# NEWSLETTER February 2010

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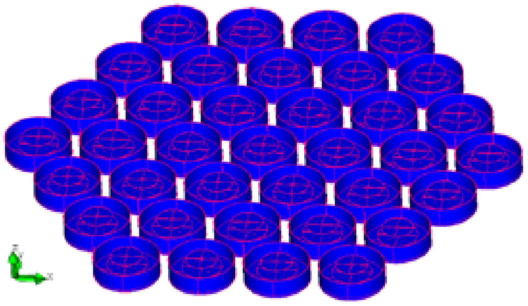
This issue focuses on two important application areas, array antennas and radar scattering analysis of objects including radar absorbing materials.

Array antenna simulations are usually based on analysis of a single antenna element in an infinite periodic structure. Here we will instead focus on finite arrays. Such simulations are more demanding in terms of computer resources but will give additional answers not available using periodic boundaries. We will show some examples illustrating the possibilities of Efield for this type of application.

Efield is well suited for RCS analysis of large vehicles such as aircraft or ships. In Efield 5.0 a unique integral formulation was introduced for applications including dielectrics or RAM which will substantially reduce the solution time. The benefits of using Efield for RCS analysis are shown by some well-known benchmark examples.

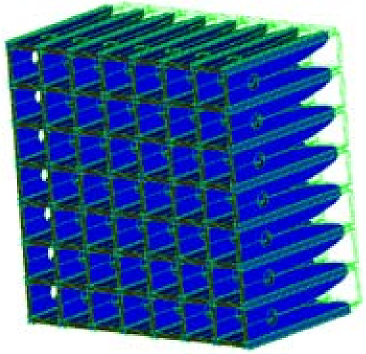
If you have any comments to this newsletter or like to ask questions, please contact us at contact@efieldsolutions.com.

## Simulating finite arrays with Efield®



Array antenna of 37 patch excited cup radiating elements

Array antennas are an important application field in antenna design. Many modern sophisticated sensor or communication systems involve a large number of antennas on one single platform and there is a strong desire to reduce the number of associated antennas. This can be done by combining functions of several systems into one single antenna. There is an increasing need for efficient simulation tools for the design of these antenna systems. The array antenna must also be integrated on the platform which introduces a number of additional design challenges in order to achieve the desired performance.



A double polarized tapered slot antenna array of 7 x 8 elements. This array was simulated using Efield FDTD

### Why simulating finite phased arrays?

Traditionally array antenna design involves simulation of a single antenna element in an infinite periodic structure using Floquet-Bloch periodic boundary conditions. All antenna elements are equal in this approach and it is not possible to simulate any edge effects. This design procedure applies well for antenna elements in the middle of a large array and will not require too much computer resources.

All real array antennas are finite and there is a need for simulation techniques that take into account effects associated with the finite size. Conformal arrays are not even periodic in such a way that the Floquet-Bloch theorem could be applied and simulation technique for finite arrays must then be applied. The limiting factor is that simulating finite antenna arrays will need large computer resources which will limit what is possible to achieve. On the other hand modern computer clusters in combination with the parallel environment offered by the Efield software will reduce the solution time.

### Numerical techniques in Efield

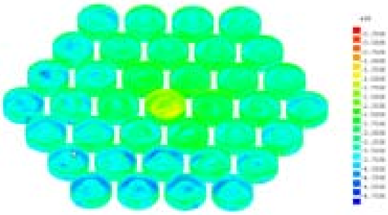
Efield offers a complete and integrated software environment for 3-D analysis of a wide range of EM applications.

- Unique solver technology in both time- and frequency-domain

## Simulating finite arrays.... (Continued)

- Full wave solvers (MoM, MLFMM, FDTD, FEM)
- Approximative solver (PO)
- Novel hybrid techniques (FDTD-FEM, MoM-PO and MLFMM-PO)

All solvers run in parallel mode which facilitates the solution of demanding simulation problems such as large finite arrays as well as large scattering objects. Efield MLFMM and FDTD-FEM are also highly suitable for simulating large finite antenna arrays.



