

Assessment of the Shadowing Effect Between Windturbines at VOR and Radar frequencies.Propagation model for estimating VOR bearing error in the presence of windturbines -hybridation of parabolic equation with physical optics

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Forum for Electromagnetic Research Methods and Application Technologies (FERMAT)

Assessment of the Shadowing Effect Between Windturbines at VOR and Radar frequencies.

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Abstract: Due to the fast-growing of green energy, projects of wind-farms are planed closer and closer to the minimum regulation distances of radio navigation devices (radar, VOR ...). To assess the impact of this windfarms close to radio-navigation devices, modelling tools are in developments [1-4]. Generally, robust modelling methods (MoM) are used to compute the field scattered by the windturbines [1, 2]. However, assumptions must be done to save memory and computation time and different modelling methods are based on physical optics [3, 4] or UTD [2]. Besides, in literature, interactions between windturbines are always neglected. This paper investigates the relevance of the latter.
Indeed, to lower their impact, a simple idea would be to place windturbines behind the one closest to the transmitting antenna to take advantage of the shadowing effect. Therefore, the shadowed windturbine scattering would be reduced. Nevertheless, this effect mainly depends on the distance and the frequency. In this paper, the necessity to account for the shadowing effect between windturbines is established at VOR and radar frequencies to notify wind-energy developer about the shadowing effect of windturbines.
The interactions between the windturbines is shown to be negligible at VOR frequency while at radar frequencies, it is not the case and need to be taking account in simulation tools.

Keywords: VOR, RADAR, windturbines, shadowing, scattering.

References:

1. C. Morlaas, M. B. Fares, and B. Souny, “Wind turbine effects on VOR system performance,” IEEE Transactions on Aerospace and Electronic Systems, vol. 44, no. 4, pp. 1464-1476, Oct. 2008.
2. M. J. Algar, L. Lozano, J. Moreno, I. Gonz´alez, and F. C´atedra, “Application of asymptotic and rigorous techniques for the characterization of interferences caused by a wind turbine in its neighborhood,” International Journal of Antennas and Propagation, Art. ID 173286, 2013.
3. D. Jenn, and C. Ton “Wind turbine Radar cross section,” International Journal of Antennas and Propagation, Art. ID 252689, 2012.
4.C. Morlaas, A. Chabory, and B. Souny, "Propagation model for estimating VOR bearing error in the presence of windturbines - hybridation of parabolic equation with physical optics", in Proc. 4th Eur. Conf. Antennas Propag. (EUCAP), Barcelona, Spain, Apr. 12-16, 2010
5. R. Douvenot, C. Morlaas, A. Chabory, and B. Souny, 'Matrix Split-Step Resolution for Propagation Based on an Exact Spectral Formulation,' ICEAA, CapTown, South Africa, September 2012.

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Assessment of the Shadowing Effect Between Windturbines at VOR and Radar frequencies

Geometric configuration :

Windturbine : ENERCON-E66.

