JOURNEES TECHNIQUES ACOUSTIQUE ET VIBRATIONS

Peut-on prévoir le bruit d'éolienne avec une seule source ponctuelle ?

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IFSTTAR

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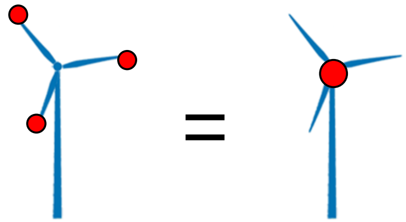
Cerema

Introduction

- Main noise sources of WT :
  aerodynamical sources at each blade [Oerlemans, 2011]

[Oerlemans, 2011]

- Global sound levels prediction :
  WT = 1 equivalent source at the hub [Makarewitz, 2011]

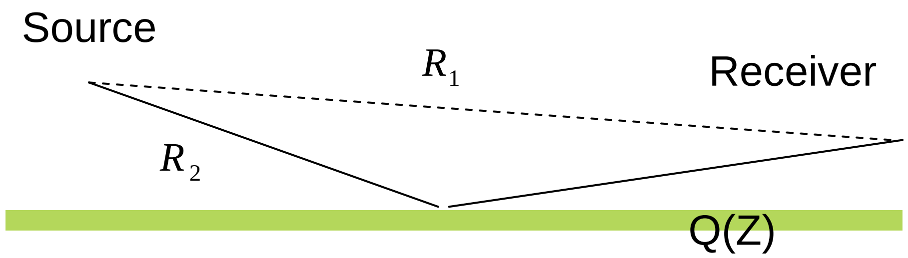


Moving sources (height change) = ground effect changes
= spectrum changes

➔ Is the one-source assumption still valid for spectrum prediction ?

Introduction

- Ground effect : a short reminder



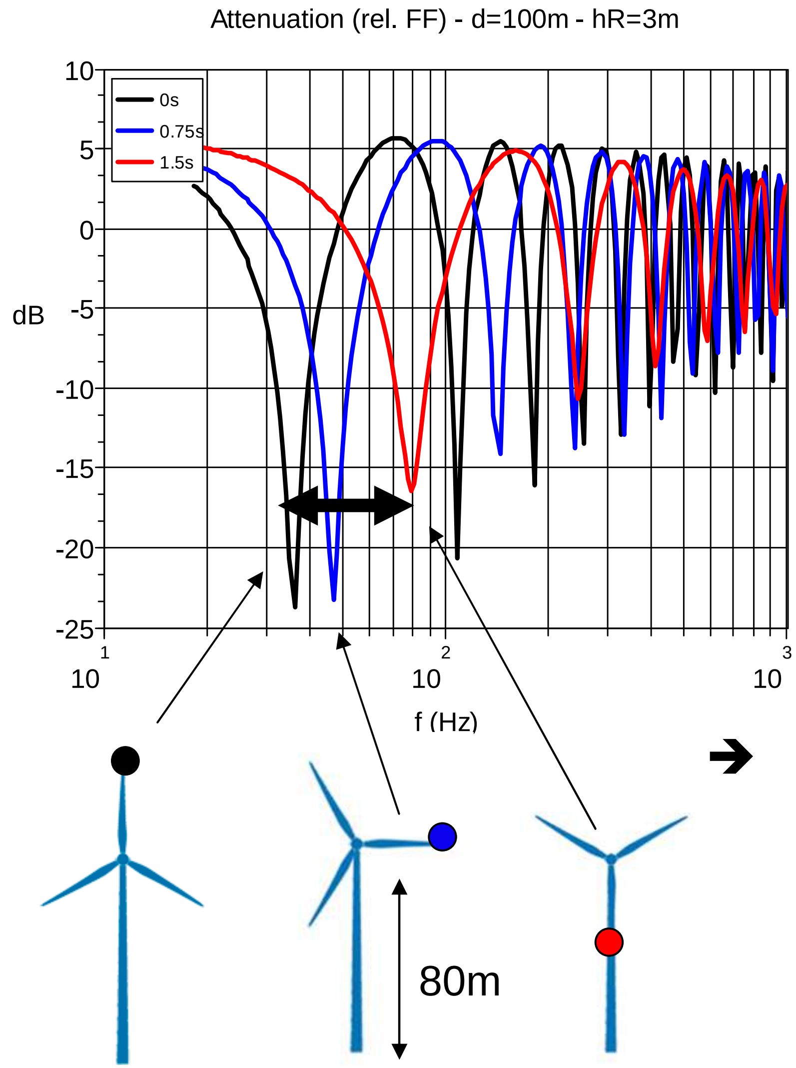
$$p_R / S = \frac{e^{ikR_1}}{R_1} + Q\frac{e^{ikR_2}}{R_2}$$

