VALIDATION OF NAVAL PLATFORM ELECTROMAGNETIC TOOLS VIA MODEL AND FULL-SCALE MEASUREMENTS

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Abstract

Reliable EMC predictions are very important in the design of a naval platform's topside. Currently EMC predictions of a Navy ship are verified by scale model and full-scale measurements. In the near future, the validation of software tools leads to an increase in the confidence in EMC predictions and (hopefully) removes the need for scale model measurements. In general, full-scale verification measurements will remain necessary although perhaps the number of measurements will be reduced. This paper presents our topside design experience, from rough estimations 40 years ago, to analytical calculations and model measurements 20 years ago, to the numerically supported process as it is now. It shows the process of validating simulation tools with model and full-scale measurements. It also describes the challenges encountered and the deficiencies of commercial tools used now and the roadmap for Thales Naval Netherlands towards integrated tools of the future.

Thales Naval Netherlands

Thales Naval Netherlands B.V., formerly Hollandse Signaalapparaten B.V. established in 1922, creates high-tech defence solutions for naval environments. We combine our extensive and long experience with an ongoing search for new techniques and possibilities. Modern and highly capable sensor suites, together with our combat management system, equip new generations of frigates, corvettes and fast attack craft throughout the world. Thales Naval Netherlands B.V. has been involved in ship topside design for more than 40 years. In those years numerous programmes have been completed for countries such as The Netherlands, Germany, the United Kingdom, Greece, Turkey, South Korea and Malaysia.

Background

The combat system of a modern Navy ship is very elaborate. It requires many radiating elements divided between various radar systems and communication equipment. These form the topside arrangement of a ship. Besides the critical factor of performance, additional factors of the design are risk of EMI, radiation hazards and unintended radiation: the EM signature of the ship. A number of factors have made structured EM topside design more important in recent years. First of all there is a sharp increase in the number of radiating elements on-board, mainly due to the increase in communication equipment. Secondly, there is a need to integrate sensors. These integrated sensor arrangements [1], or integrated masts, combine a large number of radiating and receiving elements in a small volume. Thirdly, the rise of new threats requires uninterfered sensor performance. As a last point, the requirement for stealth demands control of unintended radiation. To cope with these demands, topside design has become an interdisciplinary field in which EM engineers work together with mechanical, thermal, radar cross section, performance specialists and others. This development is called Integrated Topside Design (ITD).

Typical threats on a ship's topside are fields generated by radars and communication equipment on- and off-board resulting in system interference via the receive chain or via other paths, front-door and back-door coupling respectively. The threats also include lightning and nuclear electromagnetic pulses and general radiation hazard for personnel, fuel and ordnance.

Typical front-door coupling problems in the arrangement of equipment concern:

- Coupling between equipment operating in the same frequency range, e.g. between communication antennas and between radar antennas mutually,

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- Radar frequency equipment interfering with each other. When a radar-antenna beam illuminates an antenna of another radar, working in the same or a lower frequency band, this may disturb the radar equipment or influence its proper operation. Measures to prevent interference are: re-arrangement of the antennas and use of sensor management including time scheduling, frequency-allocation and sector blanking. These measures minimise mutual interference and therefore optimise performance of the sensor suite,
- Radar frequency equipment interfering itself, when surfaces, illuminated by the radar beam, reflect the power back into the antenna. Measures: prevent presence of reflective surfaces more or less perpendicular to the radar beam; cover surfaces with radar frequency absorbing structures (RAS).

Typical back-door coupling problems involve insufficient shielding of structures and coupling into cables. Measures are to divide the ship into several electromagnetic regions and to provide adequate shielding between all regions. Installation guides for grounding, bonding, cable separation and filtering are required. To be able to counter these effects a good prediction of the electric and magnetic field strengths on-board the ship is required. The prediction has to be performed for a large number of radiating elements and has to include interaction with the complex structure of a ship. Additionally it is required that this prediction of field levels can be performed sufficiently fast to be of use in the early design phase when the topside arrangement changes rapidly.

History

As far as we know the first electromagnetic interference case was reported in 1963, which was interference between radar and communication equipment on board of surface ships (frigates). In the Sixties of the last century a lot of work was performed in investigating the electromagnetic environment on board of ships, i.e. the fields generated by communication and radar systems in the near field, coupling effects and corrective measures.

