Numerical A&P Analysis Integrated into System Simulations for Radar and Navigation

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1. Introduction

Systems, such as navigation, landing, radar and communication systems, rely on the physics of antennas and propagation and signal processing. Their operational electrical performance is determined by the intended radiation and by the scattering of distorting objects, so-called multipath. In case of airport development or building plans close to these systems (Fig. 1), the expected electrical performance has to be predicted by appropriate means, i.e. numerical system simulations. The scattering analysis is an integral part of these system simulations which result in the decisive system parameter, may be the angle or range error used by the aircraft or by the radar depending on the system. The field analysis of the scattered or superposed field by itself does not help in almost all cases and tasks. The system simulation needs the processing of the field-quantities.
The scattering analysis of potential "false targets" or of the range reduction by shadowing for a radar are of interest too. Mostly these simulations are processed in advance before the objects are built and appear on the airports or in some close distance of the installed systems [1] – [5]. Due to the system risks, the simulations must be reliable and sufficiently accurate and, also, the numerical effort must be minimized and should be justified and tolerable.

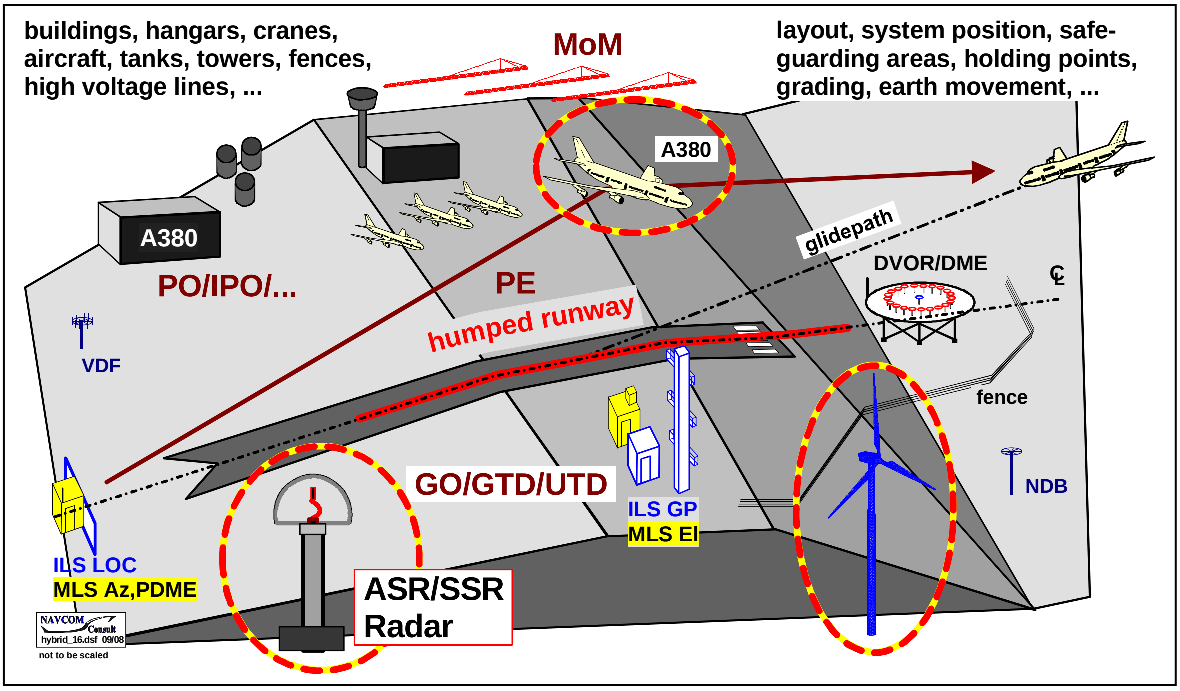

Fig. 1: Schematic of an airport, systems and various distorting objects; assignment of numerical methods

2. System simulations; Modelling and Numerical Methods

The discussed systems serve as navigation aids or air traffic surveillance means and offer the assigned system parameter or systems information to the user or operator, such as azimuth angle, distance or position or target information or also derived information for the landing aircraft, such as the difference angle to the extended centreline (called DDM, Difference of Depth of Modulation in case of the ILS Instrument Landing System). Accordingly, errors by the unwanted scattering at distorting objects (called “multipath”) may cause angle errors, distance errors, position errors etc. again depending on the system.

A typical task today is the advanced answer to the questions if a newly planned large building or the appearance of new large aircraft will have inacceptable effects on the electrical performance of the systems in question. By that, the advanced answer means a prediction of the distortions to be expected by adequate simulations before the objects are built or before the objects appear on the airport, such as the A380 or wind turbines in some distance to the systems.

