Assessment of the Shadowing Effect Between Windturbines

Ludovic Claudepierre, Rémi Douvenot, Alexandre Chabory, Christophe Morlaas

Assessment of the Shadowing Effect Between Windturbines

Ludovic Claudepierre, Rémi Douvenot, Alexandre Chabory, and Christophe Morlaas.
ENAC, TELECOM/EMA, F-31055 Toulouse, France and Toulouse University, F-31400 Toulouse, France.
E-mail: morlaas@recherche.enac.fr

***Abstract*—At VOR or radar frequencies, the field scattered by a windturbine can illuminate nearby windturbines. This depends on the distance between the two windturbines and also on the frequency. This paper proposes an assessment of the shadowing effects between two windturbines at VOR and radar frequencies for typical distances. The interactions between the windturbines is shown to be negligible at VOR frequency while at radar frequencies, it is not the case.**

***Index Terms*—VOR, RADAR, windturbines, shadowing.**

I. Introduction

Due to the fast-growing of green energy, projects of windfarms 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]–[6].

Generally, robust modelling methods (MoM) are used to compute the field scattered by the windturbines [2], [3]. However, assumptions must be done to save memory and computation time and different modelling methods are based on RCS computation [4], physical optics [5], [6] or UTD [2].

Besides, the following assumptions are found in literature: blades are sometimes considered metallic [1], [5], and 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. Here, the necessity to account for the shadowing effect between windturbines is established to notify wind-energy developer about the shadowing effect of windturbines.

In section II, the configurations of the studied problems are given. In section III, the shadowing effect for a windturbine mast at VOR frequency (114 MHz) is studied. In section IV, the same study is performed at radar frequencies (1.3 GHz and 2.7 GHz). Finally, conclusions and discussion are in section V.

II. Geometric and Electromagnetic Configuration

The modelled windturbine is an ENERCON-E66. The mast is a metallic cone (height = 64.17 m, top diameter = 2.18 m, bottom diameter = 4.17 m). The rotor blades diameter is 70 m. The windturbines are commonly separated of 2 to 5 rotor diameters. In this study a separation distance of 2 rotor diameters is used (140 m) to consider a worst case (the most significant shadowing effect).

Only one windturbine mast is considered located at 2000 m from the VOR station and the scattered field is calculated up to 1000 m behind the illuminated mast. Fig. 1 gives an illustration of the scenario.
The terrain between the VOR station and the windturbine mast is considered flat and perfectly conductor. The incident field is computed with a parabolic equation method (PE).
Physical optics (PO) is used to compute the electromagnetic scattering from the windturbine. For the sake of conciseness, the validation of PO with MLFMM is not shown in this paper and can be found in [6] at the VOR frequency. For radar frequencies, as the object dimension with respect to wavelength is larger, the PO accuracy is improved. The scattered field is computed in a plane behind the illuminated windturbine.

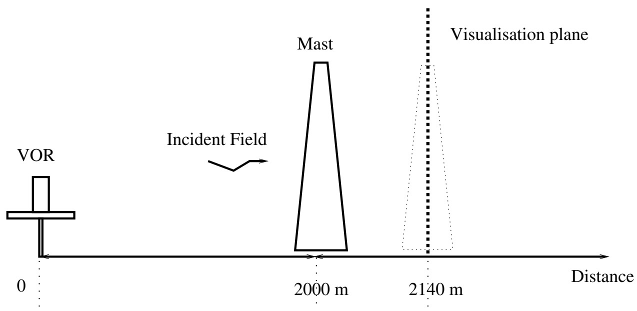

Fig. 1. Geometry of the simulations.

III. Simulations and Results for VOR Devices

The source is a C-VOR antenna at 114 MHz in horizontal polarisation with the following parameters: a half-wavelength magnetic antenna at 0.5 m above a counterweight of 3 m diameter at 3 m above the ground.

The rotor blades are not considered due to their dielectric composition which generates a lower scattering field compared to the one of the mast for this frequency [3], [6].

In Figs. 2 and 3, the incident field in the absence of windturbine and the field scattered by the windturbine are displayed. The scattered field rapidly decreases behind the windturbine mast. Thus, it rapidly becomes negligible compared to the incident field.

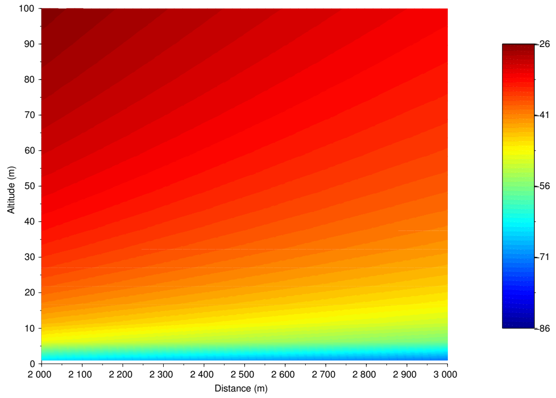

Fig. 2. Incident field (dBv/m) from a VOR station at 0 m in the absence of windturbines.