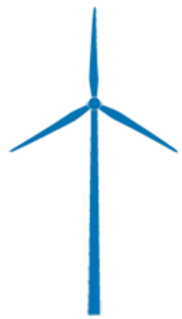
$$\Delta L = 10\log_{10}\left|1 + Q\frac{R_1}{R_2}e^{ik(R_2 - R_1)}\right|^2$$

➔ Ground effect can highly depend on source height

Introduction

- Ground effect : change in height of one WT source



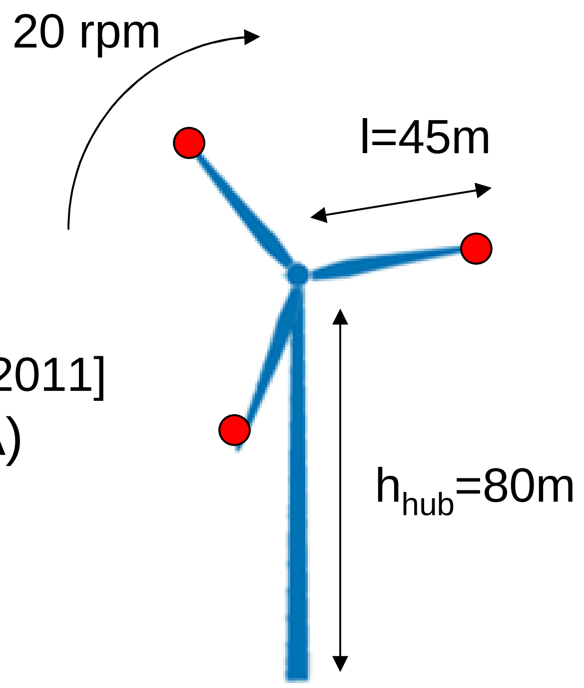


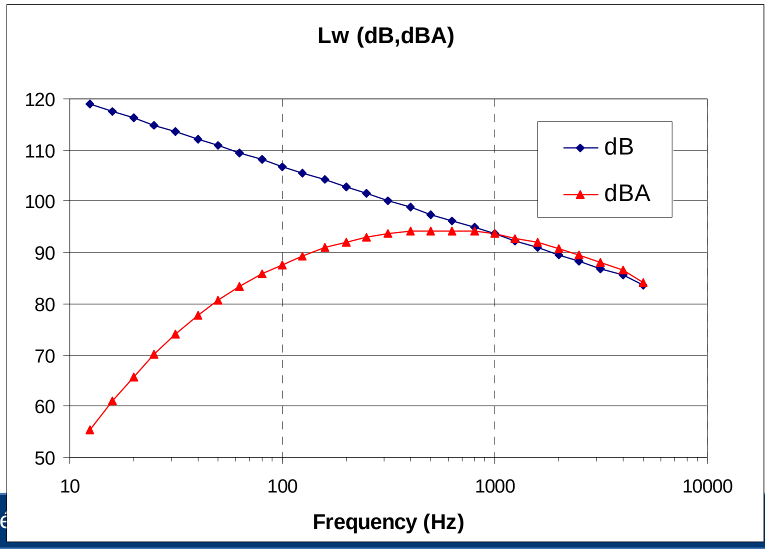
➔ Is this shift of spectrum significant for a real WT?

