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ACTIVITIES AND EXPERIENCES WITH QUALITY ASSURANCE OF CNOSSOS-EU IMPLEMENTED IN SOFTWARE

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The European harmonized method to calculate sound propagation and to predict noise levels for mapping purposes is CNOSSOS-EU, a method derived from and very similar to the French calculation method NMPB. Due to its complexity the method is affording for software developers and many activities are necessary to ensure that users of different software implementations get the "same" results for the same input scenario. In the first step some MS like Germany undertook national actions to find out the problems that must be solved. This contribution tries to focus on the most promising approach like the development of a set of about 30 test cases to rank pros and cons and to get a stable basis for the discussion between the MS. Some of these test cases are presented and discussed and the authors recommendation resulting from this work may be interesting for the further quality assurance of different software implementations.
Keywords: CNOSSOS-EU, quality assurance, test cases

1. Introduction

In near future CNOSSOS - EU [1] will be the harmonized method in Europe for noise prediction in the frame of the Directive 2002/49/EC. Especially the calculation method for sound propagation does not need any national deviation from a common procedure and therefore it should be the interest of all parties involved that different software implementations can be approved to apply exactly the same calculation algorithms.

With the series ISO 17534-1 [2] a framework to support such activities of quality assurance on an international level has been established. While the core standard contains all the necessary measures and implements the tools generally, the application for an existing and clear documented method shall be realized in a Technical Report of the series. As an example ISO 17534-3 [3] is treating the quality assurance of the calculation method ISO 9613-2 [4] implemented in software.

These method-specific Technical Reports are based on three fundamental parts. The first part are clarifications or even supplements to fill the gaps remaining with the official documentation - this is treated in the chapter "Additional Recommendations". This goes hand in hand with the second part - the development of test cases with well documented step-by-step and final results. The complete suite of test cases shall cover the most important strategies and algorithms of the method and especially those aspects that are additionally treated in the above mentioned Additional Recommendations. According to Part 1 of ISO 17534 the test cases shall comprise scenarios as simple as possible and only as complicated as necessary to prove the correct calculation related to the issue under test. These test cases are not an examination, but a support of software developers and users. Principally it is the responsibility of the designers of a calculation method, of the authors of the standard or other persons or groups finalizing a method to take care that such test cases in accordance with the mentioned requirements are published with the method. If this is not the case, such a suite of test cases can be a part of the method specific Technical Report of ISO 17534. In the case of CNOSSOS-EU it is obvious that many aspects have to be clarified and that such a set of test cases must be developed and integrated. The third part is a conformity-sheet for the software developer where he can declare the conformity of the implementation of the method with the different parts of the official documentation and the Additional Recommendations mentioned above. This declaration of conformity it is also the assurance that the test cases are correctly solved with the specific version of the software.

2. Some aspects of open issues to be clarified

The propagation model of CNOSSOS-EU is mainly based on the French method NMPB 2008 [5]. Even if it is by far more straight forward and simpler than the Harmonoise [6], the first candidate for the European harmonized calculation method, a detailed analysis showed that it is too complicated to fulfil the requirements of quality assurance according to ISO 7534-1 without any further agreements. Implemented in different software platforms on the basis of the existing documentation there are too many degrees of freedom to ensure the intended grade of precision if typical environments are modelled.

The following shall not be understood as critics about the CNOSSOS-EU propagation model - it is only an extractive summary resulting from projects about the topic.

Like all the other ray based engineering strategies CNOSSOS-EU replaces the sound wave sweeping over the ground with natural and artificial cover by some well defined ray paths. Even in the simple case where the straight line between a point source (complex sources are always dissolved in point sources) and a receiver is not blocked and free propagation occurs, some additional specifications are necessary.

