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Quality assurance for sound calculation software and its limitations

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ABSTRACT

From the side of software developers and acoustic experts applying software quality assurance aspects became more and more an essential part of their work and with a standardized framework like the series ISO 17534 we succeeded in keeping the commercial competition out of the common efforts for correct calculations. This correctness is ensured by a set of test cases constructed to disclose any deviation from the algorithms and strategies defined in the official documentation of the method. The strategy how such a test suite can effectively be designed is shown with the calculation method ISO 9613-2 (ISO/TR 17534-3) in comparison with CNOSSOS-EU:2015 (planned ISO/TR 17534-4). The fact that even erroneous regulations in the original documentation can be corrected is shown with the calculation of multiple diffraction in a downward refracting atmosphere.

Keywords: Noise, Calculation, Quality Assurance
I-INCE Classification of Subject Number: 76

1. INTRODUCTION

In the past two decades a lot of effort was made to improve the accuracy of calculation models of the “engineering type” for sound propagation. With all these engineering models like ISO 9613-2:1996 [1], Harmonoise Engineering Model [2], or NMPB:2008 [3] the sound waves swapping over the ground with all the objects above like vegetation, buildings and walls are replaced by some geometrically exact defined ray paths. Many approximations are necessary to ensure an acceptable accuracy – in this context accuracy means the agreement between calculated and measured sound pressure levels – but to keep the methods simple enough to support the necessary precision – this means that different experts applying the method shall get the same results for a given problem. These two aspects are concurrent and we will never succeed to find the universal and final calculation method. A severe problem is that the different physical phenomena like ground influence, attenuation by vegetation, screening and meteorological influences are not independent but are treated in the calculations as if they were. At the end, all these developments are a balancing act between the detailed mathematical description of obviously relevant physical phenomena, on the one hand, and the practical application in complex environments of the real world with many unknown interdependencies and therefore necessary approximations, on the other hand. An example is the inclusion of meteorology in engineering calculation models: While the calculation method ISO 9613-2 is based on a single meteorological condition favorable to propagation it was a large step driven by the European activities to include vertical temperature profiles and wind speeds in the Harmonoise Engineering Model [4]. Taking into account the above mentioned balance it was finally decided to use the calculation method NMPB:2008 as the Common European calculation method for noise mapping under the acronym CNOSSOS-EU. This acronym is in the following applied as shortcut for the legally binding text describing the calculation of sound propagation in the European directive 2015/996/EU [5].

With the International Standard ISO 17534-1 [6] measures to ensure the necessary correctness if these methods are implemented in software where defined and decided. Part 1 of this Standard defines the general frame, Part 2 is a sort of library for Test Cases and for each calculation method one of the following parts published as Technical Reports contains the method specific measures.

The main core of such a method specific documentation for quality assurance is a set of additional specifications that are necessary to clarify open issues and – in some cases – to modify existing definitions from the official publication that have proven to be erraneous and further a set of test cases with detailed step by step and final results.

The first step made in 2015 was the Quality Assurance of the calculation method ISO 9613-2:1996. The method is applied worldwide and it was necessary to correct some algorithms and procedures that were obviously not designed to be implemented with nowadays available computer-power. These last four years the main software-platforms applied ISO 9613-2 in connection with these “Additional Recommendations” of ISO/TR 17534-3 [7] and it can be stated that this strategy improved the communication between all experts engaged in software development and implementation.

Based on this positive experience the next step was to start a similar project related to the Quality Assurance of CNOSSOS-EU:2015. The method is by far more complicated than ISO 9613-2 and many additional specifications and clarifications were necessary to ensure the unambiguous interpretation of the official text in the European Directive. During the work on this planned Part 4 of ISO 17534 in Working Group 56 of ISO TC43 SC1 some implausible results where detected in the calculation of multiple diffraction with favorable propagation conditions. It was a lucky coincidence that the work for Quality Assurance was not finished that time so that an improvement could be developed – published in [8] - and integrated as an additional specification. A special Test Case was constructed to check the correct implementation of this new strategy in different software applications.

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2. The modified calculation of diffraction recommended with ISO/TR 17534-3

2.1 Additional specifications to clarify or correct the official documentation

A typical example for necessary improvements of an existing standardized procedure in the frame of quality assurance with the framework of ISO 17534 is the calculation of screening with ISO 9613-2. Due to this standard the barrier attenuation D_z is a function of z, where z is the difference between the pathlengths of diffracted an direct sound. It is calculated in case of a single barrier with

$$z = [(d_{ss} + d_{sr})^2 + a^2]^{1/2} - d \qquad (1)$$

and in case of double diffraction with

$$z = [(d_{ss} + d_{sr} + e)^2 + a^2]^{1/2} - d \qquad (2)$$

where d_{ss} is the distance from the source to the first diffraction edge, d_{sr} the distance from the second diffraction edge to the receiver, a the component distance parallel to the barrier edge between source and receiver and e the distance between the two diffraction edges in the case of double diffraction.