In the Seventies a structural approach was followed.

Representatives of Thales Naval Netherlands were members of international working groups and created several standards about environment description, coupling analysis methods, near field calculations and verification methods. Company guidelines were published and updated ever since, and standards and best practices guidelines have been developed for several navies. In this period, the analyses were performed using asymptotic equations.

In the Eighties the asymptotic formulas were replaced by numerical tools. For instance blocking analysis of radar equipment using Physical Optics tools, and mutual coupling and optimal placement analysis using Method of Moments tools. In this period also scale models have been built for design verification and optimal placement of antennas. Also in the Eighties the systems to be installed onboard were tested before installation onboard, resulting in a reduction of EMI cases. In the Nineties the work was mainly focused on an optimal topside design, and at system level it was dedicated towards support in the whole system life cycle. This means that already in the concept phase of a new system EMC specialists were involved, thus having the chance to act and prevent electromagnetic interference. This was and is rather successful, resulting in the majority of the systems being 'first time right': Thales Naval Netherlands' APAR and SMART-L radars were qualified without any EMI issue.

In the last decade we improved the top deck design process, by improving internal developed tools, using more off-the-shelf tools and validating tools on scale models and in actual environments (see **Figure 1**). These activities evolved in the Integrated Topside Design creation process, as offered to and performed for numerous navies in the world. This design process is used within our company to design and produce integrated masts accommodating radars, electronic warfare equipment and communication antennae.

Current Status

The use of scale models in the design process and full-scale verification has its disadvantages. When performing verification on board the finished ship it is very expensive to implement major design changes and EMC fixes have to be made. The use of a scale model has the advantage that major problems are identified in a phase when good EMC measures can still be implemented. It provides designers with a reasonable estimate of the real life performance of their design.

Today the flexibility and accuracy required by the EMC engineer are offered by EM simulation software. These tools offer the possibility to quickly predict the EM field strengths with the required accuracy. The use of simulations is less expensive and time consuming than production and use of a copper scale model, and perhaps more importantly it gives direct feedback on the implications of design changes.

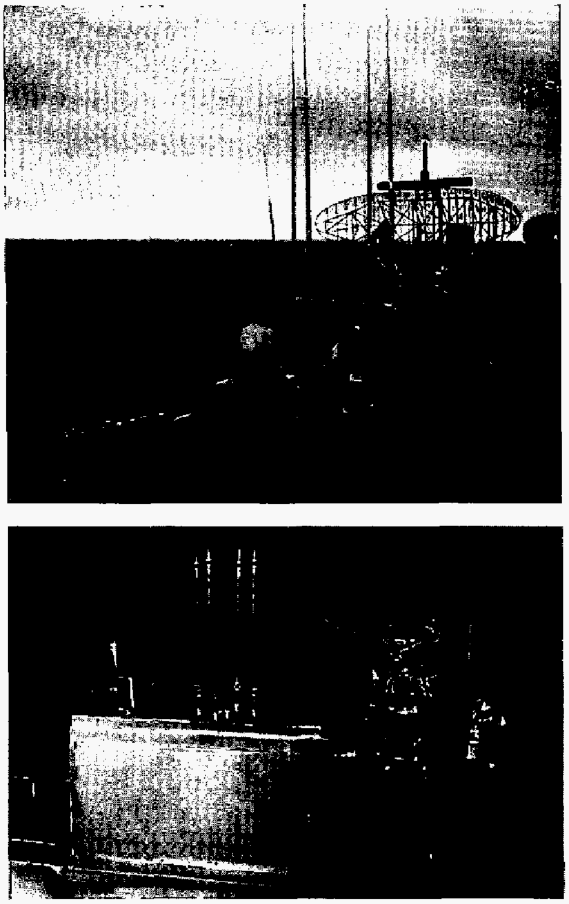

Figure 1: Full-scale situation (upper) and scale model (bottom) used in validation of tools.

The direct feedback makes simulation tools very suitable for use in an ITD team. However it has to be remembered that a simulation is still a model of the real situation, implying limited detail and accuracy. The accuracy may even be sacrificed for speed of computation by using an asymptotic computation method or a simplified model. Nevertheless, computer simulations offer an improvement over the traditional EMC analysis methods, if the software has been properly validated.