Numerical set-up

- Source model

  - Wind turbine : h_{hub}=80m, l=45m, 2MW
  - 1 omnidirectional point source / blade
  - Rotor speed : 20 rpm
  - Source spectrum : -4 dB/octave [Møller *et al.*, 2011]
  - LwA(1 source)=100 dBA (LwA(WT)=105 dBA)





Numerical set-up

- Propagation model

  - Rays model [Salomons, 2001]

    including :
    - ground effect
    - meteorological effects (downward cond., linear sound speed profile)

$$p = \sum_{m=1}^{N_{rays}} A_m e^{i\varphi_m}$$

$$\varphi_m = \omega \int c^{-1}(z)\,ds$$: meteo effect

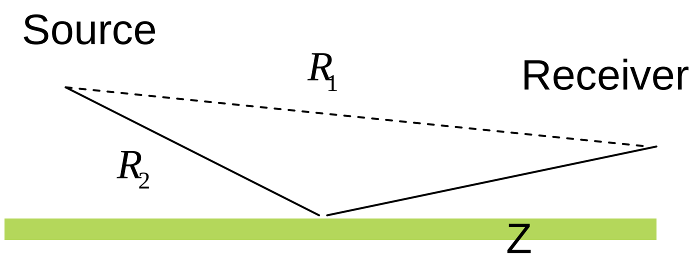
$$A_m = f_m\, A_{atm}\, Q_m^{\,N_m}\, \frac{S}{R_1}$$

atmosph. absorption (ISO 9613-1)

Ground effect

Numerical set-up

- Ground



  - Rudnick model [Rudnick, 1947]

$$p = \sum_{m=1}^{N_{rays}} f_m A_{atm} Q_m^{N_m} \frac{S}{R_1} e^{i\varphi_m}$$

$$Q_m = R_p + (1 - R_p)\, F(w)$$

$$R_p = \frac{Z_c \sin(\theta) - 1}{Z_c \sin(\theta) + 1}$$

$$F(w) = 1 + j\sqrt{\pi}\, w\, e^{-w^2} erfc(jw)$$

  - Ground impedance : [Miki, 1990]

$$Z_c = 1 + 5.5\left(\frac{f}{\sigma}\right)^{-0.632} + j \cdot 8.43\left(\frac{f}{\sigma}\right)^{-0.632}$$

σ=200 kNsm^{-4} (grass)

Numerical set-up

- Simulations

  - Simulations of 1/3rd octave band levels [12.5 Hz – 5 kHz]

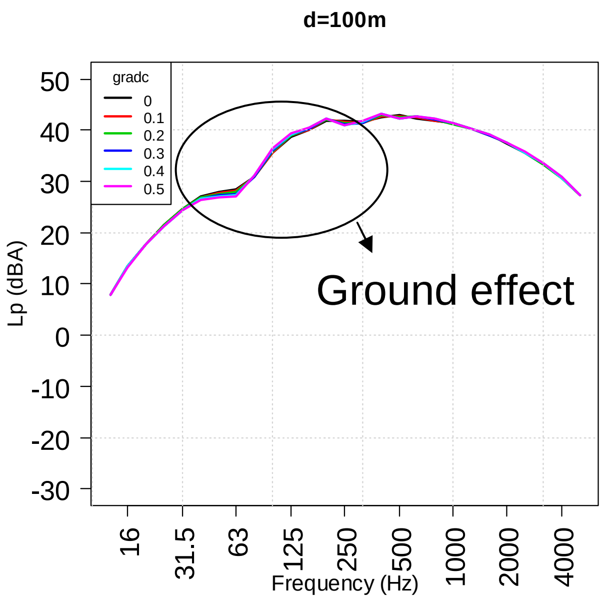
  - Simulation for every 12,5 ms over 1/3 revolution of the rotor

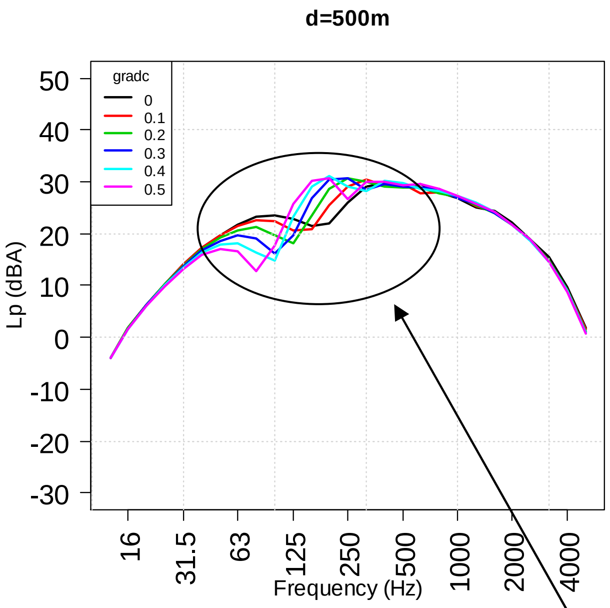
  - Distance from the WT : [100, 300, 500, 800,1000] m

