National Technical University of Athens
School of Mechanical Engineering
Faculty of Fluid Mechanics

"Simulation of sound propagation in the atmosphere using the Parabolic Equation method and application to the prediction of wind turbine noise"

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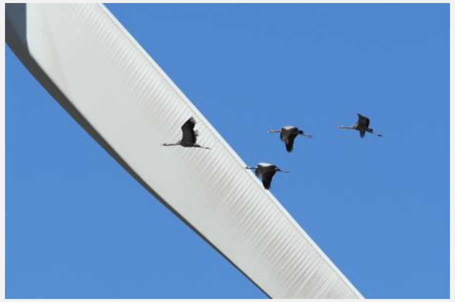
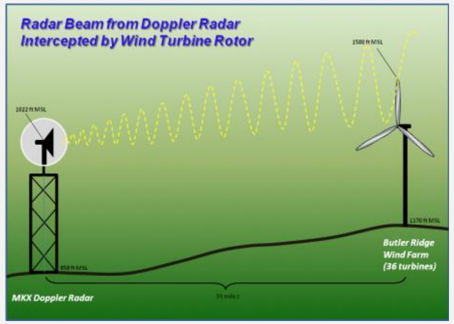
But WHY is this important?

Overpopulation and fast economic growth → increase in energy requirements→ fossil fuels depletion → need for R.E.S. → wind energy: a popular option.

Air-collision of birds and bats



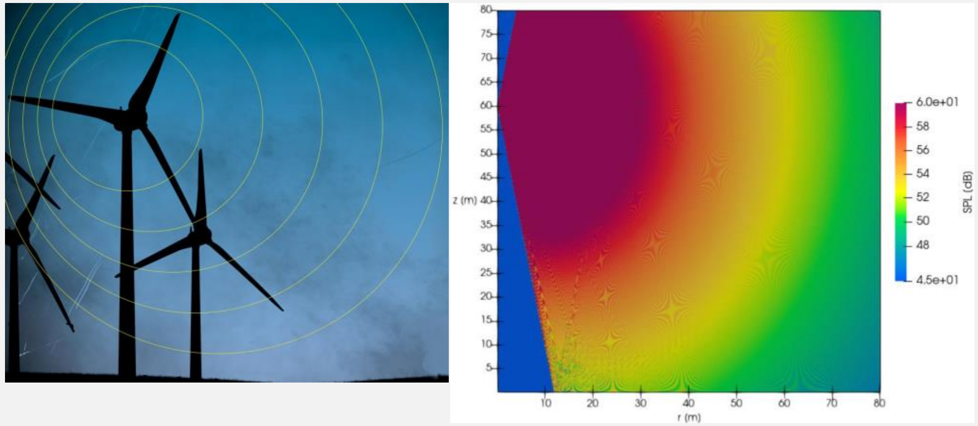
Interference with the E/M signals



Habitat loss

Drawbacks of a wind park

Noise



Visual Impact

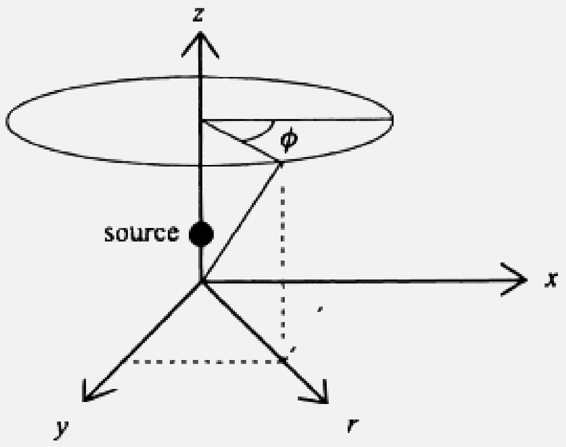
Aim of the study

The development of a model, capable of:

- simulating noise propagation in the atmosphere
- assessing the noise levels in critical distances from a W/T

The Parabolic Equation Method

Axisymmetric 3−D Helmholtz eqn.: $\frac{\partial^2 q}{\partial r^2}+\frac{\partial^2 q}{\partial z^2}+k^2\cdot q=0,\ q=p\cdot\sqrt{r}$



*Note: We’re working in the *frequency* domain!