The systems consist typically of ground and airborne antennas, transmitters and receivers and signal processing modules (Fig. 2) and the environmental propagation. Accordingly, the simulation has to reflect these functional modules by its simulating counterparts (Fig. 3); details are shown in Fig. 4.

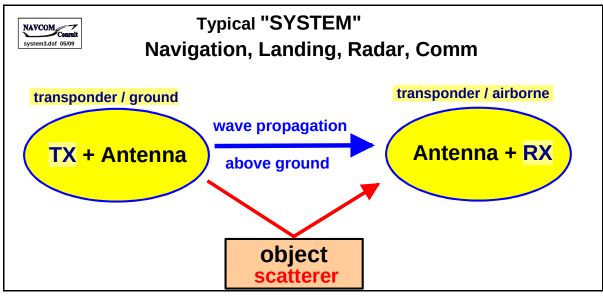

Fig. 2: Typical system

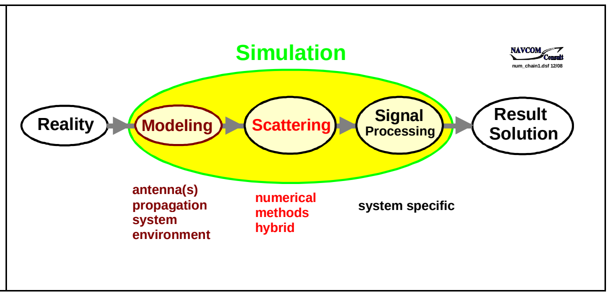

Fig. 3: Typical basic simulation flow

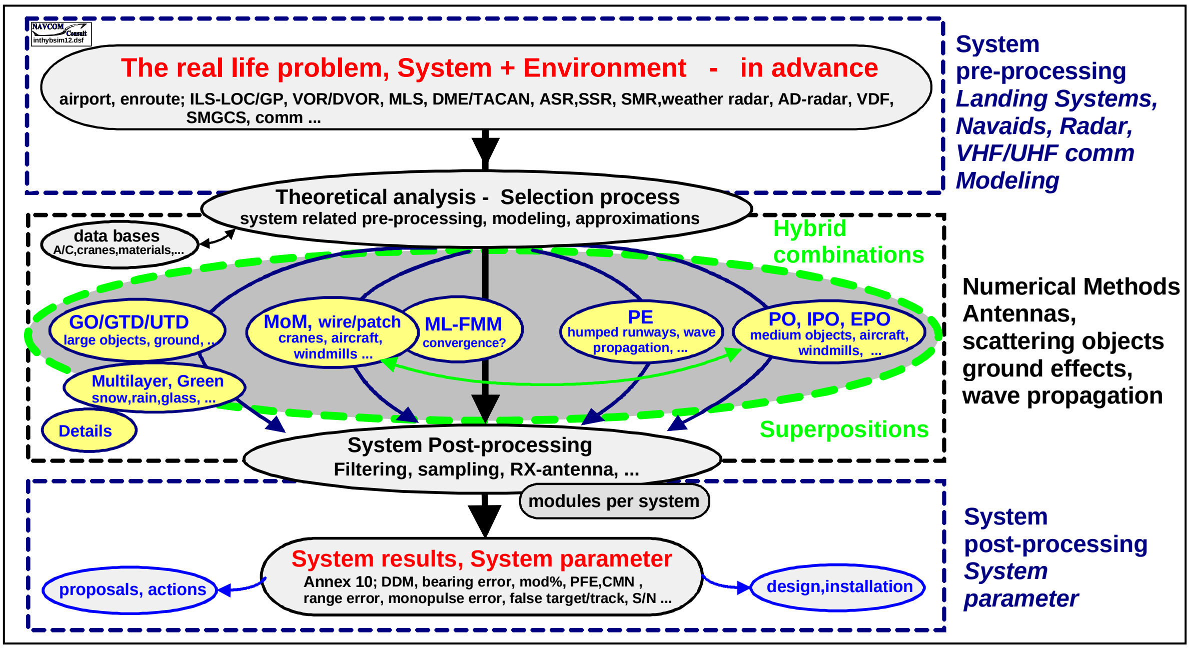

Fig. 4: Detailed flow chart of the integrated hybrid system simulation

Each block or module must reflect the correct physics. That is also for the numerical methods where the application rules must be followed strictly and artifacts may occur, e.g. discontinuities and large outliers in case of caustics if a problematic numerical method is chosen for the unsuitable situation. Sometimes, specialized system simulation tools offer just one simple basic numerical method for the scattering analysis, namely the simple PO Physical Optics applied to a flat (metallic) rectangular plate. The background is a fast analytic scattering component, namely the sinc-function sinx/x assuming the excitation by a plane wave. This may work if the scenario and the real boundary value problem allows that approximately. But in the general case the simple PO is not adequate at all, even if the object would be a flat plate. This is in particular for the gazing angle incidence case [2].

