

# Insertion loss with barriers – alternatives with improvements for a revised ISO 9613-2

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## Abstract:

The International Standard ISO 9613-2 describes an energy- and ray-based engineering model that is – due to its simplicity and clear structure - widely used for the calculation of sound propagation in the frame of legal requirements. It is clearly not developed to take various meteorological conditions into account and to allow such calculations for individual settings of wind-speed and -direction or for different temperature gradients. But with the predicted mean sound pressure level it covers the majority of such parameter variations and this led to the claim to describe downwind propagation or, equivalently, propagation under a well-developed moderate ground-based temperature inversion. With a framework of additional specifications and testcases developed in the last decade it can be – and is – implemented in software-platforms respecting the requirements of quality assurance and therefore offers a relatively high level of precision in the prediction of noise from planned industrial and infrastructure facilities. In the frame of a revision of this International Standard it is planned to integrate most of these additional specifications that have proven to reduce uncertainties and to increase the precision. Further the reason for some problems in connection with the calculation of the insertion loss of barriers was investigated and some possible alternatives for improvements are presented to open the discussion in the community of acoustic experts.

## Introduction

The International Standard ISO 9613-2 [1] presents a method to calculate the sound pressure level  $L$  at a given receiver position that is caused by the radiation of a point source with a given sound power level  $L_W$ . Extended or large sources are subdivided in point sources and can also be treated by summing up energetically the contribution  $L$  of all point sources at the receiver.

For the purpose of this consideration the basic calculation can be described by the following well known equation.

$$L = L_W - A_{div} - A_{atm} - A_{gr,eff} - A_{bar} \quad (1)$$

The sound pressure level at the receiver  $L$  is calculated from the sound power level of the source  $L_W$  by subtracting the attenuations due to geometrical divergence  $A_{div}$ , to atmospheric absorption  $A_{atm}$ , to the resulting ground effect  $A_{gr,eff}$  and a barrier effect  $A_{bar}$ . The Standard offers a “General method (in 7.3.1)” and an “Alternative method (in 7.3.2)” to calculate the ground effect here symbolized with  $A_{gr,eff}$ . It can be expressed

$$A_{gr,eff} = A_{gr} \quad (2)$$

for the general method 7.3.1 and

$$A_{gr,eff} = A_{gr} - D_{\Omega} \quad (3)$$

for the alternative method 7.3.2

$A_{gr,eff}$  is the insertion effect of the ground and describes the difference of levels above ground and with free-field conditions.  $D_{\Omega}$  is the level increase resulting from an energetic (incoherent) superposition of the direct ray and the ray reflected from a plane reflecting ground-plate. This different representation of the final insertion effect of the ground with the two methods is a certain problem, as will be shown below.

## The ground effect $A_{gr,eff}$

To study the ground effect the simplest possible scenario with a point source and a receiver in a distance  $d$  and with the same height  $h$  above a ground-plate is sufficient. With the general method 7.3.1 the acoustic properties of the terrain are characterized by the ground factor  $G$ .  $G$  is zero for reflecting ground like concrete, compacted ground or water surfaces and one for absorbing ground like porous loose earth or loose fresh snow. The level with and without the ground was calculated in all frequency bands and as A-weighted total level and the difference of these two levels is the final  $A_{gr,eff}$  shown as a function of the parameters.

The following presentations show the ground effect as a function of the height of the ray source – receiver above ground (x-axis) and of the distance (y-axis).

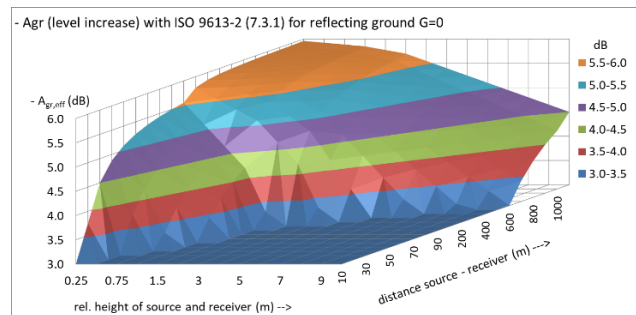


Figure 1 – The insertion effect –  $A_{gr,eff}$  calculated for reflecting ground ( $G = 0$ ) with the general method 7.3.1 and with const.  $L_w$  (lin) in all frequency bands (positive values show the level increase and negative values the level decrease at the receiver caused by the ground).

With reflecting ground the dependency shown in figure 1 is the same for all frequency-bands separately – the spectrum of the source is not relevant. The level will be increased by up to 6 dB with small heights and large distances (presumably coherent superposition was assumed).

