Analysis of the Sound Propagation Calculation Method according to ISO 9613-2

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Abstract

The author served as chairman of ISO TC43 SC1 WG61, the working group responsible for the revision of ISO 9613-2 and presents key findings from the analysis of the sound propagation model defined in this standard.

Although the formalism is simple and clearly structured, particular attention is required for the complex interaction between ground attenuation and barrier attenuation. The impact of proposed revisions on calculated sound levels at distant receiver locations is evaluated using software that implements both the current version of the standard and the planned modifications. Comparative calculations were performed for large-scale industrial sites covering several square kilometers, including models with up to 6000 individual sound sources. The results demonstrate the expected net effects of the implemented or proposed changes, both for the overall area and for individual sound propagation paths..

Keywords: *ISO 9613-2, Analysis of the sound propagation, comparative calculations, large-scale industrial sites.*

1. Introduction

This ISO 9613-2:2024 introduces approximately fifteen significant changes and additions to its 1996 predecessor. Most of these revisions are uncontroversial and reflect the quality-assurance work documented in ISO/TR 17534-3:2015, together with refinements suggested by users. Two changes, however, have given rise to serious concerns: the revised formula for the barrier attenuation D_z (Formula 18) and the revised formula for the meteorological correction K_{met} (Formula 21).

The modification of the barrier attenuation was implemented to avoid an effect of a remaining A_{bar} of 5 dB even with largest distances source-receiver and with low barrier heights if the General method 7.3.1 is applied with ISO 9613-2:1996. The modification of K_{met} was introduced based on the positive experience with this modified version of the formula in the frame of the prediction of road traffic and railway noise. After ISO 9613-2:2024 was published and implemented in software it was possible to recalculate the sound pressure levels for receivers in the vicinity of extended industrial facilities with the previous and the new version of the standard. The comparison showed that the new version led to recalculated receiver levels exceeding these calculated with the previous version systematically.
The largest level increases were detected in cases with large distance source - receiver and with barriers near the source and near the receiver. The reasons were investigated and it became clear that more time is necessary to come to a final decision.
An amendment was proposed to continue using these two formulas from the previous version until all issues have been clarified.

2. Ground effect A_{gr} and barrier effect A_{bar}

The reference scenario, shown in Fig. 1, comprises a point source and a receiver at 4 m above ground, with no intervening screen.

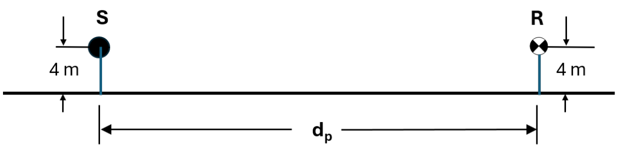

Figure 1. Scenario to determine the insertion loss of the ground

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The difference between the level calculated with ground present and that calculated under free-field conditions (4π) gives the "insertion effect" of the ground, equal to the negative ground attenuation $-A_{gr}$.

Under the Alternative Method (7.3.2), the corresponding quantity is $-(A_{gr} - D_{\Omega})$. The diagram in Fig. 2 shows this insertion effect $-A_{gr,A}$ calculated with a constant linear octave-band spectrum as the difference of the A-weighted levels.

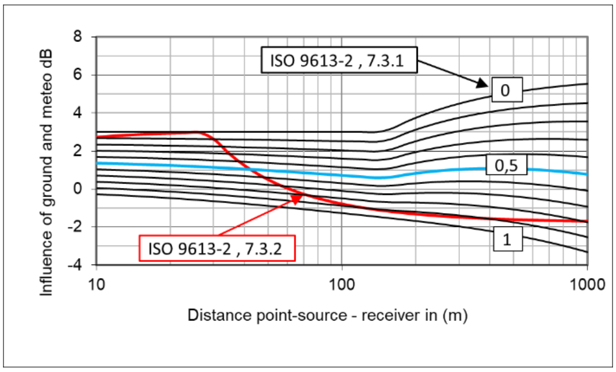

Figure 2: Negative insertion loss of the ground (deviation from free field level). $-A_{gr,A}$ is the arithmetic difference of the A-weighted receiver levels calculated first with ground and then with A_{gr} and D_{Ω} set to zero.

These results show that at large distance the more detailed ground model with different ground properties represented by the G values produces larger ground effects with higher level increases than the Alternative method 7.3.2.

The effect of barriers can be investigated with scenario Figure 3.

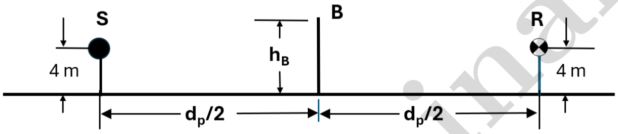

Figure 3: Source S and receiver R at 4 m above ground, with a centrally located screen of variable height.

