# Toward quality-assured software implementations of NMPB 2008 (AFNOR NF S 31-133:2011) for the calculation of outdoor noise propagation

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**Summary**
In the framework of ISO/TC 43/SC 1/WG 56 Working Group, the ISO 17534 series of standards and technical reports is being developed to deal with the quality assured implementation of calculation methods for the outdoor noise propagation. The ISO 17534 series is currently composed of two general documents (ISO 17534-1 and -2) as well as a technical report (TR) dedicated to ISO 9613-2 propagation method (ISO 17534-3). A new TR dealing with CNOSSOS-EU is currently focusing the attention of the WG. In connection with this WG, and in the wake of the publication of NMPB 2008 method (standardized in AFNOR NFS 31-133:2011 French standard), similar works have been carried out in France. On the one hand, a number of additional recommendations were prepared to correct mistakes or clarify ambiguities present in NFS 31-133:2011 document, in order to reduce the risk of mistakes in the implementation of this standard. On the other hand, a set of test-cases has been defined and documented in order to help software developers check the good implementation of this method, taking as a basis ISO 17534-3 format and content. In these test-cases, specificities of NFS 31-133 are checked such as long distance propagation, industrial source description, embankments, retrodiffraction, vehicle body-barrier interaction. The paper proposed to this session aims at presenting this work in close articulation with CNOSSOS-EU implementation.

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## 1. Introduction

NMPB 2008 has been the official predition method in France for the calculation of noise levels from terrestrial transportation since its publication in 2009 [6, 12]. It was standardized in 2011 under the reference NF S 31-133 [1]. The scope of the latter standard includes industrial noise in addition to road and railway noise. In combination to an updated emission model for road traffic [6] and another one for railbound vehicles [2] it provides a self-contained prediction framework adapted to the French rolling stock and infrastructures, provided that propagation paths between source and receiver are identified.

In 2015, a large subset of [1] was chosen by the EU to become part of the so-called CNOSSOS-EU [9] harmonized prediction method to be used in the framework of the implementation of 2002/42/EC directive [8] from January 1st 2019 on [9]. To be more specific, in CNOSSOS-EU the specification of the calculation of sound pressure levels from sound power levels for terrestrial sound sources is taken from [1].

In the years following its publication, [1] was implemented in software by various actors. Official reference libraries (road, railway, attenuation) were released in 2013 by SETRA (now Cerema) [13] to support sofware vendors[1] in a additions to the detailed test cases that are provided in [12]. These early implementations raised a few ambiguities with various potential interpretations and some errors in the specification. This emphasizes the need for quality insurance in maintaining prediction methods.

The ISO/TC43/SC1/WG56 working group develops a suitable framework published in the two first



[1] http://www.infra-transports-materiaux.cerema.fr/les-bibliotheques-logicielles-de-la-nmpb-2008-a5604.html

items of the ISO 17534 series [5, 3] and foresees for each noise prediction method a dedicated technical report as part of this series of standards. The first one was published for ISO 9613-2 [4].

The purpose of this paper is to summarize the work carried out by the authors toward assuring the quality of the software implementations of NMPB 2008 and to give an overview of the content of a possible technical report in the ISO 17534 series and of the components of a revision of the standard for NMPB 2008 [1].

The paper is organized as follows. Section 2 outlines the main additional recommendations and corrections for the implementation of NMPB 2008 in software, with reference to the specification standardized in [1]. Section 3 deals with the test cases developed to provide reference values for checking future implementations of NMPB 2008 in relation to key aspects of the method.

## 2. Recommandations for a correct implementation of NFS 31-133:2011

Although a lot of attention was given to its specification, NF S 31-133:2011 [1] is neither devoid of mistakes nor of ambiguities. Before the standard receives the necessary corrections, it is worth listing the issues identified and providing clarifications to support the software developers in their implementation of [1] and reduce the risk of inconsistencies between two independent implementations of the standard. This is the purpose of this section.

For the calculation of noise levels at a receiver due to a source NF S 31-133:2011 relies on the approximation of sound propagation along several ray paths between the source and the receiver. However, [1] says very little about the method to identify relevant propagation paths. This topic deserves a whole standard in itself and will not be developed in the following. In other words, the following recommendations assume that a propagation path has been identified whatever the method used.

