

The Electromagnetic Scattering within System Simulations for Distortions of Navigation, Landing and Radar Systems

Gerhard Greving

NAVCOM Consult, Ziegelstr. 43, D-71672 Marbach/Germany; navcom.consult@t-online.de

Abstract

Modern systems, e.g. navigation, landing, radar and communication systems, rely on the physics of antennas and propagation. Their electrical performance is determined by the intended radiation and by the scattering of distorting objects. The scattering analysis is an integral part of the system simulations. The modeling of the antennas, the environment, the distorting objects and of the system itself are the basic steps of the simulation process. This paper describes the aspects of the scattering within the state-of-the-art system simulations by evaluating actual examples, such as the new A380, a system with rotating antenna pattern and wind turbines.

1. Introduction

Numerical system simulations are carried out today for the analysis of distortions on navigation or radar systems by scattering objects. The systems are quite different in terms of application, frequency and distortion mechanism, e.g.

- Navigation and Landing systems (e.g. NDB, ILS, VOR, GPS, MLS) ranging in frequency up to 6GHz,
- ATC Air Traffic Control radar system (primary and secondary radar) at about 1GHz and 3GHz,
- Military Radar covering a wide range of system types and frequency range.

The systems consist typically of several functional parts to be modelled

- a transmitter and its associated antenna [1]
- an environmental part and wave propagation section (“scattering part”) [1]
- a receiver and its associated antenna.
- a signal processing part.

The objects to be analyzed (e.g. Fig. 1) are very much different in their geometrical and electrical sizes, their structure (e.g. resonant or long wires, large structured and/or curved surfaces), and by the much different frequencies.

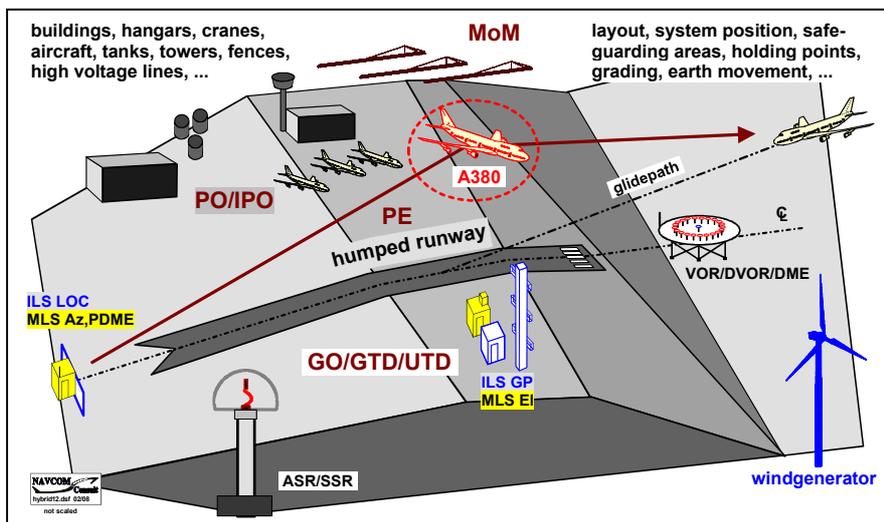


Fig. 1: Scattering objects and navigation, landing and radar systems around an airport

Some examples will be studied showing theoretical and numerical problems and aspects in the

- modeling, e.g. the grazing angle incidence [3],[4]
- numerical method, e.g. failure of simple PO and simple flat models [4],
- system modeling and its interpretation of the scattering results.

2. System Simulation and Scattering

The discussed system simulations consist of major modeling tasks, such as the sources, the environment and the system itself which includes the system processing and the subsequent numerical analysis.

In each of the modeling steps of the simulations, serious errors can be made. The most important rule for the modeling in all steps is to model as accurate as possible, but also only as required or needed. The modeling in all the steps must include the factors and parameters which have significant impacts on the final results. The numerical system simulations must reflect and model the most important parameter or quantity of interest, i.e. the so-called system parameter such as bearing or range errors. System and signal processing aspects determine the scattering analysis as well, such as sampling, filtering and spectrum in case of time variant antenna pattern rotation or rotating parts of the scattering objects, e.g. the rotor blades of wind turbines.

Quite a number of numerical methods are available today to solve the scattering characteristics of the scattering object. The selection criteria are

- The electrical size and structure of the objects to be modelled and the distance to the antennas (source points),
- The electrical size and structure of the integrated antennas,
- The distances between the antennas and the field points (e.g. locations of the aircraft in space),
- The characteristics of the ground which have to be taken into account,
- The frequency and the materials to be taken into account.
- Potential necessity of taking into account multi-reflections, mutual coupling and nearfield effects.

