
6
4
2
0
0
100
200
300
400
500
600
700
800
900
1000
Distance till source [m]



It is clear that at most frequencies, ISO 9613-2 calculates a much higher attenuation. An example is shown at 210 meter distance.

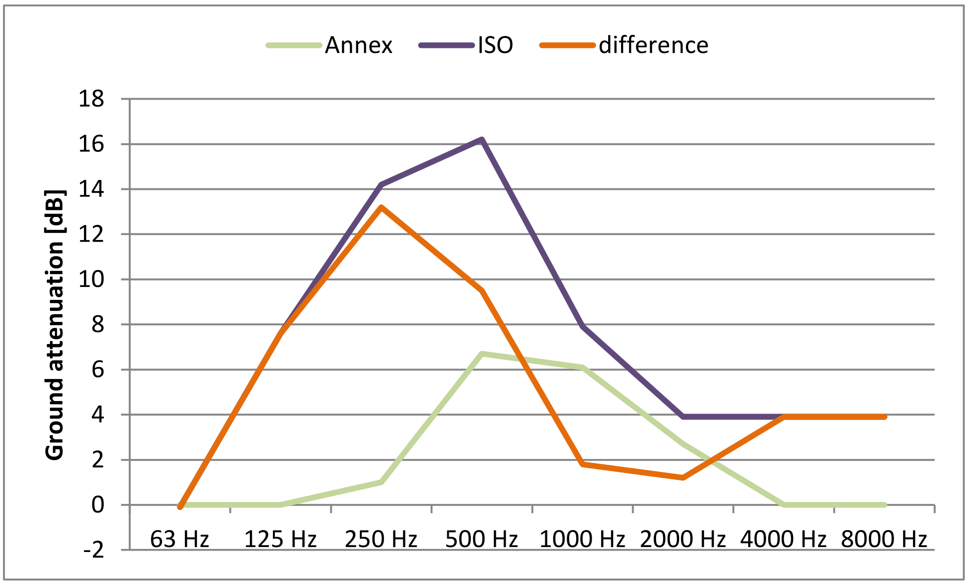


Figure 5: Comparison of ground attenuation between ISO9613 and CNOSSOS-EU:2015.

At 250Hz, the difference in ground attenuation is about 13 dB and at 500 Hz it is equal to 10 dB. This will lead to much larger contours compared to many currently used methods. For example, a calculation of railway noise resulted at larger distances in a level of L_{den} which was approximately 5 dB higher than the current Dutch national method.

The working group has acknowledged that ISO 9613-2 is not necessarily correct and that it is not impossible that CNOSSOS-EU:2015 gives more accurate results. However, because of these very large differences we feel that the ground model in CNOSSOS-EU:2015 needs to be verified in more detail.

5.29.2 *Proposed solution*

The working group has attempted to solve all issues above by changing the ground attenuation model to do the following:

1. Symmetric for source and receiver
2. Valid for high sources
3. No discontinuity
4. Comparable with Harmonoise results.

A preliminary new ground model was developed, mostly based on the current model in the Annex. This model still needs tuning and it has not been possible to verify whether the model works well enough. Therefore, the working group has concluded that, within the time we had, we have not been able to satisfactorily come up with an improved ground attenuation model. In Annex 7, we present a description of the steps to an improved ground model.

5.29.3 *Type of amendment*

This is a class 3 amendment: Worked on but no definitive solution or amendment provided.

6 Possible improvements

The working group has focused on issues where there was consensus that they should be addressed. A number of points were raised with the purpose of improving the method. It was decided that these points were outside the scope of our work.

6.1 Statistical method

A useful improvement could be to include a description to specify a statistical method. In the Annex, it is stated:

Statistical approach inside urban areas for a path (S,R)
Inside urban areas, a statistical approach to the calculation of the sound propagation behind the first line of buildings is also allowed, provided that such a method is duly documented, including relevant information on the quality of the method. This method may replace the calculation of the $A_{boundary,H}$ and $A_{boundary,F}$ by an approximation of the total attenuation for the direct path and all reflections. The calculation will be based on the average building density and the average height of all buildings in the area.

If statistical methods will be used, the group would prefer that the same method will be used by different member states. Currently, there is no description of the method which leads to the possibility that different approaches will be used.

6.2 Attenuation from vegetation and industrial sites

ISO 9613-2 allows for attenuation due to vegetation and industrial sites. This is lacking in CNOSSOS-EU:2015. The group felt that it would be a good addition but it also would have limited effect on noise mapping.

6.3 Heavy goods vehicles

There is currently one class of heavy goods vehicles. However, with new longer vehicles appearing on the road, it may be good to have the possibility for an additional class of heavy goods vehicles.

6.4 Addition of source heights

For both rail and road, the source description could be improved by including additional source heights. As computational time is no longer a strongly limiting factor, this would constitute an improvement.

6.5 Traction noise speed dependent

The current CNOSSOS-EU:2015 model does not allow for a speed dependence of railway traction noise. In reality, traction noise may be dependent on railway vehicle velocity. Allowing for a speed dependence would improve the method but within the purpose of noise mapping the effect is small.

7 Guidance

The purpose of a unified calculation method is to be able to compare results between member states. The calculation method is only part of the whole. It is important that models are built in a similar manner and that database content, such as emission factors, are determined in a similar way.

The following topics were brought up for a guidance document.

- How to compare results to previous maps and evaluate action plans
- Modelling agreements for common default data
- Define default number of reflections
- Define direction of percentage favourable in case of reflections
- Emission values for electric cars, and how to handle those sources
- Common measurement method to collect country specific emission factors (including new vehicle types)
- Method to derive road surface correction values
- Clarify how and when to use road gradients
- How to measure or determine effect of impact noise for railroads
- How to categorize rail roughness, railway vehicles and speeds when data is unavailable
- How to define transfer functions for new rail vehicles
- How to go from a train-based approach to a vehicle-based approach (huge database of vehicles)
- Emission factors for shipping noise
- How to handle source directivity of industrial noise sources.

We advise that the Commission will take the initiative to create a guidance document that deals with the subjects above and any other subjects relevant to achieving comparability of noise maps. It may even include guidance on how to go from a model to the reporting mechanism.

8 Annex 1: Complete text for section 2.8

2.8 Exposure to noise

For the assessment of the noise exposure of dwellings, and the exposure of people living in dwellings, only residential buildings shall be considered. No dwellings or people shall be assigned to other buildings without residential use such as schools, hospitals, office buildings or factories. The assignment of the dwellings, and people living in dwellings, to the residential buildings shall be based on the latest official data (depending on the Member State's relevant regulations). This process can be extended to other noise sensitive buildings in the scope of the directive.

Because aircraft calculations are typically performed on a 100m x 100m resolution grid, the specific case of aircraft noise levels at residential building facades shall be interpolated based on the nearest grid noise levels.

Determination of the Area Exposed to Noise

The assessment of the area exposed to noise is based on receiver point levels at 4 m above the terrain level calculated on a grid for individual sources.

Grid points that are located inside buildings shall be assigned a noise level result by interpolation based on nearby calculated grid noise level results outside buildings.

Depending on the grid resolution, the corresponding area is assigned to each calculation point in the grid. For example, with a 10 m x 10 m grid each assessment point represents an area of 100 square metres that is exposed to the calculated noise level.

Determination of the number of dwellings and people living in dwellings in a building

The number of dwellings, and people living in dwellings, in residential buildings are important intermediate parameters for the estimation of the exposure to noise. Unfortunately, data on these parameters is not always available. Below it is specified how these parameters can be derived from data more readily available.

Symbols used in the following are:

BA = base area of the building

DFS = dwelling floor space

DUFS = dwelling unit floor space

H = height of the building

FSI = dwelling floor space per person living in dwellings

Dw = number of dwellings

Inh = number of people living in dwellings

NF = number of floors

V = volume of residential buildings

For the calculation of the number of dwellings, and people living in dwellings, either the following case 1 procedure or the case 2 procedure shall be used, depending on the availability of data.

CASE 1: data on the number of dwellings and people living in dwellings is available

1A: The number of people living in dwellings is known or has been estimated on the basis of the number of dwelling units. In this case the number of people living in dwellings for a building is the sum of the number of people living in all dwelling units in the building:

$$Inh_{building} = \sum_{i=1}^{n} Inh_{dwelling_{unit_i}} \qquad (2.8.1)$$

1B: The number of dwellings or people living in dwellings is known only for entities larger than a building, e.g. enumeration areas, city blocks, districts or even an entire municipality. In this case the number of dwellings, and people living in dwellings, in a building is estimated based on the volume of the building:

$$Dw_{building} = \frac{V_{building}}{V_{total}} \times Dw_{total} \qquad (2.8.2a)$$

$$Inh_{building} = \frac{V_{building}}{V_{total}} \times Inh_{total} \qquad (2.8.2b)$$

The index ' *total* ' here refers to the respective entity considered. The volume of the building is the product of its base area and its height:

$$V_{building} = BA_{building} \times H_{building} \qquad (2.8.3)$$

If the height of the building is not known, it shall be estimated based on the number of floors $NF_{building}$, $NF_{building}$ assuming an average height per floor of 3 m:

$$H_{building} = NF_{building} \times 3\,\text{m} \qquad (2.8.4)$$

If the number of floors is also not known, a default value for the number of floors representative of the district or the borough shall be used.

The total volume of residential buildings in the entity considered V_{total} is calculated as the sum of the volumes of all residential buildings in the entity:

$$V_{total} = \sum_{i=1}^{n} V_{building_i} \qquad (2.8.5)$$

CASE 2: no data on the number of people living in dwellings is available

In this case the number of people living in dwellings is estimated based on the average dwelling floor space per person living in dwellings *FSI*. If this parameter is not known, a default value shall be used.

2A: The dwelling floor space is known on the basis of dwelling units.
In this case the number of people living in each dwelling unit is estimated as follows:

$$Inh_{dwelling_{unit_i}} = \frac{DUFS_i}{FSI} \qquad (2.8.6)$$

The total number of people living in dwellings for the building can now be estimated as in CASE 1A above.

2B: The dwelling floor space is known for the entire building, i.e. the sum of the dwelling floor spaces of all dwelling units in the building is known.
In this case the number of people living in dwellings is estimated as follows:

$$Inh_{building} = \frac{DFS_{building}}{FSI} \qquad (2.8.7)$$

2C: The dwelling floor space is known only for entities larger than a building, e.g. enumeration areas, city blocks, districts or even an entire municipality.

In this case the number of people living in dwellings for a building is estimated based on the volume of the building as described in CASE 1B above with the total number of people living in dwellings estimated as follows:

$$Inh_{total} = \frac{DFS_{total}}{FSI} \qquad (2.8.8)$$

2D: The dwelling floor space is unknown. In this case the number of people living in dwellings for a building is estimated as described in CASE 2B above with the dwelling floor space estimated as follows:

$$DFS_{building} = BA_{building} \times 0.8 \times NF_{building} \qquad (2.8.9)$$

The factor 0.8 is the conversion factor *gross floor area → dwelling floor space*. If a different factor is known to be representative of the area it shall be used instead and clearly documented.

If the number of floors of the building is not known, it shall be estimated based on the height of the building, $H_{building}$, which typically results in a non-integer number of floors:

$$NF_{building} = \frac{H_{building}}{3\mathrm{m}} \qquad (2.8.10)$$

If neither the height of the building nor the number of floors is known, a default value for the number of floors representative of the district or the borough shall be used.

Assigning receiver points to the façades of buildings

The assessment of the exposure of dwellings, and people living in dwellings, to noise is based on receiver point levels at 4 m above the terrain level in front of building façades of residential buildings.

For the calculation of the number of dwellings, and people living in dwellings, either the following case 1 procedure or the case 2 procedure shall be used for land based noise sources. For aircraft noise calculated according to 2.6, all dwellings, and people living in dwellings, within a building are associated to the nearest noise calculation points on the grid based on interpolation.

CASE 1: Façades split up in regular intervals on each façade

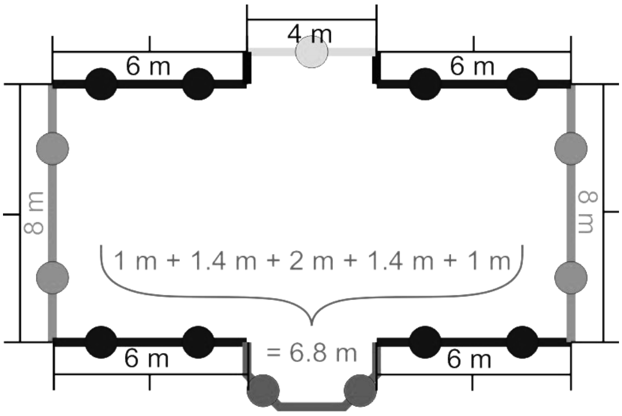


Figure a: example of location of receivers around a building following CASE 1 procedure.

a) Segments of a length of more than 5 m are split up into regular intervals of the longest possible length, but less than or equal to 5 m. Receiver points are placed in the middle of each regular interval.

b) Remaining segments above a length of 2.5 m are represented by one receiver point in the middle of each segment.

c) Remaining adjacent segments with a total length of more than 5 m are treated as polyline objects in a manner similar to that described in a) and b).

d) The number of dwellings, and people living in dwellings, allocated to a receiver point, shall be weighted by the length of the represented façade so that the sum over all receiver points represents the total number of dwellings, and people living in dwellings.

e) Only for buildings with single dwellings, or with floor sizes that indicate a single dwelling per floor level, the most exposed façade noise level is directly used for the statistics and related to the number of dwellings, and people living in dwellings.

CASE 2: Façades split up at set distance from start of polygon

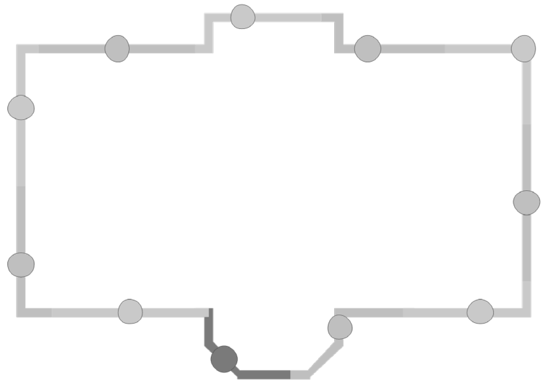


Figure b: example of location of receivers around a building following CASE 2 procedure.

a) Façades are considered separately or are split up every 5 m from the start position onwards, with a receiver position placed at the half-way distance of the façade or the 5m segment

b) The remaining section has its receiver point in its mid-point.

c) The number of dwellings, and people living in dwellings, allocated to a receiver point, shall be weighted by the length of the represented façade so that the sum over all receiver points represents the total number of dwellings, and people living in dwellings.

d) Only for buildings with single dwellings, or with floor sizes that indicate a single dwelling per floor level, the most exposed façade noise level is directly used for the statistics and related to the number of dwellings, and people living in dwellings.