As it is shown in Figure 4, the effective barrier effect $A_{bar,eff}$ – related to the A-weighted level with a flat linear spectrum – does not vanish with large distances but converges against nearly 5 dB. ($A_{bar,eff}$ in Fig.4 is identical to $A_{bar,A}$)

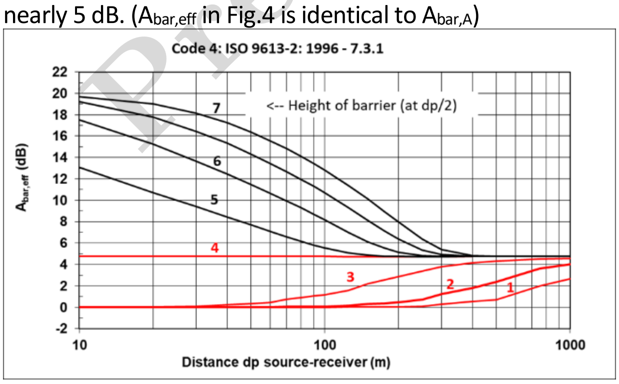

Figure 4: $A_{bar,eff}$ calculated with A_{gr} according to "General Method" (7.3.1) (ISO 9613-2:**1996**).

The same calculation with scenario Figure 3 but using the "Alternative method" 7.3.2 for the determination of A_{gr} leads to the resulting barrier effect $A_{bar,eff}$ shown in diagram Figure 5. Here the barrier effect $A_{bar,eff}$ vanishes with large distance source – receiver as we expect it.

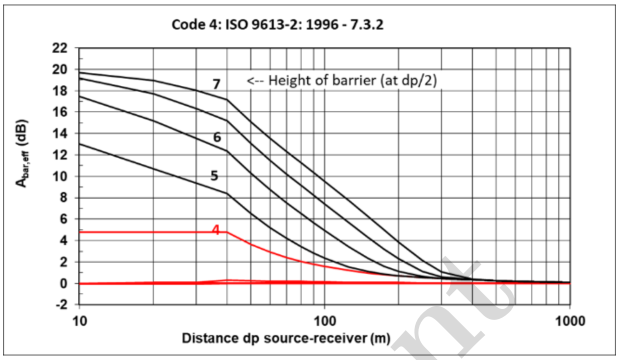

Figure 5: $A_{bar,eff}$ calculated with A_{gr} according to the "Alternative Method" (7.3.2) (ISO 9613-2:1996)

3. Modification of D_z in Version 2024

Without presenting all the equations we check the same diagram as shown in Figure 4 but now calculated with the modified equation for D_z according to the new version ISO 9613-2:2024 – see Figure 6.

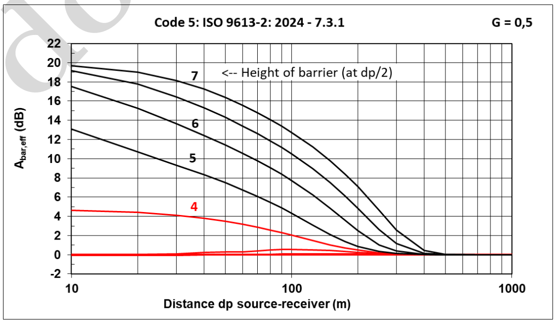

Figure 6: $A_{bar,eff}$ calculated with A_{gr} according to the "General Method" (7.3.1) (ISO 9613-2:**2024**).

Obviously, the barrier effect converges against zero – the new equation works as it was intended.

4. Problems encountered with modified formula for Dz

It shall only be noted here that after publication of ISO 9613-2:2024 the complaints about level increases (see Table 2) with recalculated projects were the starting point for the following analysis.
Based on the comparison of Figures 4 and 6 it was clear that levels should in some cases increase up to approximately 5 dB caused by the transition from the previous version to version 2024 of the standard if the "General method" 7.3.1 is applied. But the complaints based on recalculated projects were accompanied by the claim that measurements were in better agreement with the previous version. Further level increases of up to 10 dB were reported in some cases for the partial level caused by single sources – this was not explainable by the modification of the

formula for the screening effect Dz as shown with diagrams Fig. 4 and Fig.6.

First to the level increase caused by the modified Dz – formula.

Fig. 7 shows this level increase (relative to free-field 4π) caused by the ground alone (dashed curves G0 and G1 – scenario see Fig.1) and in case with a centered barrier with a low height h_B of 3 m (curves H3G0 and H3G1 – scenario see Fig.3) in dependence of the distance source S – receiver R. All calculated with ISO 9613-2:1996.