2.1 Air absorption

According to the official documentation the atmospheric attenuation coefficient α_{atm} in dB/km shall be in accordance with ISO 9613-1 [7] and determined with the nominal centre frequency for each frequency band. To allow for different temperatures and relative humidity the formulas B.1 to B.3 in annex B and the equations (3) to (5) in chapter 6.2 of ISO 9613-1 shall be applied. According to this formalism in ISO 9613-1 the centre frequency of each band is calculated with equation (6) of the standard. This leads to the values of the atmospheric-absorption attenuation coefficients in decibels per kilometer given in table 1 of ISO 9613-1. But equation (6) produces not exactly the rounded centre frequencies, but e. g. for the last frequency 7943,28 Hz instead of 8000 Hz. On the other side all frequency-dependent results presented in tables are related to 8000 Hz - therefore it is recommended to apply the rounded centre frequencies 125 Hz - 8000 Hz to calculate the atmospheric attenuation coefficient.

2.2 Calculation of the mean ground factor G_{path}

If a ray propagates above ground with varying acoustic properties described by a ground coefficient G it is necessary to calculate an average value G_{path}.

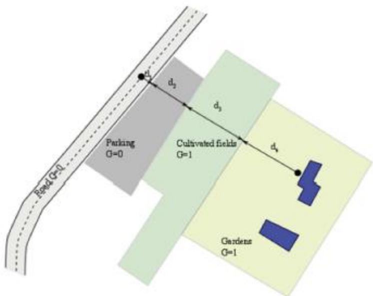

Figure 1: Different grounds with path lengths d_1, d_2, d_3 and d_4 (Figure 2.5.b in [1])

G_{path} shall be calculated as the average

$$G_{path} = \frac{\sum G_i \cdot d_i}{\sum d_i} \qquad (1)$$

But Figure 1 is a 2-dimensional plot of the ground - nothing is specified for cases where the height of the ground is varying and the ray crosses plain and slanted surfaces.

Figure 1 and the explanation in [1] says nothing about the case that the ray crosses over buildings - a very common situation in built up areas.

Taking into account typical angles of ground-surfaces it would be a good compromise to average the G-factors in a projection on the reference plane x-y and therefore to neglect the extension of these areas parallel to the sloping surface. To keep the method generally applicable it would be advantageous to take the roofs and other reflecting surfaces into account. Any other solution needs complicated additional specifications.

2.3 Screening - diffraction over top edges and around vertical edges

The strategy of selecting rays from a source S to a receiver R if the direct line of sight is blocked needs some non-ambiguous additional specifications.

Figure 2 shows a possible and recommended strategy if an object - here it is a simple cubic building - blocks the straight path S-R. One contribution is calculated with a path in a vertical plane E_V containing source S and receiver R. Additionally maximal two lateral diffracted paths in a lateral plane E_L also containing source S and Receiver R and perpendicular to plane E_V are taken into account. One of the most important points is to clarify how these lateral paths are constructed if there are many screening objects. Due to the resulting variety of possible propagation paths the definition of a clear and unambiguous strategy gets a high priority.

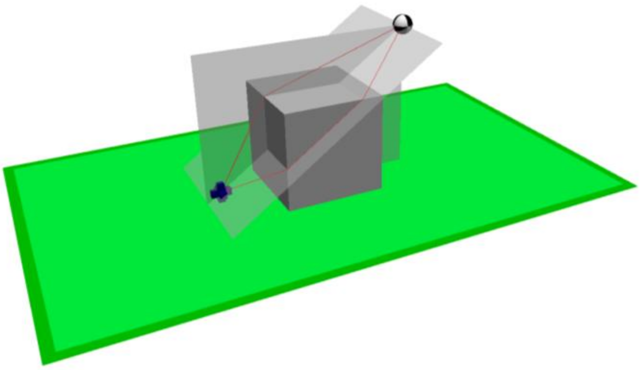

Figure 2: Vertical plane E_V and Lateral plane E_L containing the ray paths considered

With a screening edge between source and receiver CNOSSOS-EU requires to approximate the ground profile by a mean plane at each side. It must be clarified that in cases like shown in Figure 3 this mean plane between S and diffracting edge is calculated from the red profile polygon containing the shape of the building.

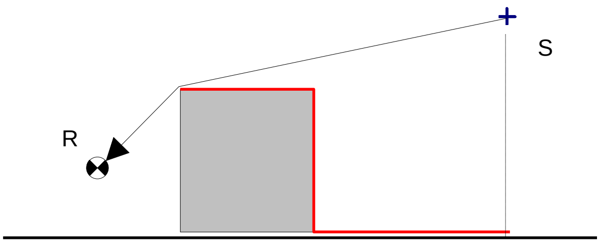

Figure 3: Profiles containing the building determines the mean ground plane

These are only few examples for strategies that need further clarification. It is obvious that it makes no sense to let this a task for each programmer individually because this will result in a corresponding large uncertainty in the results produced with different software.