9 Annex 2: TNO report including PE calculations

This Annex consists of a report commissioned by RIVM and produced by an external consultant. The content of this report is published in document https://www.rivm.nl/bibliotheek/rapporten/2019-0023_annex.pdf

10 Annex 3: M+P report on emission values road surfaces

This Annex consists of a report commissioned by RIVM and produced by an external consultant. The content of this report is published in document https:
https://www.rivm.nl/bibliotheek/rapporten/2019-0023_annex.pdf

11 Annex 4: dBvision report Bridge noise

This Annex consists of a report commissioned by RIVM and produced by an external consultant. The content of this report is published in document https:
https://www.rivm.nl/bibliotheek/rapporten/2019-0023_annex.pdf

12 Annex 5: dBvision report on Rail squeal

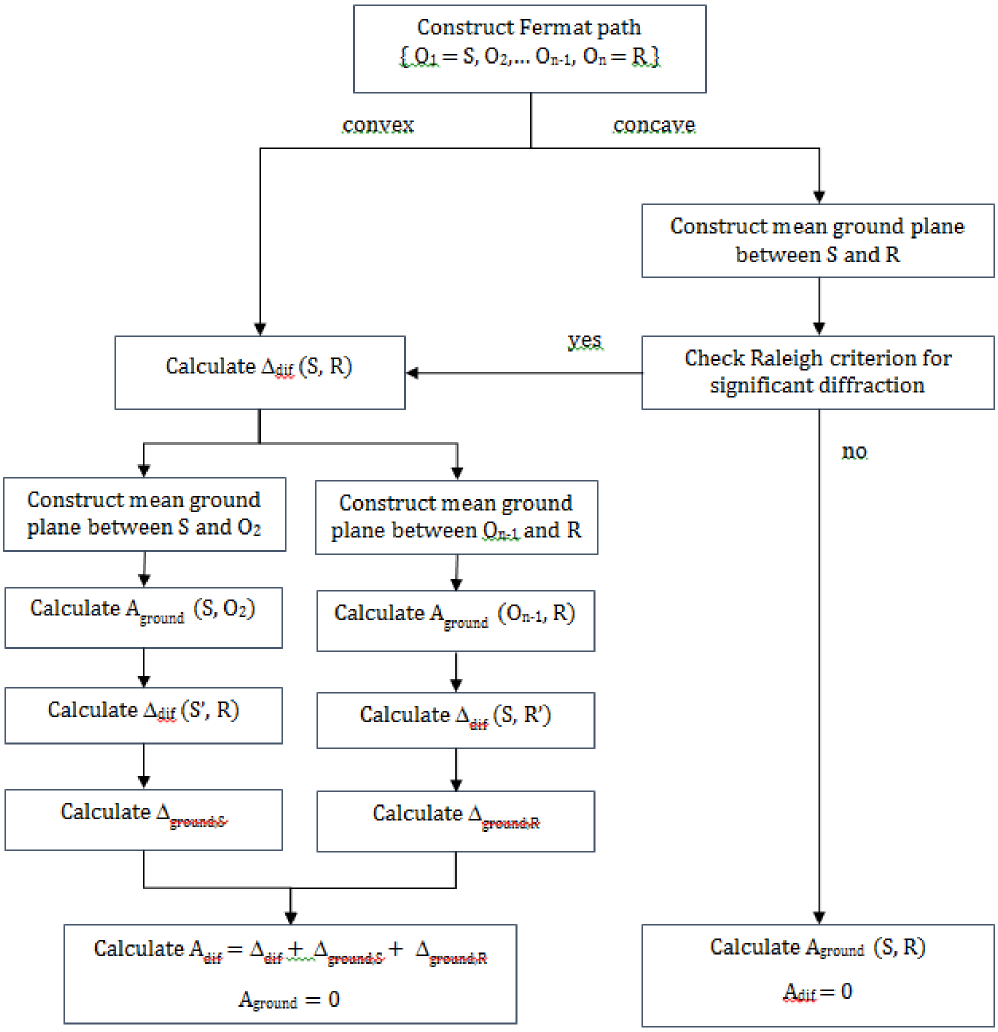
This Annex consists of a report commissioned by RIVM and produced by an external consultant. The content of this report is published in document https:
https://www.rivm.nl/bibliotheek/rapporten/2019-0023_annex.pdf

13 Annex 6: dBvision report on contact filter

This Annex consists of a report commissioned by RIVM and produced by an external consultant. The content of this report is published in document https: https://www.rivm.nl/bibliotheek/rapporten/2019-0023_annex.pdf

14 Annex 7: Research by Dirk van Maerke into an improved ground attenuation model

General outline of the method



Explanation:

- *The calculation scheme is identical for both homogeneous and favourable propagation conditions.*
- *There are two main models: one for flat or concave ground, one for convex ground.*
- *In case the direct ray between the source and the receiver is blocked by an obstacle, the convex ground model is used.*
- *In case the direct ray between the source and the receiver is not blocked, Raleigh's roughness criterion is used to determine which model to use.*

Construction of mean ground plane
… as in CD(EU) 2015/996

Construction of Fermat ray path
The Fermat path is the shortest ray path in the propagation plane connecting the source to the receiver and that does not intersect the boundary. Under homogeneous propagation conditions, the Fermat path consists of a set of straight line segments. Under favourable propagation conditions, the Fermat path consists of a set of circular arcs with radius R_d :

$$R_d = \max\ (1000,\ d_H)$$

d_H = horizontal length of the propagation path; $d_H = |x_n - x_1|$

The construction of the Fermat path is based on the path length difference function. For any three positions P_1, P_2 and P_3 in the propagation plane, the path length difference under homogeneous propagation conditions is defined as:

$$\delta = \delta_H(P_1, P_2, P_3) = \ \pm\,(|P_1P_2| + |P_2P_3| - |P_1P_3|)$$

Where $|P_iP_j|$ indicates Euclidean length of the line segment connecting P_i and P_j. The positive sign is taken if P_2 is located above the straight line connecting P_1 and P_3 and the negative sign is taken it lays below that line (see fig. 2.5.d).
For favourable propagation conditions, the path difference is evaluated as:

$$\delta = \delta_F(P_1, P_2, P_3) = \ \left|\widehat{P_1P_2}\right| + \left|\widehat{P_2P_3}\right| - \left|\widehat{P_1P_3}\right| + \min\ (0,\ 2\delta_H(P_1, P_2, P_3)\,)$$

Where $\left|\widehat{P_iP_j}\right|$ is the length of the circular arc with radius R_d connecting P_i and P_j :

$$\left|\widehat{P_iP_j}\right| = 2\,R_d\,sin^{-1}\left(\frac{\left|P_iP_j\right|}{2\,R_d}\right)$$

Note: the definition of δ_F is different from the version in CD(EU) 2015/996. Basically, it is easier to evaluate when it satisfies all the requirements for a suitable path difference function to be used with the convexity criterion below.

Note: the $2\delta_H$ correction term is applied only if P_2 is located below the straight line from P_1 to P_3 ; it is set to zero if the ray path is blocked.

Note: we can remove fig. 2.5.e because there is no need to distinguish three cases. The definition of δ_F applies to all three cases and provides coherent behaviour for the diffraction effect under homogeneous and favourable propagation conditions.

In case the direct ray path is blocked by the boundary, the Fermat path will consist of a sequence of points $\left\{O_1 = S,\ O_i = P_{k(i)}\,;\, i = 2 \ldots N-1,\ O_N = R\right\}$ which satisfies the convexity criterion:

$$for\ all\ (i,j,k)\,;\ 0\ \leq i < k < j\ \leq N\ \Rightarrow\ \delta\big(O_i, O_j, O_k\big) \geq 0$$

In case the direct ray path is not blocked by the boundary, the Fermat path will consist of three points $\{O_1 = S,\ O_2 = P_k,\ O_3 = R\}$ where P_k is the boundary point that maximizes the (negative) path length difference $\delta(S, P_k, R)$.

It is important to consider that $O_1 = S$ and $O_N = R$ are part of the Fermat path. This greatly simplifies the rest of the document, e.g. when giving formulas for A_{dif} and $A_{refl.}$

Figures 2.5.d, e and f should be changed accordingly (insofar they are still needed).

The definition above uniquely determines the Fermat path. However, it gives no indication on how to construct it efficiently.

A naïve algorithm might start with an order sequence $\{O_1 = S,\ O_i = P_i\ ; i = 2 \ldots n-1,\ O_n = R\}$, then consider all possible sequences $(i, j, k)\ ;\ 0\ \leq i < k < j\ \leq n$ and, if $\delta(P_i, P_j, P_k) < 0$, eliminate the point P_j from the sequence.

In normal words: take any two points P_i and P_j; $0\ \leq i < j\ \leq n$; draw the straight line (or the circular arc) connecting them. Then, any other point P_k; $i < k <\ j$ that is located below the line (or arc) connecting P_i and P_j cannot be part of the convex Fermat path.

The Fermat path may be constructed efficiently using the following algorithm:

1. *On input, the algorithm takes the boundary profile $P_k(x_k, H_k); k = 1 \ldots n$*
2. *Replace the first and last profile point with the positions of the source and receiver; i.e., set $H_1 = H_S$ and $H_n = H_R$.*
3. *Set $n_{left} = 1$ and $n_{right} = n$*
4. *Determine the location of the most diffracting point in between $P_{n_{left}}$ and $P_{n_{right}}$; i.e., find the position of P_k that maximizes the path length difference $\delta\left(P_{n_{left}}, P_k, P_{n_{right}}\right)$:*

   $$\delta_k = max\ \left\{\delta\left(P_{n_{left}}, P_i, P_{n_{right}}\right)\ ;\ n_{left} < i < n_{right}\right\}$$

5. *If $\delta_k < 0$ the ray path is not blocked by the boundary and Raleigh's roughness criterion is used to determine whether P_k provides significant diffraction effects or not.*
6. *If $\delta_k \geq 0$ the ray path is blocked and P_k is part of the Fermat path.*
7. *If $\delta_k \geq 0$, search for more positions to be included in the Fermat path by applying the procedure 4. to both the left and right of P_k ; i.e., setting respectively $n_{left} = k$ and $n_{right} = k$. If the path is blocked, additional candidate points with $\delta_{k'} < 0$ are ignored.*

Raleigh's roughness criterion
In case the ray path is not blocked by the boundary, the Fermat path consists of three points: $\{O_1 = S,\ O_2 = P_k,\ O_3 = R\}$.
Construct the mean ground plane between S and R and calculate:

$$\delta_{ral} = \delta(S, O_2, R) + \delta(S', O_2, R')$$

where S' and R' are the images with respect to the mean ground plane of S and R respectively.
If $\delta_{ral} < \lambda/4$, the boundary may be considered as a flat (or concave) surface with roughness and the excess attenuation is evaluated using flat/concave ground model.
If $\delta_{ral} \geq \lambda/4$, the boundary contains some elements that significantly block the ground reflected ray path and the excess attenuation must be evaluated using the convex model including diffraction.

Note: the $\delta_{dif} > -\lambda/20$ criterion has been removed because it leads to non-plausible results.

The $\lambda/20$ criterion tells us that the low barrier has significant effect in the LOW frequency range but not at higher frequencies. The Raleigh criterion tells a completely different story: at higher frequencies, the low barrier has a significant effect on the ground attenuation (because it creates a virtual source on the top of the barrier) but has no effect in the low frequency range. Combining both criteria results leads to very strange behaviour where low and high frequencies have significant diffraction effects but mid frequencies have none. Neither or'ing or 'and'ing these contradictory criteria produces plausible behaviour.

From a physical point of view, Raleigh criterion is necessary and sufficient to explain the effects of low barriers. Consider the case of almost grazing propagation over flat ground so that $\delta_{spec} = |SR'| - |SR| < \lambda/20$. Adding a 1 cm barrier in the middle would lead to $-\delta_{dif} < \delta_{spec} < \lambda/20$ and we would therefore account for a significant diffraction effect! This is exactly what the Raleigh criterion finds out In this case, the low obstacle is nothing more than a roughness element added to an overall flat ground.

For higher sources and receiver, the Raleigh criterion correctly tells us whether an obstacle blocks the ground reflected path and this is independent from the fact that $\Delta_{dif} = 0\ dB$! Consider $h_S = h_R = 4m$ and a 3.5m barrier in the middle. Although we have $\delta_{dif} < -\lambda/20$ and $\Delta_{dif} = 0\ dB$, it is not acceptable to evaluate the ground effect as if the barrier didn't exist.

Calculation of ground effect

Geometrical quantities - figure 2.5.a should be modified accordingly!

d_p= distance between the footprints of S and R on the mean ground plane and $d_p > 1m$

h_s= height of S relative to the mean ground plane and $h_s > 0.05m$

h_r= height of R relative to the mean ground plane and $h_r > 0.05m$

Note: h_s and h_r are measured perpendicular to the mean ground plane. d_p is measured along the mean plane, i.e., it is the distance between the perpendicular projections of S and R on the mean ground plane.

Where it is understood that when calculating $A_{ground}(S, O_1)$, the receiver is replaced by the position of the diffraction point nearest to the source and when calculating $A_{ground}(O_{N-1}, R)$, the source is replaced by the position of the diffraction point nearest to the receiver.

To evaluate the ground attenuation, the propagation path is split into two parts according to

d_s= horizontal position of the source in the unfolded propagation plane;

d= horizontal position of the receiver in the unfolded propagation plane;

$d_c = d_s + \frac{z_s}{z_s + z_r}\ (d_r - d_{s)}$

Where:

z_s= equivalent height of S relative to the mean ground plane

z_r= equivalent height of R relative to the mean ground plane

Under homogeneous propagation conditions $z_s = h_s$ and $z_r = h_r$

Under favourable propagation conditions:

$$z_s = h_s + \frac{{h_s}^2}{{h_r}^2 + {h_s}^2}\ \frac{{d_p}^2}{8\,R_a}$$

$$z_r = h_r + \frac{{h_r}^2}{{h_r}^2 + {h_s}^2}\ \frac{{d_p}^2}{8\,R_a}$$

$$R_a = \max\ (5000, 8\ d_p)$$

The averaged ground coefficients are evaluated as follows:

G_s= averaged ground coefficient between $d = d_s$ and $d = d_c$

G_r= averaged ground coefficient between $d = d_c$ and $d = d_r$

G_m= averaged ground coefficient between $d = d_s$ and $d = d_r$

The attenuation due to ground is evaluated as:

$$A_{ground} = -10 \lg \left[10^{-(A_{G,S}+A_{G,R})/20} + 3\,q \max\ \left(0, 10^{-A_{G,M}/10} - 1\right) + 10^{-A_D/10}\right]$$

Where

$A_{G,S}$ is the ground absorption evaluated using $G = G_s$

$A_{G,R}$ is the ground absorption evaluated using $G = G_r$

$A_{G,M}$ is the ground absorption evaluated using $G = G_m$ and replacing h_s and h_r by:

$$h_m = (h_s + h_r)/2$$

$$A_D = 20 - 3\ lg \frac{f}{1000} - 10\ lg \frac{d_p}{100}$$

Under homogeneous conditions: $q = 0$, under favourable conditions:

$$q = e^{-30\,\frac{h_s + h_r}{d_p}}$$

Explanation:

- *This section replaces the calculation of G'$_{path}$, eq. 2.5.14 and Table 2.5.b*
- $A_{G,S}$ *accounts for the ground absorption on the source side,*
- $A_{G,R}$ *accounts for the ground absorption on the receiver side,*
- *Taking* $A_{G,SR} = (A_{G,S} + A_{G,R})/2$ *is equivalent to Fresnel weighting with* $w_i = 0.5$ *for the parts of the propagation path left and right of the specular reflection point.*
- $A_{G,M}$ *accounts for additional ray paths that occur under favourable propagation conditions. Additional paths are added only if* $A_{G,M} < 0dB$*; i.e., ignoring destructive interference effects.*
- *The multiplier "q" accounts for the number of additional rays taken into consideration. This factor can be adjusted later based on feedback collected when using and testing the model.*
- A_D *accounts for turbulent scattering in the atmosphere and limits the ground effect at larger distances. Based on feedback from using the model, the constant factor of 20 dB can be adjusted later..*

The ground absorption is evaluated as:

$$A_G = -20\lg\,(1 + CR)$$

With:

$$R_f = \frac{2\,k}{d_p}\sqrt{{z_s}^2 - \sqrt{\frac{2C_f}{k}}\,z_s + \frac{C_f}{k}}\;\sqrt{{z_r}^2 - \sqrt{\frac{2C_f}{k}}\,z_r + \frac{C_f}{k}}\; - 1$$

$C_f = \cdots (eq. 2.5.16)$

with $f_m = \sqrt{2}\,f_{c,i}$ where $f_{c,i}$ the nominal centre frequency of the i-th octave band

$w = \cdots (eq. 2.5.17)$

$k = \frac{2\,\pi}{f_{c,i}}$

$R = \min\left(\max\left(R_f, R_{min}\right), R_{max}\right)$

$R_{max} = 0.4$

$R_{min} = -0.9$

$C = 1 - e^{-\frac{1}{\Delta k\;\Delta r}}\;e^{-\frac{20(1-G)}{d_p}}$

$\Delta k = 0.7\,k$

$\Delta r = \sqrt{{d_p}^2 + (z_s + z_r)^2} - \sqrt{{d_p}^2 + (z_s - z_r)^2}$

Explanation:

- *In advanced models, the ground attenuation is calculated as* $A_G = 20\lg\,(1 + Q)$
  where $Q = R + (1 - R)\,F_w$ *is the spherical reflection coefficient and* F_w *the complex transition function introduced by Chien et Soroka.*
- *For almost grazing incidence,* $R \approx -1$ *and therefore* $A_G = 20\lg\,(2\,F_w)$.
- *The formulas from NMPB provide an approximation for* F_w *. The*

approximation works fine for almost grazing incidence over soft ground but becomes invalid for $F_w > 0.5$*,* $A_G < 0\ dB$*.*

- *Instead of correcting the approximation by applying a frequency independent minimum bound* $A_{ground,H,min}$ *or* $A_{ground,F,min}$*, we now transform the* $2F_w$ *into an equivalent reflection coefficient and then clip this value to "reasonable" limits. This clipping is applied for each frequency individually.*
- *Eq. 2.5.18 and 2.5.20 are no longer needed and can be removed.*
- *The lower limit* $R_{min} = -0.9$ *with limit the ground effect to approx.* $-20\ dB$
- *The upper limit* $R_{max} = 0.4$ *with limit the ground effect to approx. +3 dB*
- *The factor* C *accounts for the loss of coherency between the direct and ground reflected rays in the high frequency range and particularly for the integration of interference effects over whole octave bands. The constant 0.7 in the calculation of* Δk *might be adjusted later based on feedback using the model.*
- *For the calculation of* C_f *we might replace eq. 2.5.17 by the original formula, linking the parameter to physical quantities and the Delauny-Bazley impedance model:*

$$w = \frac{kd_p}{|Z|^2}$$
$$|Z|^2 = Z_R{}^2 + Z_I{}^2$$
$$Z_R = 1 + 9.08\, e^{-0.75\, s}$$
$$Z_I = 11.9\, e^{-0.73\, s}$$
$$s = \log\,(f/\sigma)$$

Where σ *can be interpolated from Table 2.5.a or approximated as* $\sigma = 20000\ 10^{-2\,G^{0.6}}$

- *Alternatively, we might use the original formula which evaluates the spherical reflection coefficient as a function of the plane wave reflexion coefficient and the (approximated) complex transition function. This requires a little bit of complex algebra. The alternative solution is available in the software for testing.*

Pure diffraction

The attenuation due to diffraction is given by:

$$\Delta_{dif} = -10\lg\left(3 + \max\left(-2, \frac{40\,C"\,\delta}{\lambda}\right)\right)$$
$$C" \ = \ \ldots\ (eq.\ 2.5.23)$$

Remove $C_h = 1$

Remove "if $\Delta_{dif} < 0 : \Delta_{dif} = 0\ dB$*"; by definition* Δ_{dif} *cannot be negative anyhow.*

The path length difference δ and the parameter e are evaluated from the convex hull $\{O_1 = S,\ O_i = P_{k(i)}\ ; i = 2 \dots N-1,\ O_N = R\}$. In case $N = 3$, as for example in the case of unblocked ray paths, the path difference is calculated as indicated above and $e = 0$. In case of multiple diffraction points, i.e. when $N > 3$, the path length difference is calculated as:

- In homogeneous propagation conditions:

$$\delta = |O_1O_2| + e + |O_{N-1}O_N| - |O_1O_N|$$
$$e = |O_2O_3| + \cdots + |O_{N-2}O_{N-1}|$$

- In favourable propagation conditions:

$$\delta = |\widehat{O_1O_2}| + e + |\widehat{O_{N-1}O_N}| - |\widehat{O_1O_N}|$$
$$e = |\widehat{O_2O_3}| + \cdots + |\widehat{O_{N-2}O_{N-1}}|$$

Because we now have a formal definition of the Fermat path, we can use it to evaluate the parameters used in eq. 2.5.21. The Fermat path contains the necessary and sufficient information for calculating Δ_{dif}; this will greatly simplify the explanations in the next sections…

Calculation of the term $\Delta_{ground,S}$

In case S is located below the mean ground plane (S, O_2) :

$$\Delta_{ground,S} = \mathrm{A}_{ground}\ (S, O_2)$$

Otherwise

$$\Delta_{ground,S} = -20 \lg\ [1 +\ R_s\ D_s]$$
$$R_s =\ 10^{-A_{ground}\ (S,O_2)/20} - 1$$
$$D_s = 10^{-(\Delta_{dif}(S',R)\ -\ \Delta_{dif}(S,R))/20}$$

Where $A_{ground}(S, O_2)$ is calculated as indicated previously with the actual receiver R replaced by the diffraction point O_2 and the mean ground plane and averaged G values are calculated accordingly between S and O_2.

$\Delta_{dif}(S, R)$ is the attenuation due to diffraction between S and R as calculated above, $\Delta_{dif}(S', R)$ is calculated similarly for the virtual source S' which is the image of the real source with respect to the mean ground plane constructed between S and O_2 ; i.e. $\Delta_{dif}(S', R)$ is evaluated over the modified Fermat path $\{O_1 = S',\ O_i = P_{k(i)}\ ; i = 2 \dots N-1,\ O_N = R\}$.

Explanations:

- *Using R_s and D_s, the similarity with the calculation of A_{ground} and/or the Harmonoise model is obvious.*
- *Note that when calculating $\Delta_{dif}(S', R)$ we do not construct another Fermat path. Under the assumption of a flat ground model between S and O_2, the modified Fermat path is a true Fermat path including a specular reflexion on the mean ground plane between S and O_2.*
- *The Fermat path, together with the mean ground plane between S and O_2 contain all the information needed to evaluate $\Delta_{dif}(S, R)$ and $\Delta_{dif}(S', R)$.*
- *Because S' is deeper in the shadow than S, we should always have $D_s \leq 1$!*

Calculation of the term $\Delta_{ground,R}$

In case R is located below the mean ground plane (O_{n-2}, R) :

$$\Delta_{ground,R} = \mathrm{A}_{ground}\,(O_{n-2}, R)$$

Otherwise

$$\Delta_{ground,R} = -20\lg\,[1 + R_r\,D_r]$$

$$R_r = 10^{-A_{ground}\,(O_{n-2},R)/20} - 1$$

$$D_r = 10^{-(\Delta_{dif}(S,R') - \Delta_{dif}(S,R))/20}$$

Where A_{ground} is calculated as indicated previously with the actual source S replaced by the diffraction point O_{n-2} and the mean ground plane and averaged G values are calculated accordingly between O_{n-2} and R. $\Delta_{dif}(S,R)$ is the attenuation due to diffraction between S and R as calculated above, $\Delta_{dif}(S,R')$ is calculated similarly for the virtual receiver R' which is the image of the real receiver with respect to the mean ground plane constructed between O_{n-2} and R ; i.e. $\Delta_{dif}(S,R')$ is evaluated over the modified Fermat path $\{O_1 = S,\ O_i = P_{k(i)}\,; i = 2 \dots N-1,$ $O_N = R'\}$.

15 Annex 8: Active members of the working group

The Netherlands
Hans Herremans (I&W and chair)
Arnaud Kok (RIVM)
Annemarie van Beek (RIVM)
Germany
Lars Schade (UBA)
Juliane Bopst (UBA)
France
Gaëlle Lebreton (MTES)
Jean Philippe Regairaz (SNCF)
Dirck van Maerke (CSTB)
Hungary
Edina Balogh (KTI)
Beatrix Udvardi (KTI)
Ireland
Simon Shilton (Acustica)
Luxemburg
Isabelle Naegelen (AEV)
Denmark
Frank Pederson (MST)
Italy
Gaetano Licitra (ARPAT)
nISO WG56
Wolfgang Probst (Datakustik)

16 Annex 9: Amendments

16.1 Include dwellings in text and specify how to calculate exposed area

16.1.1 Current text Annex II [section 2.8]
Entire section

16.1.2 Proposed new text
For the assessment of the noise exposure of dwellings and the exposure of people living in dwellings, only residential buildings shall be considered. No dwellings or people shall be assigned to other buildings without residential use such as schools, hospitals, office buildings or factories. The assignment of the dwellings, and people living in dwellings, to the residential buildings shall be based on the latest official data (depending on the Member State's relevant regulations). This process can be extended to other noise sensitive buildings in the scope of the directive.

Because aircraft calculations are typically performed on a 100m x 100m resolution grid, the specific case of aircraft noise levels at residential building façades shall be interpolated based on the nearest grid noise levels.

Determination of the Area Exposed to Noise
The assessment of the area exposed to noise is based on receiver point levels at 4 m above the terrain level, calculated on a grid for individual sources.

Grid points that are located inside buildings shall be assigned a noise level result by interpolation based on nearby calculated grid noise level results outside buildings.

Depending on the grid resolution, the corresponding area is assigned to each calculation point in the grid. For example, with a 10 m x 10 m grid, each assessment point represents an area of 100 square metres that is exposed to the calculated noise level.

Determination of the number of dwellings and people living in dwellings in a building

The number of dwellings, and people living in dwellings, in residential buildings are important intermediate parameters for the estimation of the exposure to noise. Unfortunately, data on these parameters is not always available. Below, it is specified how these parameters can be derived from data more readily available.

Symbols used in the following are:
BA = base area of the building
DFS = dwelling floor space
DUFS = dwelling unit floor space
H = height of the building

FSI = dwelling floor space per person living in dwellings
Dw = number of dwellings
Inh = number of people living in dwellings
NF = number of floors
V = volume of residential buildings

For the calculation of the number of dwellings, and people living in dwellings, either the following case 1 procedure or the case 2 procedure shall be used, depending on the availability of data.

CASE 1: data on the number of dwellings and people living in dwellings is available

1A: The number of people living in dwellings is known or has been estimated on the basis of the number of dwelling units. In this case the number of people living in dwellings for a building is the sum of the number of people living in all dwelling units in the building:

$$Inh_{building} = \sum_{i=1}^{n} Inh_{dwelling_{unit_i}} \qquad (2.8.1)$$

1B: The number of dwellings or people living in dwellings is only known for entities larger than a building, e.g., enumeration areas, city blocks, districts or even an entire municipality. In this case the number of dwellings, and people living in dwellings, in a building is estimated based on the volume of the building:

$$Dw_{building} = \frac{V_{building}}{V_{total}} \times Dw_{total} \qquad (2.8.2a)$$

$$Inh_{building} = \frac{V_{building}}{V_{total}} \times Inh_{total} \qquad (2.8.2b)$$

The index ´*total*´ here refers to the respective entity considered. The volume of the building is the product of its base area and its height:

$$V_{building} = BA_{building} \times H_{building} \qquad (2.8.3)$$

If the height of the building is not known, it shall be estimated based on the number of floors $NF_{building}$, assuming an average height per floor of 3 m:

$$H_{building} = NF_{building} \times 3\,\mathrm{m} \qquad (2.8.4)$$

If the number of floors is also not known, a default value for the number of floors, representative of the district or the borough, shall be used. The total volume of residential buildings in the entity considered V_{total} is calculated as the sum of the volumes of all residential buildings in the entity:

$$V_{total} = \sum_{i=1}^{n} V_{building_i} \qquad (2.8.5)$$

CASE 2: no data on the number of people living in dwellings is available

In this case, the number of people living in dwellings is estimated based on the average dwelling floor space per person living in dwellings *FSI*. If this parameter is not known, a default value shall be used.

2A: The dwelling floor space is known on the basis of dwelling units. In this case the number of people living in each dwelling unit is estimated as follows:

$$Inh_{dwelling_{unit_i}} = \frac{DUFS_i}{FSI} \qquad (2.8.6)$$

The total number of people living in dwellings for the building can now be estimated as in CASE 1A above.

2B: The dwelling floor space is known for the entire building, i.e., the sum of the dwelling floor spaces of all dwelling units in the building is known.
In this case the number of people living in dwellings is estimated as follows:

$$Inh_{building} = \frac{DFS_{building}}{FSI} \qquad (2.8.7)$$

2C: The dwelling floor space is known only for entities larger than a building, e.g., enumeration areas, city blocks, districts or even an entire municipality.
In this case the number of people living in dwellings for a building is estimated based on the volume of the building as described in CASE 1B above with the total number of people living in dwellings estimated as follows:

$$Inh_{total} = \frac{DFS_{total}}{FSI} \qquad (2.8.8)$$

2D: The dwelling floor space is unknown. In this case the number of people living in dwellings for a building is estimated as described in CASE 2B above with the dwelling floor space estimated as follows:

$$DFS_{building} = BA_{building} \times 0.8 \times NF_{building} \qquad (2.8.9)$$

The factor 0.8 is the conversion factor *gross floor area → dwelling floor space*. If a different factor is known to be representative of the area it shall be used instead and clearly documented.
If the number of floors of the building is not known, it shall be estimated based on the height of the building, $H_{building}$, which typically results in a non-integer number of floors:

$$NF_{building} = \frac{H_{building}}{3\,\mathrm{m}} \qquad (2.8.10)$$

If neither the height of the building nor the number of floors is known, a default value for the number of floors, representative of the district or the borough, shall be used.

Assigning receiver points to the façades of buildings
The assessment of the exposure of dwellings, and people living in dwellings, to noise is based on receiver point levels at 4 m above the terrain level in front of building façades of residential buildings.
For the calculation of the number of dwellings, and people living in dwellings, either the following case 1 procedure or the case 2 procedure shall be used for land-based noise sources. For aircraft noise calculated according to 2.6, all dwellings, and people living in dwellings, within a building are associated to the nearest noise calculation points on the grid based on interpolation.

CASE 1: Façades split up in regular intervals on each façade

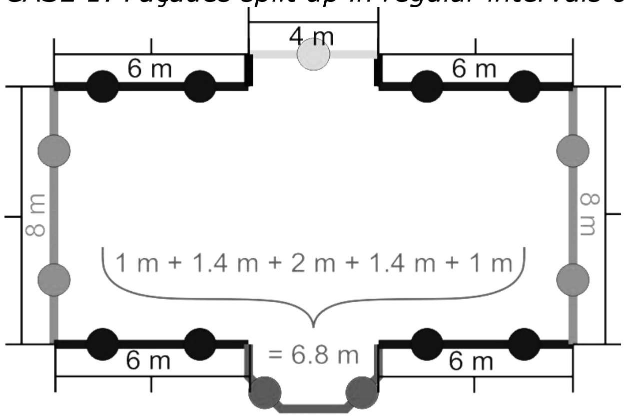


Figure a: example of location of receivers around a building following CASE 1 procedure.

a) Segments of a length of more than 5 m are split up into regular intervals of the longest possible length but less than or equal to 5 m. Receiver points are placed in the middle of each regular interval.
b) Remaining segments above a length of 2.5 m are represented by one receiver point in the middle of each segment.
c) Remaining adjacent segments with a total length of more than 5 m are treated as polyline objects in a manner similar to that described in a) and b).
d) The number of dwellings, and people living in dwellings, allocated to a receiver point, shall be weighted by the length of the represented façade so that the sum over all receiver points represents the total number of dwellings and people living in dwellings.
e) Only for buildings with single dwellings, or with floor sizes that indicate a single dwelling per floor level, the most exposed façade noise level is directly used for the statistics and related to the number of dwellings and people living in dwellings.

CASE 2: Façades split up at set distance from start of polygon

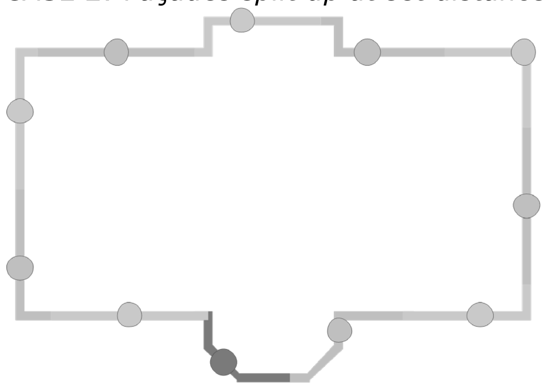


*Figure b: example of location of receivers around a building following CASE 2 procedur*e.

a) Façades are considered separately or are split up every 5 m from the start position onwards, with a receiver position placed at the half-way distance of the façade or the 5m segment
b) The remaining section has its receiver point in its mid-point.
c) The number of dwellings, and people living in dwellings allocated to a receiver point, shall be weighted by the length of the represented façade so that the sum over all receiver points represents the total number of dwellings and people living in dwellings.
d) Only for buildings with single dwellings, or with floor sizes that indicate a single dwelling per floor level, the most exposed façade noise level is directly used for the statistics and related to the number of dwellings and people living in dwellings.