### 2.1. Calculating mean ground planes

In order to obtain the so-called "mean ground plane" below a path between two points $M$ and $N$, the ground profile is in general a polyline defined by the intersection between the ground and the series of vertical planes containing the successive segments of the path polyline. The ground polyline obtained is the input of Annex E.

### 2.2. Sampling G when calculating G$_{path}$

In order to obtain G$_{path}$ along a path between $M$ and $N$:

- either G is evenly sampled on the vertical projection on a horizontal plane of the ground below the path before an average is computed ;
- or a weighted sum

$$G_{path} = \frac{\sum l_i G_i}{\sum l_i}$$

is computed, where $l_i$ is the length of vertical projection of the segment $i$ of the path between $S$ and $M$, and $G_i$ is the ground factor for segment $i$.

### 2.3. Calculation of $G'_{path}$

There is a mistake in Equation (22) of NFS 31-133:2011. The correct relation is the following one:

- If $d_p > 30(z_s + z_r)$:

$$G'_{path} = G_{path}$$

- If $d_p \leq 30(z_s + z_r)$:

$$G'_{path} = G_{path} \frac{d_p}{30(z_s + z_r)} + G_s \left(1 - \frac{d_p}{30(z_s + z_r)}\right)$$

### 2.4. Division by zero in height corrections in favorable conditions

For specific geometry configurations, it may happen that $z_s$ and $z_r$ are both zero. In this case, which is not considered in NF S 31-133:2011, height correction must be disabled in the calculation.

### 2.5. Height corrections in favourable conditions

The height corrections defined in 9.3.4 a) of [1] do not apply to $A_{ground,F,min}$ but only to the first argument of max() in equation (23) in [1].

### 2.6. Negative logarithm in the calculation of $A_{dif}$

It happens sometimes that the actual source is below the mean ground plane. In this case, the image source is located above the actual source. In these conditions: $\Delta_{dif}(S', R) < \Delta_{dif}(S, R)$ in equation (38), page 49. This may lead to the computation of a logarithm of a negative number.

To handle this case properly, equations (38) to (40) must be modified so that:

- If $\Delta_{dif}(S', R) < \Delta_{dif}(S, R)$

$$\Delta_{ground}(S, O) = A_{ground}(S, O)$$

- Otherwise

$$\Delta_{ground}(S, O) = -20 \log_{10}\big(1 + (10^{-A_{ground}(S,O)/20} - 1) \times 10^{-(\Delta_{dif}(S',R) - \Delta_{dif}(S,R))/20}\big)$$

### 2.7. Multiple diffraction in favorable conditions

When evaluating CNOSSOS-EU, it was observed that the calculation in favorable conditions in relatively long distance configurations with multiple diffraction leads to unrealistic and overestimated sound levels at the receiver[2]. It is remarkable that this issue was not reported before since the way multiple diffractions in favorable conditions are handled has not been changed in NMPB 2008 with respect to the original NMPB [7]. The current principle for the calculation of path length difference in NMPB 2008 and CNOSSOS-EU is not valid and leads to a curved diffracted ray that is shorter than the curved direct path.

Differents effective solutions for this issue have been proposed. The simplest one is arguably to state that the convex hull in favorable conditions is the shortest possible ray path from $S$ to $R$ formed by a sequence of circle-arcs connecting diffracting edges between $S$ and $R$. Only the diffracting edges that cut the direct arc $S-R$ are to be taken into account. Another approach is work with straight rays on a curved ground. The final solution is not chosen at the time of writing.

### 2.8. Vehicle body-barrier interaction in the case of a railway source - a possible approximation

Assuming that geometrical divergence and atmospheric attenuation are roughly the same for all image sources, we can factor them in calculations and retain only the effects of diffraction and reflection in the calculations of the contribution of sources images. This assumption is plausible because the ground reflection is low (since it is weighted by diffraction) and weakly dependent on the angle of incidence (since this incidence is far from the grazing incidence). Expressing the power of image sources in a relative way compared to the contribution of the original source, it is possible to integrate the vehicle body-barrier interaction effects in the power of a single equivalent source and to calculate the attenuation from it.