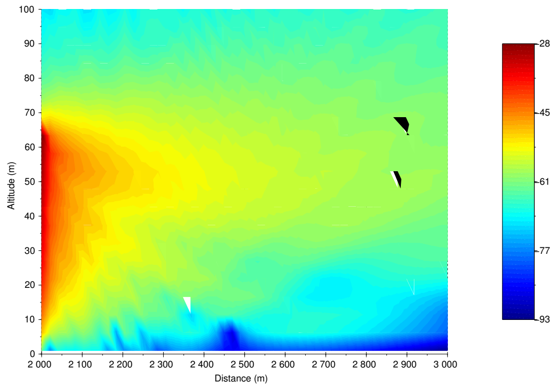

Fig. 3. Field scattered (dBV/m) by a windturbine mast at 2000 m illuminated by a VOR station at 0 m.

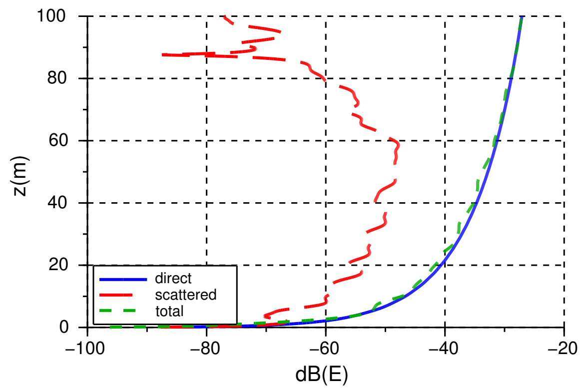

Fig. 4. Electrical fields (dBV/m) for the VOR device in the visualisation plane (z is the altitude). Scattered field (red), incident field (blue), and total field (green)

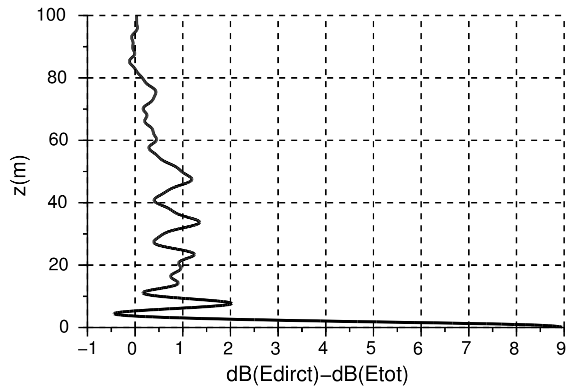

Fig. 5. Difference (dB) between the total field (dBv/m) in the presence of a mast and the incident field (dBv/m) in a vertical cut (z is the altitude) for the VOR device.

In a vertical cut at 140 m behind the mast (distance= 2140 m, the scattered field is compared with the incident field (in the absence of the mast) and with the total field (incident plus scattered field) (Fig. 4). The difference between the total field by a mast and the incident field is plotted in Fig. 5 at 140 m from the mast. The difference is lower than 2 dB and decreases for higher altitudes. Then, at two rotor distance between two windturbines, no shadowing effect can be considered for VOR system.

IV. Simulations and Results for Radar Devices

The radiation pattern of a TRAC2000 antenna at 1.3 GHz and a STAR2000 at 2.7 GHz, both in horizontal polarisation at 20 m above the ground. Antenna tilts of 1.2° and 2.3° are considered, respectively.

A. Radar at 1.3 *GHz*

The same simulation as for the VOR device is performed for a primary radar at 1.3 GHz. In the vertical cut at 140 m behind the mast, the scattered field is compared with the incident field (in the absence of windturbine) and with the total field (incident plus scattered field) in Fig. 6. The difference between the total field and the incident field is plotted in Fig. 7 at 140 m behind the mast. The maximum difference is less than 5 dB and greater than 2 dB below the mast height (64m).

Then, at two rotors distance between windturbines, the shadowing effect should be considered between successive windturbines.

B. Radar at 2.7 *GHz*

At 2.7 GHz, in a vertical cut at 140 m behind the mast the scattered field is compared with the incident field (in the absence of windturbine) and with the total field (incident plus scattered field) (Fig. 8). The difference between the total field and the incident field is also plotted in Fig. 9 at 140 m behind the mast. The maximum difference between the total field and the incident field is less than 7 dB and greater than 2 dB below the mast height (64m).