16.2 Specify façade points without reflections

16.2.1 Current text Annex II [page 168]

The assessment of population exposure to noise is based on receiver point levels at 4 m above the terrain level in front of building façades of residential buildings.

16.2.2 Proposed new text

The assessment of population exposure to noise is based on receiver point levels at 4 m above the terrain level in front of building façades of residential buildings. Reflections from the façade being considered shall be excluded from the calculation.

16.3 Rayleigh criterion

16.3.1 Current text Annex II [page 36]

In practice, for each frequency band centre frequency, the path difference δ is compared with the quantity −λ/20. If an obstacle does not produce diffraction, this for instance being determined according to Rayleigh's criterion, there is no need to calculate A_{dif} for the frequency band considered.

16.3.2 Proposed new text – option 1

In practice the following specifications are considered in the unique vertical plane containing both source and receiver (a flattened Chinese Screen in case of a path including reflections). The direct ray from source to receiver is a straight line under homogeneous propagation conditions and a curved line (arc with radius depending on the length of the straight ray) under favourable propagation conditions.

If the direct ray is not blocked, the edge D is sought which produces the largest path length difference δ (the smallest absolute value because these path length differences are negative). Diffraction is taken into account, if
- this path length difference is larger than -λ/20 and
- if the "Raleigh-criterion" is fulfilled. This is the case, if δ is larger than λ/4 – δ*, where δ* is the path length difference calculated with this same edge D but related to the mirror source S* calculated with the mean ground plane at the source side and the mirror receiver R* calculated with the mean ground plane at the receiver side. To calculate δ* only the points S*, D and R* are taken into account – other edges blocking the path S*->D->R* are neglected.

If these two conditions are fulfilled, the edge D separates the source side from the receiver side and two separate mean ground planes are calculated. Otherwise, no attenuation by diffraction is considered for this path and a common mean ground plane for the path S -> R is calculated.

For the above considerations, the wavelength λ is calculated using the nominal centre frequency and a speed of sound of 340 m/s.

16.3.3 *Proposed new text – option 2*

In practice, the following specifications are considered in the unique vertical plane containing both source and receiver (a flattened Chinese Screen in case of a path including reflections). The direct ray from source to receiver is a straight line under homogeneous propagation conditions and a curved line (arc with radius depending on the length of the straight ray) under favourable propagation conditions.

If the direct ray is not blocked, the edge D is sought which produces the largest path length difference δ (the smallest absolute value because these path length differences are negative). Diffraction is taken into account if the "Raleigh-criterion" is fulfilled. This is the case, if δ is larger than λ/4 – δ*, where δ* is the path length difference calculated with this same edge D but related to the mirror source S* calculated with the mean ground plane at the source side and the mirror receiver R* calculated with the mean ground plane at the receiver side. To calculate δ* only the points S*, D and R* are taken into account – other edges blocking the path S*->D->R* are neglected.

If these two conditions are fulfilled, the edge D separates the source side from the receiver side and two separate mean ground planes are calculated. Otherwise, no attenuation by diffraction is considered for this path and a common mean ground plane for the path S -> R is calculated.

For the above considerations, the wavelength λ is calculated using the nominal centre frequency and a speed of sound of 340 m/s.

16.4 Objects sloping more than 15 degrees are out of scope only for reflections

16.4.1 Current text Annex II [page 26]

"Partial covers and obstacles sloping, when modelled, more than 15° in relation to the vertical are out of the scope of this calculation method."

16.4.2 Proposed new text

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

16.5 With curved rays and multiple diffractions, e is the length of the sum of the arcs

16.5.1 Current text Annex II [page 41]

For a multiple diffraction, if e is the total distance along the path, O1 to O2 + O2 to O3 + O3 to O4 from the "rubber band method" ", (see Figures 2.5.d and 2.5.f) and if e exceeds 0.3 m (otherwise C" = 1), this coefficient is defined by:

16.5.2 Proposed new text

For a multiple diffraction, if e is the total path length distance between first and last diffraction point (use curved rays in case of favourable conditions) and if e exceeds 0.3 m (otherwise C" = 1), this coefficient is defined by:

16.6 If source or receiver are below the mean ground plane, do not use a null height for path length differences

16.6.1 Current text Annex II [page 40]

Calculation of the term $\Delta_{ground(S,O)}$

$$\Delta_{ground(S,O)} = -20 \times \lg\left(1 + \left(10^{-A_{ground(S,O)}/20} - 1\right) \cdot 10^{-\left(\Delta_{dif(S',R)} - \Delta_{dif(S,R)}\right)/20}\right) \quad (2.5.31)$$

where

- $A_{ground(S,O)}$ is the attenuation due to the ground effect between the source *S* and the diffraction point *O*. This term is calculated as indicated in the previous subsection on calculations in homogeneous conditions and in the previous subsection on calculation in favourable conditions, with the following hypotheses:
- $z_r = z_{o,s}$;
- G_{path} is calculated between *S* and *O;*
- In homogeneous conditions: $\bar{G}_w = G'_{path}$ in Equation (2.5.17), $\bar{G}_m = G'_{path}$ in Equation (2.5.18)*;*
- In favourable conditions: $\bar{G}_w = G_{path}$ in Equation (2.5.17), $\bar{G}_m = G'_{path}$ in Equation (2.5.20);
- $\Delta_{dif(S',R)}$ is the attenuation due to the diffraction between the image source *S′* and *R*, calculated as in the previous subsection on pure diffraction;

- $\Delta_{dif(S,R)}$ is the attenuation due to the diffraction between *S* and *R,* calculated as in Subsection VI.4.4.b.

Calculation of the term $\Delta_{ground(O,R)}$

$$\Delta_{ground(O,R)} = -20 \times \lg\left(1 + \left(10^{-A_{ground(O,R)}/20} - 1\right) \cdot 10^{-\left(\Delta_{dif(S,R')} - \Delta_{dif(S,R)}\right)/20}\right) \quad (2.5.32)$$

Where

- $A_{ground\ (O,R)}$ is the attenuation due to the ground effect between the diffraction point O and the receiver R. This term is calculated as indicated in the previous subsection on calculation in homogeneous conditions and in the previous subsection on calculation in favourable conditions, with the following hypotheses: $z_s = z_{o,r}$
- G_{path} is calculated between *O* and *R.*

The G'_{path} correction does not need to be taken into account here as the source considered is the diffraction point. Therefore, G_{path} shall indeed be used in the calculation of ground effects, including for the lower bound term of the equation which becomes -3(1- G_{path}).

- In homogeneous conditions, $\bar{G}_w$=G_{path} in Equation (2.5.17) and $\bar{G}_m$=G_{path} in Equation (2.5.18);
- In favourable conditions, $\bar{G}_w$=G_{path} in Equation (2.5.17) and $\bar{G}_m$ =G_{path} in Equation (2.5.20);
- $\Delta_{dif(S,R')}$ is the attenuation due to the diffraction between *S* and the image receiver *R*', calculated as in the previous section on pure diffraction;
- $\Delta_{dif(S,R)}$ is the attenuation due to the diffraction between *S* and *R*, calculated as in the previous subsection on pure diffraction.

16.6.2 *Proposed new text*

Calculation of the term $\Delta_{ground(S,O)}$

$$\Delta_{ground(S,O)} = -20 \times \lg\left(1 + \left(10^{-A_{ground(S,O)}/20} - 1\right) \cdot 10^{-\left(\Delta_{dif(S',R)} - \Delta_{dif(S,R)}\right)/20}\right) \quad (2.5.31)$$

where

- $A_{ground(S,O)}$ is the attenuation due to the ground effect between the source *S* and the diffraction point *O*. This term is calculated as indicated in the previous subsection on calculations in homogeneous conditions and in the previous subsection on calculation in favourable conditions, with the following hypotheses:
- z_r=$z_{o,s}$;
- G_{path} is calculated between *S* and *O;*
- In homogeneous conditions: $\bar{G}_w$= G'_{path} in Equation (2.5.17), $\bar{G}_m$= G'_{path} in Equation (2.5.18)*;*
- In favourable conditions: $\bar{G}_w$= G_{path} in Equation (2.5.17), $\bar{G}_m$= G'_{path} in Equation (2.5.20);

- $\Delta_{dif(S',R)}$ is the attenuation due to the diffraction between the image source *S′* and *R*, calculated as in the previous subsection on pure diffraction;
- $\Delta_{dif(S,R)}$ is the attenuation due to the diffraction between *S* and *R,* calculated as in Subsection VI.4.4.b.

In the special case where the source lies below the mean ground plane: $\Delta_{dif(S,R)} = \Delta_{dif(S',R)}$ and $\Delta_{ground(S,O)} = A_{ground(S,O)}$

Calculation of the term $\Delta_{ground(O,R)}$

$$\Delta_{ground(O,R)} = -20 \times \lg\left(1 + \left(10^{-A_{ground(O,R)}/20} - 1\right) \cdot 10^{-\left(\Delta_{dif(S,R')} - \Delta_{dif(S,R)}\right)/20}\right) \qquad (2.5.32)$$

where

- $A_{ground\ (O,R)}$ is the attenuation due to the ground effect between the diffraction point *O* and the receiver *R*. This term is calculated as indicated in the previous subsection on calculation in homogeneous conditions and in the previous subsection on calculation in favourable conditions, with the following hypotheses:
- $z_s = z_{o,r}$
- G_{path} is calculated between *O* and *R.*

The G'_{path} correction does not need to be taken into account here, as the considered source is the diffraction point. Therefore, G_{path} shall indeed be used in the calculation of ground effects, including for the lower bound term of the equation which becomes -3(1- G_{path}).

- In homogeneous conditions, $\bar{G}_w = G_{path}$ in Equation (2.5.17) and $\bar{G}_m = G_{path}$ in Equation (2.5.18);
- In favourable conditions, $\bar{G}_w = G_{path}$ in Equation (2.5.17) and $\bar{G}_m = G_{path}$ in Equation (2.5.20);
- $\Delta_{dif(S,R')}$ is the attenuation due to the diffraction between *S* and the image receiver *R*', calculated as in the previous section on pure diffraction;
- $\Delta_{dif(S,R)}$ is the attenuation due to the diffraction between *S* and *R*, calculated as in the previous subsection on pure diffraction.

In the special case where the receiver lies below the mean ground plane: $\Delta_{dif(S,R')} = \Delta_{dif(S,R)}$ and $\Delta_{ground(O,R)} = A_{ground(O,R)}$

16.7 Diffraction around vertical edges must be specified

16.7.1 Current text Annex II [page 41]

Equation (2.5.21) may be used to calculate the diffractions on vertical edges (lateral diffractions) in case of industrial noise. If this is the case, $A_{dif} = \Delta_{dif(S,R)}$ is taken and the term A_{ground} is kept. In addition, A_{atm} and A_{ground} shall be calculated from the total length of the propagation path. A_{div} is still calculated from the direct distance *d*. Equations (2.5.8) and (2.5.6) respectively become:

Δ_{dif} is indeed used in homogeneous conditions in equation (2.5.34).

$$A_H = A_{div} + A_{atm}^{path} + A_{ground,H}^{path} + \Delta_{dif,H(S,R)} \quad (2.5.33)$$

$$A_F = A_{div} + A_{atm}^{path} + A_{ground,F}^{path} + \Delta_{dif,H(S,R)} \quad (2.5.34)$$

16.7.2 *Proposed new text*

Equation (2.5.21) may be used to calculate the diffractions on vertical edges (lateral diffractions) in case of industrial noise. If this is the case, $A_{dif} = \Delta_{dif(S,R)}$ is taken and the term A_{ground} is kept. In addition, A_{atm} and A_{ground} shall be calculated from the total length of the propagation path. A_{div} is still calculated from the direct distance *d*. Equations (2.5.8) and (2.5.6) respectively become:

Δ_{dif} is indeed used in homogeneous conditions in equation (2.5.34).

$$A_H = A_{div} + A_{atm}^{path} + A_{ground,H}^{path} + \Delta_{dif,H(S,R)} \quad (2.5.33)$$

$$A_F = A_{div} + A_{atm}^{path} + A_{ground,F}^{path} + \Delta_{dif,H(S,R)} \quad (2.5.34)$$

Lateral diffraction is considered only in cases, where the following conditions are met:

- The source is a real point source – not produced by segmentation of an extended source like a line- or area source.
- The source is not a mirror source constructed to calculate a reflection.
- The direct ray between source and receiver is entirely above the terrain profile.
- In the vertical plane containing S and R the path length difference δ is larger than 0, i.e., the direct ray is blocked. Therefore, in some situations, lateral diffraction may be considered under homogeneous propagation conditions but not under favourable propagation conditions.

If all these conditions are met, up to two laterally diffracted propagation paths are taken into account in addition to the diffracted propagation path in the vertical plane containing source and receiver. The lateral plane is defined as the plane that is perpendicular to the vertical plane and also contains source and receiver. The intersection areas with this lateral plane are constructed from all obstacles that are penetrated by the direct ray from source to receiver. In the lateral plane, the shortest convex connection between source and receiver, consisting of straight segments and encompassing these intersection areas, defines the vertical edges that are taken into account when the laterally diffracted propagation path is constructed.

To calculate ground attenuation for a laterally diffracted propagation path, the mean ground plane between the source and the receiver is calculated taking into account the ground profile vertically below the propagation path. If, in the projection onto a horizontal plane, a lateral propagation path cuts the projection of a building, this is taken into account in the calculation of G_{path} (usually with $G = 0$) and in the calculation of the mean ground plane with the vertical height of the building.

16.8 Reflected rays are curved depending on total length

16.8.1 Current text Annex II [page 39]

In favourable conditions, it is considered that the three curved sound rays SO, OR, and SR have an identical radius of curvature Γ defined by:

$$\Gamma = \max\left(1000, 8d\right) \quad (2.5.24)$$

16.8.2 Proposed new text

In favourable conditions the three curved sound rays SO, OR, and SR have an identical radius of curvature Γ defined by:

$$\Gamma = \max\left(1000, 8d\right) \quad (2.5.24)$$

Where d is defined by the 3D distance between source and receiver of the unfolded path.

16.9 G_{path} is based on a 2D projection

16.9.1 Current text Annex II [page 33]

None

16.9.2 Proposed new text (directly below figure 2.5.b)

The distances d_n are determined by a 2D projection on the horizontal plane.

16.10 Specify unmodified heights for formula 2.5.20

16.10.1 Current text Annex II [page 35]

In the equation of $A_{ground,H}$ the heights …

b) The lower bound of $A_{ground,F}$ depends on the geometry of the path:

16.10.2 Proposed new text

In equation 2.5.15 ($A_{ground,H}$) the heights …

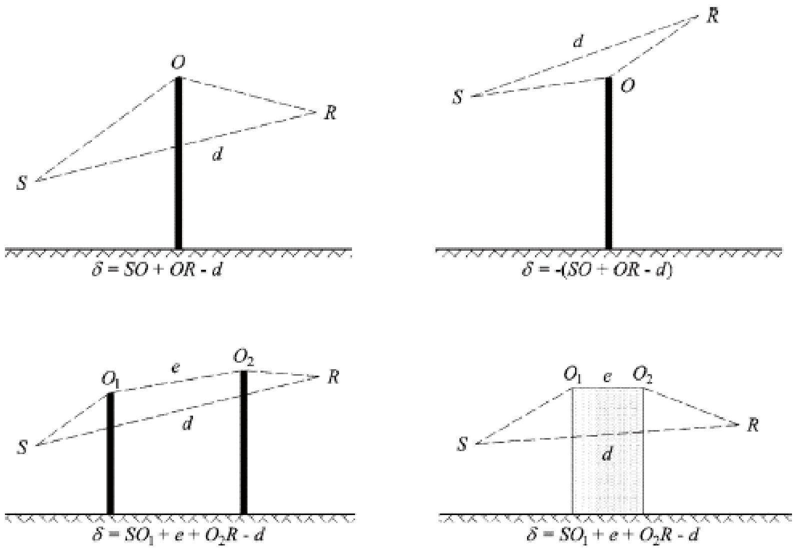
b) The lower bound of $A_{ground,F}$ (calculated with unmodified heights) depends on the geometry of the path:

16.11 Multiple diffractions in homogeneous condition

16.11.1 Current text Annex II [page 38]

Figure 2.5.d

Calculation of the path difference in homogeneous conditions. O, O_1, and O_2 are the diffraction points



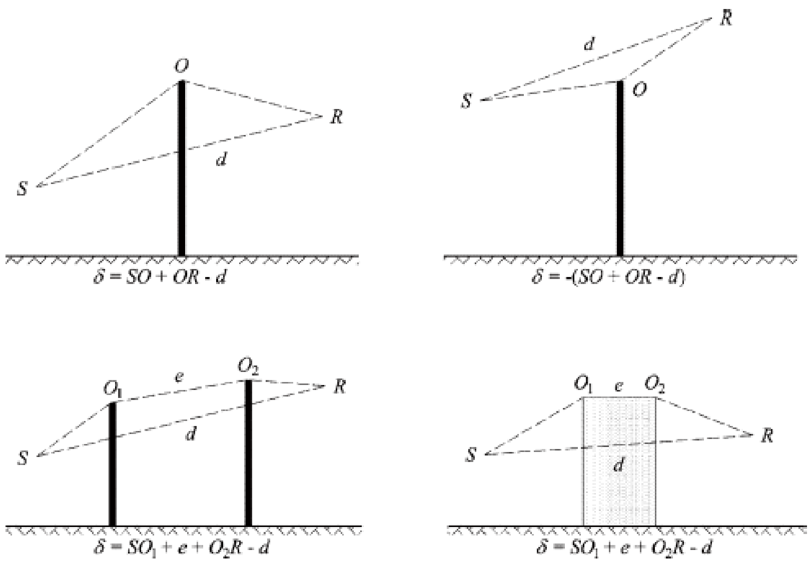
Note: For each configuration, the expression of δ is given.