With more than two barriers it is recommended to apply the last equation choosing the two most effective barriers.

With software implementations of ISO 9613-2 many problems arose due to ambiguities of these definitions. Equation (1) can be derived from the principle that the shortest path source-barrier edge-receiver is relevant, but equation (2) makes only sense if the two edges of a double barrier are parallel. With software applications with many objects like buildings and barriers this condition is an extremely seldom case and therefore it makes no sense to implement it.

This problem was solved by defining a more general procedure to find the propagation paths that are regarded as representative as it is shown in Figure 1 for the propagation from a source S (red) to a receiver R (green). One path crossing the objects blocking the direct line S-R is the shortest “ribbon-band-line” in a vertical plane containing S and R and up to two further paths are the shortest convex polygon lines in a lateral plane that includes also S and R and is perpendicular to the first plane.

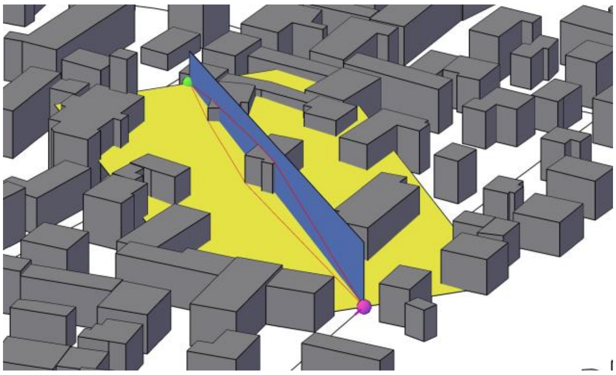

Figure 1: Construction of the shortest paths from source to receiver in a vertical plane (blue) and a lateral plane (yellow)

2.2 Test cases to check the correct implementation

In ISO/TR 17534-3 a set of 19 Test Cases is included with about 68 tables with step-by-step and final results. The Test Cases are constructed to cover all the important algorithms and to check their correct implementation following the principle: as simple as possible and only as complicated as necessary. An example is the Test case shown in Figure 2 that was constructed to check the calculation of diffraction over top and laterally for a short barrier where the properties of the ground varies along the propagation path.

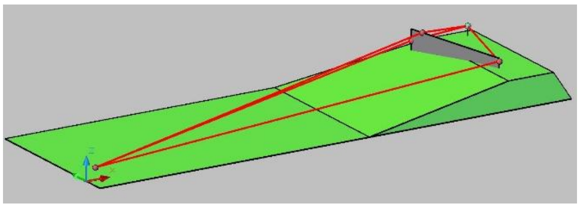

Figure 2: Short barrier with varying heights and acoustic properties of the ground

Another example where more objects like buildings are blocking the line of sight is shown with Figure 3. The aim of this Test Case is to include the construction of paths representing the laterally diffracted sound in more complicated scenarios.

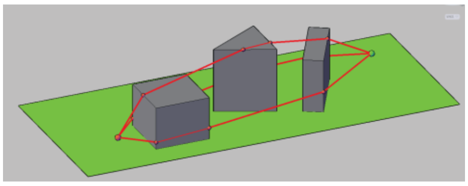

Figure 3: Three building blocking the direct line of sight between source and receiver

A further important part of this framework of quality assurance are the conformity sheets where the developer of the software product under test declares that all the relevant parts of the official documentation and the additional specifications are correctly included and that the results for all test cases can be reproduced in the defined intervals.

3. Quality assurance for the implementation of CNOSSOS-EU

3.1 Problems encountered and proposed solution

The calculation method for sound propagation CNOSSOS-EU is based on the French method NMPB 2008. As described in the introduction above, the calculation method showed some strange and not plausible results when it was applied in Noise-Mapping-Projects. From experts in the Netherlands it was reported that screening by objects like buildings and embankments may be strongly underestimated in special cases with favourable propagation conditions and therefore noise levels in urban areas can be overestimated by 5 to 10 dB.

The reason for these not plausible results is the method how the diffracted ray paths are constructed. Figure 4 – scenario 1 with source S (height 3 m), receiver R (height 5 m) in a distance of roughly 1 km and barrier B with a height of 10 m - shows in the upper part the well-known ribbon-band-construction related to homogeneous propagation conditions to find the difference between the pathlengths of diffracted and direct sound and from that the resulting barrier attenuation.