Then, at two rotors distance between windturbines, the

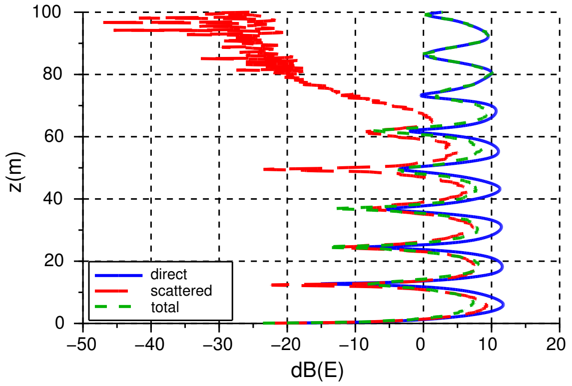

Fig. 6. Electric fields (dBV/m) in a vertical cut (z is the altitude); Scattered field (red), Incident field (blue), and total field (green) at 1.3 GHz

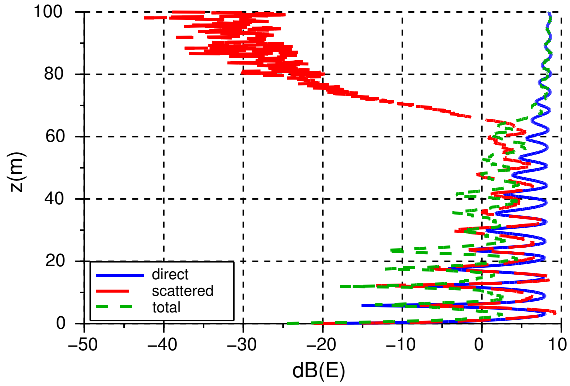

Fig. 8. Electric fields (dBv/m) for a radar device at 2.7 GHz in a vertical cut (z is the altitude). Scattered field (red), incident field (blue), and total field (green).

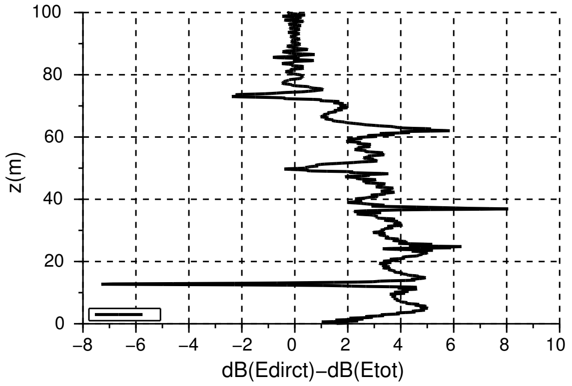

Fig. 7. Difference (dB) between the total field (dBV/m) and the incident field (dBV/m) in a vertical cut (z is the altitude) at 1.3 GHz

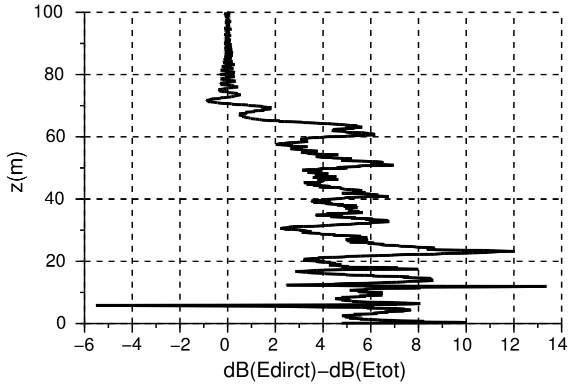

Fig. 9. Difference (dB) between the total field (dBv/m) and the incident field (dBv/m) in the visualisation plane (z is the altitude) at 2.7 GHz.

shadowing effect must be considered between successive windturbines and the alignment of windturbines may be an efficient strategy to reduce the windturbines effects.

Moreover, at this frequency, the rotor-blade may increase the shadowing effect and should be taken into account in further works.

V. Conclusion

The assessment of the shadowing effect behind a windturbine for the windturbine alignment has been addressed at VOR (114 MHz) and radar frequencies (1.3 GHz and 2.7 GHz).

For the VOR system, no significant shadowing effect is observed. Thus, windturbines alignment is not efficient to reduce their impact. Moreover, windturbine interactions can be neglected in electromagnetic simulation tools.

For radar, the difference between the incident field and the total field is around 5 dB and 6 dB for 1.3 GHz and 2.7 GHz, respectively. Hence, it could be relevant to align windturbines to reduce their impact. Besides, the windturbine interactions must be accounted in electromagnetic simulation tools.

Acknowledgment

The authors wish to acknowledge the DGA/DSNA/DTI for supporting this work.

References

[1] D. de la Vega, C. Fernández, O. Grande, I. Angulo, D. Guerra, Y. Wu, and P. Angueira, J. L. Ordiales, "Impact of wind farms on radiocommunication services," *Proc. in Int. Symp. on Broadband Multimedia Systems and Broadcasting (BMSB)*, 2011.

[2] M. J. Algar, L. Lozano, J. Moreno, I. González, and F. Cátedra, "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] 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.

[4] D. Jenn, and C. Ton "Wind turbine Radar cross section," *International Journal of Antennas and Propagation*, Art. ID 252689, 2012.

[5] A. C. Casanova, P. H. Pathak, and M. C. Ramon, "Modeling windmill interference via hybrid parabolic equation and Equivalent Current approximation methods," *Proc. in Int. Conf. on Electromagnetics in Advanced Applications (ICEAA)*, 2011.

[6] 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.