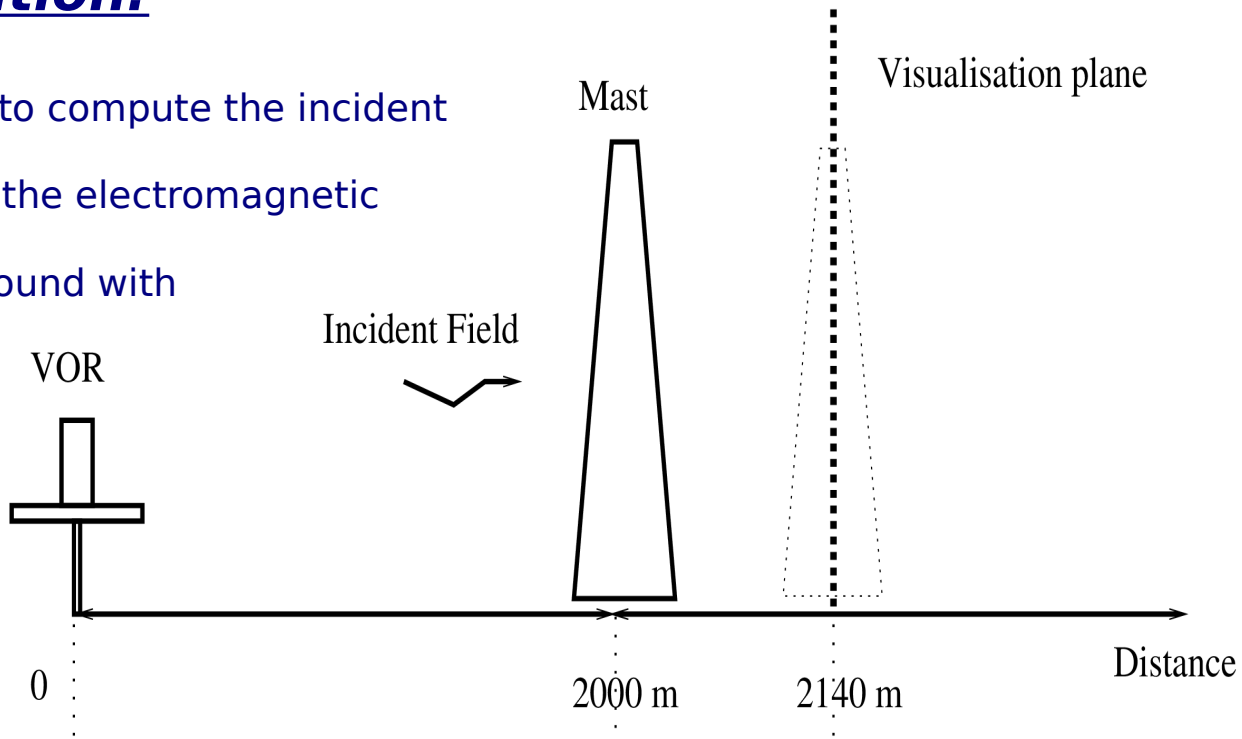
- Mast: metallic cone :
  height = 64.17 m, Rotor blades diameter = 70 m
  top diameter = 2.18 m,
  bottom diameter = 4.17 m.

Distances :

- Separation distance between winturbines : 2 rotor-blades diameters (140 m) Lowest common separation distances (the most significant shadowing effect).
- VOR station to windturbine mast: 2000m, mast to scattered field : up to 1000m.

Electromagnetic consideration:

- Parabolic equation method (PE) is used to compute the incident field on the windturbine mast [5].
- Physical optics (PO) is used to compute the electromagnetic scattering from the windturbine [4].
- The VOR antenna is at 3m above the ground with a counterweight of 3m diameter.
- The radars are a TRAC2000 at 1.3GHz and a STAR2000 at 2.7GHz. The antennas are at 20m above the ground.
- The polarization is horizontal.