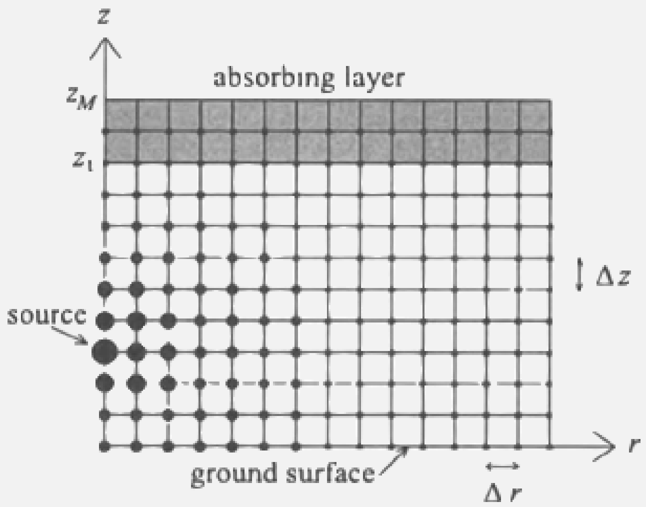
Numerical Discretization

- using Central Differences Method and Crank-Nicholson Integration (CNPE)

- taking into account:
  - Ground surface and top-of-the-grid boundary conditions

    $$\left(\frac{p_c}{v_{c,z}}\right)_{z=0 \text{ or } z_M} = Z\rho c$$

  - Top surface absorbing layer



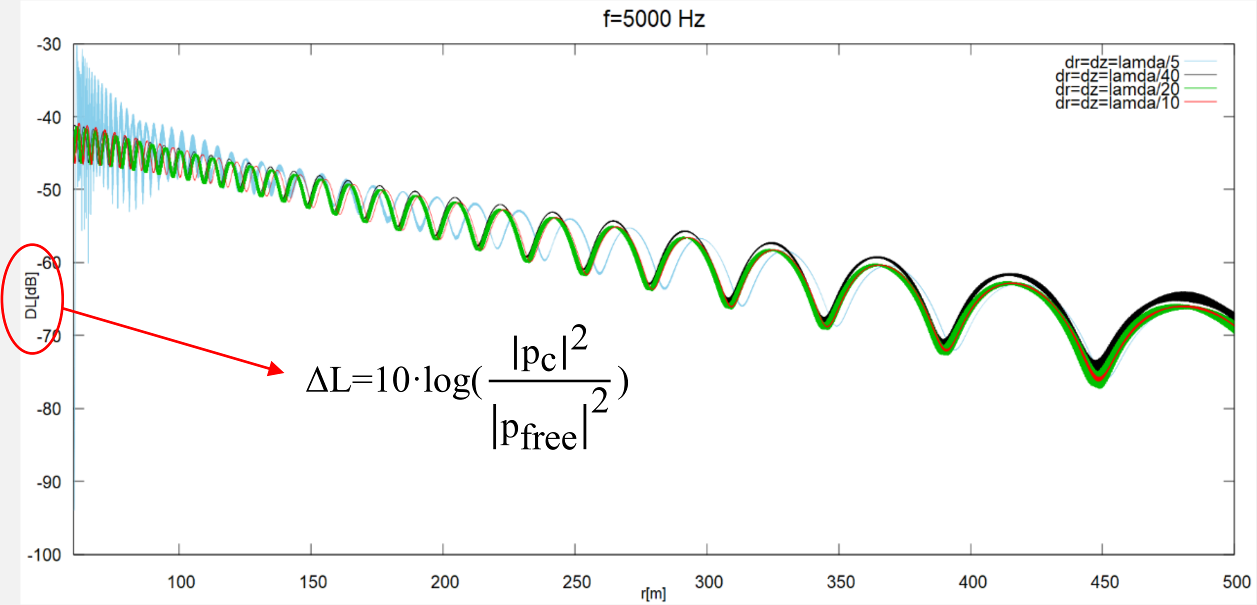
  - Atmospheric absorption, ground absorption and spherical spreading losses.