Surface currents on the array antenna of 37 patch excited cup radiating elements

## Antenna excitation functionality in Efield

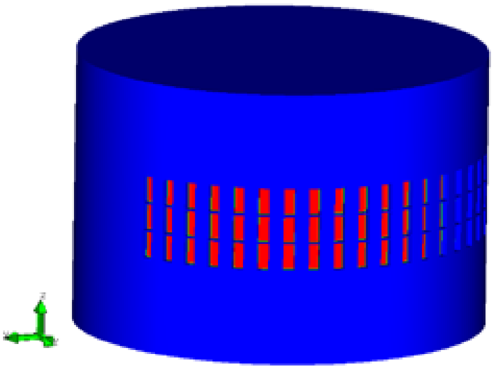
Efield offers a number of different excitation methods such as voltage excitations on wire nodes and surface edges in FD. Efield TD includes point sources, voltage and current sources. Homogeneous and inhomogeneous waveguide ports for TE, TM and TEM modes are available in both FD & TD.

A port will act as a mode excitation surface but also as an absorbing boundary condition that absorbs any modes travelling in the opposite direction. Ports are used for:

- Excitation of waveguide modes.
- Registration of waveguide modes.

## Conformal Arrays

A conformal antenna is an antenna that conforms to a prescribed shape which is not necessarily optimized for antenna performance. The shape can be some part of an airplane, high-speed train, or other vehicle. The purpose is to build the antenna so that it becomes integrated with the structure and does not cause extra drag. The shape of the surface can be singly curved as the fuselage or wings of an airplane or doubly curved as the nose.



The cylindrical C-band array with three rows of 18 elements each, extending over about 120° in the azimuth

For a conformal array the radiation pattern can not be written as the product of an element factor and an array factor. This complicates both analysis and synthesis. For arbitrarily shaped bodies, no exact analytical solution exists. Instead, numerical methods have to be used.

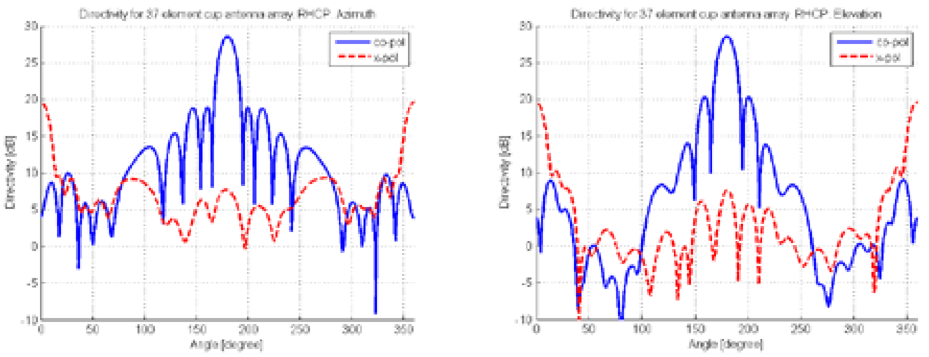
## An array of patch excited cup elements

The patch excited cup antenna is an end-fire type of radiator which consists of two patches placed in a circular cup. The bottom patch is fed by four probes. The antenna element is designed to cover two frequency bands.

The array consists of 37 patch excited cups arranged in a hexagonal lattice. Each patch antenna has four probes. The array was simulated with Efield MLFMM. All ports where excited with equal amplitude. Some data for the simulation is given below. Each probe was excited with a 90° phase shift in order to generate right handed circular polarization (RHCP) and excited with a 50 Ω coaxial (TEM) waveguide port.

| Geometry data for the cup array | |
|---|---|
| Number of cups | 37 |
| Diameter of cups | 160 mm |
| Element distance (x-axis) | 0.72λ |
| Number of ports | 148 |

| Simulation data | |
|---|---|
| Number of nodes | 21 191 |
| Number of triangles | 42 826 |
| Number of MoM unknowns | 62 239 |
| Time (excluding post processing) | 2.3 h[1] |