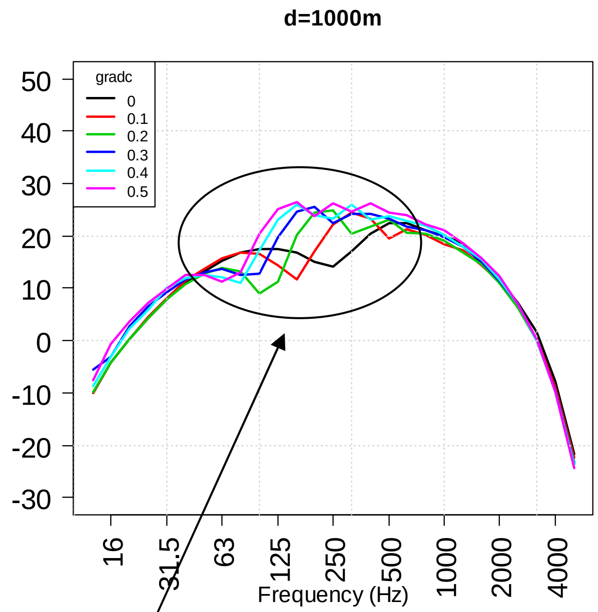
  - Meteorological conditions : $\partial_z c =$ [0, 0.1, 0.2, 0.3, 0.4, 0.5] s^{-1}