3. Test cases

The core of a method specific Technical Report is a set of test cases with step by step and final results to support programmers and software users. As it was mentioned above, the main strategies and algorithms shall be taken into account and each test case should be as simple as possible and only as complex as necessary to fulfil this requirement.

Figures 4 and 5 show the scenario for such a test case as an example. The acoustic properties of the ground are different in three sections A1, A2 and A3 (ground factors G of 0.9, 0.5 and 0.2) and the absolute ground height increases between edge K1 and edge K2 from 0 m to 10 m. There are two screens with 12 m height absolute, and the absorption coefficient of screen B1 varies in the frequency bands from 63 Hz to 8000 Hz between 0.1 and 0.7. The absolute heights of source S and receiver R are 1 m and 11.5 m.

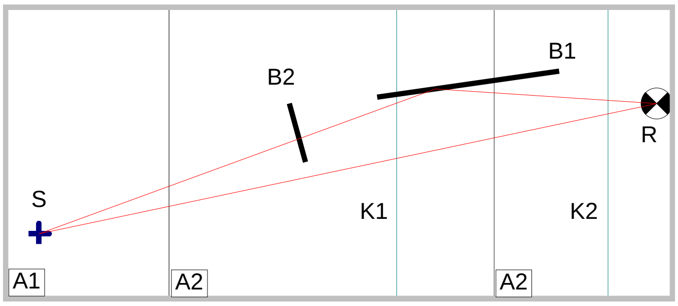

Figure 4: Test case with a screening and a reflecting barrier

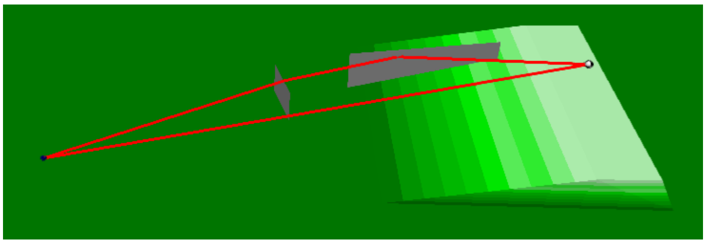

Figure 5: Scenario of this test case in 3D-view

The main aspect of this test case is to check whether the influence of the screening barrier B2 on the sound ray reflected at barrier B1 is calculated in accordance with the relevant documentation.

Reporting the step by step and the final results needs 8 tables. As an example table 1 shows the calculation steps for the direct sound and table 2 for the screened and reflected sound. The abbreviations are not explained here - they are in accordance with the official documentation [1].

Table 1: Calculation steps for the direct sound

f in Hz	63	125	250	500	1000	2000	4000	8000	
L_W in dB	93	93	93	93	93	93	93	93	
α_{atm}	0.1	0.4	1.0	1.9	3.7	9.7	33.1	118.4	
A_{atm} in dB	0.02	0.08	0.20	0.37	0.71	1.89	6.43	23.02	
A_{div} in dB	56.78	56.78	56.78	56.78	56.78	56.78	56.78	56.78	
$A_{boundary,H}$ in dB	-1.26	-1.26	-1.26	2.12	-1.26	-1.26	-1.26	-1.26	
$A_{boundary,F}$ in dB	-1.26	-1.26	-1.26	-1.26	-1.26	-1.26	-1.26	-1.26	**Total**
L_H in dB	37.46	37.40	37.28	33.73	36.77	35.60	31.05	14.46	44.54
L_F in dB	37.46	37.40	37.28	37.11	36.77	35.60	31.05	14.46	44.95
L in dB	**37.46**	**37.40**	**37.28**	**35.74**	**36.77**	**35.60**	**31.05**	**14.46**	**44.75**
A-weighting in dB	-26.2	-16.1	-8.6	-3.2	0.0	1.2	1.0	-1.1	
L_A in dB	**11.26**	**21.30**	**28.68**	**32.54**	**36.77**	**36.80**	**32.05**	**13.36**	**41.41**