Directivity for the 37 element cup antenna array

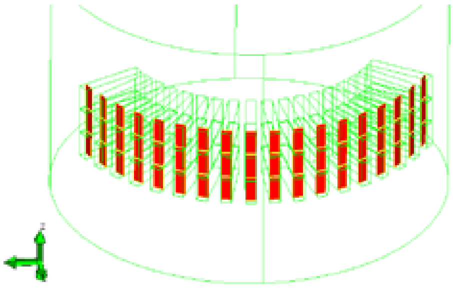
# A conformal array example

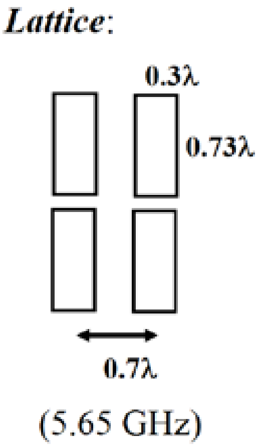
The cylindrical C-band array was formed by rectangular apertures on a cylinder surface. The diameter of the cylinder was 600 mm and it has 54 azimuthally polarized waveguide aperture elements with 0.7λ spacing at 5.65 GHz in the E-plane. There are three rows with 18 elements each, extending over about 120° in the azimuth.

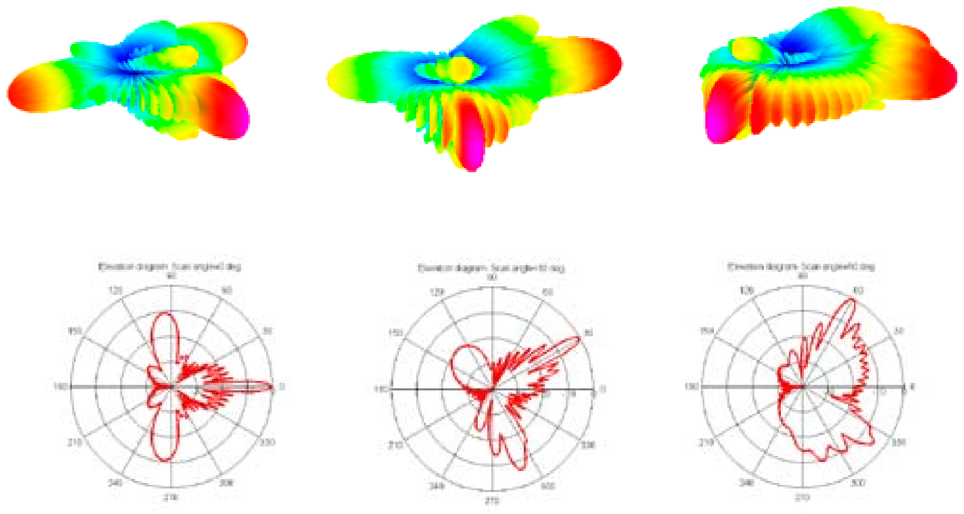
The radiating elements on the cylinder are forming a circular array. In a similar way as for the linear array case it is possible to impose phase values to each element so that they add up coherently in a certain scanning direction. Far-field patterns were generated for different scanning angles by assuming constant amplitudes. See below.

| Simulation data | |
|---|---|
| Number of nodes | 41 000 |
| Number of triangles | 82 000 |
| Number of MoM unknowns | 123 000 |
| Time (excluding post processing) | 2.5 h[1] |

1/ Two processors on an AMD Dual Core Opteron 285 2.6 GHz with 16 GB RAM







Scan angle: 0°

Scan angle: 30°

Scan angle: 60°

Simulated far-field patterns for different scan angles using constant amplitude

## RCS simulation of objects including lossy dielectric and magnetic materials with Efield®

Designers regularly require insight into the scattering properties of an object. Insights from such analysis are typically used either to minimize the scattering of an object (e.g. stealth designs) or to improve radar performance in stealth environments. The advancement of methods for the lowering of scattering from objects includes the use of advanced composite materials and the accurate analysis of a targets scattering properties is becoming increasingly difficult.