Writing the contribution of the image source at order $i \geq 0$:

$$L_{p,i} = L_{W,i} - A_{geo,i} - A_{atm,i} - A_{dif,i} - 10i\log(1-\alpha)$$

And assuming $A_{geo,i} \approx A_{geo,0}$ and $A_{atm,i} \approx A_{atm,0}$ we can write:

$$\begin{aligned} L_{p,i} = (L_{W,i} - A_{dif,i} + A_{dif,0} - 10i\log(1-\alpha)) \\ -A_{geo,0} - A_{atm,0} - A_{dif,0} \end{aligned}$$

And:

$$\begin{aligned} L_p &= \oplus_i L_{p,i} \\ L_p &= L_{W,eq} - A_{geo,0} - A_{atm,0} - A_{dif,0} \\ L_{W,eq} &= \oplus_i \big(L_{W,i} - A_{dif,i} + A_{dif,0} \\ &\quad -10n\log(1-\alpha)\big) \end{aligned}$$

This defines the power of the equivalent source and allows the attenuation calculation for a single source at the position of the original source. Obviously, the calculation must be performed separately for the two lower source heights defined by [1]. The correction $(A_{dif,i} + A_{dif,0})$ is easily calculated from the position of the source and of the receiver at the top of the screen with respect to the mean ground plane and does not require a detailed description of the ground. This allows a strict separation of the emission model as in the reference software libraries available from Cerema, i.e. *RailwayEmissionNMPB08.dll* for emission and *PropagationNMPB08.dll* for propagation.

If the strict separation of emission from propagation is not a requirement it remains possible to carry out a non-appromated calculation.

### 2.9. Non-automatic detection of embankments

This correction applies only in the specific case of a measurement near a road in order to characterize its noise emission. The systematic and automatic search of embankments may unnecessarily slow down the algorithm in general and particularly in the case of strategic noise maps calculation. Therefore the slope correction will be performed only when explicitly requested by the user. The implementation will allow the user to activate or deactivate this option. In no case the algorithm will automatically search for candidate segments to generate the correction of embankments. However, the algorithm will check that the conditions listed in [1] are met. It is stipulated that the criteria of angle and distance apply in the plane perpendicular to the road and not in the plane of propagation. It is the responsibility of the user (or host software) to provide the geometric and semantic information needed for this verification. In particular:

- a segment must be marked with the attribute "EMBANKMENT";
- segments representing the road pavement must be marked with the attribute "PLATFORM";
- the option "CHECK_EMBANKMENT" must be enabled in the software.

### 2.10. Obstacles

In 9.5.1 "The obstacles where at least one dimension is less than 0,5 m" refers to the surface hit by a ray, not the whole obstacle.

[2] Hans J.A. van Leeuwen, personal communication.

### 2.11. Attenuation through absorption

In 9.5.1, no references are given for the absorption coefficient $\alpha_r$ of the possible obstacles. There are two options to consider for this coefficient depending on the configuration of the site and the available data:

- For diffuse field absorption conditions, absorption coefficient should preferably be issued from EN 20354 (cited in EN 1793-1);
- For specular absorption, absorption data should be issued from EN 1793-5, on the basis on reflection indexes $RI_i$ ($i$ being the third octave considered) with the following correspondence:

$$\alpha_{r,i} = 1 - |RI_i|^2$$

## 3. Development of test cases

### 3.1. Global overview of the test cases

This work was carried out on the basis of document ISO/TR 17534-3 and taking into account the different specificities of NF-S 31133:2011. An overview of the various test cases is presented in Table I. In this table, the documents used to define the configuration of the test cases are specified where appropriate. Furthermore, details are provided concerning the geometry, the type of source (road, train, industry or arbitrary) as well as the possible contribution due to diffraction (H: horizontal or V: vertical).

In these test-cases, input emission data for road and train sources have respectively been chosen to comply with [10, 2].

- Road emission has been modeled at one relative height (0.05 m) with a sound power level of 80 dB(A) ([10, Table I.8]);
- Train emission has been modeled with three source heights (0, 0.5 and 4 m) and their respective horizontal and vertical directivities according to [1, Sec. 7.4]. In this case, emission data for sources at 0 and 0.5 m have been taken from [2] for TGV 00-100 (TGV-SE) and TGV 38 (La Poste) rolling stock. Emission data for the third source has been assumed as a constant flat spectrum (in dB) for the third octaves considered.

For industrial source, specific temperature, relative humidity and atmospheric pressure values have been used to evaluate the atmospheric attenuation as specified by [1, Sec. 9.2].