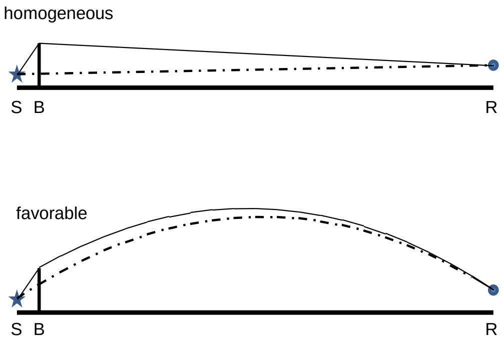

Figure 4: The direct ray path (dash-dot) and the diffracted ray over top of the barrier for both propagation conditions as defined with CNOSSOS-EU:2015 (scenario 1)

With favorable propagation conditions the straight lines from homogeneous conditions are replaced by arcs with a radius R_{curv} that is a function of the distance between source and receiver.

The attenuations due to diffraction calculated with CNOSSOS-EU:2015 are shown in the columns with header "scenario 1" in Table 1.The attenuations are smaller with favorable compared to homogeneous conditions in agreement with expectation.

Table 1: Attenuation due to diffraction for all scenarios and for both propagation conditions

Frequency Hz	Attenuation due to pure diffraction Δ_{diff} dB calculated with									
	CNOSSOS-EU:2015						proposed modification			
	scenario 1		scenario 2		scenario 3		scenario 2		scenario 3	
	hom	fav	hom	fav	hom	fav	hom	fav	hom	fav
63	6.9	6.5	6.3	0.0	9.6	3.8	6.3	3.7	9.6	6.5
125	8.2	7.8	7.5	0.0	11.8	2.6	7.5	2.4	11.8	7.8
250	10.1	9.5	9.2	0.0	14.3	0.0	9.2	0.0	14.3	9.5
500	12.5	11.7	11.3	0.0	17.1	0.0	11.3	0.0	17.1	11.7
1000	15.1	14.3	13.8	0.0	20.0	0.0	13.8	0.0	20.0	14.3
2000	17.9	17.0	16.5	0.0	22.9	0.0	16.5	0.0	22.9	17.0
4000	20.8	19.9	19.4	0.0	25.9	0.0	19.4	0.0	25.9	19.9
8000	23.8	22.9	22.3	0.0	28.9	0.0	22.3	0.0	28.9	22.9

With scenario 2 shown in Figure 5 the barriers B1 – B6 with heights between 6 m and 12 m are inserted. The detailed coordinates are not reported here – they can be taken from the original publication [8].

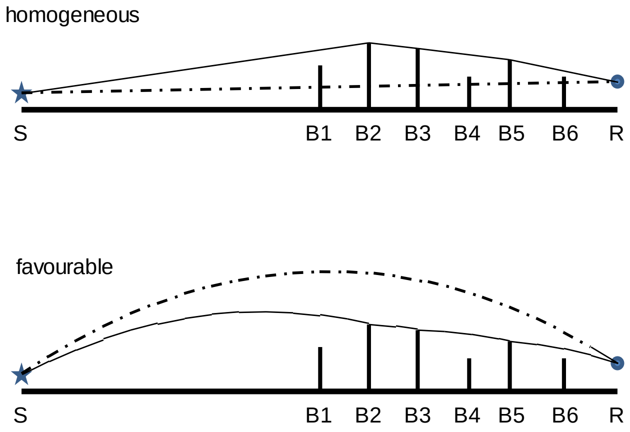

Figure 5: Scenario 2 with barriers B1 – B6 and relevant ray paths in agreement with the definition in CNOSSOS-EU:2015

The upper part in figure 5 (homogeneous conditions) defines on basis of the ribbon-band-construction the relevant diffraction edges B2, B3 and B5 and in the lower part (favorable conditions) these same edges are connected with arcs. As it is shown in the columns with the header “scenario 2” in Table 1, no attenuation due to diffraction is calculated for this case and the curved direct ray is assumed to propagate undisturbed by the barriers.

Now a scenario 3 is created combining scenarios 1 and 2 as it is shown in Figure 6.

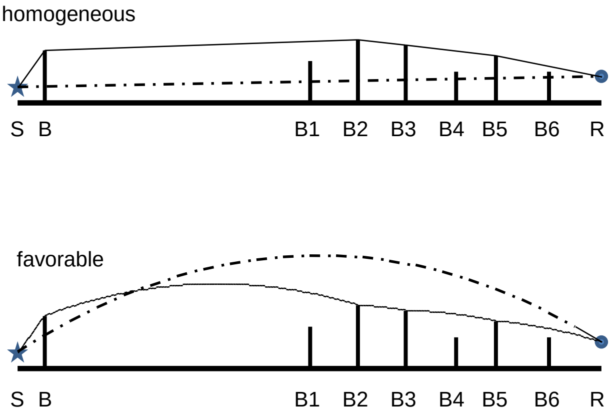

Figure 6: Scenario 3 with all barriers of scenario 1 and scenario 2 combined

The attenuations with this scenario 3 calculated for favorable conditions with CNOSSOS-EU:2015 are with exception of the lowest two frequency bands 0 dB, as it is shown in Table 1. This means that the high attenuations of barrier B in scenario 1 are reduced to 0 dB if the barriers B1 – B6 are inserted additionally – a result not plausible and not in agreement with expectation even taking into account the approximation of the sound wave by geometrically defined ray-paths.