Results

- Immission mean sound levels spectrum





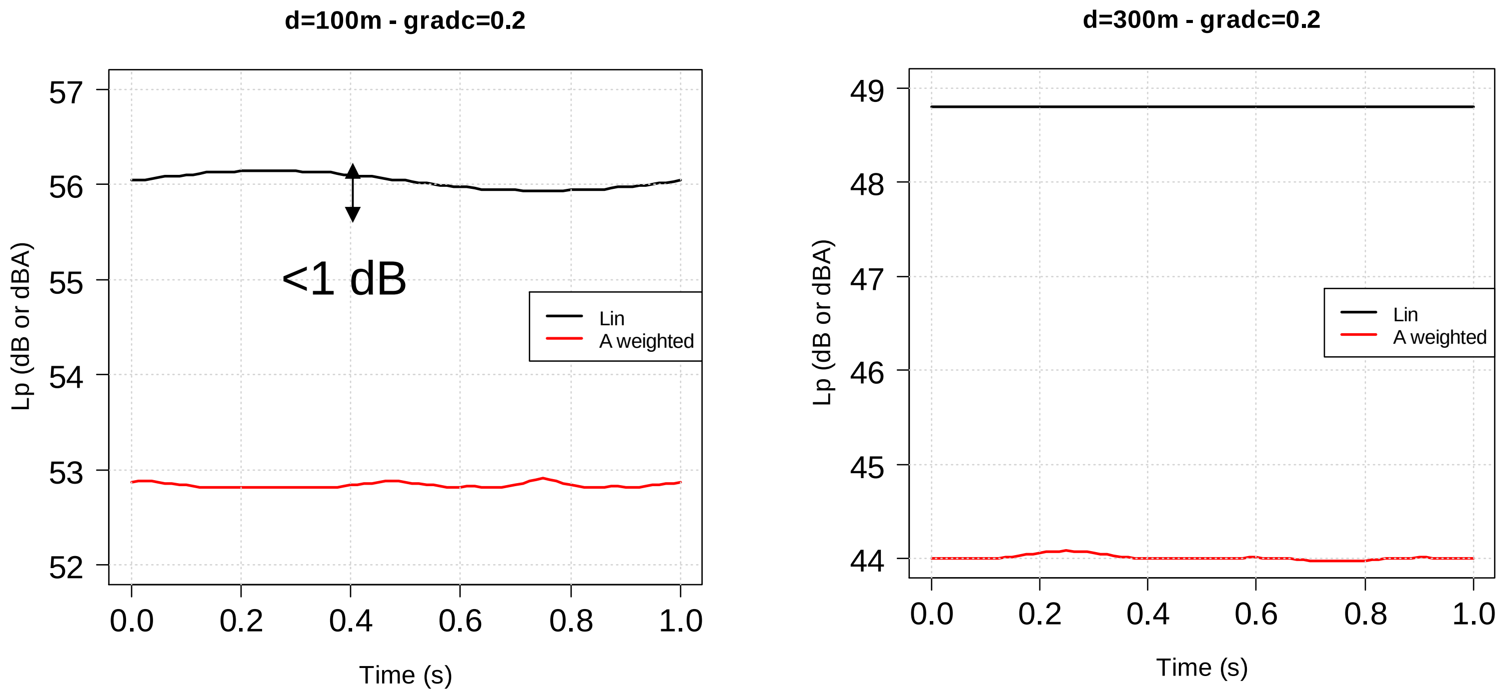


No influence of the meteo effect

Influence of the meteo effect on the ground effect

Results

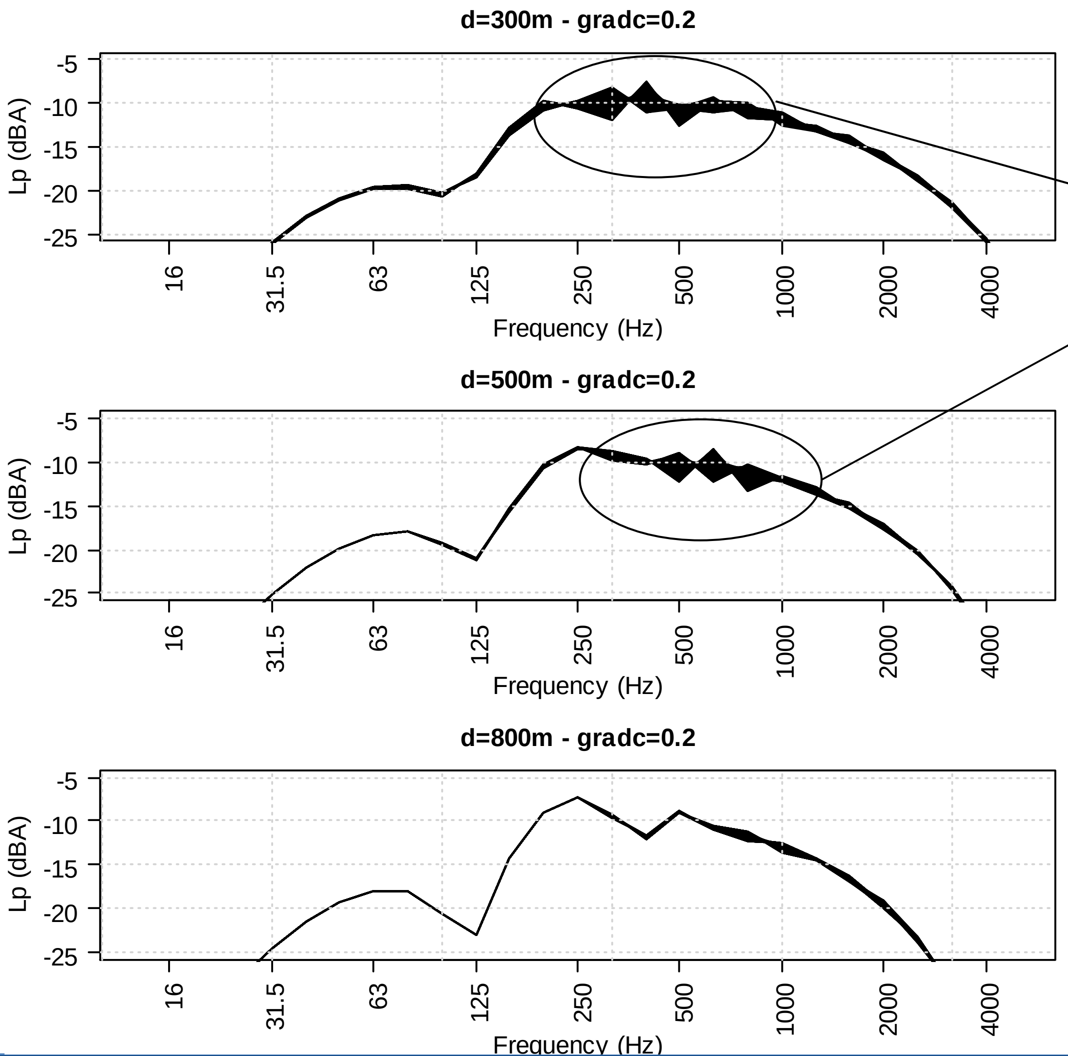
- Immission global sound levels