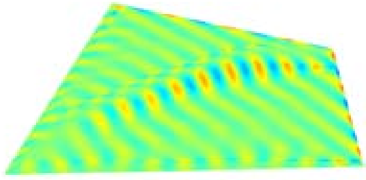
# RCS simulation of objects... (continued)

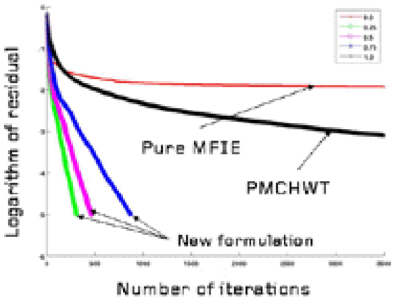
## The Efield solution

Efield can be used for scattering analysis of mixed metallic and dielectric bodies of large electrical size. The Efield® MLFMM is an efficient tool for scattering analysis and especially for calculating monostatic RCS. The MLFMM solver uses the MRI (Minimal Residual Interpolation) method that will drastically reduce the simulation time in case of monostatic RCS computations when the numbers of incident angles are large.

## New formulation for dielectric materials in Efield MoM/MLFMM

Different integral formulations are available in Efield MoM and MLFMM that improves accuracy or decreases the solution time. In most commercial MoM based solvers CFIE formulations are only available for pure PEC structures. A new innovative integral formulation for problems involving mixed PEC and dielectric or magnetic bodies was introduced in Efield 5.0. Most commercial solvers use the so called PMCHWT (Poggio-Miller-Chang-Harrington-Wu-Tsai) formulation which has very poor convergence properties. The formulation used in the EfieldFD solver decreases the number of iterations to reach convergence dramatically with large savings in solution time.

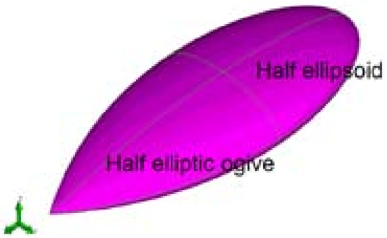




Simulation of RCS for UAV with RAM at leading edges (left) using an improved integral equation formulation for mixed PEC and dielectric problems. Convergence study at 500 MHz. Comparison with standard PMCHWT formulation (right).

## NASA Almond

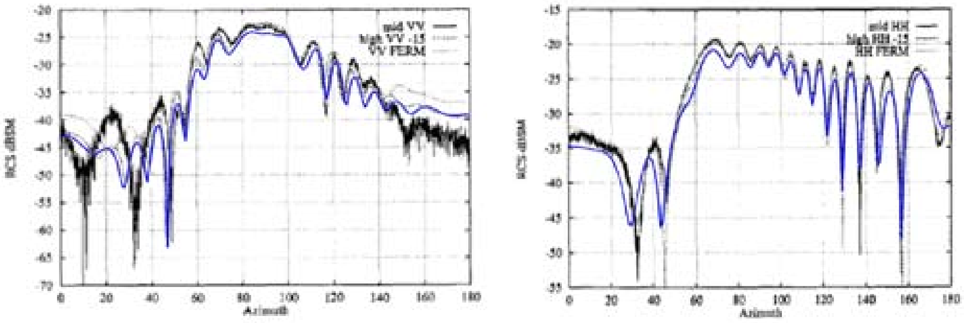
Woo et al. published measured and simulated results for a range of simple RCS benchmark targets [Antennas & Propagation Magazine Vol. 35, February 1993]. These targets are defined mathematically to ensure that the correct shape is simulated. The NASA almond is a doubly curved surface with a pointed tip. It is not a simple body-of-revolution (BOR) shape and is essentially flattened in the z-axis, relative to the y-axis. It has low RCS when viewed in the tip angular sector. Elsewhere, a surface normal is always pointing back toward the radar creating a bright high-level specular RCS return.