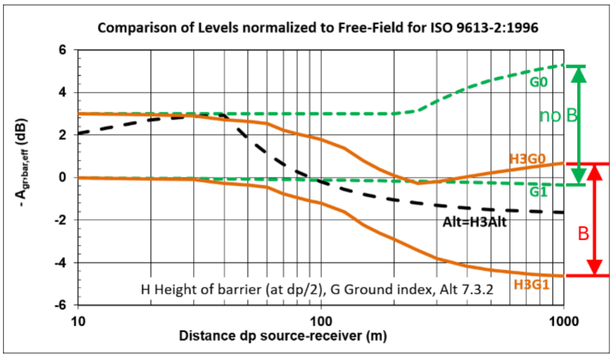

Figure 7: Level increase caused by the ground (no barrier) with G equal 0 and 1 applying the General method 7.3.1 and with the Alternative method 7.3.2 (dashed line)

The levels calculated using the Alternative method 7.3.2 (dashed curve "Alt=H3Alt") - converge at large distances against – 1,7 dB in both cases with and without barrier. With the General method 7.3.1 we get for the level increase caused by the ground between -0,4 dB with porous ground (G=1) and +5,3 dB with hard reflecting ground (G=0).

With the barrier with its upper edge below the straight-line S-R the interval of level increases caused by the combined effect of ground and barrier with G = 1 and G = 0 is shifted about 5 dB downwards to the interval

$-4{,}6 \text{ dB} \leq -A_{gr,bar,eff} \leq 0{,}7 \text{ dB}$.

The same curves calculated with ISO 9613-2:2024 are shown with Fig. 8.

Based on the comparison of these two diagrams Fig. 7 and Fig. 8 it can be stated:

With the previous version of ISO 9613-2 the ground effect (level increase caused by the ground rel. free field) is reduced by about 5 dB by the remaining A_{bar} of about 5 dB at large distances. Even if this barrier effect should vanish because K_{met} was implemented to simulate the effect of curved rays with large distances, this "short-coming" as a consequence of using the same formula for both strategies 7.3.1 and 7.3.2 helped to reduce the large level increase caused by the ground with the General method 7.3.2. Fig. 7 shows that this – under isolated view physically not justified - remaining A_{bar} can be seen as a method to get an interval for the level increase with all types of ground with the ground influence based on the Alternative method in the center. If we remove these low barriers the levels jump upward by about 5 dB. But it should be taken into account that with the typically extended models applied today there are always diffracting edges along the 2D-ray paths below the straight line of sight.

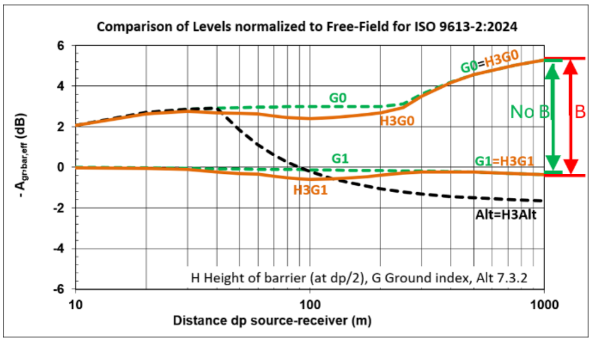

Figure 8: Level increase caused by the ground (with low barrier) as shown with Fig. 7, but calculated with Version 2024 of ISO 9613-2

Fig. 8 shows that this "streamlining" of the methods 7.3.1 and 7.3.2 was eliminated. The level jump between "no barrier" and "with barrier" was eliminated, but a level increase of up to 5 dB can be the consequence. With the Alternative Method 7.3.2 the levels are for all cases of ground always lower than with the General method 7.3.1 at large distances.

5. Alternative formulation of K_{met}

While the above treated modification of Dz with the version 2024 led to level increases up to 5 dB a further modification of the correction for meteorological effects Kmet led to level increases up to 10 dB for some ray-paths. The modification was developed many years ago to reduce the level jump at the transition from single to double diffraction and was applied all these years with the calculation of sound propagation for traffic noise.

If sound is diffracted by a barrier near the source and a second barrier comes into play by increasing its height hB2 as shown in Fig. 9, the level will be reduced in one step by some dB.

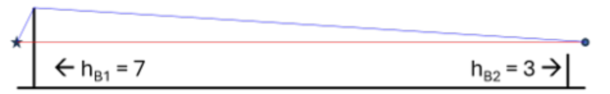

Figure 9: Scenario with 2 barriers, the level normalized with free-field level is determined as function of the height h_{B2}

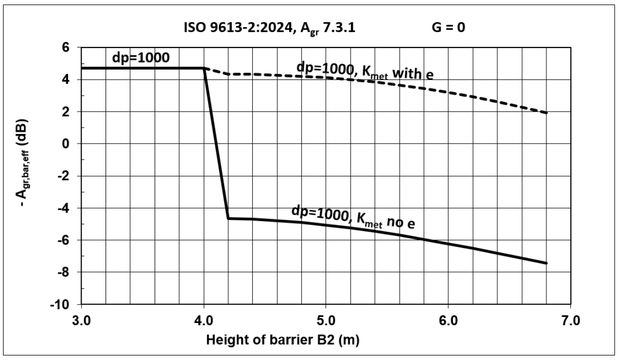

Figure 10: Level increase $-A_{gr,bar,eff}$ relative to free-field with two barriers with distance S – R of 1000 m - case Version 1996 (K_{met} without e) and case version 2024 (formula of K_{met} applying e – dashed line).