The use of simulation software in the topside EM design of a complex ship platform has been validated by performing simulations and comparing these to scale model and full-scale measurements. A number of software tools have been validated using previously made and new measurements on Netherlands Navy and other ships. This includes measurement data of front-door and back-door effects, on-board field levels and far field performance. An example is given in **Figure 2** for the model in **Figure 3**.

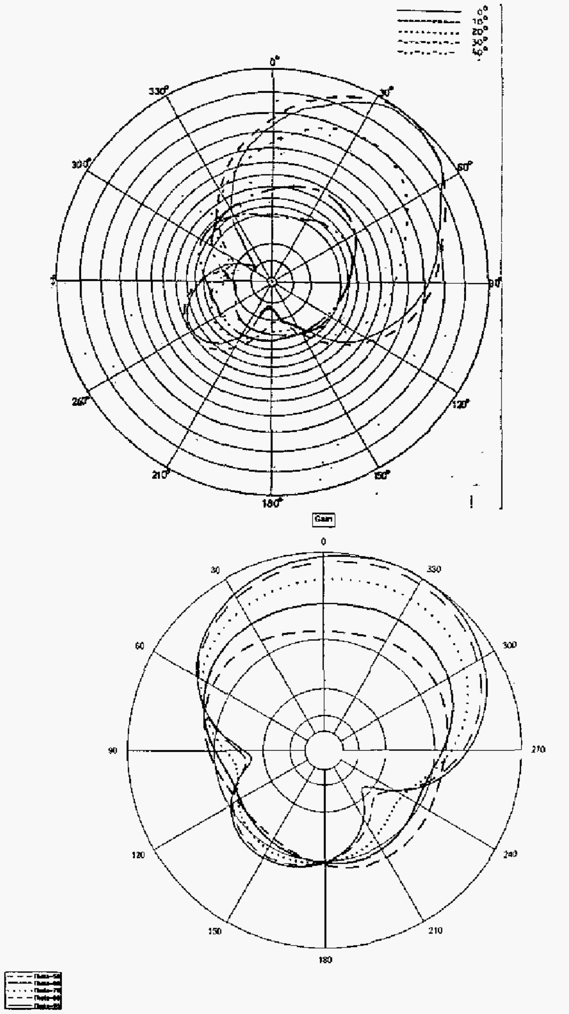

Figure 2: Measurement results (upper) compared to simulation results (bottom).

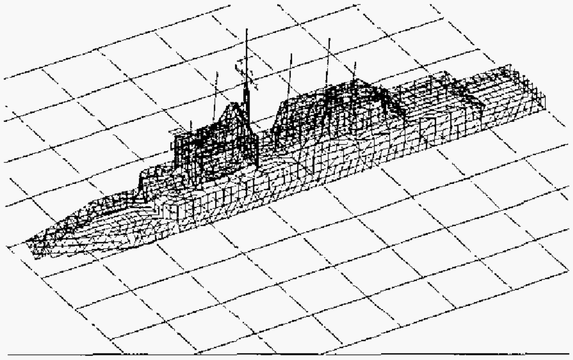

Figure 3: Model used in validation process.

A number of difficulties have been encountered in the simulation process, most notably seemingly trivial exercises such as defining geometry in a simulation correctly and keeping simulation complexity manageable. If not controlled properly, the calculation time quickly becomes too long to be practical in the design process. In general a well-defined simulation can be used to replace model measurements. A computer-generated model is given in Figure 4. The entire model or parts thereof are used in simulations, depending on requirements.

A general accuracy in the design phase within 3 dB for field levels on-board is acceptable. Additional validation models are shown in Figure 5, Figure 6, Figure 7 and Figure 8.

Critical for a good simulation is knowledge of the sensors in question. The emission and susceptibility characteristic of all equipment on-board has to be available. To be able to quickly perform analyses in the design phase, an EM database of equipment has to be available and be kept up to date.