- assuming the starting field to be a monopole source in an unbounded, non-refracting atmosphere:

$$q(0,z) = \underbrace{q_0(z-z_0)}_{\text{direct field}} + C \cdot \underbrace{q_0(z+z_0)}_{\text{ground reflections field}},$$

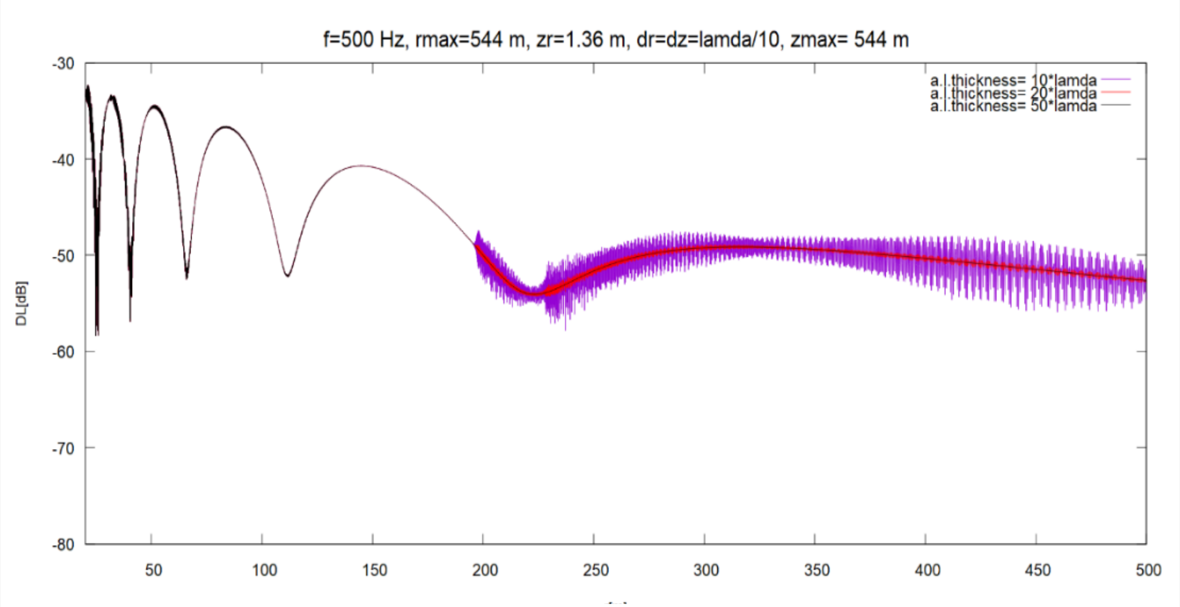
Numerical Parameters Study

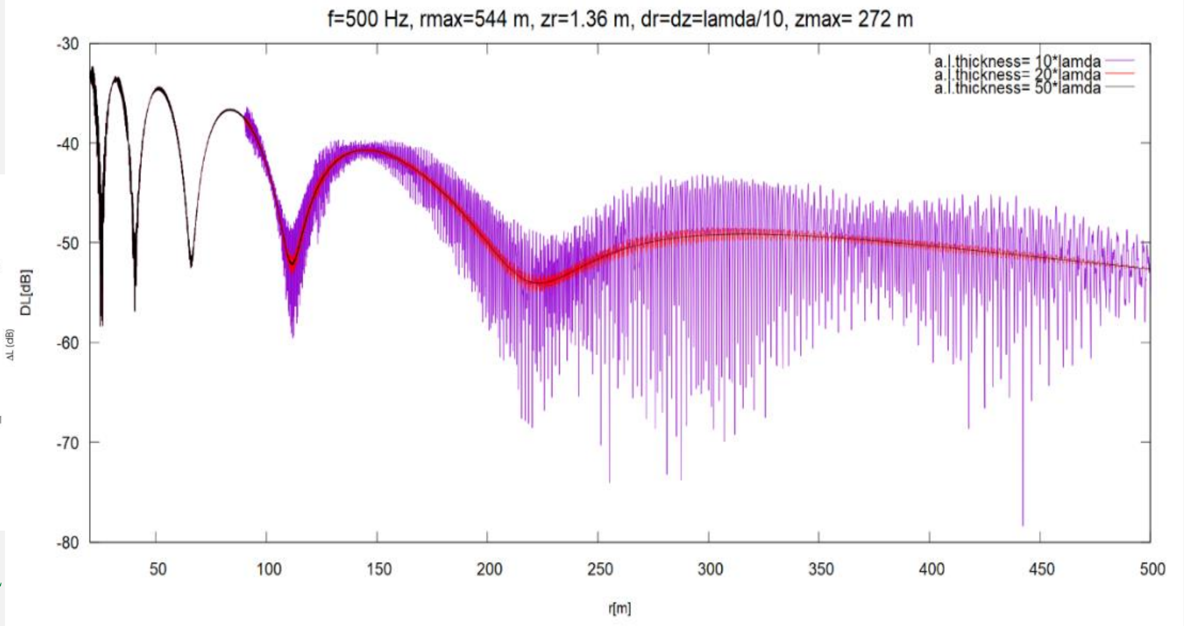
Grid Density



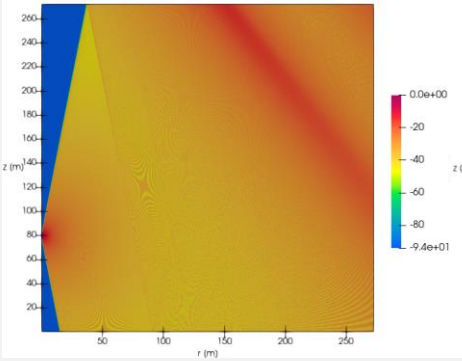
$$\Delta L=10\cdot\log\left(\frac{|p_c|^2}{|p_{free}|^2}\right)$$