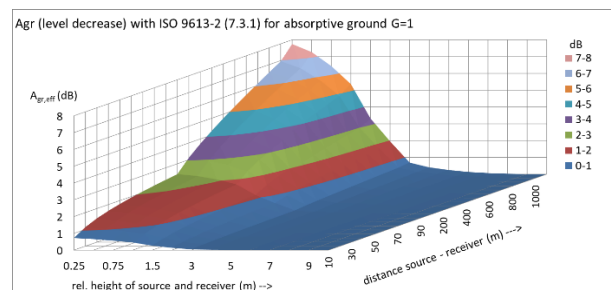


Figure 2 – The negative insertion effect +  $A_{gr,eff}$  calculated for absorptive ground ( $G = 1$ ) with the general method 7.3.1 and with const.  $L_w$  (lin) in all frequency bands (positive values show the corresponding level decrease).

For all  $G$  values other than zero the dependency shown with figures 1 and 2 are frequency dependent. The two extremes with  $G = 0$  and  $G = 1$  prove that the qualification of the surface is important and may have an influence on the calculated results that increases with increasing distance and that should not be neglected.

With the alternative method 7.3.2 the ground factor  $G$  is not an input parameter. The source spectrum is not relevant and equation (3) describes the negative insertion effect directly.

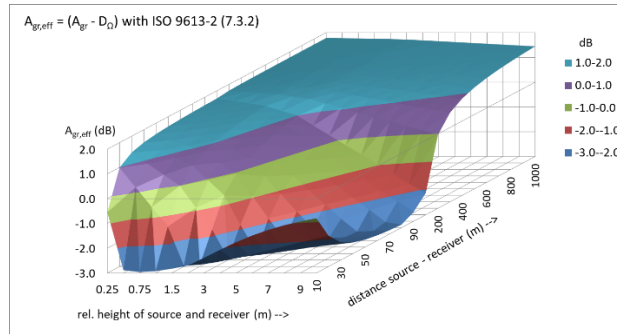


Figure 3 – The negative insertion effect +  $A_{gr,eff}$  calculated for any ground with the alternative method 7.3.2 (positive values show the corresponding level decrease).

It shall only be mentioned that the ground effect with the alternative method is in relatively good agreement with the frequency dependent calculation 7.3.1 if a ground factor of about 0,8 is chosen.

## The barrier attenuation $A_{bar}$

### Problems with the actual specification

In ISO 9613-2 a barrier attenuation  $D_z$  is defined by

$$D_z = 10 \lg[3 + (C_2/\lambda)C_3zK_{met}] \text{ dB} \quad (4)$$

The symbols shall not be explained here – the equation is identical to equation (14) in the Standard and the abbreviations are defined there. The focus is here on the correction factor  $K_{met}$  for meteorological conditions with

$$K_{met} = \exp\left[-(1/2000)\sqrt{d_{ss}d_{sr}d/(2z)}\right] \text{ for } z > 0$$

with

$$K_{met} = 1 \text{ for } z \leq 0 \quad (5)$$

To investigate the parameter influences the same scenario with source and receiver – with a height of 4 m above the plane ground – is used. But now a barrier with its height as input parameter is located in the center between source and receiver.

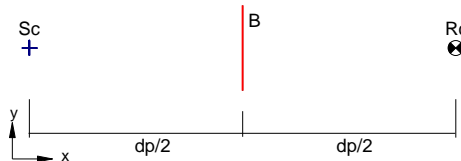


Figure 4 – Scenario with source  $Sc$ , receiver  $Rc$  and barrier  $B$  at the center

First the results of the barrier calculation with the alternative method 7.3.2 are shown in the diagram figure 5 (the abbreviation  $A_{bar,eff}$  is used to characterize the insertion loss of the barrier based on the resulting reduction of the A-weighted levels at the receiver). Here and in the following the calculated values of  $D_z$  were not limited to 20 dB.

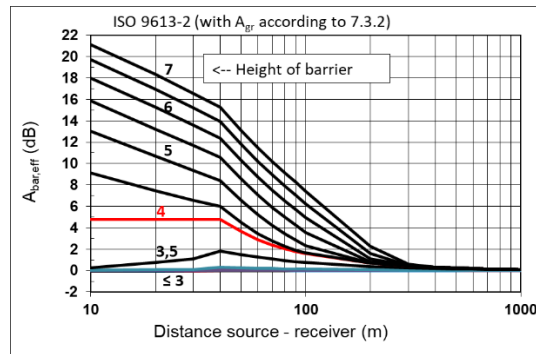


Figure 5 – Insertion loss of the barrier in dependence of the distance source – receiver calculated with the alternative method 7.3.2

The results are in accordance with expectation. For barrier heights above 4 m – this is the height of the direct ray  $S_c - R_c$  – the insertion loss decreases with increasing distance down to zero in about 300 m. This is a result of the correction  $K_{met}$  – see figure 6 - that “simulates” approximately the increasing height of a ray that is curved with favorable propagation conditions.