The reason for this unexpected result is the strategy to regard the same barrier edges as relevant under favorable conditions as they were found for homogeneous conditions applying the ribbon-band-method. The proposed and tested solution is to construct the path for favorable conditions completely analogous as for homogeneous conditions as a convex envelope but with arcs instead of straight lines. Connecting source S with all barrier edges and the receiver R the first diffracting edge is defined by the maximal gradient of the arc at source S – if this gradient is the largest for the arc from source S to the receiver R the curved direct ray is not blocked. In case a barrier edge is found that way this is taken as the starting point for the next arc and this is repeated till the receiver R is reached.

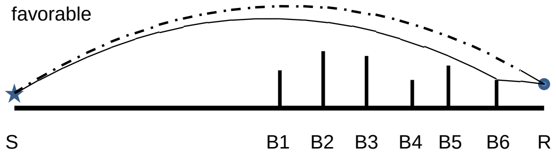

Figure 7: Ray paths for scenario 2 (favorable) calculated with the proposed method

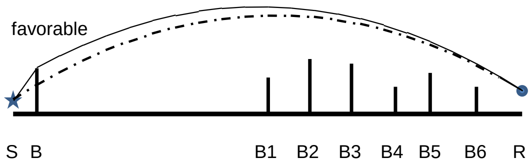

Figure 8: Ray paths for scenario 3 (favorable) calculated with the proposed method

Applying this proposed solution we get for scenario 2 under favorable conditions the ray path shown in Figure 7 and for scenario 3 the ray path shown in Figure 8. The attenuations calculated on the basis of the proposed strategy shown in the last 4 columns of Table 4 are now in agreement with our expectation taking into account the behavior of sound waves in a downward refracting atmosphere.

3.2 Test cases to check the correct implementation of CNOSSOS-EU

The above described modification is only one aspect that had to be taken into account in the preparation of a draft for a new ISO/TR 17534-4 related to Quality assurance of CNOSSOS-EU. Some other additional specifications were necessary to make the official text unambiguous and precise for the implementation in different software platforms.

The set of 19 Test Cases developed with ISO/TR 17534-3 (related to ISO 9613-2) was extended and now this complete set contains 28 cases.

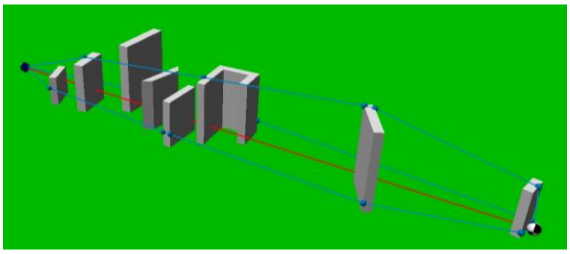

Figure 9: Test Case with 8 buildings and calculation-rays for homogeneous conditions

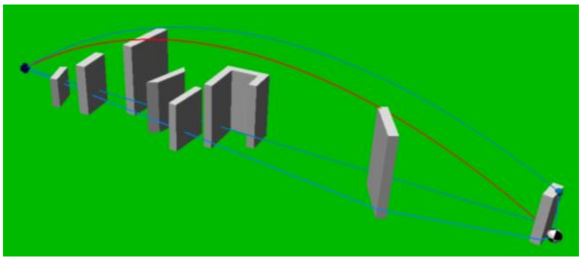

Figure 10: Test Case with 8 buildings and calculation-rays for favourable conditions

Figures 9 and 10 show the last Test Case No. 28 constructed so that the “correct” calculation of the ray paths can be checked – correct in the sense that the above explained solution is assumed to be integrated in a revised version of CNOSSOS-EU.

At the time this paper is written a working draft of the planned ISO/TR 17534-4 is just finalized by ISO TC43 SC1 WG 56. Therefore all the above is only a report from ongoing work and far from being decided and accepted. But it was the aim to give an impression of the many activities that are necessary to reach the target – a calculation method unambiguously defined and described that can be implemented in different software platforms and used by different experts even in different countries with the intended high precision.

6. REFERENCES

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