Top grid surface height and absorbing layer thickness

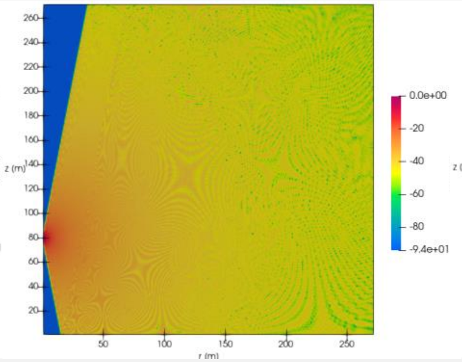




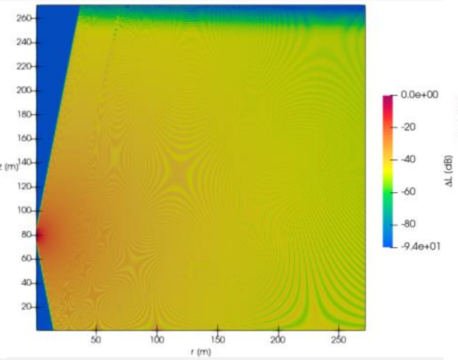
z_{max}= 272 m



No absorbing layer



Absorbing layer of thickness 10·λ

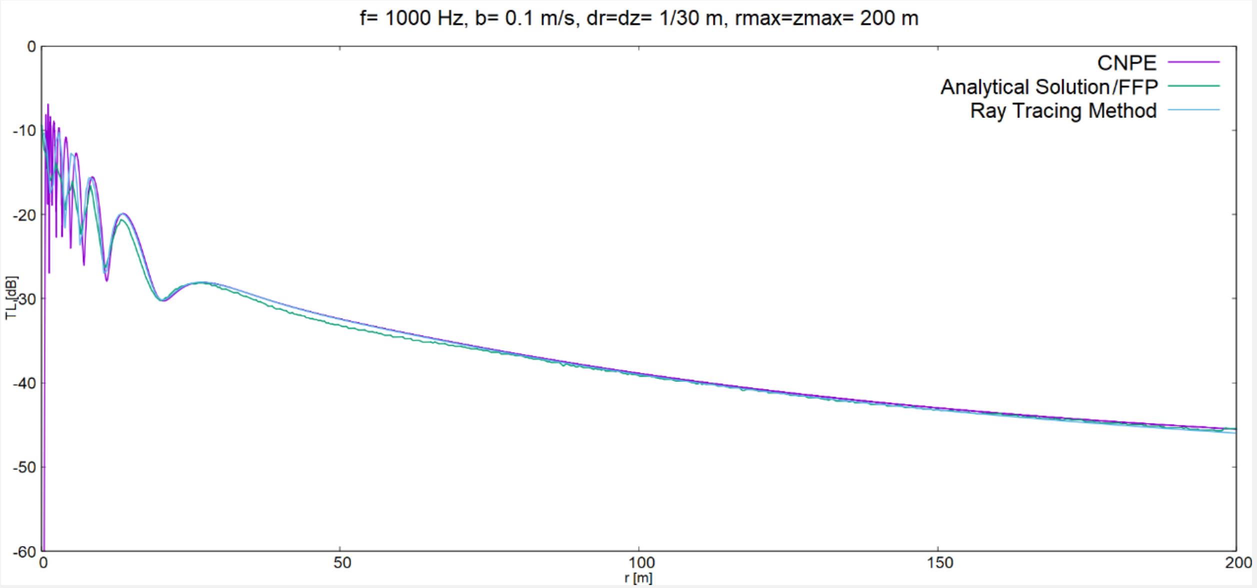


Absorbing layer of thickness 50·λ

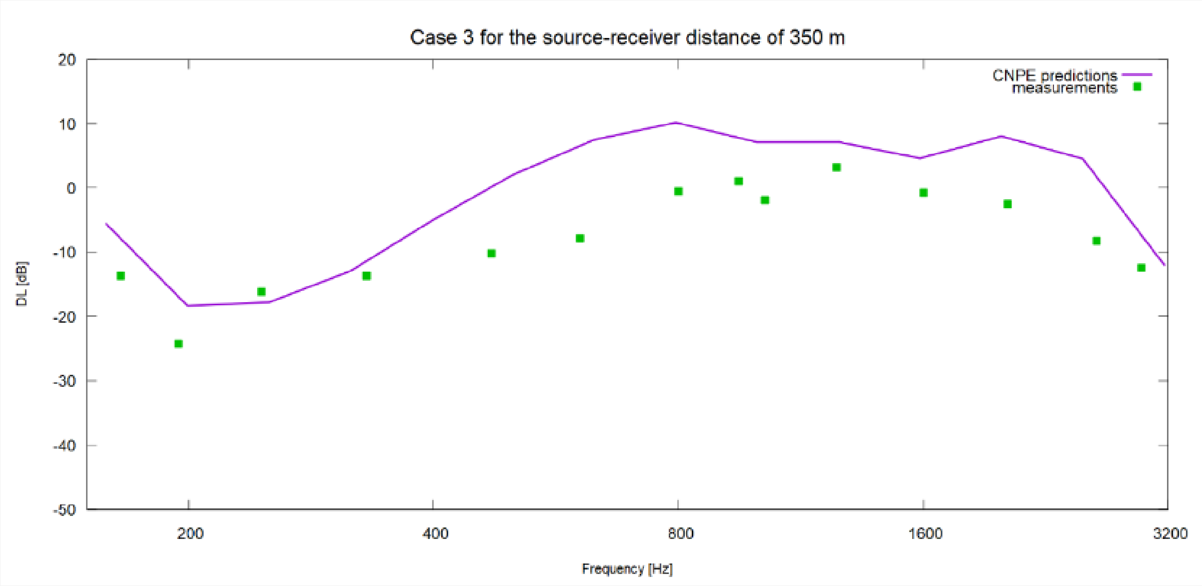
Results

Code Validation

Comparison with benchmark cases



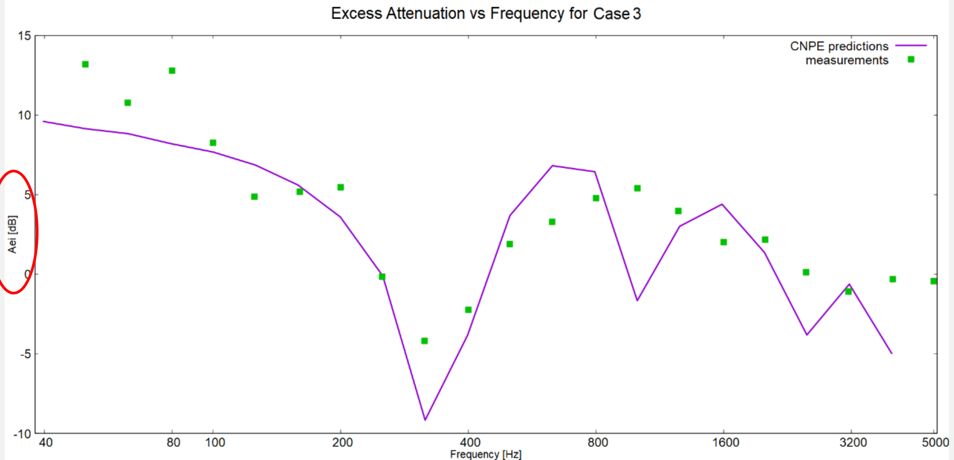