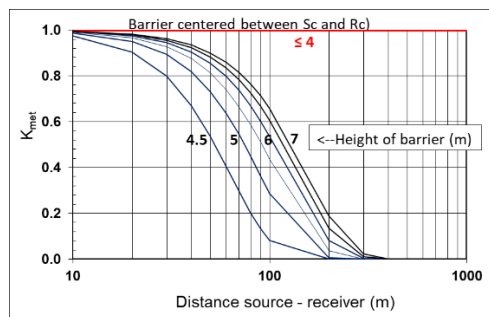


Figure 6 – Dependency of  $K_{met}$  from the distance source - receiver for some barrier heights

With lower barriers (e. g. 3,5 m) and negative path length differences the resulting shape of the curve comes from the superposition of two effects. The insertion loss of the barrier  $A_{gr}$  is calculated with equation (6).

$$A_{bar} = D_z - A_{gr} > 0 \quad (6)$$

With small distances up to about 40 m the path length difference and  $D_z$  increases with distance and the ground attenuation  $A_{gr}$  is negligible. With further increasing distance  $D_z$  the increasing  $A_{gr}$  dominates and reduces the insertion loss of the barrier due to equation (6).

The same dependency of the barrier insertion loss from the distance but calculated with the general method 7.3.1 is shown in figure 7.

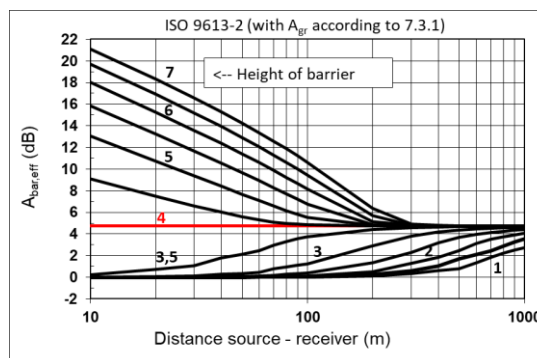


Figure 7 – Insertion loss of the barrier in dependence of the distance source – receiver calculated with the general method 7.3.1

The curves in figure 7 were calculated using the quality assured version of ISO 9613-2, this means the additional recommendations in chapter 6 of ISO/TR 17534-3 [2] have been applied.

The diagram shows that all curves converge for large distances against the value of about 5 dB – this is the result of equation (4) even with a value of zero for  $K_{met}$ .

This is a well-known shortcoming of the barrier calculation in combination with the general method 7.3.1 – it is not in accordance with experience or with expectation that a barrier even not blocking the direct ray will produce an insertion loss of about 5 dB with largest distances of 1 km.

The reason may be that the equations 3, 4 and 5 have been constructed on the basis of the framework of method 7.3.2. Then this method of barrier calculation was combined with the more sophisticated general method 7.3.1 for the inclusion of a more detailed ground model with different G factors.

There are two principally possible ways to improve this situation.

### ***Calculation of Dz with circular bended rays***

The first strategy is to replace the correction  $K_{met}$  and to calculate the path-length difference  $z$  with circular bended rays as they are applied in the calculation method CNOSSOS [3] for favorable propagation conditions in connection with some improvements for multiple diffraction [4].

This more “physical” approach was implemented and tested – the result with a radius of the rays depending on the distance  $S_c$ - $R_c$  as specified in CNOSSOS is shown in the diagram figure 8.

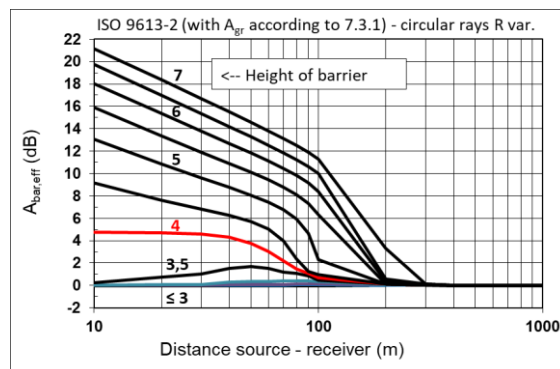


Figure 8 – Insertion loss of the barrier in dependence of the distance source – receiver calculated with the general method 7.3.1 and circular bended rays with a radius as specified in CNOSSOS

The curves are now in agreement with the general expected result of an insertion loss vanishing with large distances.

