Computing the Influence of Wind Turbines on RF systems taking into account terrain.

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1. Introduction

The main effects of wind turbines on radars have been described in previous papers [1-3]. They include shadowing by the larger parts and generation of false echoes. Previous studies have been focusing on the influence of moving objects, such as wind turbines, on aeronautical and maritime radars, usually working in the L/S band and in the X-band respectively. Here, we will not only take into account terrain properties, but also compute systems very close to each other and at lower frequencies, where UTD is not valid any more. Also, particular attention will be paid to the computations of systems that are in the near-field of the antenna.

2. Shadowing

If we consider as a good approximation for the effects of the shadowing by a perfectly conducting electric plate the computation of the diffractions around the vertical edges of this plate, we usually obtain a good agreement with a more elaborate UTD computation when the antenna is sufficiently far away from the turbine as to be considered as a point source. All figures here assume vertical polarization. We could even use the standard ITU diffraction formulas to approximate the attenuation of the turbine by:

$$L(\nu) \quad [dB] = 6.867 + 20 * \log_{10}[\sqrt{(\nu - 0.1)^2 + 1} + \nu - 0.1] \tag{1}$$

where $\nu = a\sqrt{\frac{2}{l\lambda}}$ and $\frac{1}{l} = \frac{1}{d_1} + \frac{1}{d_2}$, with the distances the distances to the radar and the observer. This allows us to easily represent the interference pattern (Fig. 1).

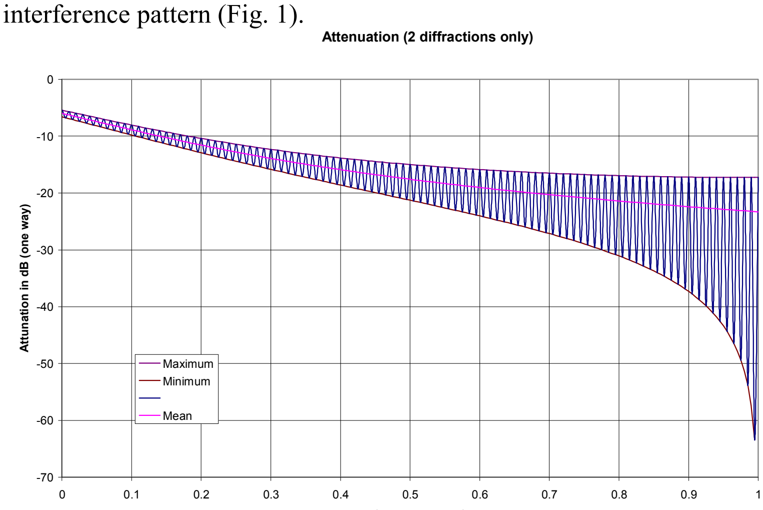

Fig. 1: Interference pattern behind a turbine.

We had also shown that there was a deep shadow zone (where the field was attenuated more than 22.3 dB) up to the following distance:

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$$d_{schaduw} = \frac{1}{[5\lambda/(4R_t^2) - 1/d_{radar}]} \tag{2}$$

However, this interference pattern does not occur if the turbine is not illuminated by the radar or the communication system. This aspect was, due to the flatness of Belgium, mostly neglected up to now. Recently, terrain data of acceptable accuracy became freely available from NGA/NASA Shuttle Radar Topography Mission for a large part of the world including Belgium. We have verified that the difference between the more accurate data of the National Geographic institute and this particular distance does not exceed the accuracy of the data (+- 3 m; Fig. 2).