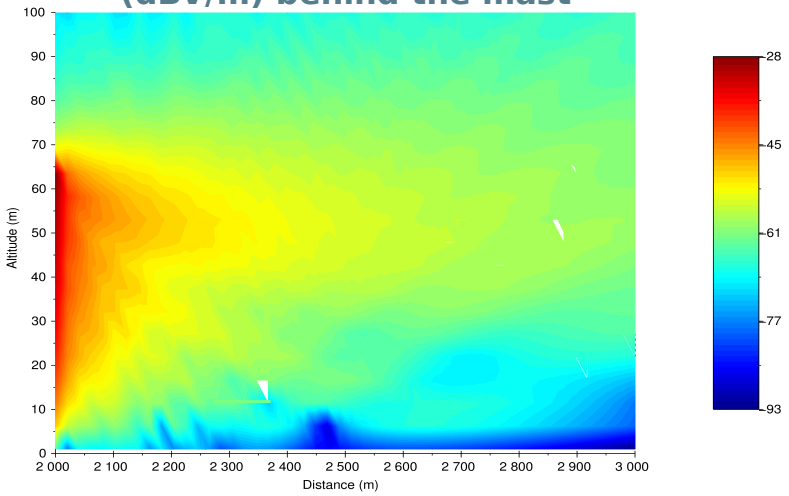


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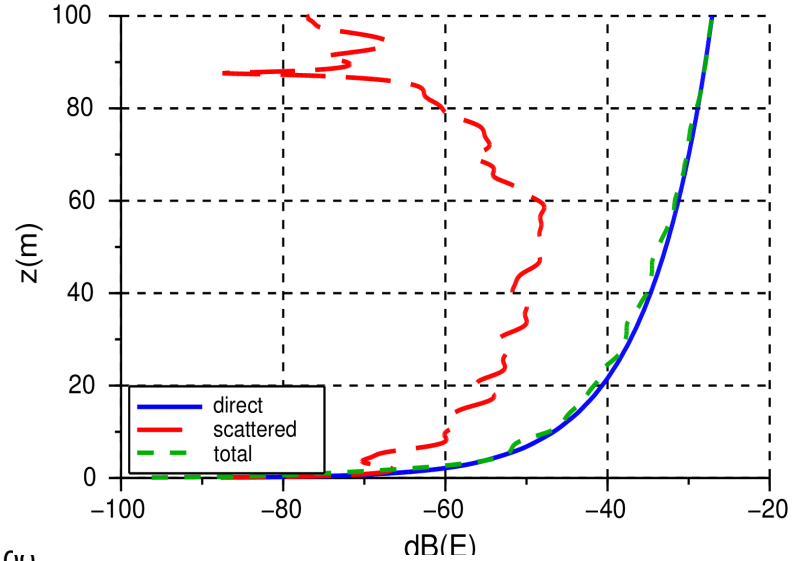
Assessment of the Shadowing Effect Between Windturbines at VOR and Radar frequencies

Simulations and results:

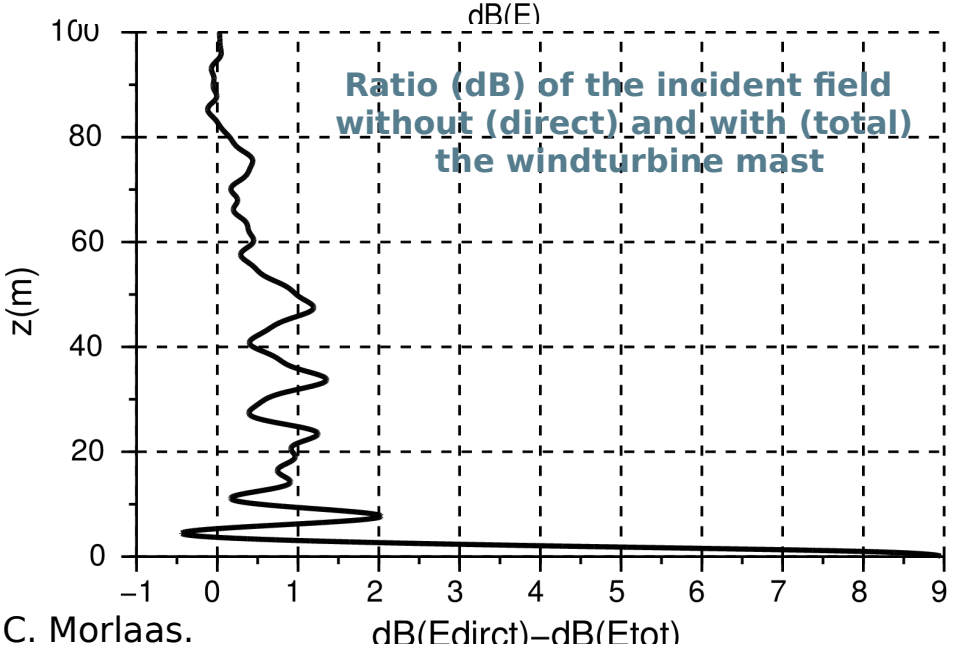
Electrical Scattered field (dBV/m) behind the mast



Electrical fields (dBV/m) in a vertical plane at 140 m behind the mast



Ratio (dB) of the incident field without (direct) and with (total) the windturbine mast