Typically, the electrical distances to be taken into account are very large compared to the wavelength. Also, the objects are typically large compared to the wavelength, e.g. the A380 aircraft and wind turbines at 100MHz. The effects of these objects have to be evaluated systematically under all operational scenarios. By that often a large number of computer runs have to be carried out. In order to perform that in a reasonable time frame it is essential to define a simulation scheme which offers first the required accuracy but second to achieve the results by a practical effort in terms of computer storage and computing time.

In this situation the wide range of powerful discretization methods (finite element, finite differences, finite integration) cannot be used unfortunately, except for the analysis of details in case of a hybrid application. In order to reduce the computation time, asymptotic and high frequency numerical methods are used wherever possible. Also, brute force schemes by applying rigorous methods generally are impossible to apply. By that a suitable tradeoff between quite a number of conditions has to be processed (e.g. system requirements, accuracy, effort, time).

The following methods [1] are mainly used for the scattering and wave propagation analysis

- IPO *I*mproved *P*hysical *O*ptics (i.e. an extended PTD version)
- GTD/UTD (*G*eometrical or *U*niform *T*heory of *D*iffraction)
- MoM and MLFMM (*M*ethod of *M*oments; *M*ulti *L*evel *F*ast *M*ultipole *M*ethod) as rigorous methods
- PE (*P*arabolic *E*quation).

These and other methods are used in a hybrid manner in the so-called IHSS-scheme (*I*ntegrated *H*ybrid *S*ystem *S*imulations; Fig. 2) depending on the scenario and the application.

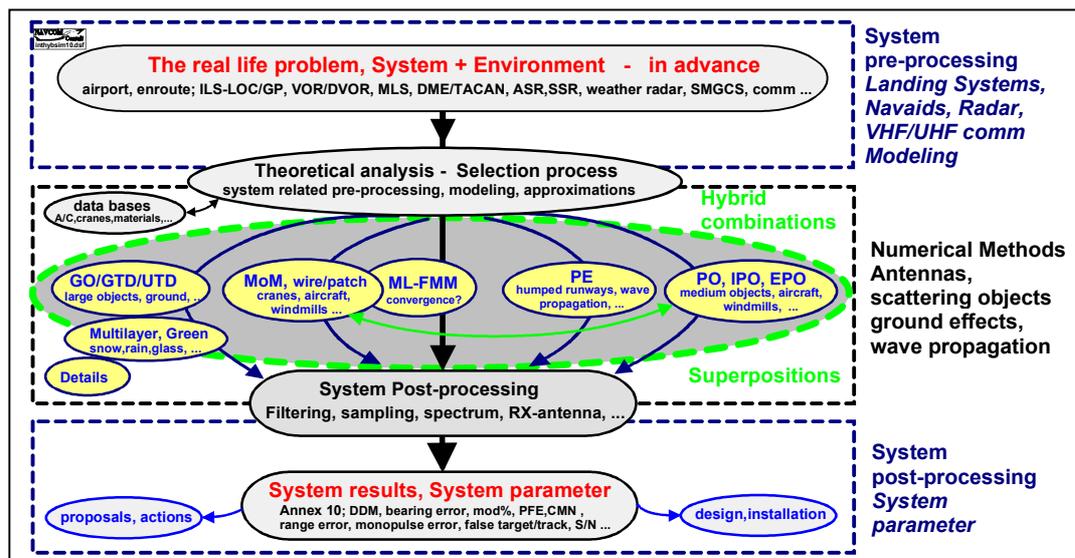


Fig. 2: Detailed signal flow of the developed and routinely exercised system simulation scheme IHSS