Figures 9 and 10 show that the level jump with the transition from single to double diffraction was reduced with the new version but the levels are now about 10 dB higher after the transition from single to double diffraction with $h_{B2} \geq 4{,}2$ m.

6. Recalculation of large projects

Pending further clarification of the issues related to the two formulae for D_z and K_{met}, it is therefore recommended that ISO 9613-2:2024 be amended to ensure that these two formulae are used in accordance with the previous version. All the other modifications remain.
The software-platform CadnaA used for noise-calculations and acoustic surveillance of large industrial facilities since more than 30 years was applied to perform these comparative calculations – in the following only some results are presented.
Table 1 shows the extension of six industrial areas included in this investigation. Table 2 shows the increase of levels caused by the transition to version 2024 and Table 3 proves that these level increases are avoided by switching back to the former version with the two formulas as it is formulated in the proposed amendment.

Table 1. Six different industrial areas with different plants completely modeled and calculated with DIN ISO 9613-2

Nr	Source area		
	Extension in m (approx.)	Number of sources (approx.)	Distance receiver - source-area (approx.)
1	200 m x 1,2 km	700	15 m - 150 m
2	550 m x 600 m	1000	15 m - 250 m
3	600 m x 1,2 km	750	30 m - 1 km
4	1 km x 3 km	6000	100 m - 1 km
5	1 km x 2 km	6000	100 m - 1,5 km
6	1,5 km x 2 km	6000	250 m - 2,5 km

Table 2. Level differences Version 1996 -> Version 2024

Nr	Comparison DIN ISO 9613-2 (1996) -> ISO 9613-2 (2024) Deviation (dB) at the receiver of		
	the total level caused by all plants	the partial level of complete plants	the partial level of single sources
1	0,1 - 1,2	1,8 - 6,6	-0,2 - 7,5
2	0 - 1,0	-	-0,7 - 8,9
3	0,8 - 2,2	0,6 - 4,8	0 - 6,4
4	1,0 - 3,5	0,2 - 11,7	0 - 13,7
5	0,9 - 2,2	0,7 - 7,2	-1,3 - 12,5
6	0,8 - 2,2	0,2 - 6,4	-0,1 - 10,5

The results shown in Table 2 were the catalyst for the detailed investigation partially presented here. Finally, Table 3 proves that these level increases can be avoided if the two formulas are reset to the state of the previous version according to the planned amendment.

Table 3. Level differences
Version 1996 -> Version 2024 + Amendment

Nr	Comparison DIN ISO 9613-2 (1996) -> ISO 9613-2 (2024) Amd Deviation (dB) at the receiver of		
	the total level caused by all plants	the partial level of complete plants	the partial level of single sources
1	< 0,1	-0,1 - 0,1	-0,2 - 0,1
2	-0,1 - 0,1	-	-0,9 - 0,1
3	< 0,1	< 0,1	-0,1 - 0,1
4	< 0,1	-0,1 - 0,1	-0,2 - 0,1
5	-0,1 - 0	-0,4 - 0,1	-1,4 - 0,1
6	< 0,1	-0,1 - 0	-0,3 - 0,1

7. Consequences

The deeply hidden and not easy to detect reason for the problem with the formula for D_z is the treatment of A_{gr} and A_{bar} as independent terms in the final summation equation while they interact differently in the two strategies 7.3.1 and 7.3.2. The analysis in Figures 7 and 8 can be the key for all further decisions and should thoroughly be investigated. Measurements around industrial facilities show better agreement with the previous formulation shown with the example presented with Table 3. To get the necessary time for a final clarification it seems to be the best procedure to apply the former version of the two formulas for D_z and K_{met} in accordance with the proposed amendment. Turning back the equation for K_{met} is from the author's view without alternative based on the findings presented with Figures 9 and 10.

ISO 9613 is a 'lean' engineering method that is often described as too little detailed when it comes to reproducing real-world physics. This study once again confirms the established view that, even with this simple framework, considerable effort is required to implement the procedure in a precise and transparent manner and thus make it suitable for the field of legally regulated noise-control. This should always be borne in mind before considering the inclusion of other physical phenomena that are only relevant in rare cases.

8. Acknowledgements

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