Comparison with the measurements of the Rock Springs experiment



Application to real W/T cases

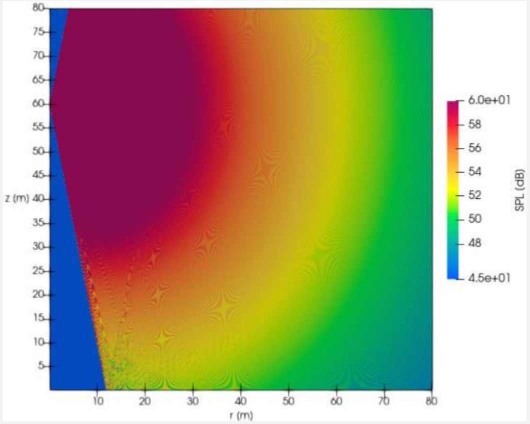
Comparison with the measurements of the Lyse experiment

$$A_{e,i} = \Delta L_e - \Delta L_i - 20 \cdot \log\left(\frac{r_i}{r_e}\right)$$



Overview

Problem: W/T noise



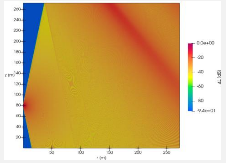
model for atm. noise propagation

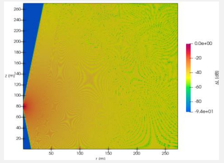
