Validation of Engineering Methods for Calculating Acoustical Diffraction by Screens

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Introduction

EDF has to deal with the industrial noise of its installations.

Industrial noise calculation often leads to real 3D diffraction problems on quite hard ground with tonal sources - like transformers- which induces strong interference patterns even at a large distance from the screen. These kind of spatial level variations have to be taken into account in order to make a good prediction of the screen efficiency.

The use of wave-based methods such as BEM is not adapted to the large geometry of complex 3D problems.

Usual simplified methods (ISO, NMPB, …) are often based on the calculation of the difference between the direct and the diffracted path lengths. Even if the standardized methods recommend the energetic summation of each diffraction path contributions, a complex pressure summation can be done. Lam [1] and Muradali & Fyfe [2] showed that this approach can be useful to simulate the interference pattern.

In this context EDF led a study with the aim of validating such a simplified method. In this paper the results of a comparison between the simplified model, some measurements and a 3D code based on Linearized Euler Equations are presented for the case of a cubic screen.

The reference results

The test case a monopole placed at 1 m in front of a cubic screen ($3m^3$) on a flat hard ground. The chosen frequency is 200 Hz which is between the tonal components that can be heard near to transformer areas (100 Hz and its first harmonics).

The calculated reference results are provided by EOLE a 3D code based on Linearized Euler Equations developed by EDF [3]. Due to boundary condition problems, EOLE calculations are valid only in the range of 10 meters behind the screen.

In addition, some 1/6 scaled measurements have been done in an semi-anechoic room.

Figure 1 (a) and (b) show a comparison between the calculated and the measured reference data in an horizontal plane at 1 meter above the ground. The equivalent distance between 2 measured points is 60 cm. The equivalent sound power level of the source is 115 dB at 200 Hz. The calculations are made on a 10 cm regular mesh grid.

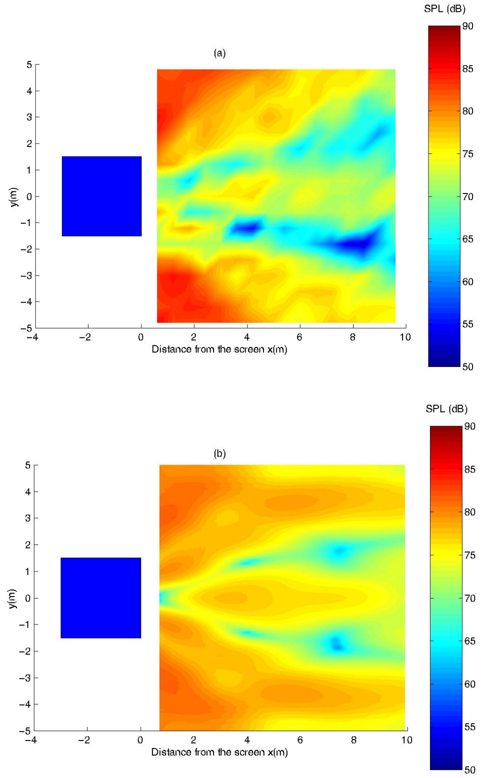

Figure 1 : (a) Measured data. (b) EOLE

The simplified Model (SModel)

Figure 2 illustrates the 4 possible diffracted paths over the screen.

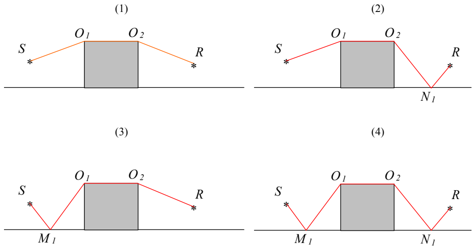

Figure 2 : the 4 possible paths over the screen.

As well, there are also 4 paths for each side of the screen.

The total pressure at the receiver p_T is determined by summing the complex pressures p_i due each of the 12 diffracted paths coming from the source.

$$p_T = \sum_{i=1}^{12} p_i = \sum_{i=1}^{12} A_i e^{jkr_i} \qquad (1)$$

Where : A_i is the amplitude of the pressure due to the ith path calculated according to ISO 9613-2 [3],

r_i is the length of the i^{th} path,

k is the wavenumber.

The result of such a model (called “Smodel”) is showed on Figure 3 .