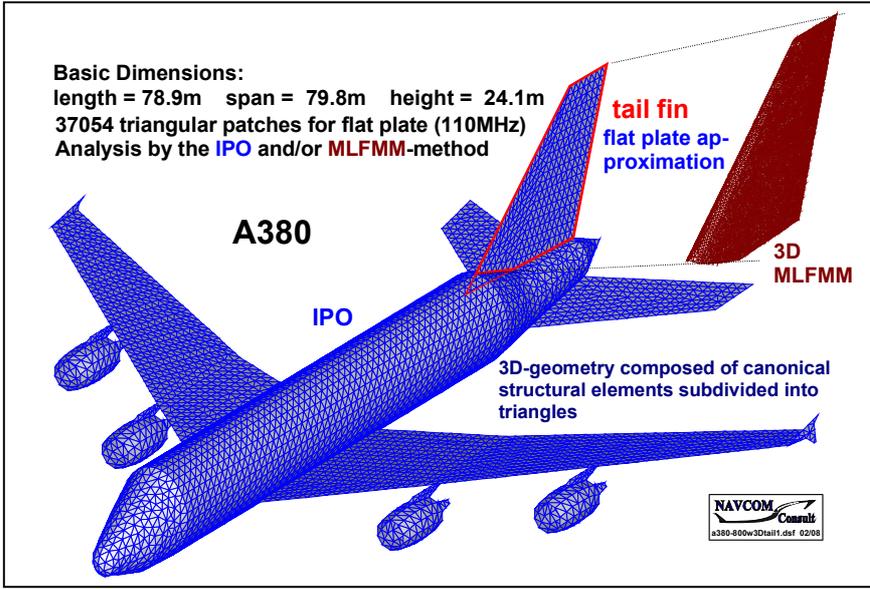


Fig. 3: 3D-model of the new aircraft A380 for ILS-system simulations

4). The case of the VOR/DVOR-navigation system is chosen. The scattered signal of the rotated pattern creates an unwanted spectrum which is analyzed numerically

- Numerical analysis of the Doppler effects of rotating blades of wind turbines WT on primary radar (Fig. 5). The radar cross section RCS [1,2,4] has been proposed to characterize the effects of the turbines. It is explained that this attempt is not valid. The scattered signal spectrum of the rotating blades is numerically analyzed.

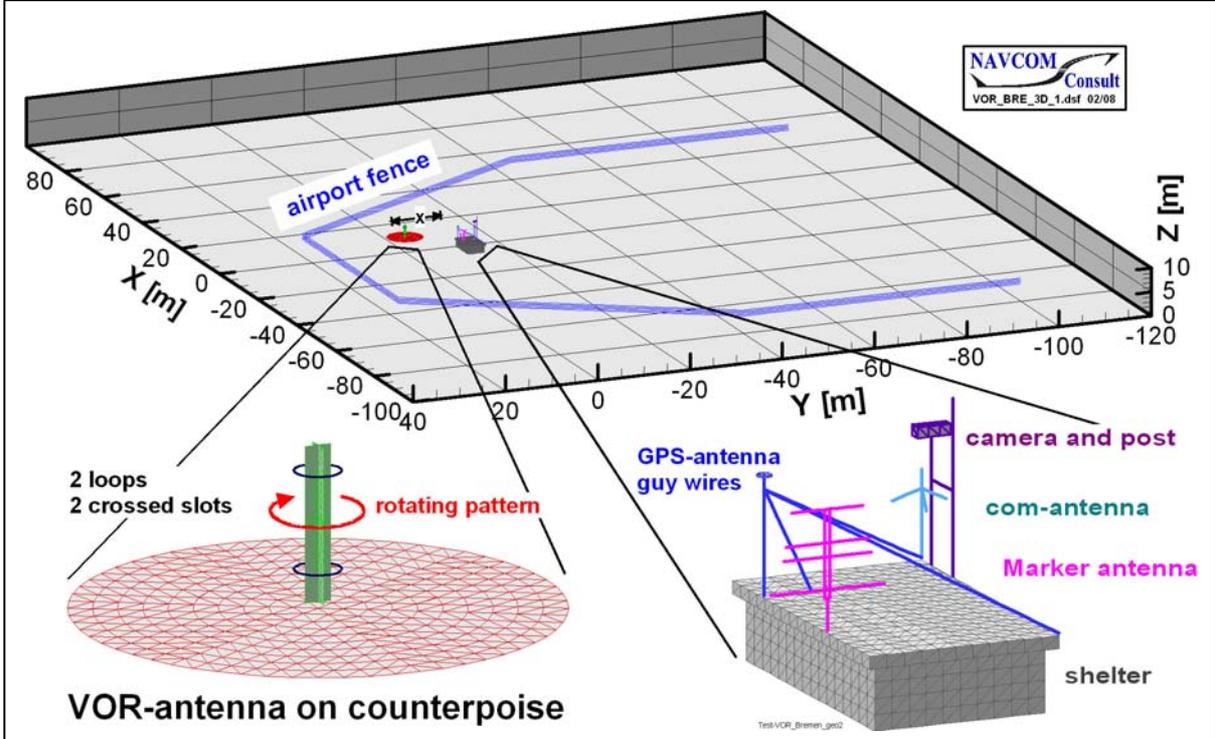


Fig. 4: Numerical 3D-model of a VOR-antenna having a rotating antenna pattern and a set of close and extended scattering objects in the analyzed scenario; spectral analysis

Several challenging actual scattering examples shall be discussed in the following shortly and in more detail on the conference:

- Efficient numerical system analysis of the A380 with regard to the Instrument Landing System ILS (Fig. 3; [3]) for all relevant operational scenarios. This is in particular for the parallel taxiways where the angle of incidence is grazing.
- Numerical analysis of the distortions of systems with rotating antenna patterns by close large objects (Fig.