The numerical methods to be used depend on the size and structure of the objects to be analyzed: wire type structure, electrically very large objects, flat or curved surfaces, combinations of differently structured objects, nearfield scenarios etc. Also the relationship to the wave propagation determines the simulation methodology, such as an aircraft on a parallel taxiway to humped runway where the aircraft lands in the shadow of the hump. In this and other cases a hybrid approach is applied where different scattering analysis methods and wave propagation methods are combined and superposed. Often approximate methods are applicable (PO, PTD/IPO, GTD/UTD), but often as well rigorous methods have to be applied in order to get the required accuracy and reliability of the solutions in an acceptable time frame. However, rigorous or quasi-rigorous methods are often not applicable or require non-available resources on typical modern workstations, such as the Method-of-Moments MoM or the Multi-level-Fast-Multipole Method MLFMM.
Even the same object may require different analysis methods depending on the scenario. In the grazing angle case, i.e. on the parallel taxiway or for rolling off) the effects of the tailfin have to be analyzed by MoM or MLFMM (Fig. 5) for ILS landing systems (VHF 110MHz, horizontal polarisation). However, a systematic analysis of large structures by MoM/MLFMM is almost impossible.

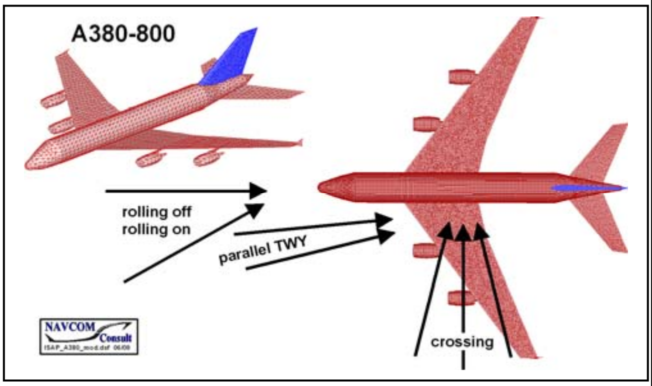

Fig. 5: Numerical 3D-model of an A380; different illumination angles; model consisting of a large number of metallic triangular patches

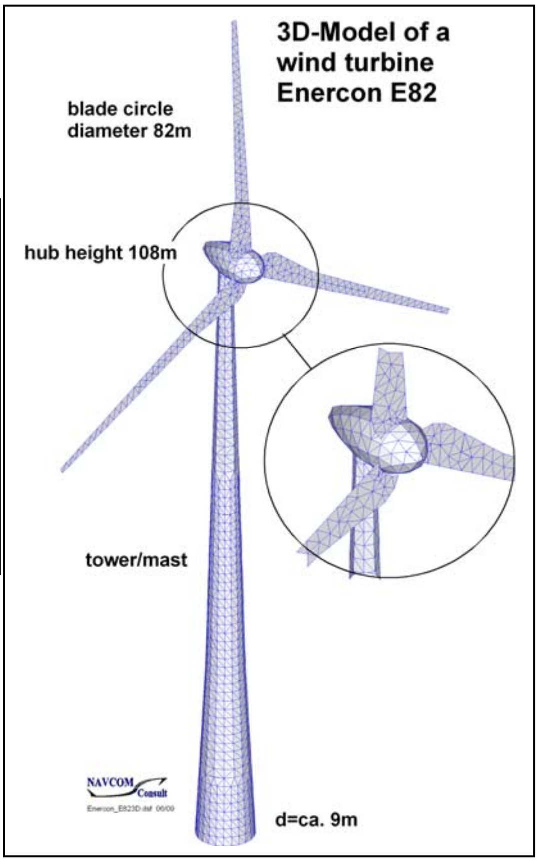

Fig. 6: Numerical 3D-model of a wind turbine Enercon E82 consisting of a large number of triangular patches

