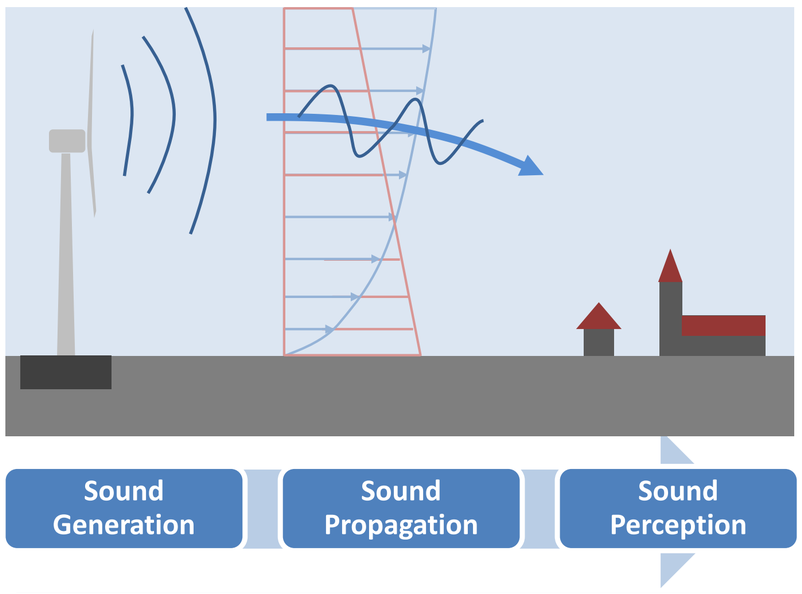
Overview of numerical methods for simulation of sound propagation emitted from wind turbines



Motivation and Aims

The growth in onshore wind turbines causes an increase of sound emission affecting local residents. Aim of the cooperative project “WEA-Akzeptanz” (BMWi, project ref. no. 0324134A) is to increase the acceptance of wind turbines by affected residents. Acoustical, meteorological and topographical influencing factors are relevant for the sound propagation. This work focuses on numerical simulations of the sound propagation in the atmosphere, which will be validated by measurements (c.f. Martens, Rolfes EAWE Abstract 2017).

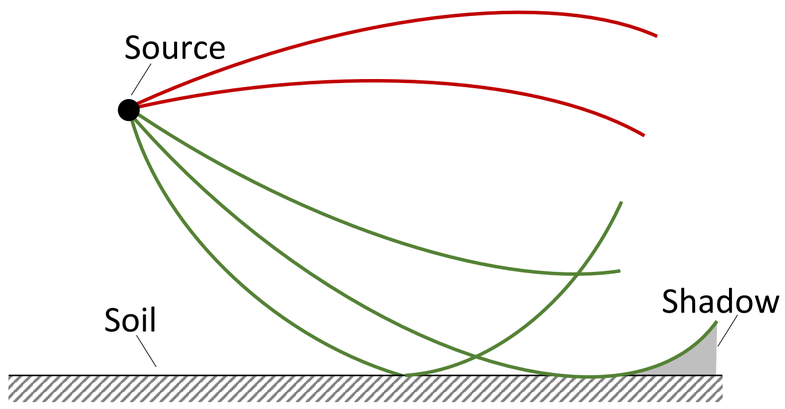
Specification of Parameters and Effects

Influencing Factors

- Acoustics: Speed of sound, sound pressure level, frequency, air absorption
- Meteorology: Wind speed, turbulence, temperature, density
- Topography: Soil characteristics, irregular terrain, obstacles

Geometrical Effects

- Influence of temperature (Fig. 1)
- Influence of wind (Fig. 2) → outweigh temperature influence
- Turbulence → sound scattering leads to fluctuations in sound pressure level → outweigh temperature and wind influence
- Diffraction into shadow zones



Normal weather
-> Temperature decreases with height
Thermal inversion
-> Temperature increases with height

Figure 1: Refraction of sound due to temperature

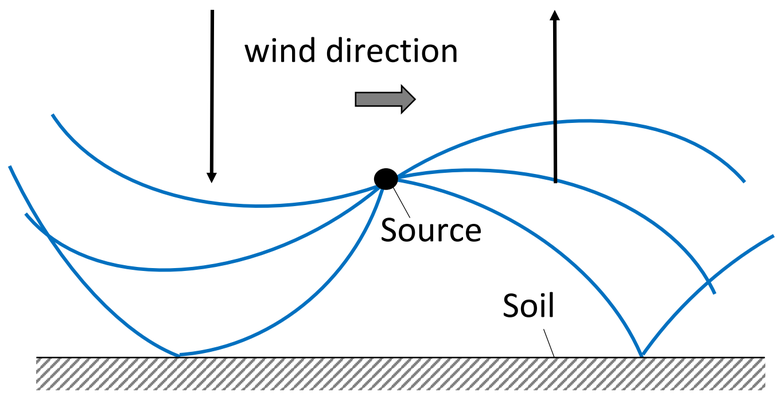
Possible numerical methods

Methods	Characteristics	Suitable
FEM (Finite Element Method)	not for free field	—
BEM (Boundary Element Method)	not for temperature, wind, turbulence	o
Raytracing	no wave phenomena	o
PE-Method (Parabolic Equation Method)	only one-way (no back-scattering)	+
FFP (Fast Field Program)	only for layered atmosphere	o
FD-TD (Finite Difference Time Domain)	high computation effort, works not for long distances	o

PE-M. Variations	Characteristics	Suitable
CN-PE-Method (Crank Nicolson)	grid-space limited to 1/10 wavelength	o
GT-PE-Method (Generalized Terrain)	implementation of topography, like CN-PE in flat surfaces	+
GF-PE-Method (Green’s Function)	larger grid-space → fast computation	o

$c_{eff} = c - v_w$
c decreases with height

$c_{eff} = c + v_w$
c increases with height



Wind speed v_w
Speed of Sound c

Figure 2: Refraction of sound due to wind

References:
- „computational atmospheric acoustics“, E.M. Salomons, 2001, Springer-Science+Buisness Media, B.V
- „A Review of the Influence of Meteorological Conditions on Sound Propagation”, Uno Ingard, 1953, The Journal of the Acoustical Society America

Conclusion

- Complex thematic with a lot of influencing factors and effects which are mutually dependent
- Not just one correct solution → every option has pros and cons

PE-Method is most suitable to implement all influencing factors and effects

Jasmin Hörmeyer, M.Sc.
Prof. Dr.-Ing. habil. Raimund Rolfes

Supported by:
Federal Ministry for Economic Affairs and Energy
Projektträger Jülich Forschungszentrum Jülich

Institut für Statik und Dynamik
Prof. Dr.-Ing. habil. Raimund Rolfes
Appelstr. 9A, 30167 Hannover
Tel.: +49 511 762 3867