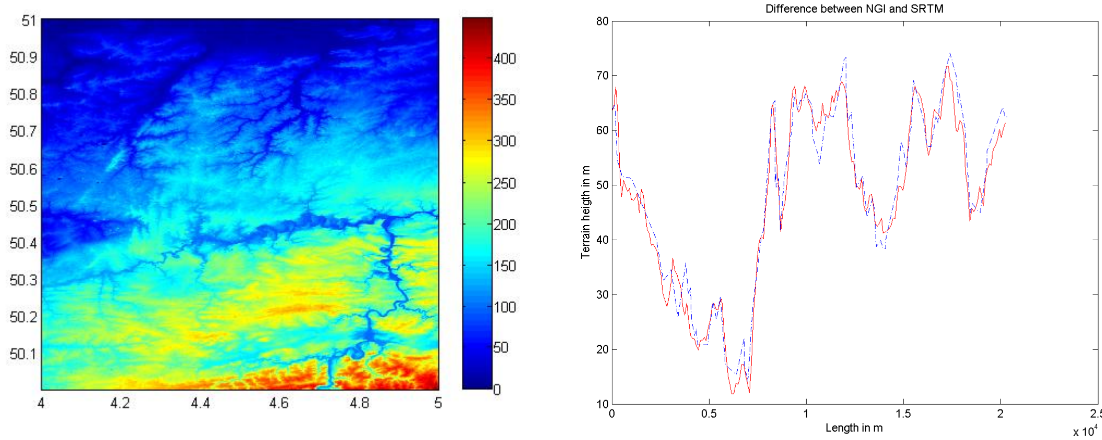

Fig. 2: left: terrain of Belgium (x-axis=° East; y-axis=° North); right: comparison between the data provided by the Belgian National Geographic institute and the SRTM (one random cut over about 20 km).

Adding the height above the chord assuming normal wave propagation (by using a fictitious earth radius equal to 4/3 of the real earth radius), we can determine both the visibility angle and the non-illuminated part (Fig. 3).

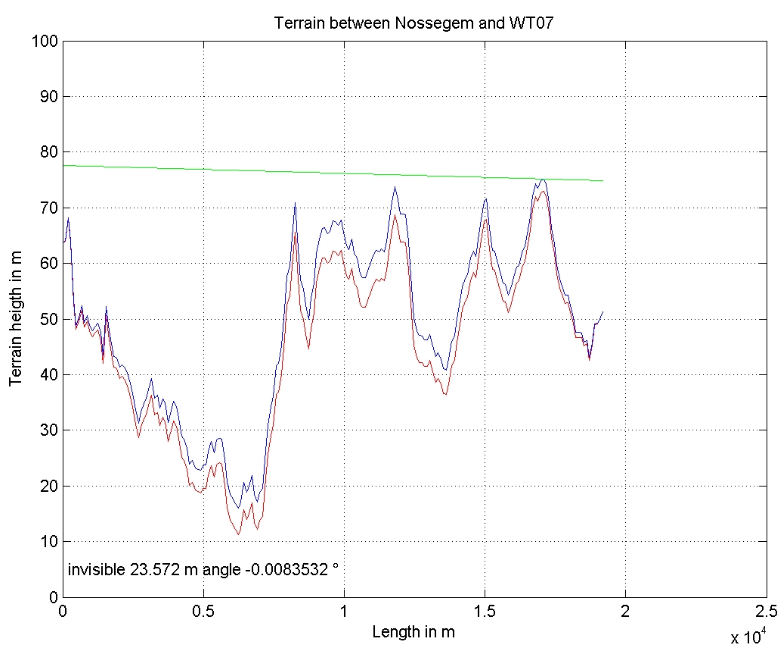

Fig. 3: determination of the non-illuminated part taking into account terrain, showing that the lowest 23.6 m are not visible from the RF source located at 0 on a 14 m high tower.

For very close systems, a complete description of the antenna is required. A significant difference between an approximation by a point source (Fig. 4, left) and a linear array (Fig. 4, right) with nearly no shadowing can be seen. The deep shadowing behind the tower has also nearly disappeared.