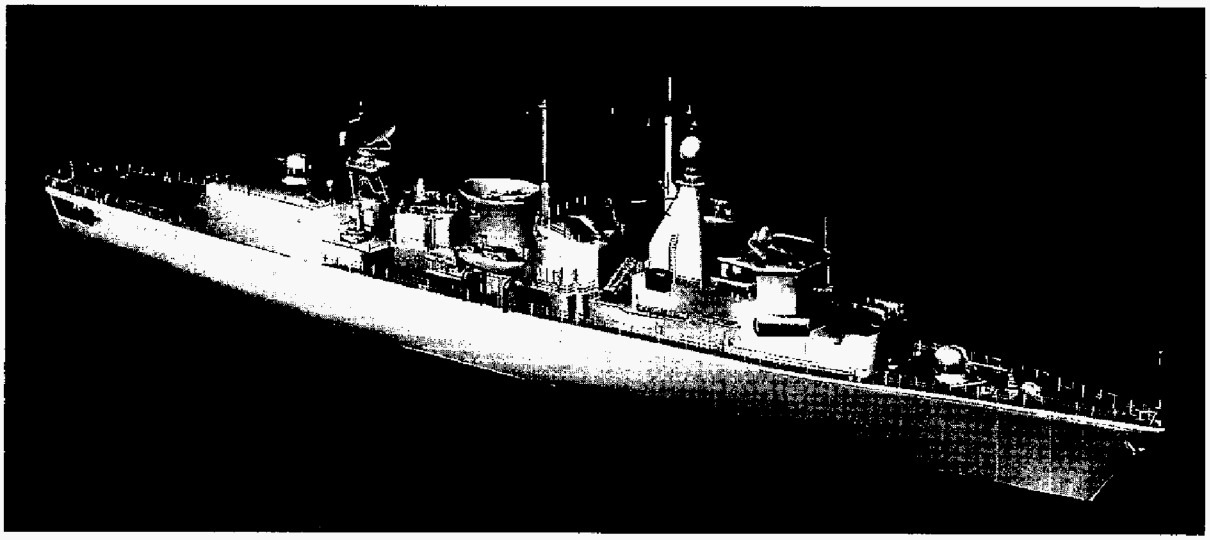

Figure 4: One of the models used in the EM simulation tool.