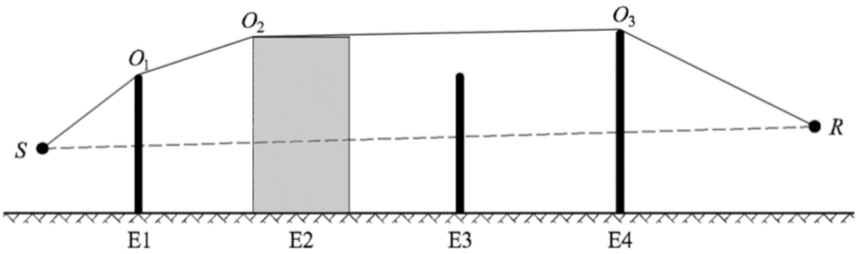
16.11.2 *Proposed new text*

Homogeneous conditions

Figure 2.5.d

Calculation of the path difference in homogeneous conditions. O, O_1, and O_2 are the diffraction points





$$\delta = SO_1 + O_1O_2 + O_2O_3 + O_3R - SR$$

Note: For each configuration, the expression of δ is given

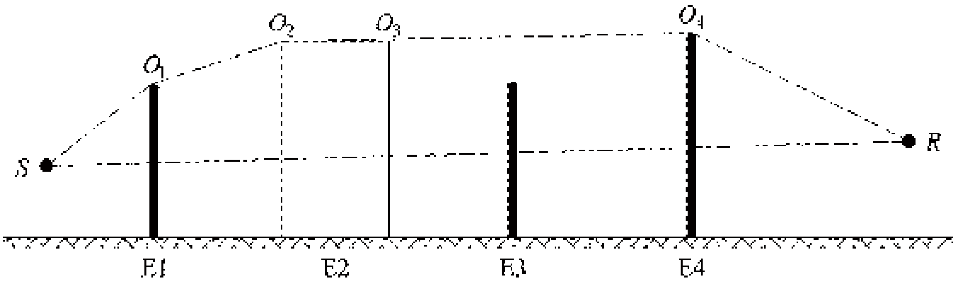
16.12 Multiple diffractions in favourable conditions

16.12.1 Current text Annex II [page 40]

- determine the convex hull defined by the various potential diffraction edges;
- eliminate the diffraction edges which are not on the boundary of the convex hull;
- calculate *δF* based on the lengths of the curved sound ray, by breaking down the diffracted path into as many curved segments as necessary (see Figure 2.5.f)

$$\delta_F = \hat{S}O + \sum_{i=1}^{n-1} O_i\hat{O}_{i+1} - \hat{O}_nR - \hat{S}R \qquad (2.5.28)$$

Figure 2.5.f
Example of calculation of the path difference in favourable conditions, in the case of multiple diffractions



In the scenario presented in figure 2.5.Figure 2.5.f, the path difference is:

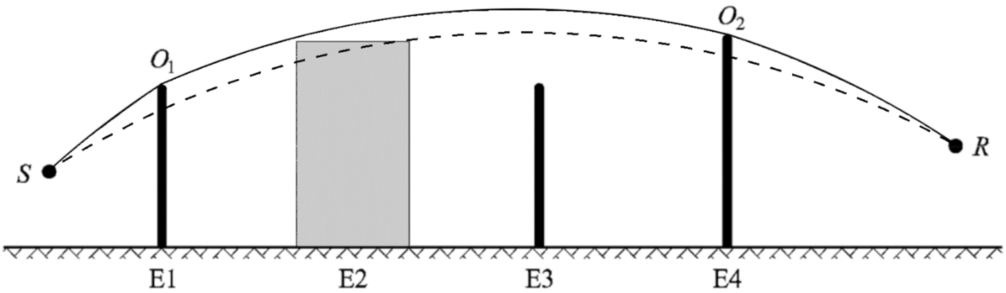
$$\delta_F = \hat{S}O_1 + O_1\hat{O}_2 + O_2\hat{O}_4 + \hat{O}_4R - \hat{S}R \qquad (2.5.29)$$

16.12.2 Proposed new text

$$\delta_F = \hat{S}O + \sum_{i=1}^{n-1} O_i\hat{O}_{i+1} - \hat{O}_nR - \hat{S}R \qquad (2.5.28)$$

Under favourable conditions, the propagation path in the vertical propagation plane always consists of segments of a circle whose radius is given by the 3D-distance between source and receiver, 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.

Figure 2.5.f
Example of calculation of the path difference in favourable conditions, in the case of multiple diffractions



In the scenario presented in figure 2.5.Figure 2.5.f, the path difference is:

$$\delta_F = \hat{S}O_1 + O_1\hat{O}_2 + \hat{O}_2R - \hat{S}R \qquad (2.5.29)$$

16.13 Remove the word local for velocity (traffic speed)

16.13.1 Current text Annex II [page 8]

The speed v_m is a representative speed per vehicle category: in most cases the lower of the maximum legal speed for the section of road and the maximum legal speed for the vehicle category. If local measurement data is unavailable the maximum legal speed for the vehicle category shall be used.

16.13.2 Proposed new text

The speed v_m is a representative speed per vehicle category: in most cases the lower of the maximum legal speed for the section of road and the maximum legal speed for the vehicle category. If measurement data is unavailable, the maximum legal speed for the vehicle category shall be used.

16.14 Correct semi free field emission

16.14.1 Current text Annex II [page 7]

In this model, each vehicle (category 1,2,3,4 and 5) is represented by one single point source radiating uniformly in the 2-π half space above the ground.

16.14.2 Proposed new text

In this model, each vehicle (category 1,2,3,4 and 5) is represented by one single point source radiating uniformly.

16.15 A weighting 2.1.1 vs 2.5.11

16.15.1 Current text Annex II [page 7]

Calculations are performed in octave bands for road traffic, railway traffic and industrial noise, except for the railway noise source sound power, that uses third octave bands. For road traffic, railway traffic and industrial noise, based on these octave band results, the A-weighted long term average sound pressure level for the day, evening and night period, as defined in Annex I and referred to in Art. 5 of Directive 2002/49/EC, is computed by summation over all frequencies:

$$L_{Aeq,T} = 10 \times \lg \sum_{i=1} 10^{(L_{eq,T,i} + A_i)/10} \qquad (2.1.1)$$

where
Ai denotes the A-weighting correction according to IEC 61672-1
i = frequency band index and
T is the time period corresponding to day, evening or night.

16.15.2 *Proposed new text*
Calculations are performed in octave bands for road traffic, railway traffic and industrial noise, except for the railway noise source sound power, which uses third octave bands. For road traffic, railway traffic and industrial noise, based on these octave band results, the A-weighted long term average sound pressure level for the day, evening and night period, as defined in Annex I and referred to in Art. 5 of Directive 2002/49/EC, is computed by the method described in sections 2.2, 2.3, 2.4 and 2.5.

16.15.3 *Current text Annex II [page 31]*
AWC is the A-weighting correction according to the international standard IEC 61672-1:2003.

16.15.4 *Proposed new text*
AWC is the A-weighting correction according to the values in the table below

Frequency [Hz]	63	125	250	500	1000	2000	4000	8000
$AWC_{f,I}$ [dB]	-26.2	-16.1	-8.6	-3.2	0	1.2	1.0	-1.1

16.16 A unit is needs to be defined for the speed vehicle

16.16.1 *Current text Annex II [page 17]*
V is their speed in the j-th for…

16.16.2 *Proposed new text*
V is their speed [km/h] in the j-th for…

16.17 Error in French version of Table G-3

16.17.1 *Current text French Corrigendum [page 5]*
$L_{r,VEH,i}$

16.17.2 *Proposed new text*
$L_{H,VEH,i}$

16.18 Table g-5 the values of the coefficients LW0idling for Diesel locomotive (c. 2 200 kW) at the 6350 Hz frequency seem wrong, and centre frequencies are incorrect in a few tables

16.18.1 *Current text Annex II []*

					$L_{W,0,idling}$
Frequentie					Voe
	d		d		
	Diesel-locomotief (c. 800 kW)		Diesel-locomotief (c. 2 200 kW)		Dies
	bron A	bron B	bron A	bron B	bron A
800 Hz	95,2	92,7	101,7	99,2	90,9
1 000 Hz	95,1	93,0	101,6	99,5	91,8
1 250 Hz	95,1	92,9	99,3	97,1	92,8
1 600 Hz	94,1	93,1	96,0	95,0	92,8
2 000 Hz	94,1	93,2	93,7	92,8	90,8
2 500 Hz	99,4	98,3	101,9	100,8	88,1
3 160 Hz	92,5	91,5	89,5	88,5	85,2
4 000 Hz	89,5	88,7	87,1	86,3	83,2
5 000 Hz	87,0	86,0	90,5	89,5	81,7
6 350 Hz	84,1	83,4	31,4	30,7	78,8
8 000 Hz	81,5	80,9	81,2	80,6	76,2
10 000 Hz	79,2	78,7	79,6	79,1	73,9

16.18.2 *Proposed change*

316 Hz to 315 Hz
3160 Hz to 3150 Hz
6350 Hz to 6300 Hz

Change:
31.4 to 81.4
30.7 to 80.7

16.19 Reflections from vertical obstacles

16.19.1 Current text Annex II []

An obstacle is considered to be vertical if its slope in relation to the vertical is less than 15°.

When dealing with reflections on objects which slope in relation to the vertical is more or equal to 15° the object is not considered.

16.19.2 Proposed new text

Surfaces of objects are only considered as reflectors if their slopes are less than 15° with respect to the vertical. Reflections are considered only for paths in the vertical propagation plane, i.e., not for laterally diffracted paths. For the incident and reflected paths, and assuming the reflecting surface is to be vertical, the point of reflection (which lays on the reflecting object) is constructed using straight lines under homogeneous and curved lines under favourable propagation conditions. The height of the reflector when measured through the point of reflection and viewed from the direction of the incident ray, shall be at least 0.5 m. After projection onto a horizontal plane, the width of the reflector when measured through the point of reflection and viewed from the direction of the incident ray, shall be at least 0.5 m.

16.20 Equation 2.4.1 is incorrect

16.20.1 Current text Annex II [page 25]

-source lines representing moving vehicles, each associated with sound power LW and directivity as a function of the two orthogonal coordinates to the axis of the source line and sound power per metre LW' derived by means of the speed and number of vehicles travelling along this line during day, evening and night; The correction for the working hours, to be added to the source sound power to define the corrected sound power that is to be used for calculations over each time period, CW in dB is calculated as follows:

$$C_W = -10\lg\left(\frac{l \times n}{1000 \times V \times T_0}\right) \qquad (2.4.1)$$

Where:
V Speed of the vehicle [km/h];
n Number of vehicles passages per period [-];
l Total length of the source [m].

16.20.2 Proposed new text

-source lines representing moving vehicles are calculated according to formula 2.2.1

16.21 Reflection between train and nearside noise barrier

16.21.1 Current text Annex II [page 42]

Attenuation through retro-diffraction

In the geometrical research of sound paths, during reflection on a vertical obstacle (barrier wall, building), the position of the impact of the ray in relation to the upper edge of this obstacle determines the more or less significant proportion of energy effectively reflected. This loss of acoustic energy when the ray undergoes a reflection is called attenuation through retro-diffraction.

In the case of potential multiple reflections between two vertical walls, at least the first reflection shall be considered.

In the case of a trench (see for example Figure 2.5.h), the attenuation through retro-diffraction shall be applied to each reflection on the retaining walls.

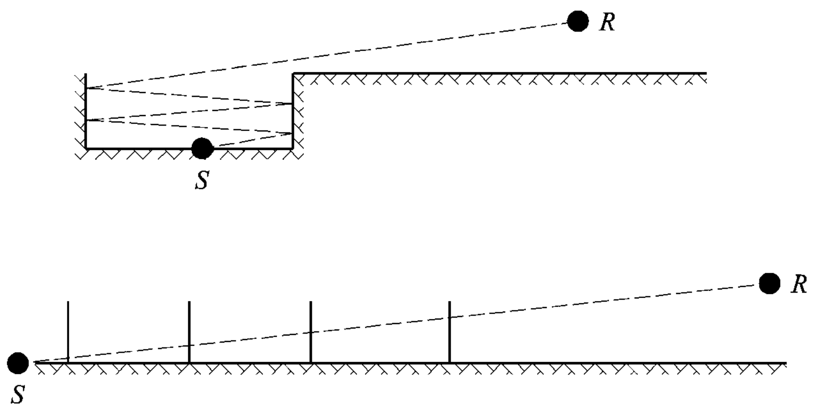


Figure 2.5.h: Sound ray reflected to the order of 4 in a track in a trench: actual cross-section (top), unfolded cross-section (bottom)

In this representation, the sound ray reaches the receiver 'by successively passing through' the retaining walls of the trench, which can therefore be compared to openings.

When calculating propagation through an opening, the sound field at the receiver is the sum of the direct field and the field diffracted by the edges of the opening. This diffracted field ensures the continuity of the transition between the clear area and the shadow area. When the ray approaches the edge of the opening, the direct field is attenuated. The calculation is identical to that of the attenuation by a barrier in the clear area.

The path difference δ' associated with each retro-diffraction is the opposite of the path difference between *S* and *R* relatively at each upper edge *O*, and this in a view according to a deployed cross-section (see Figure 2.5.i).

$$\delta' = -\left(SO + OR - SR\right) \tag{2.5.36}$$

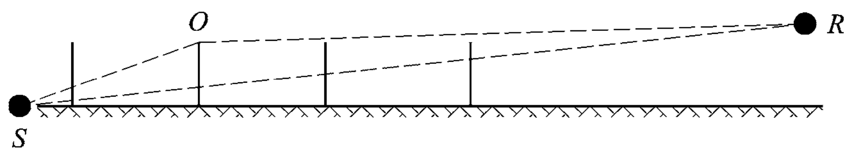


Figure 2.5.i: The path difference for the second reflection

The 'minus' sign of Equation *(2.5.36)* means that the receiver is considered here in the clear area.

Attenuation through retro-diffraction $\Delta_{retrodif}$ is obtained by Equation *(2.5.37)*, which is similar to Equation *(2.5.21)* with reworked notations.