### 3.2. Software infrastructure

In order to calculate the acoustic quantities for these different test cases, we used a homemade Scilab code developed in parallel to the design of NMPB 2008 [11]. This code performs the following steps:

- Description of the geometry (path, obstables)
- Evaluation of atmospheric and divergence attenuation terms

Figure 1. Geometry of T05.

- Evaluation of diffraction, retrodiffraction
- Long term sound evel calculation
- Test case results formatting in AsciiDoc[3] format

An AsciiDoc compiler was then used to typeset the results of the test cases in HTML and PDF format. Therefore the process is fully automated from site descriptions to report. This is eliminates the risk of inconsistencies due to copy/paste errors.

### 3.3. Key examples

In this section, details (Configuration, input and output data) are discussed for two test cases.

- A site with horizontal hard ground ($G = 0$) and industrial source
- A site with spatially varying heights and acoustic properties and multiple diffraction

The first test case (T05) describes a basic configuration with a flat ground having homogeneous properties (G=0), with an industrial source $S$ and a receiver $R$. Here, specific temperature, specific relative humidity and atmospheric pressure values have been used to evaluate the atmospheric attenuation $A_{atm}$: $T = 15\ C$, $RH$=70 % and $P_0 = 101325\ Pa$). The geometry is described in Figure 1 and results are presented Figure 2.

In this case, there is no differences between favorable and homogeneous conditions and the long term level can be calculated as:

$$L_{eq,LT} = L_w - (A_{div} + A_{atm} + A_{ground}) \qquad (1)$$

The second example (T18) is characterized by two types of ground (having for ground factor either $G = 0$ or $G = 1$). A road is located on the top of one embankment, 6 m above terrain. A barrier is located next to the road, and a building is positioned close to the edge of the embankment. This building is considered long enough along y-axis to neglegt vertical diffraction contributions (See [10, I.4]). The geometry is described in Figure 3 and results are presented for favorable conditions in Figure 4.

Here, a double diffraction occurs, and we have (for example here in favorable conditions):

$$L_F = L_w - (A_{div} + A_{atm} + A_{dif,F}) \qquad (2)$$

where

[3] http://www.methods.co.nz/asciidoc/

Table I. Description of the test-cases.

| TC | References | Description | Relief | Source | Diff |
|---|---|---|---|---|---|
| T01 | [3, T01] | Horizontal and homogeneous ground | Flat | Arbitrary | |
| T02 | [3, T01] | T01 with a source located at more than 2000m from the receiver | Flat | Arbitrary | |
| T03 | [3, T01], [10, I.8] | T01 with a road source | Flat | Road | |
| T04 | [3, T01] | T01 with a train source | Flat | Train | |
| T05 | [3, T01] | T01 with an industrial source | Flat | Industry | |
| T06 | [3, T02] | T03 with a different ground | Flat | Road | |
| T07 | [3, T03] | T03 with a different ground | Flat | Road | |
| T08 | [3, T04] | Horizontal ground with spatially varying acoustic properties | Flat | Road | |
| T09 | [3, T06], [10, I.2] | Ground with spatially varying heights and acoustic properties - Strong embankment | Slope | Road | |
| T10 | [3, T06], [10, I.3] | T09 with diffraction | Slope | Road | H |
| T11 | [3, T06], [10, I.1] | Ground with spatially varying heights and acoustic properties - Small embankment | Slope | Road | |
| T12 | [3, T06], [10, I.2] | T11 with ground and diffraction effects depending on the frequencies | Slope | Road | H |
| T13 | [3, T08] | Horizontal and homogeneous ground with an oblique long barrier | Barrier | Road | H |
| T14 | [3, T09] | Horizontal and homogeneous ground with a large and tall building | Building | Road | V |
| T15 | [3, T11] | Site with homogeneous ground properties and a cubic building | Building | Road | H, V |
| T16 | [3, T19] | Reflection on vertical barrier based on T09 | Slope and barrier | Road | |
| T17 | [1, 9.5.2] | T16 with retrodiffraction | Slope and barrier | Road | H |
| T18 | [10, I.4] | Site with spatially varying heights and acoustic properties and multiple diffraction | Slope, barrier, building | Road | H |
| T19 | [1, 7.4.6] | Site with vehicle-body barrier interaction for a low railway source - Retrodiffraction | Barrier | Train | H |
| T20 | [1, 7.4.6] | Vehicle-body barrier interaction for a low railway source far away from the barrier | Barrier | Train | H |
| T21 | [1, 7.4.6] | Source height limitation of vehicle-body barrier interaction for a high railway source | Barrier | Train | H |

