Prediction of noise propagation – a summary of the special session of DAGA 2000 on immission prognosis

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The annual meeting of the German acoustical society, the so-called DAGA, started March 2000 with a special session on the state-of-the-art of immission prognosis. General aspects of basic physical properties affecting the approaches to model noise propagation outdoors were discussed in relation to engineering-like and empirical methods to achieve satisfactory prognosis results. 10 papers were presented ranging from numerical calculation of wave propagation to in-situ measurements of the immission of airplane noise. Emphasis was laid in taking meteorological influence into account.

1. Introduction

The general approach to estimate the immission from a given noise source is to take a valid guideline, introduce the appropriate parameters of the environmental condition into the calculation procedure and end up with a dB-number, which pretends to give some long-term average in a certain correlation to a real measurement. The guidelines differ not only internationally but also depend on the noise source itself, suggesting that sound, radiated e.g. from traffic, propagates in another way than sound radiated from a power plant. Several initiatives have started to improve the empirical guidelines. Some try to take meteorological conditions – at least in some general classifications – into account. Others aim at a better modelling of the reflection and absorption of the ground outdoors, i.e. on taking the surface impedance into account. Since sound waves obviously do not propagate according to physics which differs in e.g. France from Germany, efforts must be undertaken to harmonise guidelines internationally – at least within Europe. Furthermore, the chance of improving the guidelines according to scientific and engineering findings must be investigated. To stimulate the discussion a special session was organised on occasion of the annual meeting of the German acoustical society in March 2000. The following papers were presented:

- M. Meyer (Oldenburg University): Numerical modelling of wave propagation – a general survey of acoustic transmission models and their capabilities.
- R. Blumrich and D. Heimann (DLR, Inst. of the Physics of the Atmosphere, Oberpfaffenhofen): Modelling of sound propagation in consideration of topographical and atmospheric influences.
- E. Salomons (TNO Institute of Applied Physics, Delft): Outdoor noise control in The Netherlands. Current engineering models and new developments.
- J. Kragh, B. Plovsing (DELTA A&V, Lyngby): Propagation models for use in the new nordic prediction methods for environmental noise.
- F.-Th. Winter (Munich International Airport): Flight path optimisation – results of noise monitoring in 1998/ 1999.
- R. Bütikofer, G. Thomann (EMPA, Dübendorf): Validation of aircraft noise calculations.
- K. B. Rasmussen (DTU, Dept. of Acoustic Technology, Lyngby): Sound propagation over screens and earth berms under the influence of wind.
- D. Heimann (DLR, Inst. of the Physics of the Atmosphere, Oberpfaffenhofen): Sound-level prediction in inhomogeneous terrain: Towards consistent simulations of atmosphere and acoustics.
- I. Noordhoek, E. Salomons (TNO Institute of Applied Physics, Delft): Sound propagation over hills under various meteorological conditions.
- D. Kühner (deBAKOM, Odenthal): Sound propagation – requirements for a new sound propagation model.

It is planned to publish the papers as a whole as a “technical and applied contribution” in the journal ACUSTICA united with ACTA ACUSTICA. The following report gives an overview on the discussion of the special session and summarizes the major results.

2. Meteorology

The impact of wind and temperature on acoustic wave propagation is well known. The sound speed varies spatially and temporally. The atmospheric boundary layer is characterized by a sound speed profile, which variance is governed by turbulent structures. Turbulence is not only affecting the wave propagation by forward scattering with “smooth” alterations of the direction of propagation, but also by backscattering, which becomes important for the calculation of the noise immission within shadow zones. Elaborate models of micro-meteorology are developed by now, taking into account not only the similarity theorems of a stationary, turbulent flow along a smooth boundary but also topographic conditions like earth berms, screens, valleys and hills. In particular Heimann and Blumrich reported on such approaches. Noordhoek and Salomons showed systematic calculations of sound propagation over a hill (parabolic approximation) when taking the micro-meteorologically determined sound speed profile into account. Rasmussen completed the observations with elaborate measurements in a down-scaled laboratory set-up.

The existing guidelines (e.g. VDI 2714/ 20 or ISO 9613) aim at a general “downwind” condition, which is often violated in the sense that large sound speed gradients over screens or earth berms cause a significant increase of noise level in the shadow zone. Statements on noise immission could be “user-friendly” improve by providing statistical estimates based on the meteorological forecast (Kühner). The long-term observations reported by Kühner suggest the invention of so-called stability classes of meteorological conditions, which are well established in the case of air-pollution calculations. Kühner incorporates such classes in an advanced ray-tracing calculation procedure and reckoned that 3 classes might be sufficient, compared to 6 to 7 classes in air-pollution models.

