

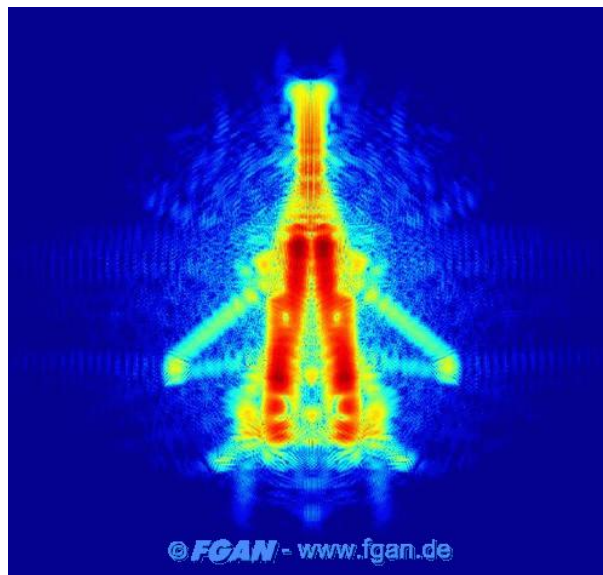
Research Area: Antennas and Scattering

Numerical Simulations of Scattered Electromagnetic Fields

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FARAD High-Frequency EM Simulation Tool

FARAD (FAst Ray-tracing Algorithm with ray Density normalisation) is a ray tracing software designed for the electromagnetic modelling of arbitrarily large objects. The tool has been developed at FGAN-FHR and is based on discrete rays, which are used for finding the relevant propagation paths. These rays are traced according to the well-known Shooting and Bouncing Rays (SBR) technique, which allows for a practically unlimited number of reflections. The SBR approach is combined with the Physical Optics (PO) and Physical Theory of Diffraction (PTD), which are used to calculate scattered field contributions at each intersection of a ray with the object. An additional implementation of the Uniform Theory of Diffraction (UTD) has proved to become an important enhancement when multiple interactions with the object are relevant. This is of special interest for the accurate modelling of cavities, where rays might be diffracted at the aperture and propagate into the cavity. According to the UTD implementation, these diffracted rays can be traced further through the scenario and generate additional PO and PTD contributions, which might be relevant for the total scattered fields. Thus, a hybrid GO/UTD-PO/PTD simulation code has been developed, with the laws of GO and UTD (i.e. law of reflection and diffracted rays on the Keller cone) serving for calculating the geometrical propagation paths while PO and PTD are used for the calculation of field contributions.



Analysis of scattering centers at an aircraft (calculated with FARAD)

Further enhancements of the code include the modelling of arbitrary surfaces by importing reflection and transmission coefficients from tables and the adequate treatment of curved surfaces.

Due to the fast generation of results for different frequencies and aspect angles, scattering studies which generally require enormous simulation efforts are possible within a reasonable amount of time. Thus, for example, the ray tracing tool is able to provide data for the generation of 1-dimensional range profiles of the object as well as two-dimensional images of the object, which are essential for the analysis of scattering centers and optimization concerning Low Observability (LO).

The FEBI Numerically Exact Tool



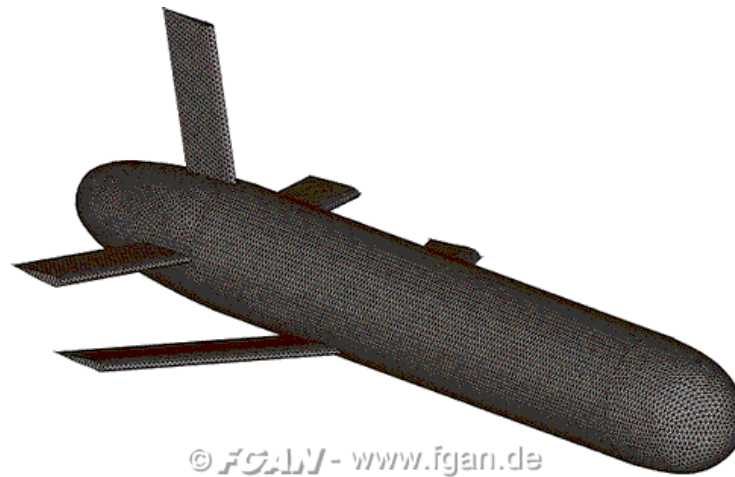
Current distribution on aircraft (calculated with FEBI)