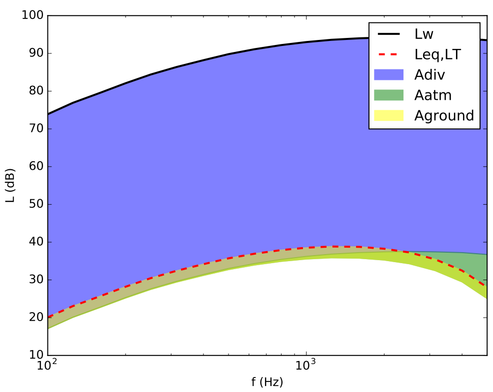


Figure 2. Results for T05 (filled areas represent the various types of attenuation between source level $L_w$ and receiver level $L_{eq,LT}$). The spectrum is smoothed for the representation but the calculations are in third-octave bands.

$$A_{dif,F} = \Delta_{dif,F} + \Delta_{ground(S,O_1),F} \quad (3)$$
$$+ \Delta_{ground(O_2,R),F} \quad (4)$$

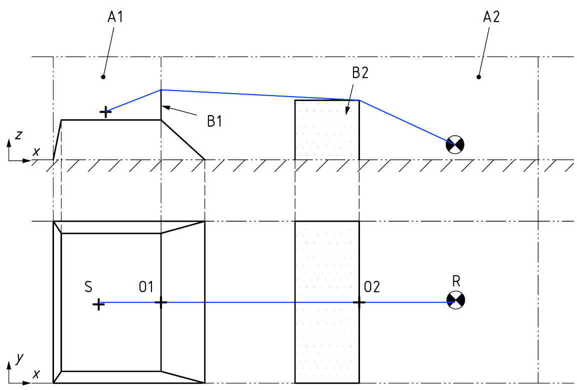


Figure 3. Geometry of T18.

## 4. Conclusions

Although a lot of attention was paid to the specification of NMPB 2008 and although the method was implemented in software in parallel to its specification, it is neither free from errors nor from ambigui-

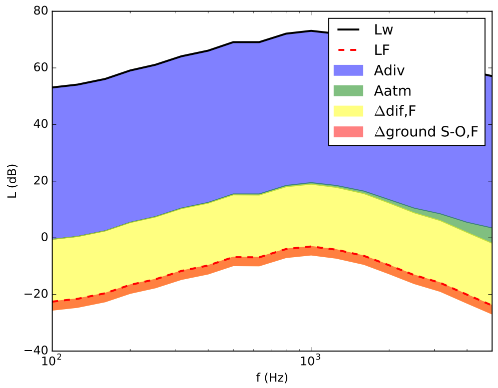


Figure 4. Results for T18 in favorable conditions (filled areas represent the various types of attenuation between source level $L_w$ and reveiver level $L_F$). The spectrum is smoothed for the representation but the calculations are in third-octave bands.

ties. Our experience with the design of NMPB 2008 indicates that the designers tend to focus on the general operation of the method, and to work on ideal configurations but may overlook singularities that become more critical when the number of sources is low. Physicists may be happy with qualitative criteria but one should keep in mind that programmers need quantitative ones. Moreover, when preparing a prediction scheme, it is difficult to foresee all the possible configurations that occur in real world calculations.

In this context, quality insurance is highly relevant since it provides a convenient framework for collecting and handling corrections and clarifications in a dedicated document before updating the implemented standard, and for the additional material like test cases required to support software vendors in their task.

We presented a review of the most significant changes and clarifications to be applied to the standardized NMPB 2008. We also contributed a large set of test cases covering both basic and more advanced aspects of NMPB 2008. These elements are likely to be either included in an ISO 17534 technical report or in an updated version of NF S 31-133. But they are also highly relevant for the developpement of quality assurance for CNOSSOS-EU. In turn the quality assurance from NF S 31-133 is likely to benefit from the work toward the quality assurance of CNOSSOS-EU.

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