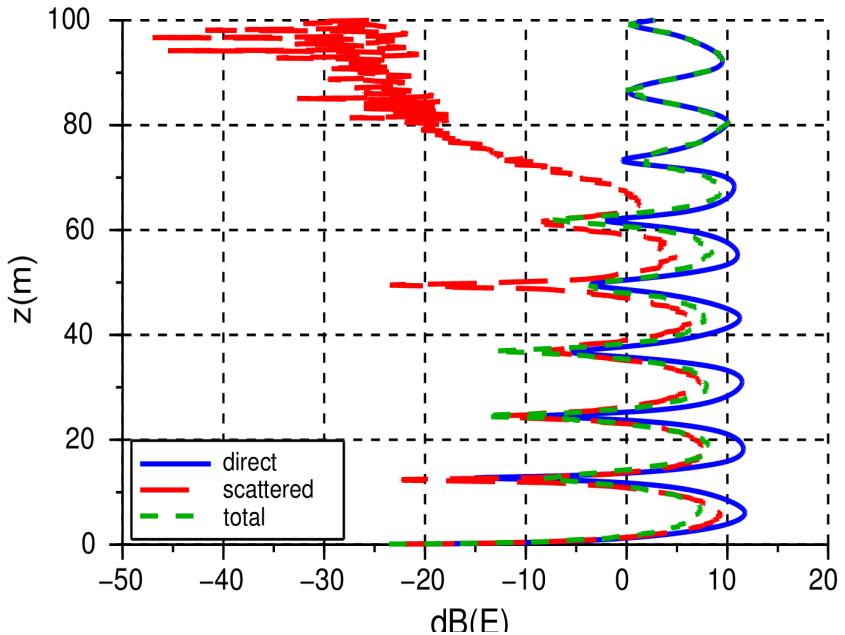
- **For the VOR frequency at 114MHz,** the scattered field rapidly decreases behind the windturbine mast.
  It rapidly becomes negligible compared to the incident field.

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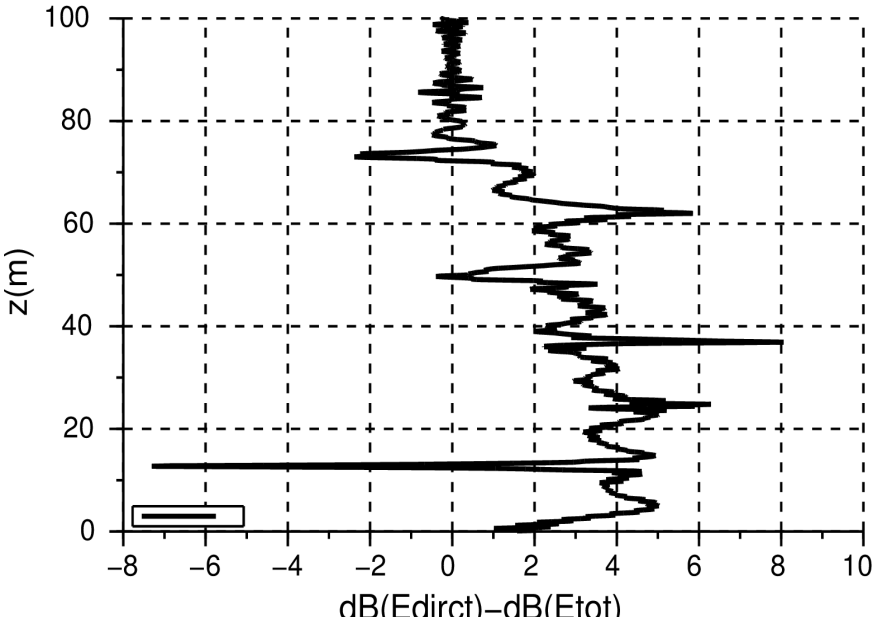
Assessment of the Shadowing Effect Between Windturbines at VOR and Radar frequencies

Simulations and results: TRAC2000 Radar at 1.3GHz

Electrical fields (dBV/m) in a vertical plane at 140 m behind the mast



Ratio (dB) of the incident field without (direct) and with (total) the windturbine mast



- **For the radar frequency at 1.3GHz** at two rotors distance between windturbines **the shadowing effect should be considered** between successive windturbines.