➔ AM due to ground effect is negligible on global sound level prediction

Results

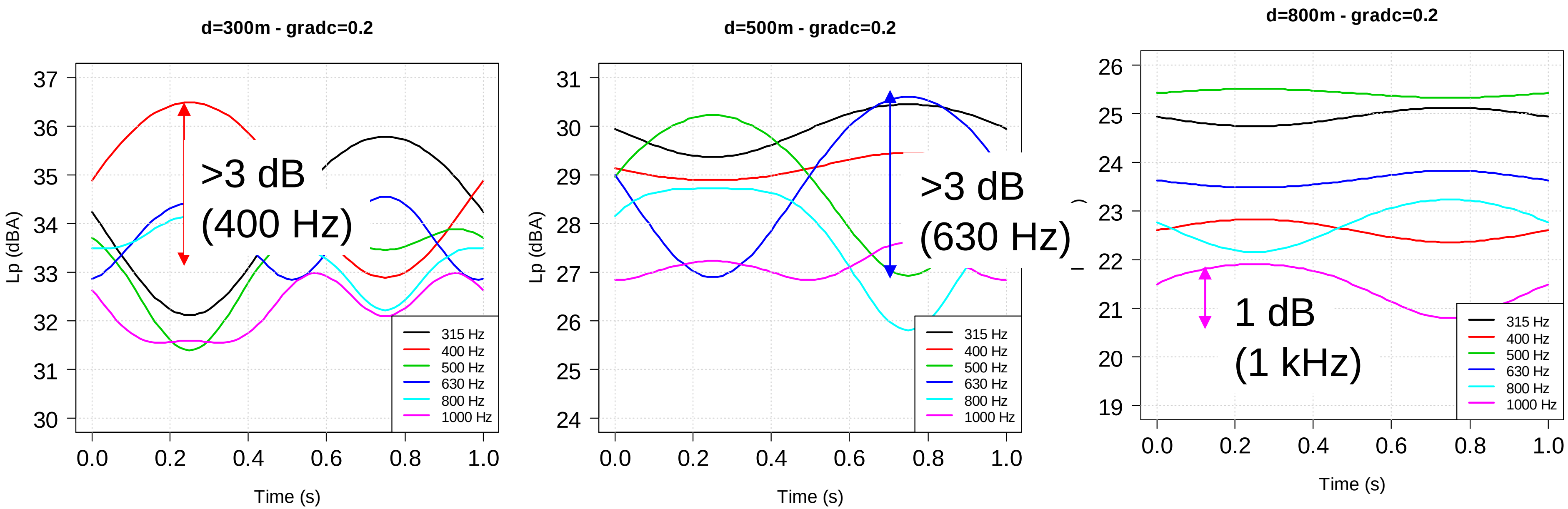
- Spectral AM by ground effects



Time fluctuations of spectral amplitude due to the ground effect

Results

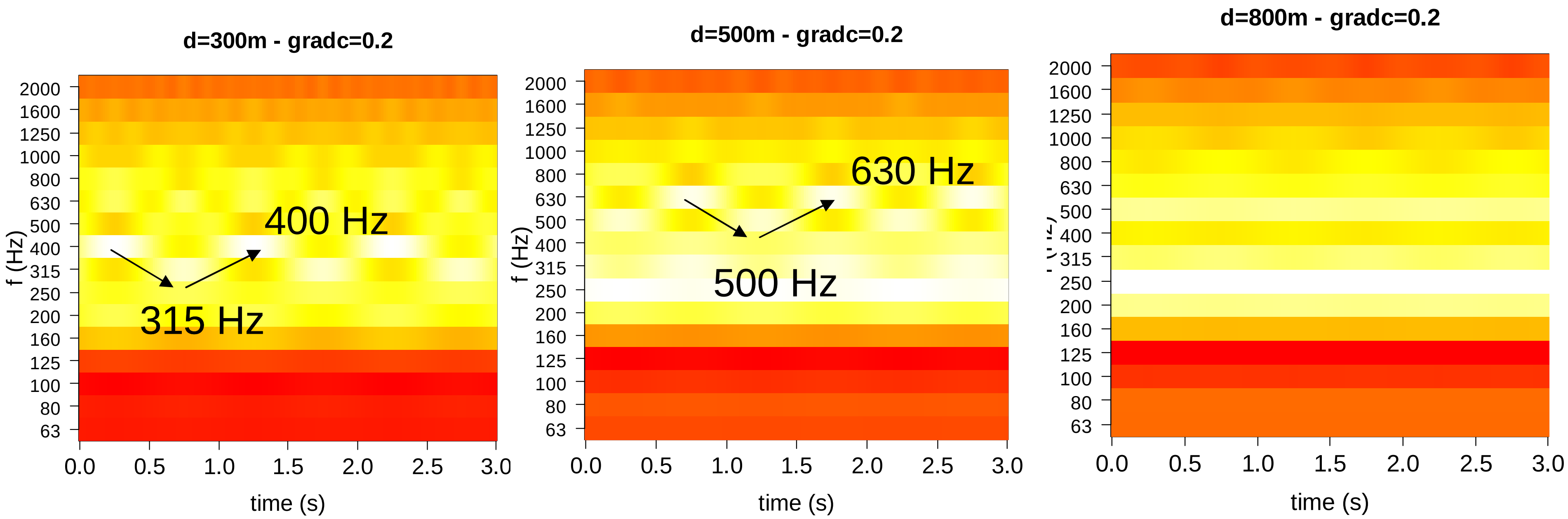