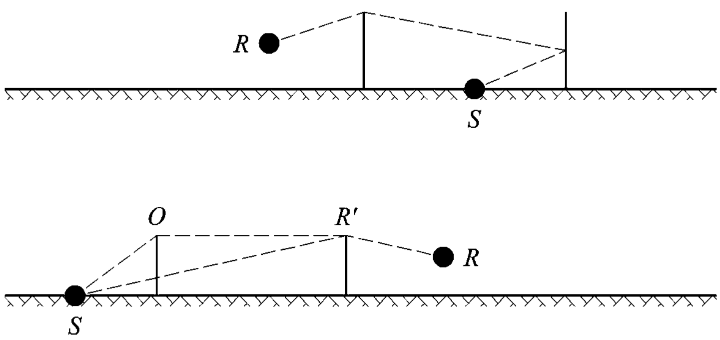
$$\Delta_{retrodif} = \begin{cases} 10C_h \cdot \lg\left(3 + \frac{40}{\lambda}\delta'\right) & if \quad \frac{40}{\lambda}\delta' \geq -2 \\ 0 & otherwise \end{cases} \quad (2.5.37)$$

This attenuation is applied to the direct ray each time it 'passes through' (reflects on) a wall or building. The power level of the image source *S*' therefore becomes:

$$L_{W'} = L_W + 10 \times \lg\left(1 - \alpha_r\right) - \Delta_{retrodif} \quad (2.5.38)$$

In complex propagation configurations, diffractions may exist between reflections, or between the receiver and the reflections. In this case, the retro-diffraction by the walls is estimated by considering the path between source and first diffraction point R' (therefore considered as the receiver in Equation *(2.5.36)*). This principle is illustrated in Figure 2.5.j.

Figure 2.5.j: The path difference in the presence of a diffraction: actual cross-section (top), unfolded cross-section (bottom)



In case of multiple reflections, the reflections due to every single reflection are added.

16.21.2 *Proposed new text*
Same as above but with new chapter:

When there is a noise barrier or obstacle close to the track, the sound rays from the source are successively reflected off this obstacle and off the lateral face of the railway vehicle. In these conditions, the sound rays pass between the obstacle and railway vehicle body before diffraction from the top edge of the obstacle.

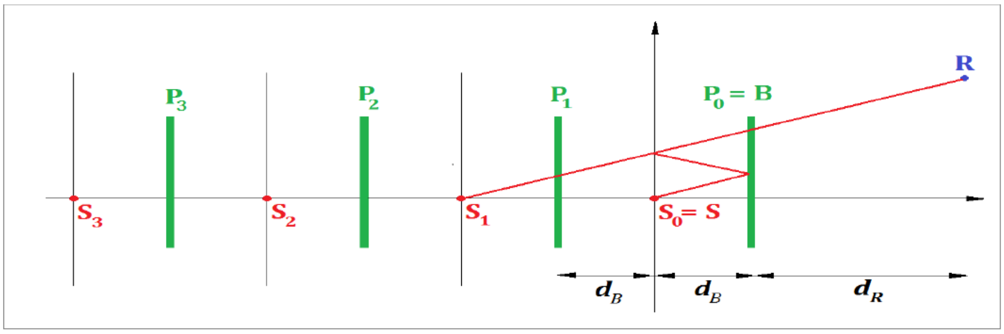
To take multiple reflections between railway vehicle and a nearby obstacle into account, the sound power of a single equivalent source is calculated. In this calculation ground effects are ignored.

To derive the sound power of the equivalent source the following definitions apply:

- The origin of the coordinate system is the nearside railhead
- A real source, is located at S (d_s=0, h_s), where h_s is the height of the source relative to the railhead
- The plan h=0 defines the cars' body
- A vertical obstacle with top at B (d_b, h_b)
- A receiver located at a distance d_R > 0 behind the obstacle where R has coordinates (d_b+d_R,h_R)

The inner side of the obstacle has absorption coefficients α(f) per octave band. The railway vehicle body has an equivalent reflection coefficient C_{ref}. Normally C_{ref} is equal to 1. Only, in the case of open flat-bed freight wagons a value of 0 can be used.

In this configuration, multiple reflections between the railway vehicle body and the obstacle can be calculated using image sources positioned at $S_n\ (d_n = -2n \cdot d_B, h_n = h_s)$, n=0,1,2,..N; as shown in the figure below:



The sound power of the equivalent source is expressed by:

$$L_{W,eq} = 10\lg\left(\sum_{n=0}^{N} 10^{L_{W,m}/10}\right)$$

Where the sound power of the partial sources is given by:

$$L_{W,n} = L_W + \Delta L_n$$

$$\Delta L_n = \Delta L_{geo,n} + \Delta L_{dif,n} + \Delta L_{abs,n} + \Delta L_{ref,n} + \Delta L_{retrodif,n}$$

With:

L_W the sound power of the real source

$\Delta L_{geo,n}$ a correction term for spherical divergence

$\Delta L_{dif,n}$ a correction term for diffraction by the top of the obstacle

$\Delta L_{abs,n}$ a correction term for the absorption at the inner side of the obstacle

$\Delta L_{ref,n}$ a correction term for reflection from the railway vehicle body

$\Delta L_{retrodif,n}$ a correction term for the finite height of the obstacle as a reflector

The correction for spherical divergence is given by

$$\Delta L_{geo,n} = 20\lg\left(\frac{r_0}{r_n}\right)$$
$$r_n = |S_n R| = \sqrt{\left(d_n - (d_b + d_R)\right)^2 + (h_n - h_R)^2}$$

The correction for diffraction by the top of the obstacle is given by:
$\Delta L_{dif,n} = D_0 - D_n$

Where D_n is the attenuation due to diffraction, calculated by means of formula 2.5.21 where $C'' = 1$, for the path linking source S_n to receiver *R,* taking into account diffraction at the top of the obstacle B:

$$\delta_n = \pm(|S_n B| + |BR| - |S_n R|)$$

The correction for absorption on the inner side of the obstacle is given by:

$$\Delta L_{abs,n} = 10 \cdot n \cdot \lg(1 - \alpha)$$

The correction for reflection from the railway vehicle body is given by:

$$\Delta L_{ref,n} = 10 \cdot n \cdot \lg\left(C_{ref}\right)$$

The correction for the finite height of the reflecting obstacle is taken into account by means of retro-diffraction. The ray path corresponding to an image of order $N > 0$ will be reflected *n* times by the obstacle. In the cross section, these reflections take place at distances $d_i = -(2i - q)d_b, i = 1,2,..n$. We note $P_i(d = d_i, h = h_b), i = 1,2,..n$ as the tops of these reflecting surfaces. At each of these points a correction term is calculated as:

$$\Delta L_{retrodif,n} = \begin{cases} \sum_{i=1}^{n} \Delta L_{retrodif,n,i} & if\ n > 0 \\ 0 & if\ n = 0 \end{cases}$$

Where $\Delta L_{retrodif,n,i}$ is calculated for a source at position S_n an obstacle top at P_i and a receiver at position *R′.* The position of the equivalent receiver *R′* is given by *R′=R* if the receiver is above line of sight from S_n to *B*; otherwise the equivalent receiver position is taken on the line of sight vertically above the real receiver; i.e.,

$$d_{R'} = d_R$$
$$h_{R'} = max\left(h_R, h_B \frac{d_B + d_R - d_n}{d_B - d_n}\right)$$

16.22 Steel bridges and railway noise

16.22.1 Current text Annex II [page 23]

In the case where the track section is on a bridge, it is necessary to consider the additional noise generated by the vibration of the bridge as a result of the excitation caused by the presence of the train. Because it is not simple to model the bridge emission as an additional source, given the complex shapes of bridges, an increase in the rolling noise is used to account for the bridge noise. The increase shall be modelled exclusively by adding a fixed increase in the noise sound power per each third octave band. The sound power of only the rolling noise is modified when considering the correction and the new $L_{W,0,rolling-and-bridge,i}$ shall be used instead of $L_{W,0,rollingonly,i}$:

$$L_{W,0,rolling-and-bridge,i} = L_{W,0,rolling-only,i} + C_{bridge} \text{ dB} \qquad (2.3.18)$$

where C_{bridge} is a constant that depends on the bridge type, and $L_{W,0,rolling-only,i}$ is the rolling noise sound power on the given bridge that depends only on the vehicle and track properties.

Correction for other railway-related noise sources

Various sources like depots, loading/unloading areas, stations, bells, station loudspeakers, etc. can be present and are associated with the railway noise. These sources are to be treated as industrial noise sources (fixed noise sources) and shall be modelled, if relevant, according to the following chapter for industrial noise.

16.22.2 Proposed new text

In the case where the track section is on a bridge, it is necessary to consider the additional noise generated by the vibration of the bridge as a result of the excitation caused by the presence of the train. The bridge noise is modelled as an additional source of which the sound power per vehicle is given by

$$L_{W,0,\text{bridge},i} = L_{R,\text{TOT},i} + L_{H,\text{bridge},i} + 10 \times \lg(N_a) \text{ dB} \qquad (2.3.18)$$

where $L_{H,\text{bridge},i}$ is the bridge transfer function. The bridge noise $L_{W,0,\text{bridge},i}$ represents only the sound radiated by the bridge construction. The rolling noise from a vehicle on the bridge is calculated using (2.3.8) through (2.3.10), by choosing the track transfer function that corresponds to the track system that is present on the bridge. Barriers on the edges of the bridge are generally not taken into account.

In the section on Source directivity, directly after equation (2.3.15) the following is added

Bridge noise is modelled at source A (h = 1), for which omni-directionality is assumed.

Table G-7 is replaced by a table with default values of bridge transfer function $L_{H,bridge,i}$. Table G-3 is extended with a track transfer function for direct fastening systems that are applied on bridges (valid for concrete as well as steel bridges). The values are listed here:

Freq [Hz]	$L_{H,\text{bridge},i}$		$L_{H,\text{track},i}$
	+10 dB(A)	+15 dB(A)	direct fastening
50	85,2	90,1	75,4
63	87,1	92,1	77,4
80	91,0	96,0	81,4
100	94,0	99,5	87,1
125	94,4	99,9	88,0
160	96,0	101,5	89,7
200	92,5	99,6	83,4
250	96,7	103,8	87,7
316	97,4	104,5	89,8
400	99,4	106,5	97,5
500	100,7	107,8	99,0
630	102,5	109,6	100,8
800	107,1	116,1	104,9
1000	109,8	118,8	111,8
1250	112,0	120,9	113,9
1600	107,2	109,5	115,5
2000	106,8	109,1	114,9
2500	107,3	109,6	118,2
3160	99,3	102,0	118,3
4000	91,4	94,1	118,4
5000	86,9	89,6	118,9
6350	79,7	83,6	117,5
8000	75,1	79,0	117,9
10000	70,8	74,7	118,6

16.23 Rail squeal

16.23.1 Current text Annex II [page 21]

Curve squeal is a special source that is only relevant for curves and is therefore localised. As it can be significant, an appropriate description is required. Curve squeal is generally dependent on curvature, friction conditions, train speed and track-wheel geometry and dynamics. The emission level to be used is determined for curves with radius below or equal to 500 m and for sharper curves and branch-outs of points with radii below 300 m. The noise emission should be specific to each type of rolling stock, as certain wheel and bogie types may be significantly less prone to squeal than others.

The applicability of these sound power spectra shall normally be verified on-site, especially for trams.

Taking a simple approach, squeal noise shall be considered by adding 8 dB for R < 300 m and 5 dB for 300 m < R < 500 m to the rolling noise sound power spectra for all frequencies. Squeal contribution shall be applied on railway track sections where the radius is within the ranges mentioned above for at least a 50 m length of track.

16.23.2 Proposed new text

Curve squeal is a special source that is only relevant for curves and is therefore localised. Curve squeal is generally dependent on curvature, friction conditions, train speed, track-wheel geometry and dynamics. As it can be significant, an appropriate description is required. At locations where curve squeal occurs, generally in curves and turnouts of railroad switches, suitable excess noise power spectra need to be added to the source power. The excess noise may be specific to each type of rolling stock, as certain wheel and bogie types may be significantly less prone to squeal than others. If measurements of the excess noise are available that take sufficiently the stochastic nature of squeal into account, these may be used.

If no appropriate measurements are available, a simple approach can be taken. In this approach, squeal noise shall be considered by adding the following excess values to the rolling noise sound power spectra for all frequencies.

Train	5 dB for curves with 300 m < R ≤ 500m and L_{track} ≥ 50m 8 dB for curves with R ≤ 300m and L_{track} ≥ 50m 8 dB for switch turnouts with R ≤ 300m 0 dB otherwise
Tram	5 dB for curves and switch turnouts with R ≤ 200 m 0 dB otherwise

where l_{track} is the length of track along the curve and R is the curve radius.

The applicability of these sound power spectra or excess values shall normally be verified on-site, especially for trams and for locations where curves or turnouts are treated with measures against squeal.

16.24 Rail pad stiffness

16.24.1 Current text Annex II [page 14]

Represents an indication of the ‘acoustic’ stiffness

Stiff (800-1000MN/m)

16.24.2 Proposed new text

Represents an indication of the ‘dynamic’ stiffness

Hard (800-1000MN/m)

16.25 Contact filter and Rail Roughness

16.25.1 Current text Annex II [page 130,131,132]
Tables G-1 (part 2) and G-2

16.25.2 Proposed new text

$L_{r,TR,i}$		
Wavelength	Rail Roughness	
	E	M
	EN ISO 3095:2013 (Well maintained and very smooth)	Average network (Normally maintained smooth)
2 000 mm	17,1	35,0
1 600 mm	17,1	31,0
1 250 mm	17,1	28,0
1 000 mm	17,1	25,0
800 mm	17,1	23,0
630 mm	17,1	20,0
500 mm	17,1	17,0
400 mm	17,1	13,5
315 mm	15,0	10,5
250 mm	13,0	9,0
200 mm	11,0	6,5
160 mm	9,0	5,5
125 mm	7,0	5,0
100 mm	4,9	3,5
80 mm	2,9	2,0
63 mm	0,9	0,1
50 mm	−1,1	-0,2
40 mm	−3,2	-0,3
31,5 mm	−5,0	-0,8
25 mm	−5,6	-3,0
20 mm	−6,2	-5,0
16 mm	−6,8	-7,0
12,5 mm	−7,4	-8,0
10 mm	−8,0	-9,0
8 mm	−8,6	-10,0
6,3 mm	−9,2	-12,0
5 mm	−9,8	-13,0
4 mm	−10,4	-14,0
3,15 mm	−11,0	-15,0
2,5 mm	−11,6	-16,0
2 mm	−12,2	-17,0
1,6 mm	−12,8	-18,0
1,25 mm	−13,4	-19,0
1 mm	−14,0	-19,0
0,8 mm	−14,0	-19,0

Table G-2
Coefficients A3,i for the contact filter

$A_{3,i}$					
Wavelength	Wheel load 50 kN - wheel diameter 360 mm	Wheel load 50 kN - wheel diameter 680 mm	Wheel load 50 kN - wheel diameter 920 mm	Wheel load 25 kN - wheel diameter 920 mm	Wheel load 100 kN - wheel diameter 920 mm
2 000 mm	0,0	0,0	0,0	0,0	0,0
1 600 mm	0,0	0,0	0,0	0,0	0,0
1 250 mm	0,0	0,0	0,0	0,0	0,0
1 000 mm	0,0	0,0	0,0	0,0	0,0
800 mm	0,0	0,0	0,0	0,0	0,0
630 mm	0,0	0,0	0,0	0,0	0,0
500 mm	0,0	0,0	0,0	0,0	0,0
400 mm	0,0	0,0	0,0	0,0	0,0
315 mm	0,0	0,0	0,0	0,0	0,0
250 mm	0,0	0,0	0,0	0,0	0,0
200 mm	0,0	0,0	0,0	0,0	0,0
160 mm	0,0	0,0	0,0	0,0	-0,1
125 mm	0,0	0,0	-0,1	0,0	-0,2
100 mm	0,0	-0,1	-0,1	0,0	-0,3
80 mm	-0,1	-0,2	-0,3	-0,1	-0,6
63 mm	-0,2	-0,3	-0,6	-0,3	-1,0
50 mm	-0,3	-0,7	-1,1	-0,5	-1,8
40 mm	-0,6	-1,2	-1,3	-1,1	-3,2
31,5 mm	-1,0	-2,0	-3,5	-1,8	-5,4
25 mm	-1,8	-4,1	-5,3	-3,3	-8,7
20 mm	-3,2	-6,0	-8,0	-5,3	-12,2
16 mm	-5,4	-9,2	-12,0	-7,9	-16,7
12,5 mm	-8,7	-13,8	-16,8	-12,8	-17,7
10 mm	-12,2	-17,2	-17,7	-16,8	-17,8
8 mm	-16,7	-17,7	-18,0	-17,7	-20,7
6,3 mm	-17,7	-18,6	-21,5	-18,2	-22,1
5 mm	-17,8	-21,5	-21,8	-20,5	-22,8
4 mm	-20,7	-22,3	-22,8	-22,0	-24,0
3,15 mm	-22,1	-23,1	-24,0	-22,8	-24,5
2,5 mm	-22,8	-24,4	-24,5	-24,2	-24,7
2 mm	-24,0	-24,5	-25,0	-24,5	-27,0
1,6 mm	-24,5	-25,0	-27,3	-25,0	-27,8
1,25 mm	-24,7	-28,0	-28,1	-27,4	-28,6
1 mm	-27,0	-28,8	-28,9	-28,2	-29,4
0.8 mm	-27,8	-29,6	-29,7	-29,0	-30,2