The result shown in figure 9 was obtained with the same concept – ground attenuation according to 7.3.1 and circular bended rays, but now with a fixed radius of 5 km. The result is an increase of the range of effectiveness of the barrier.

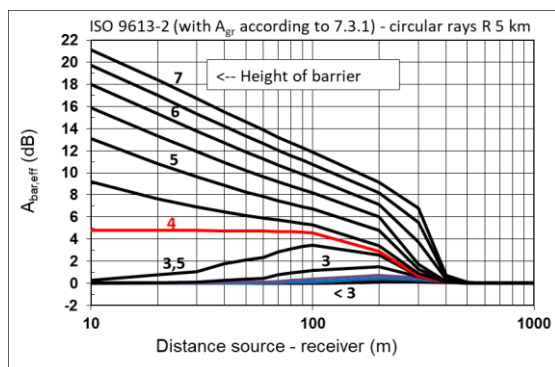


Figure 9 – Insertion loss of the barrier in dependence of the distance source – receiver calculated with the general method 7.3.1 and circular bended rays with a fixed radius 5 km

### Modified concept to integrate $K_{met}$

The described integration of bended rays for the calculation of the barrier effect is a complicated switch because many other aspects – e. g. lateral diffraction or reflection – must thoroughly be adapted. On the other side it is the target of the revision to keep ISO 9613-2 as a clear and straightforward engineering method and therefore it would be advantageous to integrate the long-range effect of vanishing insertion loss of barriers with the empiric correction  $K_{met}$ . The modified integration of  $K_{met}$  in the calculation of the barrier attenuation  $D_z$  with equation (7) in combination with the modified calculation of  $K_{met}$  with equation (8) and (9) seems to be a candidate to fulfil the requirements.

$$D_z = 10 \lg \left[ 1 + \left( 2 + \left( \frac{c_2}{\lambda} \right) c_3 z \right) K_{met} \right] \text{ dB} \quad (7)$$

$$K_{met} = \exp \left[ - (1/2000) \sqrt{d_{ss} d_{sr} d / (2(z - z_{min}))} \right] \quad (8)$$

with

$$z_{min} = -2\lambda / (C_2 C_3) \quad (9)$$

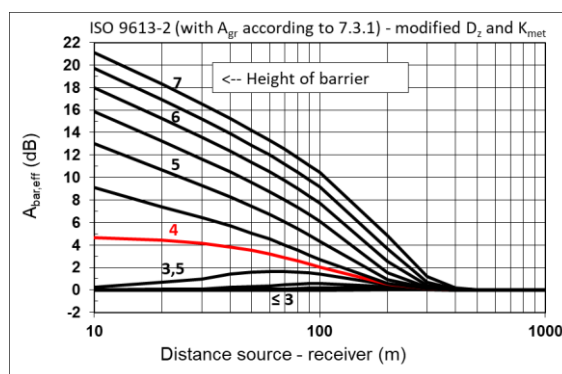


Figure 10 – Insertion loss of the barrier in dependence of the distance source – receiver calculated with the general method 7.3.1 and with the modified calculation of  $D_z$  and  $K_{met}$

The diagram figure 10 shows that the curves for barrier heights lower than 4 m – the height of the straight ray between source and receiver – show the expected form. With 4 m the barrier attenuation is about 5 dB and decreases continuously with increasing distance – thus simulating the larger height of a curved ray above the barrier. With the lower barrier height of 3,5 m the path-length difference  $z$  is smallest with small distances of 10 m and the barrier attenuation is zero, but it increases with increasing distance due to the decreasing absolute value of  $z$  tending against this 5 dB value. Contradictory is the effect of the increasing height of the simulated bending of the ray with  $K_{met}$  and therefore the curve is bended downwards with distances larger than 80 m and tends to zero again.

These results were presented to support an open discussion in the relevant acoustic community. The modification of an existing International Standard with such a broad basis of applicants shall thoroughly weight the pros and cons.

## References

[1] ISO 9613-2, *Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation* (International Organization for Standardization, Geneva, Switzerland, 1996).

[2] ISO/TR 17534-3, *Acoustics – Software for the calculation of sound outdoors – Part 3: Recommendations for quality assured implementation of ISO 9613-2 in software according to ISO 17534-1* (International Organization for Standardization, Geneva, Switzerland, 2015)

[3] COMMISSION DIRECTIVE (EU) 2015/996 of 19 May 2015 establishing common noise assessment methods according to Directive 2002/49/EC of the European Parliament and of the Council

[4] W. Probst, L. Schade: *Calculation of Multiple Diffraction in a Downward Refracting Atmosphere With Ray-Based Engineering Models*. Acta Acustica Vol. 105 (2019), 226 – 230.