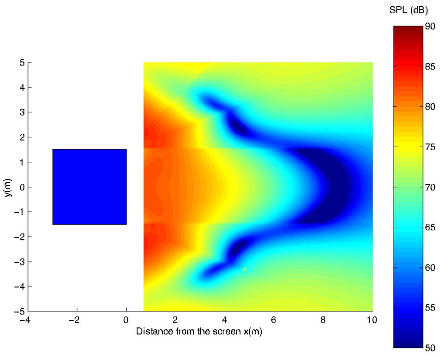

Figure 3 : Results of the SModel

Discussion

As it is displayed on Figure 3, there is an overprediction of the level just behind the screen to a distance from the screen of about 4 meters. There is also an important dip around 8 meters. This is due to the limited number of contributions that is taken into account. It leads to create unrealistic and steep patterns. Theoretically, a good representation of the phenomena is to consider a large number of path around the screen. This kind of approach is under development but the first results are hopeful. As it is illustrated on Figure 5, the resulting spatial profile (called “multipath”) is very close to the reference results with no unrealistic patterns at all.

(b)

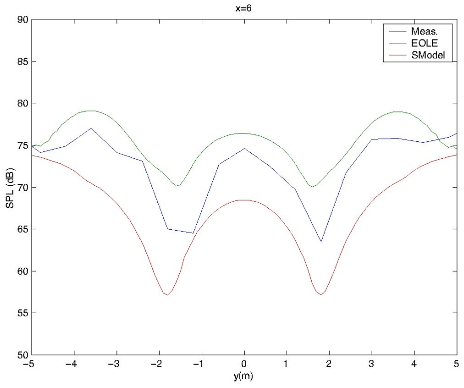

Figure 4 : (a) a transversal profile at x=9m

The discontinuities at y=+/- 1.5 that can be seen on Figure 3 come from the way ISO 9613 takes the thickness of the screen into account for the calculation of A_i.

The Figure 5(b) illustrates the good representation of the interference patterns : the localisation of the maximums and the minimums is coherent with the reference data.

The reflections at the boundaries in the EOLE calculation are visible beyond a distance of 9m from the screen.

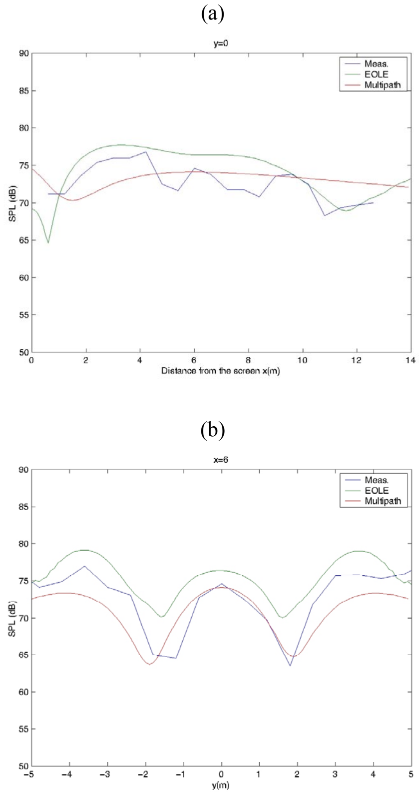

Figure 5 : (a) a longitudinal profile at y=0m. (b) a transversal profile at x=9m**.**

Conclusion

Using an ISO like model to reproduce interference pattern at low frequencies at a few meters behind the screen can lead to make large errors. It cannot be directly implemented in an engineering calculation tool.

One way to improve the calculation will be to modify the calculation of the A_i factor by taking into account the fact that there are an large number of possible paths around the screen – theoretically an infinity. This is under development.

The quality of this model has also to be checked at larger distance from the screen. The EOLE calculations could be extended farther by using a Kirchhoff integral approach.

References

[1] Lam, Y. W., Using Maekawa’s Chart to Calculate Finite Barrier Insertion Loss. Applied Acoustics, 1994, 42, 29-40.

[2] Muradali, A. & Fyfe, K. R., A study of 2D and 3D Barrier Insertion Loss using Improved Diffraction-based Methods. Applied Acoustics, 1998, 53, 49-75.

[3] M. Guivarch, Proposition d’équations pour la propagation acoustique en écoulement non uniforme, $5^{ème}$ CFA, Septembre 2000, Lausanne, Suisse.

[4] ISO 9613-2 – Acoustics – Attenuation of sound during propagation outdoors – Part 2