16.27 Impact noise

16.27.1 Current text Annex II [page 136]
Table G-4

16.27.2 *Proposed new text*

Table G-4

Coefficients $L_{R,IMPACT,i}$ for impact noise

$L_{R,IMPACT,i}$	
Wavelength	Single switch/joint/crossing/100 m
2 000 mm	22,0
1 600 mm	22,0
1 250 mm	22,0
1 000 mm	22,0
800 mm	22,0
630 mm	20,0
500 mm	16,0
400 mm	15,0
315 mm	14,0
250 mm	15,0
200 mm	14,0
160 mm	12,0
125 mm	11,0
100 mm	10,0
80 mm	9,0
63 mm	8,0
50 mm	6,0
40 mm	3,0
31,5 mm	2,0
25 mm	-3,0
20 mm	-8,0
16 mm	-13,0
12,5 mm	-17,0
10 mm	-19,0
8 mm	-22,0
6,3 mm	-25,0
5 mm	-26,0
4 mm	-32,0
3,15 mm	-35,0
2,5 mm	-40,0
2 mm	-43,0
1,6 mm	-45,0
1,25 mm	-47,0
1 mm	-49,0
0,8 mm	-50,0

16.28 Rail directivity

16.28.1 *Current text Annex II [page 23]*

$$\Delta L_{W,dir,ver,i} = \left(\left|\frac{40}{3} * \left[\frac{2}{3} * \sin(2 * \psi) - \sin(\psi)\right] * \lg\left[\frac{f_{c,i} + 600}{200}\right]\right|\right)$$

16.28.2 *Proposed new text*

$$\Delta L_{W,dir,ver,i} = \left(\frac{40}{3} * \left[\frac{2}{3} * \sin(2 * |\psi|) - \sin(|\psi|)\right] * \lg\left[\frac{f_{c,i} + 600}{200}\right]\right)$$

16.29 Emission values road vehicles

16.29.1 Current text Annex II [page 124]
Table F-4

16.29.2 Proposed new text
Table F-1 Coefficients $A_{R,i,m}$ and $B_{R,i,m}$ for rolling noise and $A_{P,i,m}$ and $B_{P,i,m}$ for propulsion noise

Category	Coefficient	63	125	250	500	1000	2000	4000	8000
1	A_R	83,4	86,8	86,1	92,5	99,8	96,6	85,8	76,2
	B_R	39,2	37,5	32,2	18,4	24,9	25,8	32,1	35,1
	A_P	98,0	90,3	89,7	88,3	86,8	89,7	85,1	78,0
	B_P	2,8	6,1	5,6	5,4	5,1	3,5	5,3	6,3
2	A_R	88,2	91,4	91,0	99,2	100,2	94,3	86,6	82,2
	B_R	27,7	23,7	16,6	18,3	28,8	32,6	31,0	28,2
	A_P	105,3	99,4	98,5	99,4	101,5	98,6	91,7	84,6
	B_P	-2,4	-0,6	-1,0	3,8	5,9	5,0	3,3	1,3
3	A_R	90,4	93,2	94,4	104,6	105,3	98,4	89,3	83,8
	B_R	30,3	26,9	22,1	26,1	33,7	35,2	35,6	34,0
	A_P	107,8	102,2	102,2	104,9	104,6	100,1	93,5	86,7
	B_P	0,8	0,3	0,3	5,6	6,2	4,4	3,9	2,3
4a	A_R	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	B_R	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	A_P	93,0	93,0	93,5	95,3	97,2	100,4	95,8	90,9
	B_P	4,2	7,4	9,8	11,6	15,7	18,9	20,3	20,6
4b	A_R	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	B_R	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	A_P	99,9	101,9	96,7	94,4	95,2	94,7	92,1	88,6
	B_P	3,2	5,9	11,9	11,6	11,5	12,6	11,1	12,0
5	A_R								
	B_R								
	A_P								
	B_P								

16.30 New correction values for road surfaces

16.30.1 Current text Annex II [page 125,126]
Complete Table F4

16.30.2 Proposed new text

Description	**Min speed at which it is valid [km/h]**	**Maximum speed at which it is valid [km/h]**	**Cate-gory**	α_m **(63 Hz)**	α_m **(125 Hz)**	α_m **(250 Hz)**	α_m **(500 Hz)**	α_m **(1 kHz)**	α_m **(2 kHz)**	α_m **(4 kHz)**	α_m **(8 kHz)**	β_m
Reference road surface	--	--	1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
			2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
			3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
			4a/4b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
1-layer ZOAB	50	130	1	0,0	5,4	4,3	4,2	-1,0	-3,2	-2,6	0,8	-6,5
			2	7,9	4,3	5,3	-0,4	-5,2	-4,6	-3,0	-1,4	0,2

Description	Min speed at which it is valid [km/h]	Maximum speed at which it is valid [km/h]	Cate-gory	α_m (63 Hz)	α_m (125 Hz)	α_m (250 Hz)	α_m (500 Hz)	α_m (1 kHz)	α_m (2 kHz)	α_m (4 kHz)	α_m (8 kHz)	β_m
			3	9,3	5,0	5,5	-0,4	-5,2	-4,6	-3,0	-1,4	0,2
			4a/4b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
2-layer ZOAB	50	130	1	1,6	4,0	0,3	-3,0	-4,0	-6,2	-4,8	-2,0	-3,0
			2	7,3	2,0	-0,3	-5,2	-6,1	-6,0	-4,4	-3,5	4,7
			3	8,3	2,2	-0,4	-5,2	-6,2	-6,1	-4,5	-3,5	4,7
			4a/4b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
2-layer ZOAB (fine)	80	130	1	-1,0	3,0	-1,5	-5,3	-6,3	-8,5	-5,3	-2,4	-0,1
			2	7,9	0,1	-1,9	-5,9	-6,1	-6,8	-4,9	-3,8	-0,8
			3	9,4	0,2	-1,9	-5,9	-6,1	-6,7	-4,8	-3,8	-0,9
			4a/4b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
SMA-NL5	40	80	1	10,3	-0,9	0,9	1,8	-1,8	-2,7	-2,0	-1,3	-1,6
			2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
			3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
			4a/4b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
SMA-NL8	40	80	1	6,0	0,3	0,3	0,0	-0,6	-1,2	-0,7	-0,7	-1,4
			2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
			3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
			4a/4b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Brushed down concrete	70	120	1	8,2	-0,4	2,8	2,7	2,5	0,8	-0,3	-0,1	1,4
			2	0,3	4,5	2,5	-0,2	-0,1	-0,5	-0,9	-0,8	5,0
			3	0,2	5,3	2,5	-0,2	-0,1	-0,6	-1,0	-0,9	5,5
			4a/4b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Optimised brushed down concrete	70	80	1	-0,2	-0,7	1,4	1,2	1,1	-1,6	-2,0	-1,8	1,0
			2	-0,7	3,0	-2,0	-1,4	-1,8	-2,7	-2,0	-1,9	-6,6
			3	-0,5	4,2	-1,9	-1,3	-1,7	-2,5	-1,8	-1,8	-6,6
			4a/4b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Fine broomed concrete	70	120	1	8,0	-0,7	4,8	2,2	1,2	2,6	1,5	-0,6	7,6
			2	0,2	8,6	7,1	3,2	3,6	3,1	0,7	0,1	3,2
			3	0,1	9,8	7,4	3,2	3,1	2,4	0,4	0,0	2,0
			4a/4b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Worked surface	50	130	1	8,3	2,3	5,1	4,8	4,1	0,1	-1,0	-0,8	-0,3
			2	0,1	6,3	5,8	1,8	-0,6	-2,0	-1,8	-1,6	1,7
			3	0,0	7,4	6,2	1,8	-0,7	-2,1	-1,9	-1,7	1,4
			4a/4b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hard elements in	30	60	1	27,0	16,2	14,7	6,1	3,0	-1,0	1,2	4,5	2,5
			2	29,5	20,0	17,6	8,0	6,2	-1,0	3,1	5,2	2,5

Description	**Min speed at which it is valid [km/h]**	**Maximum speed at which it is valid [km/h]**	**Cate-gory**	α_m **(63 Hz)**	α_m **(125 Hz)**	α_m **(250 Hz)**	α_m **(500 Hz)**	α_m **(1 kHz)**	α_m **(2 kHz)**	α_m **(4 kHz)**	α_m **(8 kHz)**	β_m
herring-bone			3	29,4	21,2	18,2	8,4	5,6	-1,0	3,0	5,8	2,5
			4a/4b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Hard elements not in herring-bone	30	60	1	31,4	19,7	16,8	8,4	7,2	3,3	7,8	9,1	2,9
			2	34,0	23,6	19,8	10,5	11,7	8,2	12,2	10,0	2,9
			3	33,8	24,7	20,4	10,9	10,9	6,8	12,0	10,8	2,9
			4a/4b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Quiet hard elements	30	60	1	26,8	13,7	11,9	3,9	-1,8	-5,8	-2,7	0,2	-1,7
			2	9,2	5,7	4,8	2,3	4,4	5,1	5,4	0,9	0,0
			3	9,1	6,6	5,2	2,6	3,9	3,9	5,2	1,1	0,0
			4a/4b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Thin layer A	40	130	1	10,4	0,7	-0,6	-1,2	-3,0	-4,8	-3,4	-1,4	-2,9
			2	13,8	5,4	3,9	-0,4	-1,8	-2,1	-0,7	-0,2	0,5
			3	14,1	6,1	4,1	-0,4	-1,8	-2,1	-0,7	-0,2	0,3
			4a/4b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Thin layer B	40	130	1	6,8	-1,2	-1,2	-0,3	-4,9	-7,0	-4,8	-3,2	-1,8
			2	13,8	5,4	3,9	-0,4	-1,8	-2,1	-0,7	-0,2	0,5
			3	14,1	6,1	4,1	-0,4	-1,8	-2,1	-0,7	-0,2	0,3
			4a/4b	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Erratum letter report 2019-0023
Amendments for CNOSSOS-EU

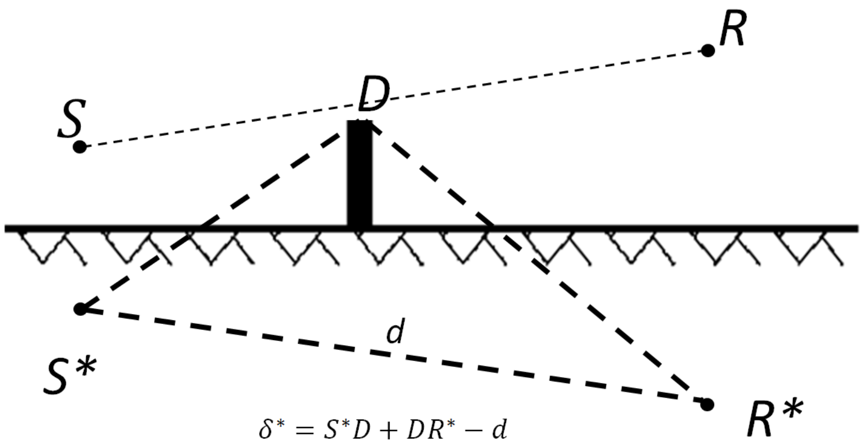
Bilthoven: 22 august 2019
Subject: Erratum letter report 2019-0023

In RIVM letter report 2019-0023 an incorrect table for emission factors of motor vehicles has been published. It concerns table F1 in section 16.29. The published values are for vehicles on standard road surfaces in the Netherlands. It should have been for EU average vehicles on EU standard road surfaces.

Furthermore, RIVM has received some comments on the report that lead us to make some minor changes.

ir C.M. van Luijk
head department of Environmental Quality
RIVM
Netherlands

(1) *Page 21 section 5.4.2*
Figure 1 has incorrect variable names. Both S' and R' should be changed to S* and R*. The leads to the following figure:



(2) *Page 32 section 5.20.2*
The exact definition of rail directivity in NMPB is slightly different from our proposed text. It is suggested to use the exact definition. The current text is:

"We propose to change the location of the absolute symbol so that the results in NMPB and CNOSSOS-EU:2015 are the same:

$$\Delta L_{W,dir,ver,i} = \left(\frac{40}{3} * \left[\frac{2}{3} * \sin(|2 * \psi|) - \sin(|\psi|)\right] * \lg\left[\frac{f_{c,i} + 600}{200}\right]\right)$$

"

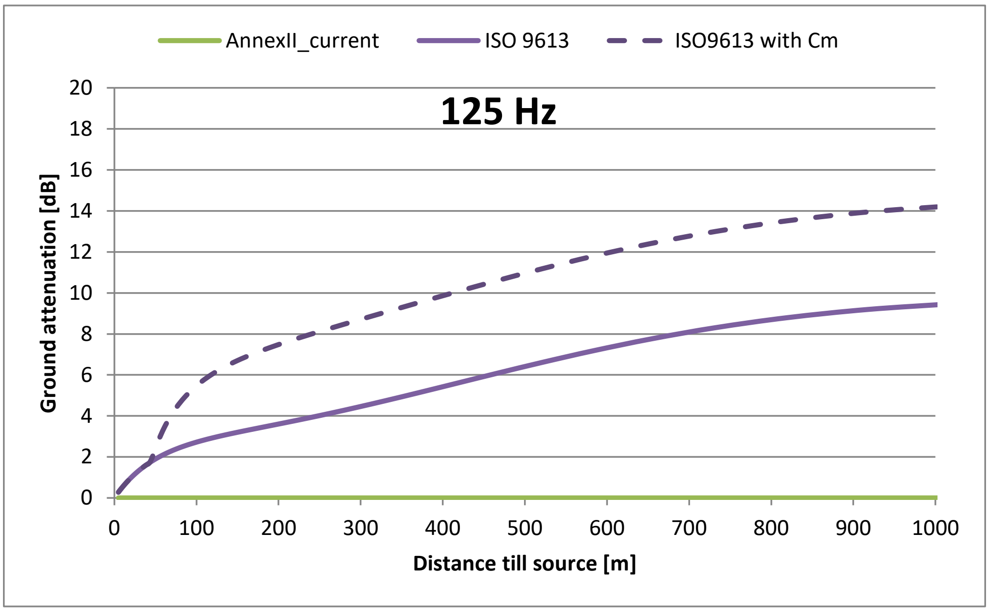
We propose to change this to the following:
"We propose to change the definition so that the results in NMPB and CNOSSOS-EU:2015 are the same:

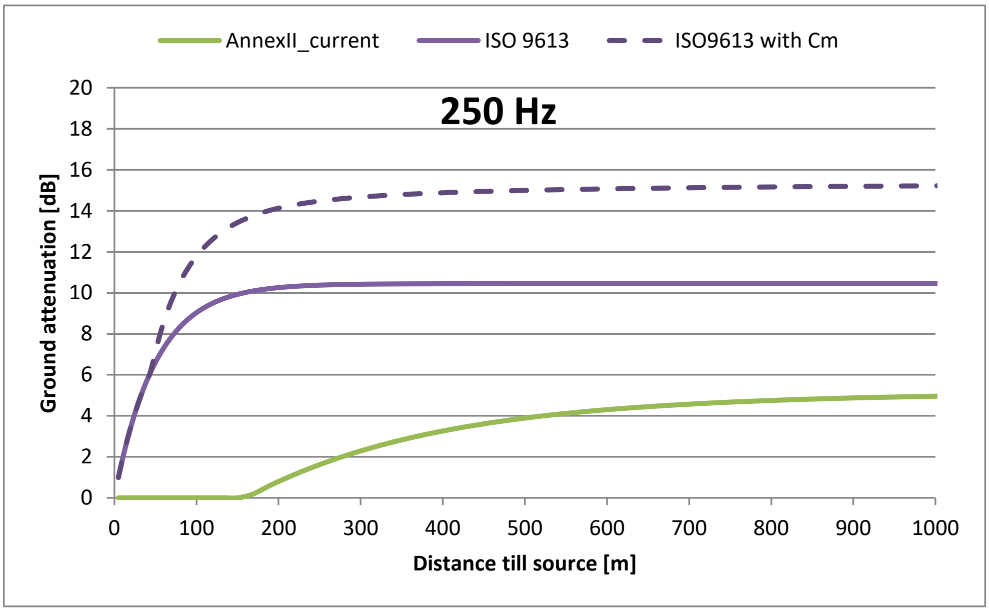
$$\Delta L_{W,dir,ver,i} = \left(\frac{40}{3} * \left[\frac{2}{3} * \sin(|2 * \psi|) - \sin(\psi)\right] * \lg\left[\frac{f_{c,i}+600}{200}\right]\right) \text{ for angles } 0 < \psi < \pi/2$$

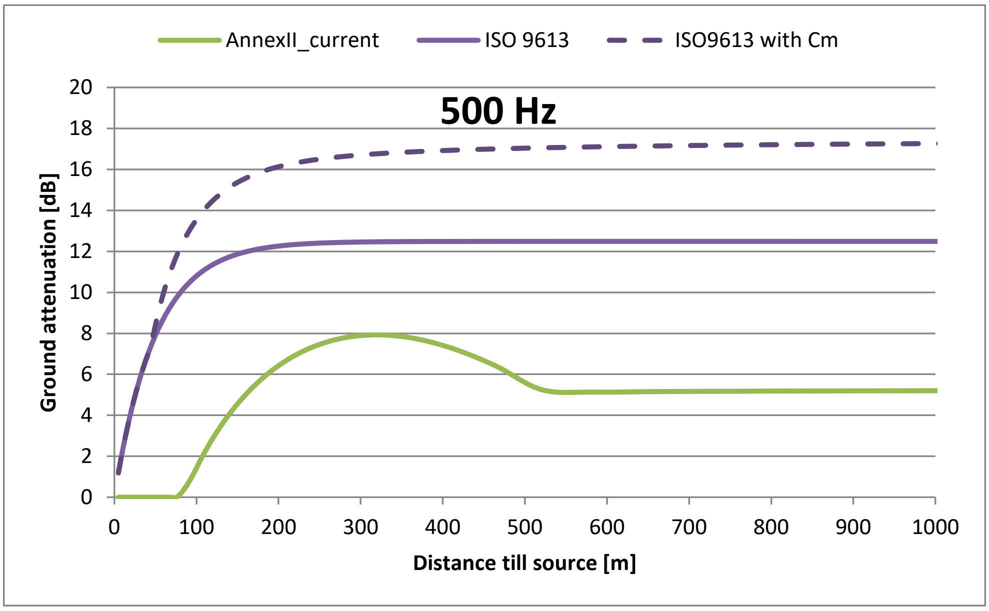
"

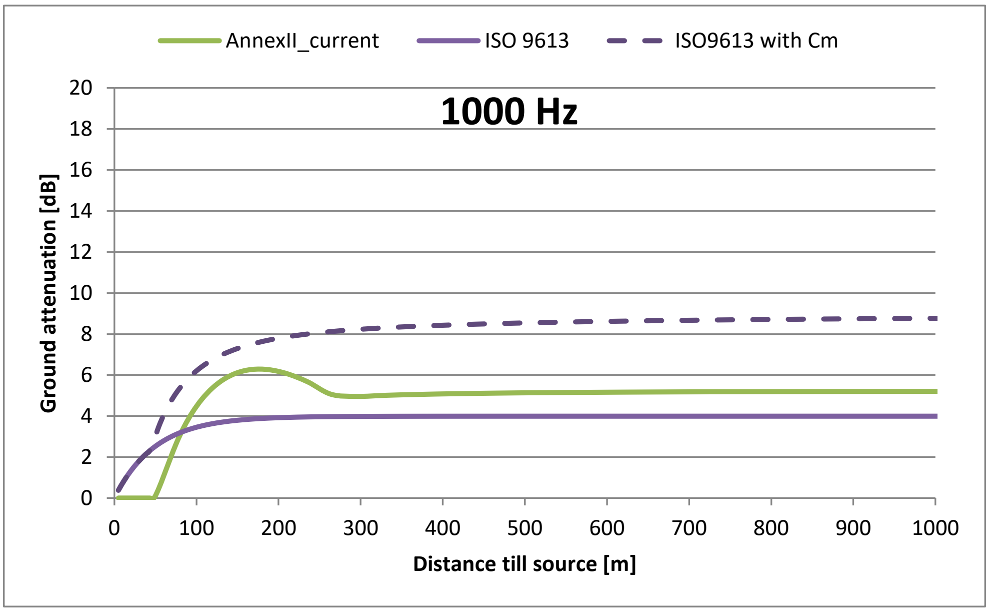
(3) *Pages 42-45 section 5.29.1.3*
The figures in section 5.29.1.3 can be clarified by including the noise frequency the figure represents. Each figure represents results for a single octave band starting at 125Hz and increasing until 8000Hz.

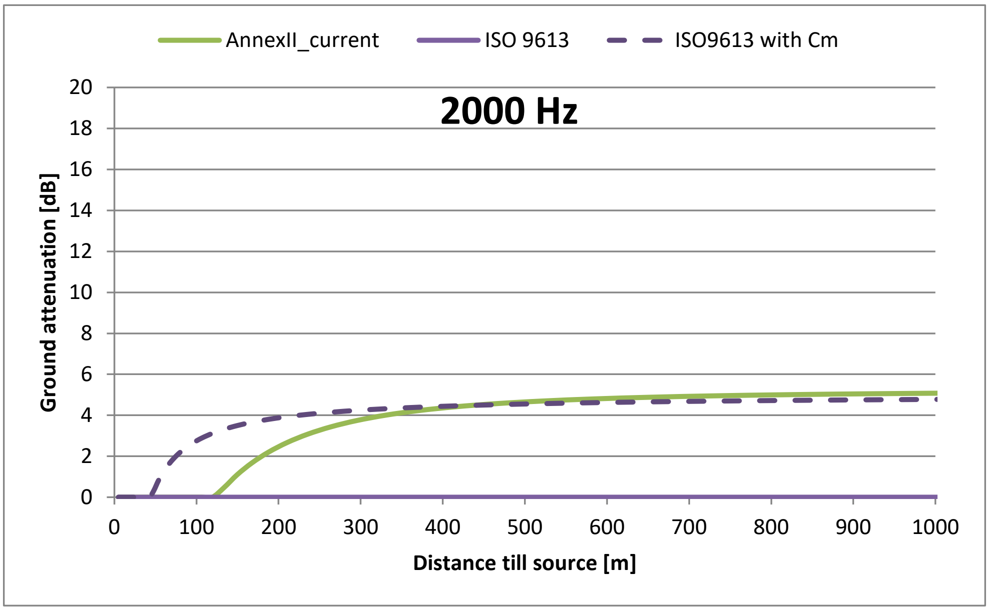
We propose to use following figures:

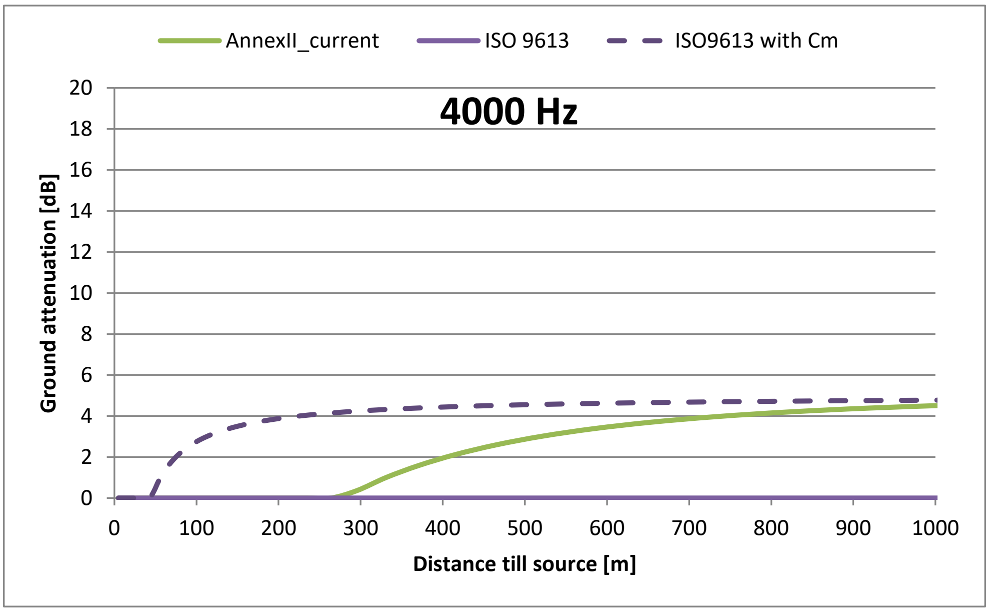


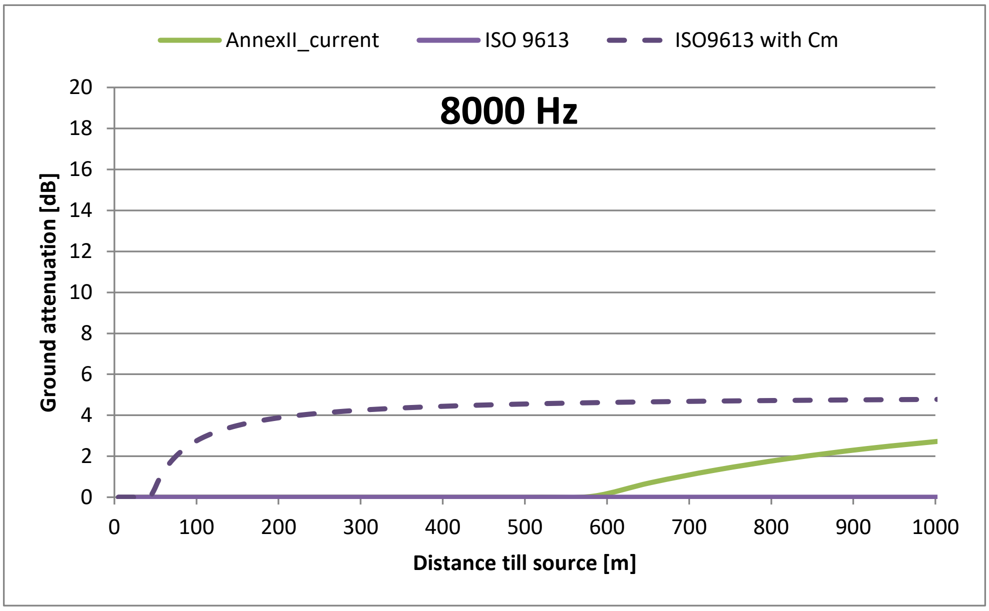



AnnexII_current
ISO 9613
ISO9613 with Cm
500 Hz
Ground attenuation [dB]
Distance till source [m]
0
2
4
6
8
10
12
14
16
18
20
0
100
200
300
400
500
600
700
800
900
1000


AnnexII_current
ISO 9613
ISO9613 with Cm
1000 Hz
Ground attenuation [dB]
Distance till source [m]
0
2
4
6
8
10
12
14
16
18
20
0
100
200
300
400
500
600
700
800
900
1000


AnnexII_current
ISO 9613
ISO9613 with Cm
2000 Hz
Ground attenuation [dB]
20
18
16
14
12
10
8
6
4
2
0
0
100
200
300
400
500
600
700
800
900
1000
Distance till source [m]


AnnexII_current
ISO 9613
ISO9613 with Cm
4000 Hz
Ground attenuation [dB]
20
18
16
14
12
10
8
6
4
2
0
0
100
200
300
400
500
600
700
800
900
1000
Distance till source [m]



(4) *Page 70 Annex 8*
In this section a spelling error was made with one of the names of participants and a typographical error was made.

"Dirck van Maercke" is changed to "Dirk van Maerke" and "nISO WG56" to "ISO WG56"

(5) *Page 90 section 16.21.2*
It has been suggested to clarify when train barrier interaction does not need to be taken into account. Therefore an extra sentence is included.

The current text is:
The inner side of the obstacle has absorption coefficients α(f) per octave band. The railway vehicle body has an equivalent reflection coefficient C_{ref}. Normally C_{ref} is equal to 1. Only, in the case of open flat-bed freight wagons a value of 0 can be used.

The clarified text is:
The inner side of the obstacle has absorption coefficients $\alpha(f)$per octave band. The railway vehicle body has an equivalent reflection coefficient C_{ref}. Normally C_{ref} is equal to 1. Only, in the case of open flat-bed freight wagons a value of 0 can be used. If $d_B>5h_b$ or $\alpha(f)\geq 0.8$ no train barrier interaction is taken into account.

(6) *Page 97 section 16.28*
This change is similar to the one in section 5.20.2. The current text is:
"
Current text Annex II [page 23]

$$\Delta L_{W,dir,ver,i} = \left(\left|\frac{40}{3} * \left[\frac{2}{3} * \sin(2*\psi) - \sin(\psi)\right] * \lg\left[\frac{f_{c,i}+600}{200}\right]\right|\right)$$

Proposed new text

$$\Delta L_{W,dir,ver,i} = \left(\frac{40}{3} * \left[\frac{2}{3} * \sin(2 * |\psi|) - \sin(|\psi|)\right] * \lg\left[\frac{f_{c,i} + 600}{200}\right]\right)$$

"

This is changed to:

"

Current text Annex II [page 23]

, and for − π/2 < ψ < π/2 by:

$$\Delta L_{W,dir,ver,i} = \left(\left|\frac{40}{3} * \left[\frac{2}{3} * \sin(2 * \psi) - \sin(\psi)\right] * \lg\left[\frac{f_{c,i} + 600}{200}\right]\right|\right)$$

Proposed new text

, and for 0 < ψ < π/2 by

$$\Delta L_{W,dir,ver,i} = \left(\frac{40}{3} * \left[\frac{2}{3} * \sin(2 * |\psi|) - \sin(\psi)\right] * \lg\left[\frac{f_{c,i} + 600}{200}\right]\right)$$

"

(7) *Page 98 section 16.29.2*

The table is incorrect. It currently reflects values valid only for the Netherlands. This table is changed to:

Category	Coefficient	63	125	250	500	1000	2000	4000	8000
1	A_R	83.1	89.2	87.7	93.1	100.1	96.7	86.8	76.2
	B_R	30.0	41.5	38.9	25.7	32.5	37.2	39.0	40.0
	A_P	97.9	92.5	90.7	87.2	84.7	88.0	84.4	77.1
	B_P	-1.3	7.2	7.7	8.0	8.0	8.0	8.0	8.0
2	A_R	88.7	93.2	95.7	100.9	101.7	95.1	87.8	83.6
	B_R	30.0	35.8	32.6	23.8	30.1	36.2	38.3	40.1
	A_P	105.5	100.2	100.5	98.7	101.0	97.8	91.2	85.0
	B_P	-1.9	4.7	6.4	6.5	6.5	6.5	6.5	6.5
3	A_R	91.7	96.2	98.2	104.9	105.1	98.5	91.1	85.6
	B_R	30.0	33.5	31.3	25.4	31.8	37.1	38.6	40.6
	A_P	108.8	104.2	103.5	102.9	102.6	98.5	93.8	87.5
	B_P	0.0	3.0	4.6	5.0	5.0	5.0	5.0	5.0
4a	A_R	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	B_R	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	A_P	93,0	93,0	93,5	95,3	97,2	100,4	95,8	90,9
	B_P	4,2	7,4	9,8	11,6	15,7	18,9	20,3	20,6
4b	A_R	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	B_R	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	A_P	99,9	101,9	96,7	94,4	95,2	94,7	92,1	88,6
	B_P	3,2	5,9	11,9	11,6	11,5	12,6	11,1	12,0
5	A_R								
	B_R								
	A_P								
	B_P								

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