mathematics: P.E. method

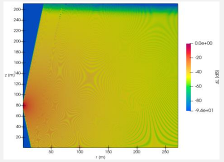
$$\boxed{\frac{\partial^2 q}{\partial r^2}+\frac{\partial^2 q}{\partial z^2}+k^2\cdot q=0,\ q=p\cdot\sqrt{r}}$$

code development (discretization)

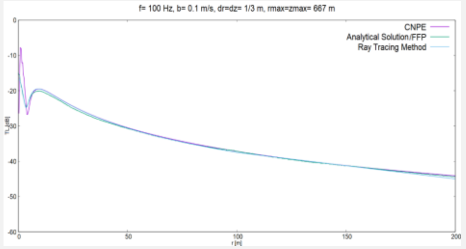
numerical parameters study



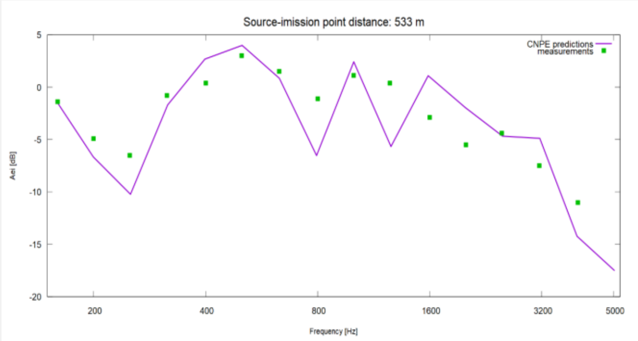




model validation



Application to real W/T cases



THANK YOU FOR YOUR ATTENTION!

Questions?