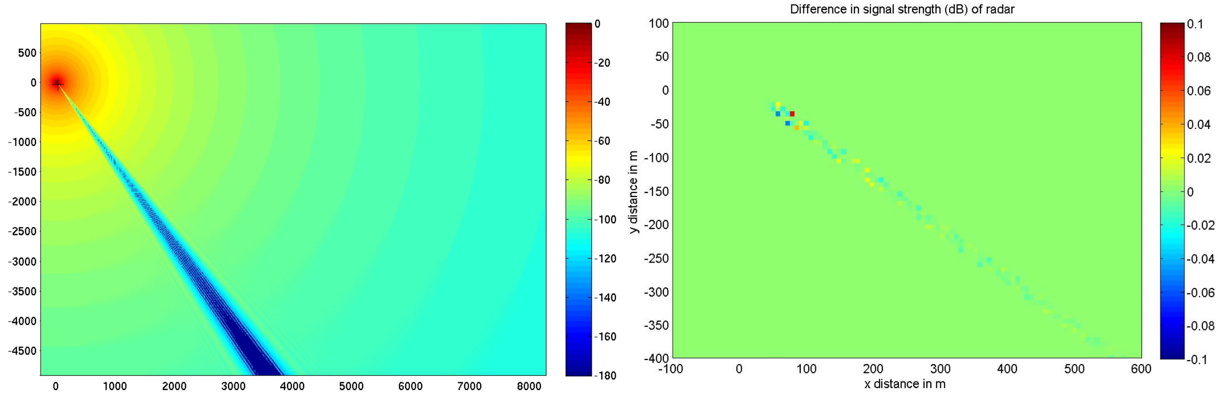

Fig. 4: difference between the radar considered as a point source and a linear equidistant array.

3. False Echoes

Here too, combined effects of near-field and visibility can be observed. Because the tower is inclined due to the curvature of the earth with respect to the RF source, the radar cross section will never attain the very large theoretical far-field values (Fig. 5). We distinguish the 3 zones: the first for d<R, the RCS increases with the square of the distance, then it increases with the square root, to obtain its final value as found in the textbooks [4] at a distance of about $2D^2/\lambda$, where D is the largest illuminated part of the tower. The effect of the inclination of the earth is shown in the dash-dotted line.