The fast FEBI tool is a very powerful and efficient research simulation tool for numerically exact modeling of complex electromagnetic problems in the frequency domain. It fully combines various numerical modeling approaches through appropriate field formulations allowing for the efficient solution of a wide range of electromagnetic problems. Fields in regions exterior to the objects are formulated in the Boundary Integral (BI) part based on the Boundary Integral Method (BIM). Particularly, they are expressed on the boundaries of the objects (Huygens' surfaces) with Integral Equations (IEs), using equivalent surface current formulations according to equivalence principle. The IEs can be the well known Electric Field Integral Equation (EFIE), the Magnetic Field Integral Equation (MFIE), or their linear combination known as Combined Field Integral Equation (CFIE). They are solved by the Method of Moments (MoM) with Galerkin's testing using Rao-Wilton-Glisson (RWG) basis functions.

The resulting system of equations is solved by a recursive iterative solution technique using a multilevel iterative preconditioning strategy with several nested iteration loops. According to this, the innermost iteration loop is broken after (or before) each matrix-vector product and another iteration loop is started in order to compute a left-hand side (or right-hand side) preconditioner. This concept is extended to include further preconditioner levels in a recursive manner. The inner iteration loops of the recursive solver can work with various approximations of the original system matrix, which are cheaper to evaluate than the original matrices but are still good enough to precondition the outer iteration loop.

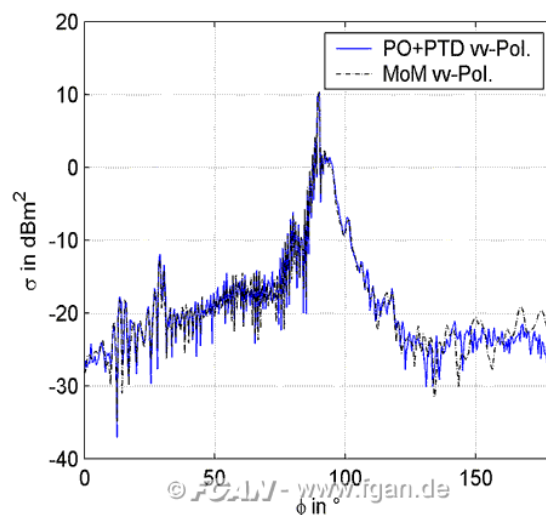
It is noticed that the CFIE is free of interior resonances and has better convergence behaviour within the iterative solver. The drawback of the CFIE is that it cannot be used for simulation of open surfaces, since it involves the MFIE, which provides proper modeling only of closed surfaces. Consequently, for simulation of open dish-like surfaces the EFIE is used.

The pertinent matrix-vector multiplications within each iteration step are accelerated by a very powerful implementation of the Multilevel Fast Multipole Method (MLFMM), in which the k-space representations of the basis functions are expanded in terms of spherical harmonics resulting in significant savings of memory requirements. For monostatic computations or when the same problem is solved for different excitation frequencies, the start vectors for the iterative solution can be determined by phase correction due to the phase variation of the incident field, extrapolation or interpolation of previous solutions, or projection of the equation system to previous solutions. Using these start vectors, the number of iterations can be reduced considerably for many problems. Dielectric volume regions can also be treated with Finite Element (FE) functional and are fully coupled with the BI part through field continuity conditions on the dielectric segments of the Huygens' surfaces.



Generic missile

Using the fast FEBI tool, relatively large targets with complex shape are treated conveniently providing numerically exact simulation results.



RCS of generic missile, comparison of FARAD and FEBI results

Projects in the field of:
Antennas and Scattering

- Conformal Antenna Array for ERAKO
- Conformal Array Pattern Synthesis
- Fast Integral Methods
- Hybrid Methods
- Metamaterials
- Numerical Simulation of Scattered Fields
- Planar-3D-Simulation

- Scattering of Aerial Vehicles
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