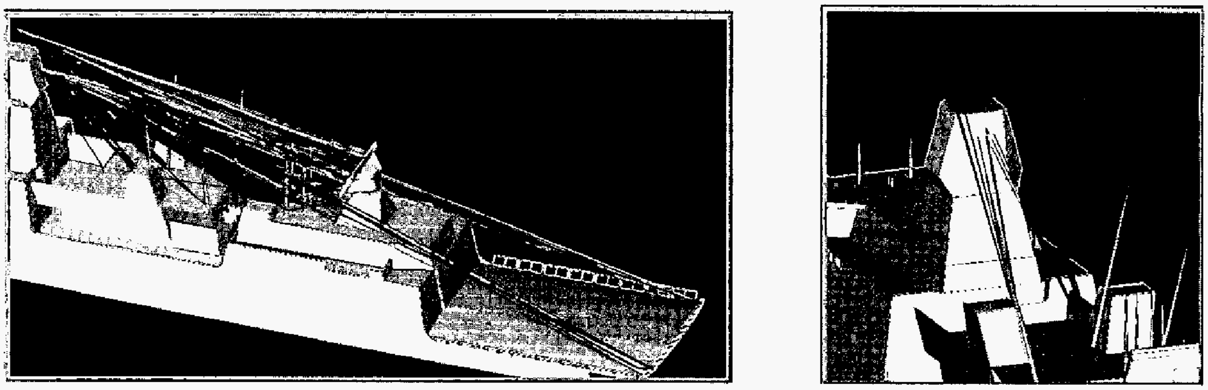

Figure 5: Ray Tracing & Ray Casting simulation

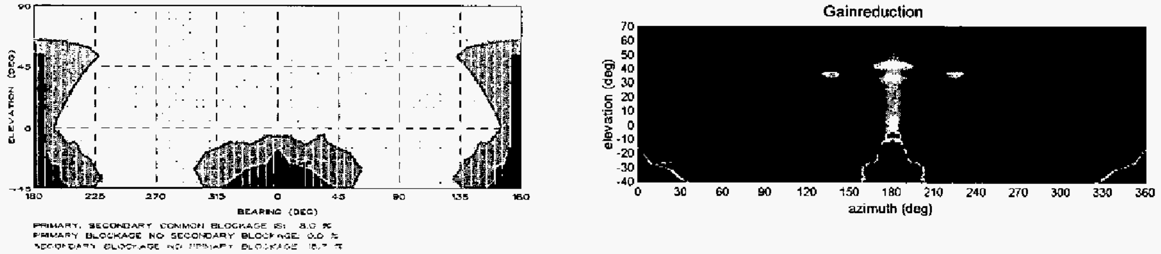

Figure 6: Visual blocking and associated gain reduction of a search radar.

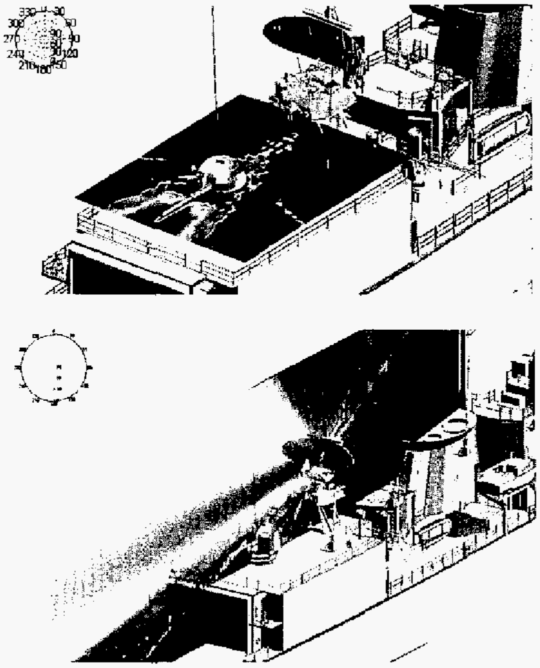

Figure 7: Radiation field pattern of search radar (top) and RadHaz zone on ship deck (bottom)

Areas of Improvement of EM Tools

During these validations we found a number of areas of improvement of current EM simulation tools, with respect to the application at Thales Naval Netherlands. The first criterion of a tool is the accuracy of the solver core. Many of the tools use solving methods that have been used before and produce reasonable results. Although important, the core of most available tools is acceptable.

The main issue with current EM tools is in the application in a design environment, specifically in input and output functions. A limitation was that tools were only useful on a limited frequency range. However, a trend in EM tools is to hybridise full Maxwell solving codes (e.g. MoM) with asymptotic codes (e.g. UTD) to provide a user with an efficient tool for a large frequency range. This is a very useful trend.

One seemingly trivial issue is the definition of structures in simulation tools. A lot of improvement has been made in this area over the last years. However we still find that the ship and sensor models made by designers are still not easily imported in an EM tool.

Most tools are general field strength calculation tools. This is useful for performance and radiation hazard analyses, however for EMI additional steps are required. Furthermore the largest part of a naval platform is within the near field of many sensors, due to the wavelength-distance relation (HF antennae) or due to the dimension of the sensor with respect to the wavelength. This is a major challenge when using numerical electromagnetic tools for naval platforms.

EM Tools Roadmap

The roadmap towards integrated EM tools at Thales Naval Netherlands dictates a flexible and capable EM simulation suite that can be used in the design phase of naval platforms. The suite contains an EM database in which sensors and equipment are stored, with all their relevant parameters such as emission and susceptibility characteristics. The characteristics are available for in-band and out-of-band frequencies. The geometry of naval platforms is also stored in this database, with material properties attached to structures. A generic database allows export of data to several simulation modules, while it also functions as a flexible input programme for several CAD data standards.

The suite consists of several simulation modules that allow analysis across a wide frequency range with the right complexity for any problem. Not only are there modules for field calculation, but also for direct calculation of receiver interference, cable coupling and other analyses. Accurate shielding of structures, cable coupling and receiver chain characteristics are required for full front-door and back-door EMI analyses. And this should be performed for frequencies not only in the operating bands, but also for out-of-band frequencies.