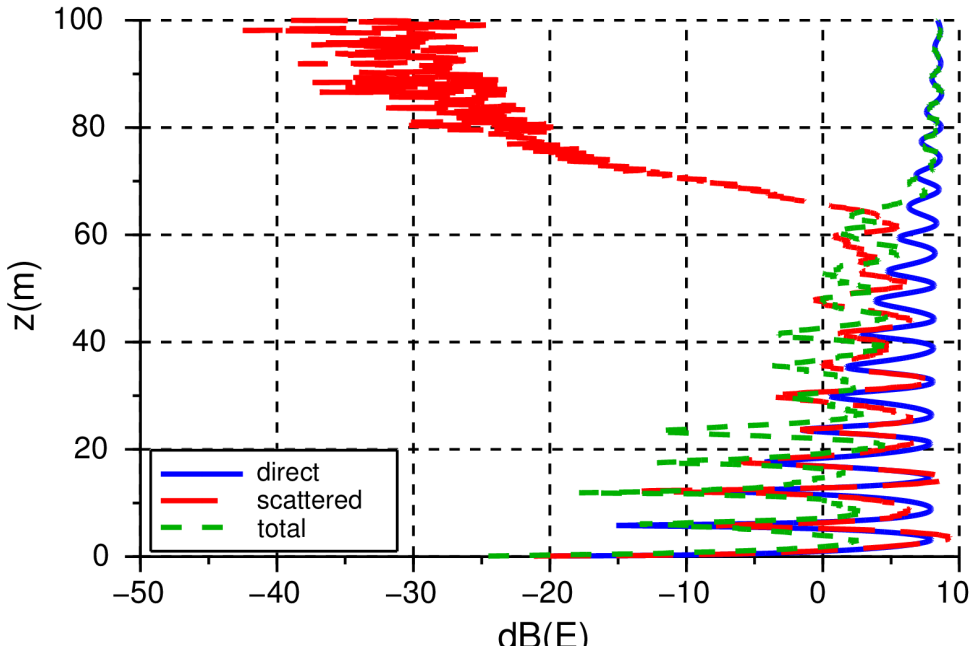
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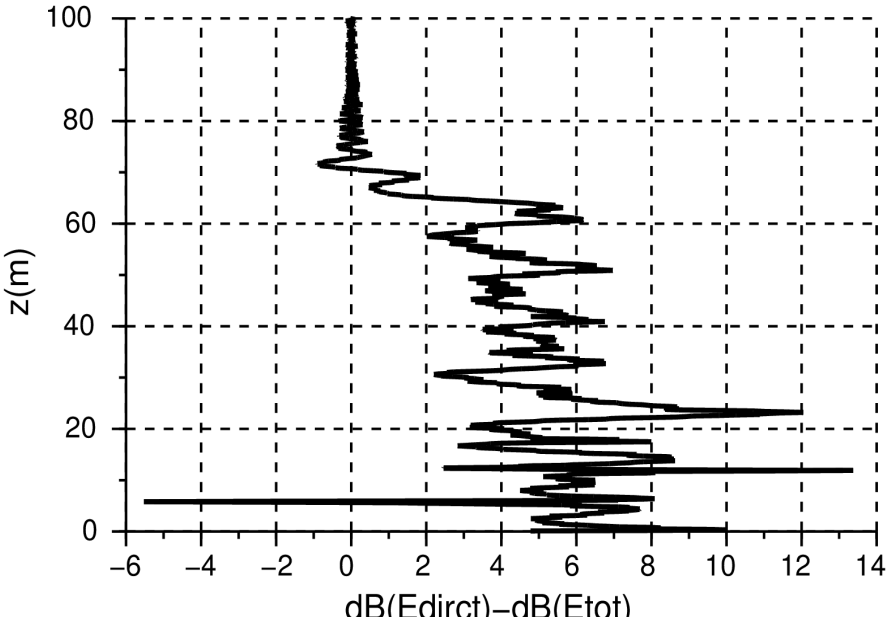
Simulations and results:

STAR2000 Radar at 2.7GHz

Electrical fields (dBV/m) in a vertical plane at 140 m behind the mast



Ratio (dB) of the incident field without (direct) and with (total) the windturbine mast



- **For the radar frequency at 2.7GHz,** at two rotors distance between windturbines **the shadowing effect must be considered** between successive windturbines

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Conclusion:

It has been investigated the assessment of the shadowing effect behind a windtur-bine mast for the windturbine alignment at VOR (114 MHz) and radar frequencies (1.3 GHz and 2.7 Ghz).

For further work it will be relevant to add the rotor-blades effect

Incident field ratio w/ and w/o windturbine	VOR 114MHz	Radar 1.3GHz	Radar 2.7GHz
Max. Difference	< 2dB	< 5dB	< 7dB
Typical Difference	1 dB	> 2 dB	> 4dB
Neglect winturbine interactions?	Yes	May be	No

For the **VOR system**, no significant shadowing effect is observed.
- Windturbines alignment is not efficient to reduce their impact.
- Windturbine interactions can be neglected in electromagnetic simulation tools.

For **radar frequencies**, the incident field ratio with and without windturbine shadowing is around 4 dB and 6 dB for 1.3 GHz and 2.7 Ghz, respectively.
- It could be relevant to align windturbines to reduce their impact.
- Windturbine interactions must be accounted in electromagnetic simulation tools.

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