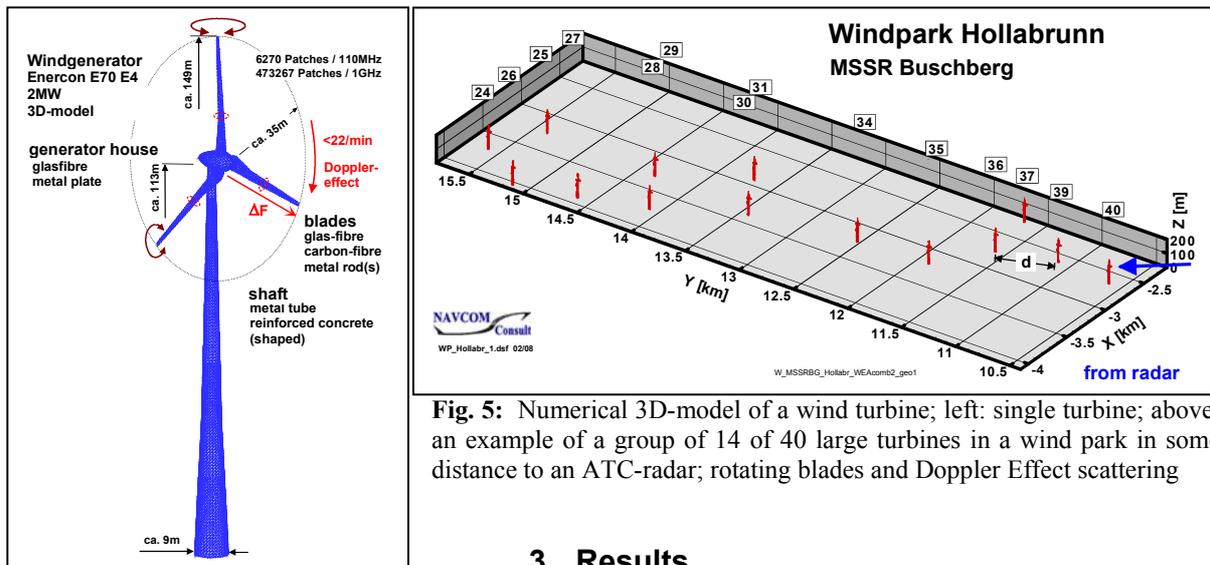


Fig. 5: Numerical 3D-model of a wind turbine; left: single turbine; above: an example of a group of 14 of 40 large turbines in a wind park in some distance to an ATC-radar; rotating blades and Doppler Effect scattering

3. Results

The following basic results have been achieved related to the numerical modeling, scattering analysis and methods:

- For the A380, in many cases of the scenario on airports the standard 3D-patch model (Fig. 3) is sufficient for the IPO-method having a flat tail approximation. However, in other scenarios, such as in the back of the Localizer-antennas and on the parallel taxiway under grazing angle incidence, the full 3D-tailfin has to be used in combination with MoM and/or MLFMM numerical methods have to be chosen. Simple flat plate models and simple PO-methods yield wrong results and are not justified by arguments of fast computation and simple modeling. The achieved numerical results agree quite well with presented field measurements.
- The case of the rotating VOR-antenna (Fig. 4) in the presence of close and extended objects can be analyzed only by a rigorous approach in the scattering part and by an advanced signal processing spectrum analysis approach of the time variant periodic field distortions. The numerical results agree again quite good with the available field measurements. The adapted spectrum scheme for the DVOR-system has been developed too.
- The scattering of wind turbines (Fig. 5) is often tried to characterize by the radar cross section RCS. It will be shown by theoretical and numerical means, that the RCS for wind turbines on the ground is not defined. The rotating blades produce a scattering spectrum by the Doppler-Effect. Numerical results achieved by the detailed 3D-model and the application of the IPO-method will be shown for radar and navigation systems. Results for the scattered Doppler spectrum and the shadowing of turbines will be presented.

4. Conclusions

Modern systems in the field of navigation and radar systems require the simulation of the electrical performance under the impact of distorting complex scattering objects in advance. A systematic approach has been discussed where the scattering analysis is an integral part embedded into the system simulation, consisting of a system related advanced pre- and post-processing. Three examples have been presented due to the modeling aspects and the selection and application of the numerical methods for the scattering analysis. Despite the complexity of the overall simulation the agreement between the simulations and the measurements is quite good showing the wide capabilities of modern numerical scattering analysis methods enabled by the recent dramatic increase of computer capabilities. The available concepts and the advanced numerical methods do not justify over-simple models and crude methods.

5. References

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