Elaborate micro-meteorological models provide not only the wind- and temperature-field over an irregular terrain by using refined models of impulse and heat-transfer in grid calculations but go “back to the roots” in numerically solving the Navier-Stokes equation. Since this equation incorporates any motion of a fluid, i.e. not only micrometeorology but also the acoustic wave motion, a numerical approach of high precision and dynamic range should in principal provide the “true” calculation of wave propagation in the moving fluid without any further separation. Heimann points out that the “unification” already exists, the direct numerical simulation (DNS) – there is “only” a lack of computing power and of course of highly sophisticated numerical approaches, which are capable of an intelligent discrimination between buoyant, turbulent and acoustic motion.

3. Wave propagation

Numerical calculations of acoustic wave propagation are well established in underwater acoustics and seismic prospecting. An overview on the main procedures ray tracing, fast field calculation, normal mode decomposition, and parabolic equation (PE) method was given by Meyer. The geometrical approximation of wave propagation by means of rays is still by far the fastest way to calculate noise propagation, and is used in several commercially available programmes. There is still capacity for further improvement which yields interference possibility (Kühner) and diffraction properties. The development of a fast wave equation solver along easy-to-calculate ray paths is still open.

Meyer demonstrated the large capacity of the PE approach to enhance calculation speed. Very efficient numerical procedures are capable to calculate several thousand wavelengths of propagation within the order of minutes on a standard PC today. Slowly changing atmospheric conditions can be introduced into repeated calculations yielding a good statistical representation of a certain propagation condition. The result is achieved in a reasonable time. The PE method can as well be used for solving propagation equations of statistical moments of the wave property. The statistical quality of the turbulent medium is reflected in the statistics of the wave. Certain simplifying statistical assumptions allow even for analytic solutions of the propagation of statistical moment (Ostashev et al.[1),2)]). Numerical PE calculations for statistical moments are not yet investigated. Range dependant environment and varying propagation conditions are already incorporated in PE schemes.

4. Sources

Kühner pointed out that the source size is directly related to the spatial coherence of the radiated wave field. Large sources will in general smooth out interference effects from diffraction, ground wave etc. On the other hand become large sources small at sufficient distance, yielding e.g. a ground wave dip in the excess attenuation of a distant railway track. It is in principle possible to take these well-known physical properties of wave propagation into account in fast ray-tracing based calculation schemes. A differentiated investigation of a real, extended noise source becomes more and more important. A noise abatement measure on one part of a source reveals others which have been masked before. Additionally, detailed knowledge of radiation characteristics is often necessary to improve noise reduction, especially for aircraft noise.

Költzsch gave a distinguished lecture[3)] on flow acoustics during the DAGA 2000. He reviewed the challenges and possibilities of flow noise reduction on aircrafts, including engine noise. He stated that altering certain boundary conditions near the location of noise-source generation could effectively change the radiation characteristics, e.g. directing sound energy to above instead of aside. The details of the directivity of the sound radiation from aircrafts is an important parameter for improving measures against noise impacts near airports. Regrettably these details are not provided by the manufacturer, and are in general kept as classified data. By taking own measurements into account the EMPA in Switzerland (Bütikofer, Thomann) was able to develop a surprisingly accurate prognosis scheme named FLULA for the use in the vicinity of airports. The validation of the scheme demands for a precise determination of the trajectory of the airplane in the order of a few meters. Measurements and FLULA demonstrate that it is possible to improve noise reduction around airports just by optimising trajectories of airplanes according to their individual properties of the acoustic radiation pattern and to weather conditions. Winter presented a long-term survey of trajectories of the Munich International Airport with the associated noise immission. Rather small changes of the main trajectories yielded a significant reduction of noise impact. The remaining problem is the difficulty to force pilots to follow a given trajectory with higher precision than usual.

5. Perspectives

The contributions show the possibilities and chances of improving existing prediction schemes and guidelines for calculating noise impact outdoors. The rapidly developing computing power enables to take physical wave-propagation properties into account in simple ray-tracing based procedures. The advanced Nordic method improves classical approaches by including the Fresnel-zone concept (Kragh, Plovsing). Interference, frequency-dependent impedance etc. are taken into account on a geometrical basis of wave propagation within one Fresnel zone. The associated geometry is very effectively calculated.

On the long run it will be possible to use DNS for detailed calculations. Elaborate models of micrometeorology are already available and wait for being incorporated in prediction schemes. Improved knowledge of details of the noise source radiation becomes obligatory for an effective improvement in the calculation of immission. Enhanced knowledge is also necessary for a better model of the effective impedance of the boundary in order to predict near-ground wave propagation. Salomons reported combined effects of (acoustic) near-ground boundary layer properties and impedance, including roughness, being combined in an “effective” impedance[4)], which alters noise propagation over water clearly from that along a rigid boundary.

References

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