- Time fluctuations of 1/3rd octave bands amplitude



➔ AM not negligible for distances < 800m

Results

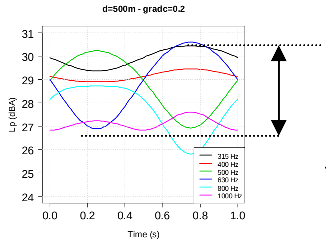
- Spectrograms



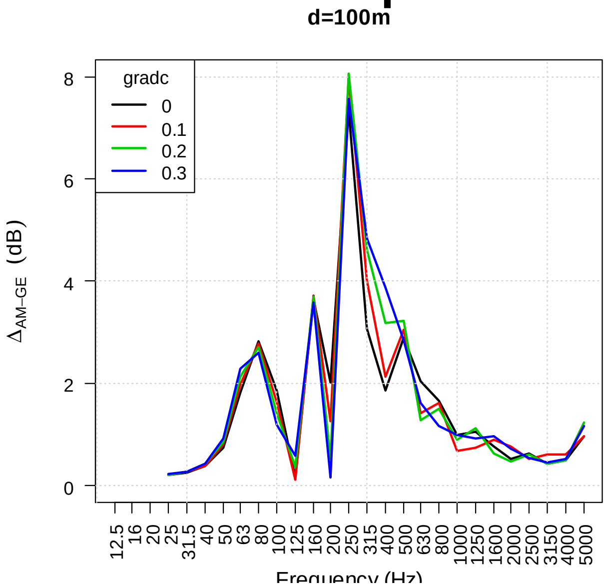
➔ AM due to ground effect = frequency modulation