To ensure fast execution of simulation, several demanding modules make use of parallel or distributed computing. Other techniques, such as the fast multipole method, also allow for quick calculations. This ensures optimum use of processing power and time and allows the suite to be used in the design phase when frequent changes occur. Data exchange between modules and database allows for version control in the design process.

Conclusion

A large number of tools, ranging from asymptotic formulas to full simulation software, are used in the topside design process at Thales Naval Netherlands. These are validated over the years by comparing the simulations with full-scale and model measurements. Currently no stand-alone software tool fully complies with the application needs at Thales Naval Netherlands. Especially input and output are lacking, also an EM database and provisions for complete EMI analyses lack. Continuing validation on-board naval platforms increases the confidence in the tools used.

The roadmap towards integrated EM tools for Thales Naval Netherlands dictates to use a suite of programmes which offers capability for all ITD EM challenges, front-door and back-door coupling both in-band and out-of-band. This suite is coupled to an EM and structure database to assist in making quick calculations during the many iterations of the design phase. Fast executing solver cores, by parallel or distributed calculation and new solver methods, further assist in the design phase. The integrated EM tools form the path towards integrated sensor arrangements.

References

1. Integrated Sensor Arrangement (ISA) study, CODEMA project, 2002-2005.

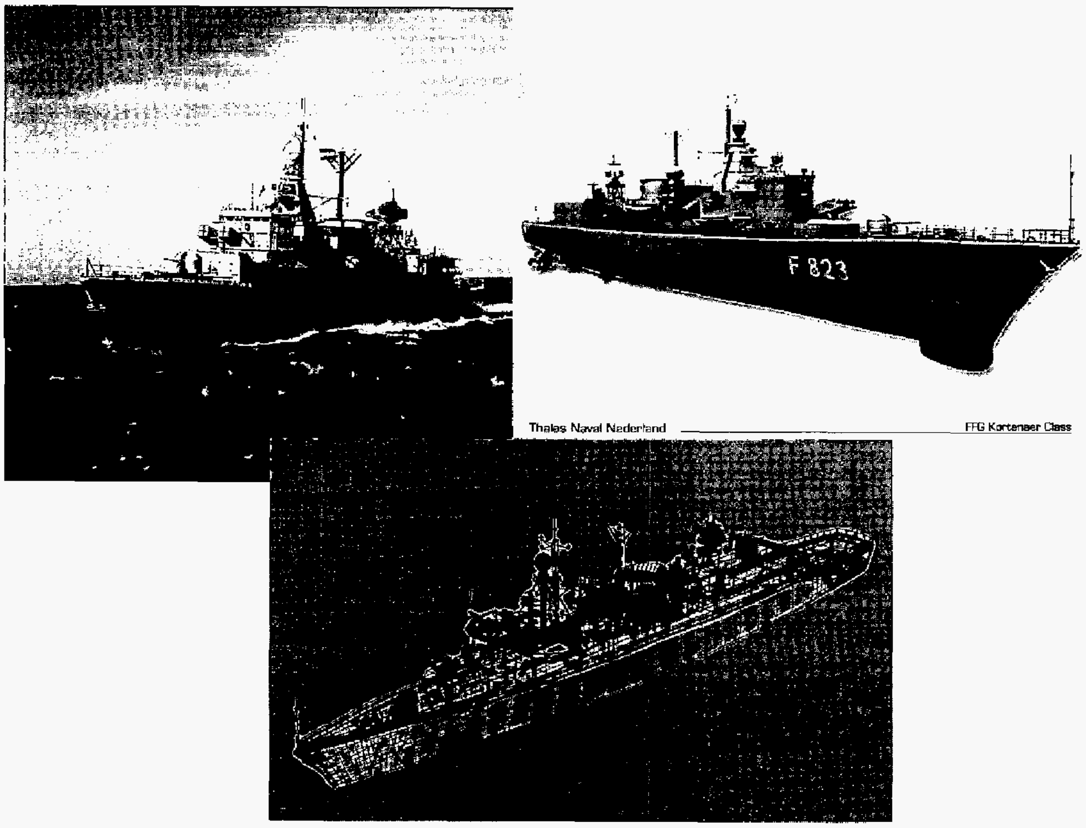

Figure 8: Transformation of naval platform to simulation model.