Table 2: Calculation steps for the screened and reflected sound

f in Hz	63	125	250	500	1000	2000	4000	8000	
L_W in dB	93	93	93	93	93	93	93	93	
dL_{abs}	-0.46	-0.97	-1.55	-2.22	-3.01	-3.98	-5.23	-3.01	
$dL_{retrodif}$	2.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
L_W in dB	**90.08**	**92.03**	**91.45**	**90.78**	**89.99**	**89.02**	**87.77**	**89.99**	
α_{atm}	0.1	0.4	1.0	1.9	3.7	9.7	33.1	118.4	
A_{atm} in dB	0.02	0.08	0.21	0.38	0.73	1.92	6.56	23.48	
A_{div} in dB	56.95	56.95	56.95	56.95	56.95	56.95	56.95	56.95	
$A_{boundary,H}$ in dB	5.62	7.40	9.65	12.22	15.00	17.88	20.83	22.99	
$A_{boundary,F}$ in dB	5.09	6.70	8.79	11.26	13.97	16.82	19.75	22.72	**Total**
L_H in dB	27.49	27.60	24.65	21.23	17.32	12.27	3.44	-13.43	32.13
L_F in dB	28.01	28.31	25.50	22.19	18.34	13.32	4.51	-13.16	32.84
L in dB	**27.76**	**27.97**	**25.10**	**21.74**	**17.86**	**12.83**	**4.01**	**-13.29**	**32.50**
A-weighting in dB	-26.2	-16.1	-8.6	-3.2	0.0	1.2	1.0	-1.1	0.0
L_A in dB	**1.56**	**11.87**	**16.50**	**18.54**	**17.86**	**14.03**	**5.01**	**-14.39**	**23.47**

Figures 6 and 7 show another example of a test case to check diffraction around a more complex building with varying ground properties and heights.

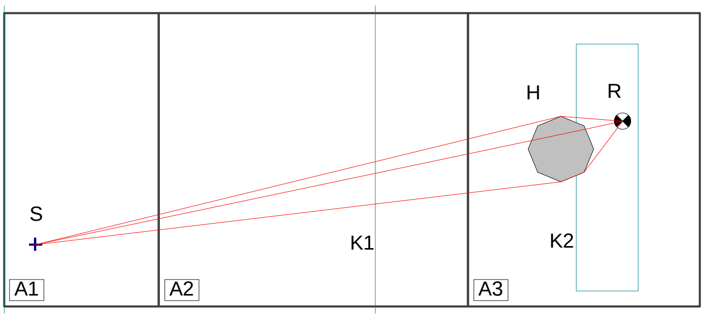

Figure 6: Diffraction with an 8-edged building on ground with varying properties

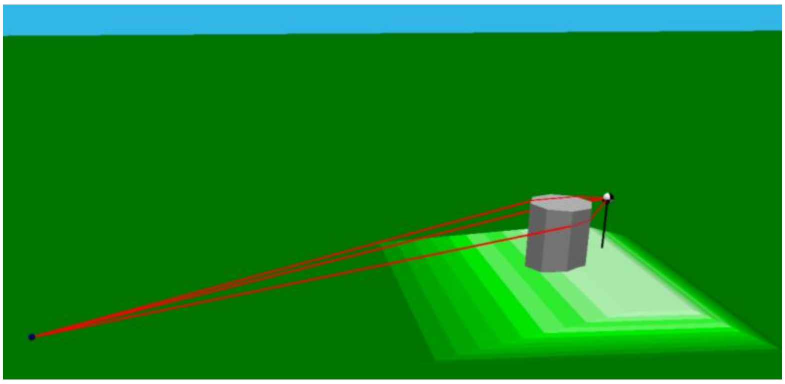

Figure 7: 3D-view on the scenario with an 8-edged building

Based on the development of some test cases we assume that problems may arise from the application of a "mean plane" instead of the real ground profile in cases where buildings and other objects block the direct path. From our point of view the intended procedure of quality assurance is absolutely necessary to make CNOSSOS-EU an acceptable and precise tool in the frame of a harmonized strategy to handle environmental noise in Europe.

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