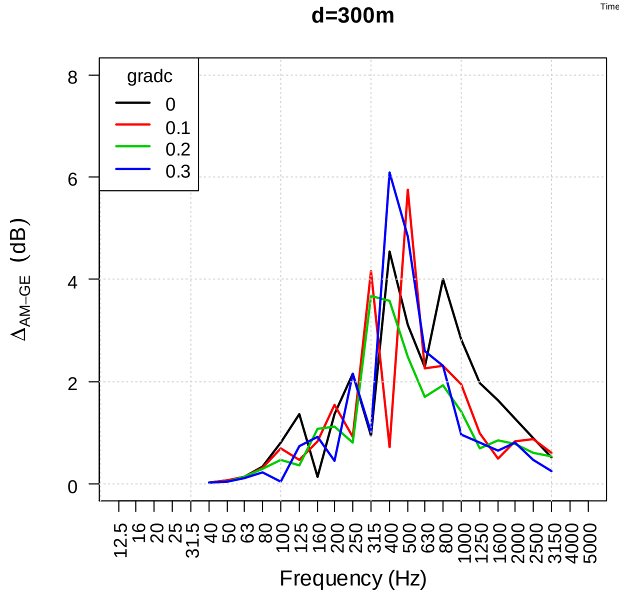
Results

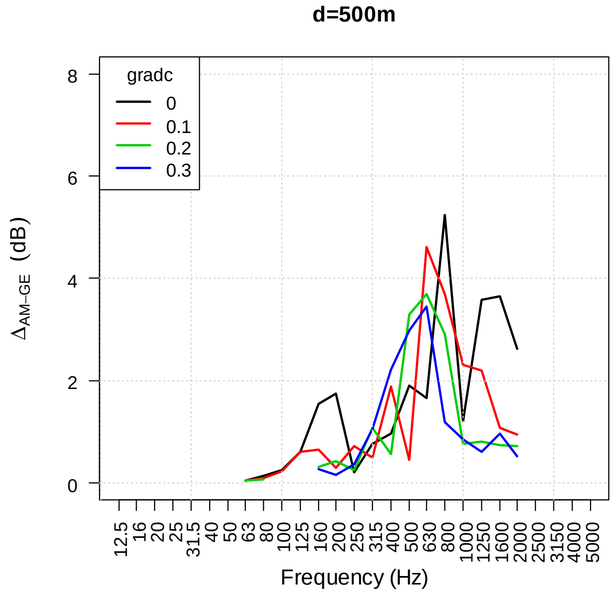
- AM depth

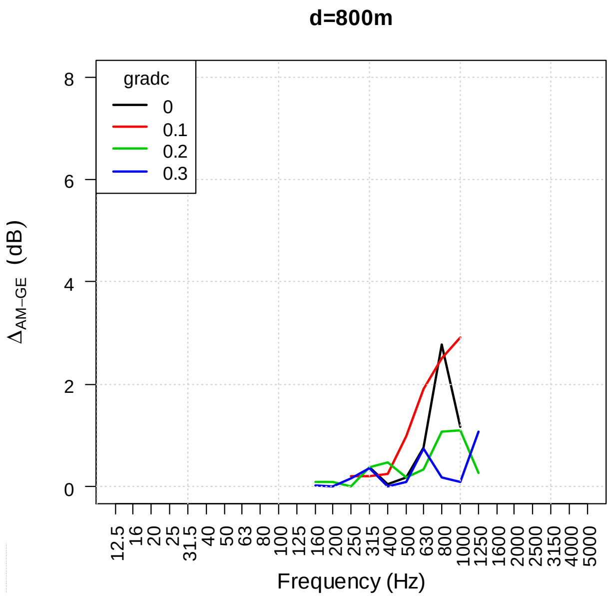


Δ_{AM_GE}







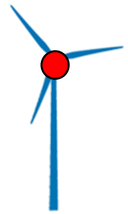


- Frequencies affected by AM increase with distance
- AM depth decreases with distance
- AM depth decreases with meteo effect

Conclusions

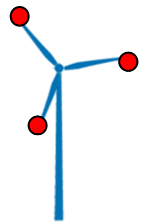
- Global sound level predicition :
  - no effect of AM due to ground effect

  ➔ the one equivalent source model is sufficient



- Spectrum prediction : AM of spectrum if
  - d < 500 – 800m
  - low meteorological effects

  ➔ the one equivalent source model is not sufficient



Outlooks

[Oerlemans, 2011]

- Because of the source directivity is omnidirectional here, the AM due to ground effect may be underestimated

- Further calculations including

  - Directivity of each source
  - More complex propagation model (PE or TLM)
  - Influence of the hub height

Merci de votre attention

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