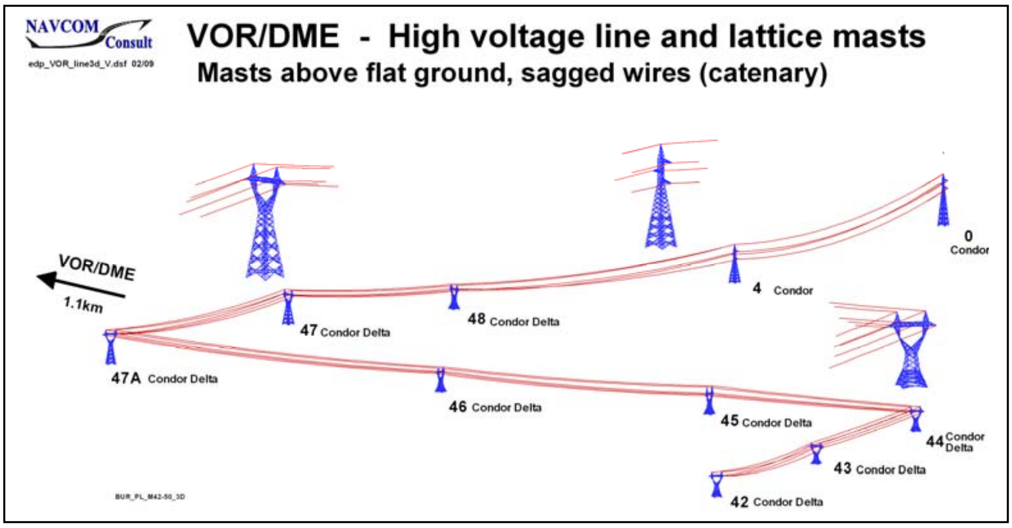

Fig. 7: Numerical 3D model of a high voltage line and lattice type masts close to a navigation station

Other actual complicated numerical models are shown in the Fig. 6 for radar and navaids and Fig. 7 for navaids applications. Details and results will be given on the conference.

3. Applications and Results

Only one example of a complicated case shall be shown in this paper. More examples and comparisons with measurements will be shown in the conference presentation.
The system parameter result for the ILS (Instrument Landing System) has been calculated on the runway for a rolling on position of an A380 inclined by about 30° on the airport Frankfurt. The so-called "raw data" and the processed filtered data are shown in Fig. 8 which agrees quite well with equivalent measured data also shown in the graphic.

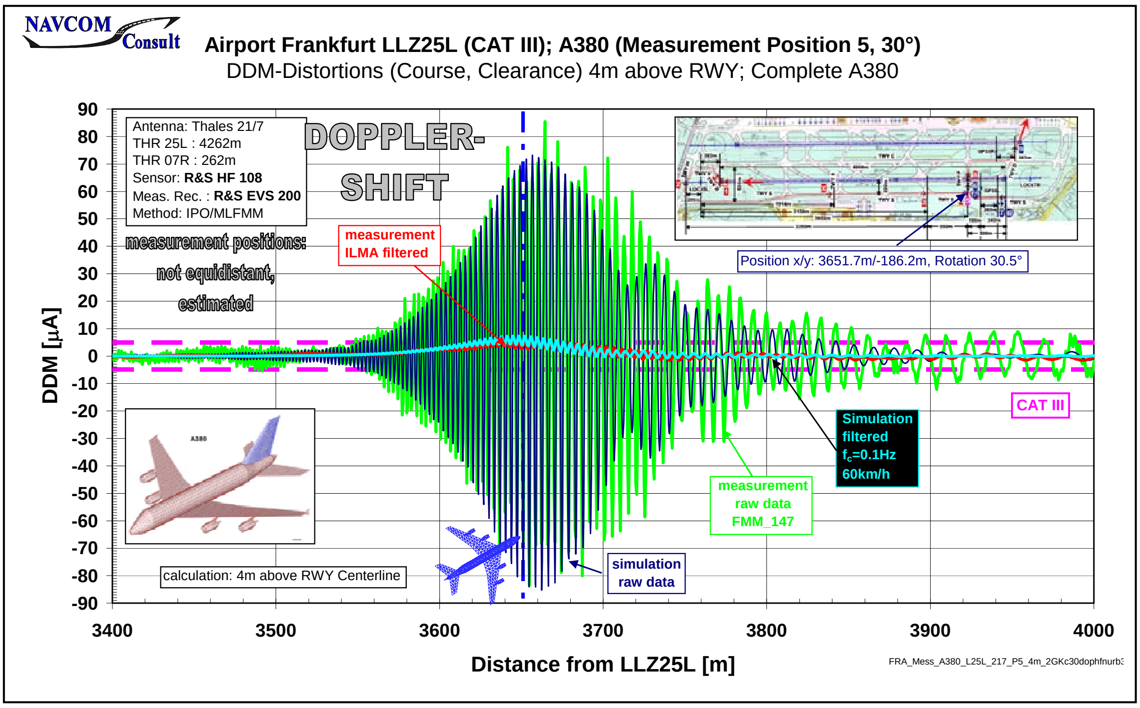

Fig. 8: Simulation of the DDM-system distortions caused by an A380 halting inclined for rollon

4. Conclusions and Summary

Modern system simulations rely on advanced antenna and propagation modelling, scattering analysis and subsequent signal processing. Even complicated cases can be solved today and can be used for the performance prediction of systems under the impact of distorting scattering objects. The agreement between the simulations and the measurements has shown to be excellent and promising.

References

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