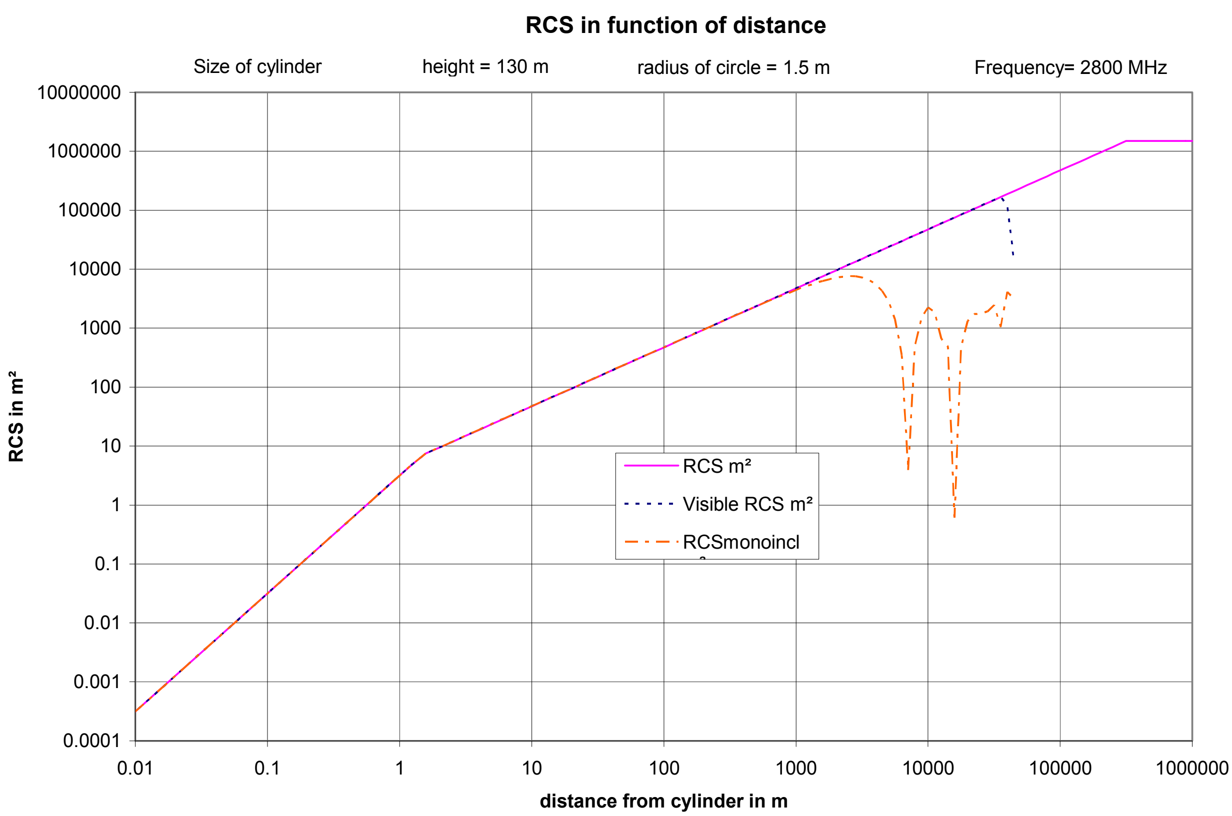

Fig. 5: Near-field monostatic radar cross section of a turbine tower.

4. Communication system.

Here, we have uses moment methods to compute the fields accurately. The difference between the field with and without the turbine has been computed for 12 different positions of nacelle and blades. The 2 worst cases are shown in Fig. 6. By placing the communication antennas below the lowest blade position, we have limited the effects to 8.32 dB at 118 MHz and 3.20 dB at 156.3 MHz. One antenna was placed at 35 m above the ground, and the receiving antenna was placed at 25 m above the ground. For maritime communications using FM, those small variations (and at a low modulation frequency) will not influence significantly the intelligibility of the speech.

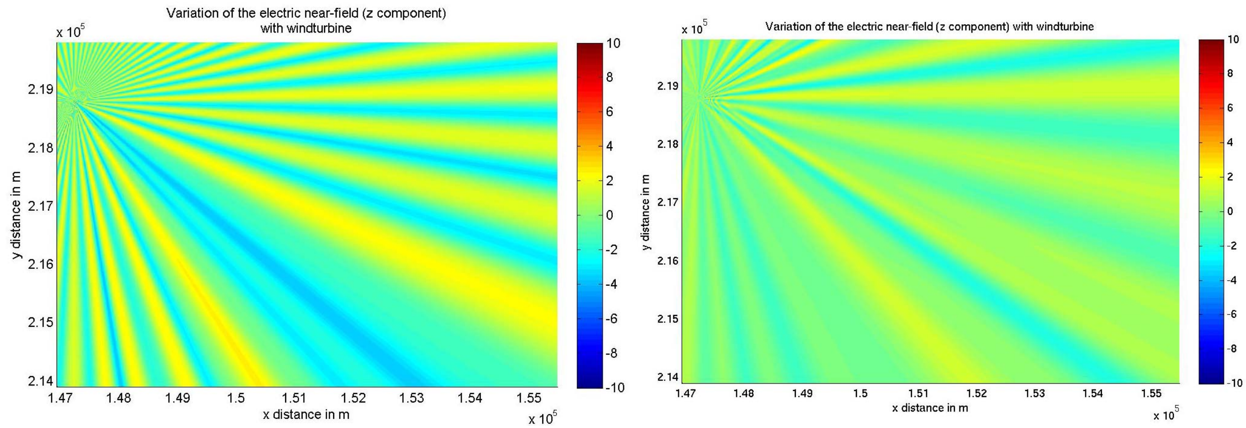

Fig. 6: Worst case deviations (left: 118 MHz, nacelle WE, blades 40°; right 156.3 MHz, nacelle NS, blades 40°).

5. Conclusions

The study of close objects requires significantly different methods than those used in standard (previous) studies (aeronautical and maritime). We have shown that with a good antenna and turbine modeling, it is possible to place the turbine much closer than would be allowed with the standard procedures and assumptions. In fact, in this case the turbine is located at about 40 m from the RF systems. For the radar systems, the configuration was such that the radar coverage in the direction of the tower was not required (it was looking towards the shore for a maritime radar) and that this sector could be turned off.

6. Acknowledgments

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7. References

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