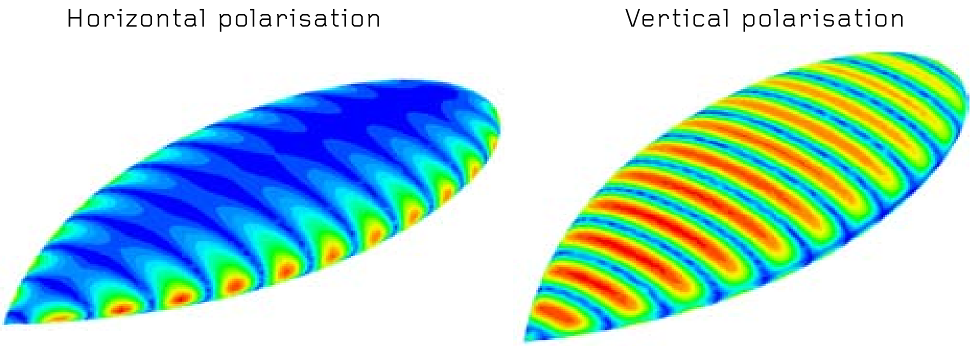
## Definition of geometry

Efield has the means to easily generate simple and complex mathematical shapes like the NASA almond. The mathematically curved surfaces of the target were generated by the built-in Efield macro function from NURBS control points. In this way a mathematically precisely defined shape may be created to almost arbitrary accuracy. Two different geometrical configurations were used in the simulations with the length of 9.936 inch and of 2.5 m respectively.

## Monostatic RCS of 9 inch PEC case at 7 GHz



Monostatic RCS of 9 inch PEC NASA almond at 7 GHz in azimuth plane. Polarization VV (left) and polarization HH (right). Results were taken from Woo et al.

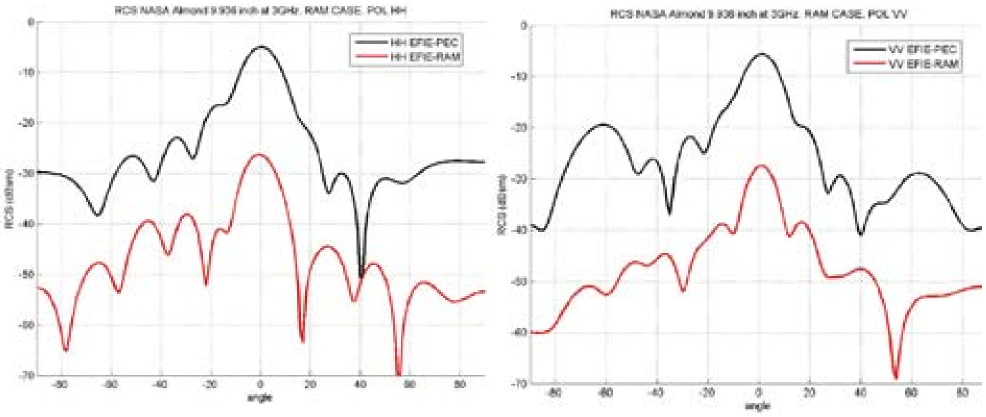


Surface currents of 9 inch PEC NASA almond at 7 GHz

## Monostatic RCS of 9 inch coated case at 3 GHz

Monostatic RCS was simulated at 3 GHz in upper x-z-plane. Model and simulation data

- Thickness of the coating = 0.1λ (10 mm)
- Material parameters for the coating: $\varepsilon_r = 3.0 - 2.0i$, $\mu_r = 2.0 - 1.0i$
- Edge size = 5 mm, 8132 elements, 19230 unknowns

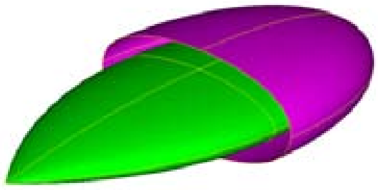


Monostatic RCS of 9 inch coated NASA almond at 3 GHz in upper x-z plane. In black pure PEC case and in red the coated case with $\varepsilon_r = 3-2i$, $\mu_r = 2-i$.

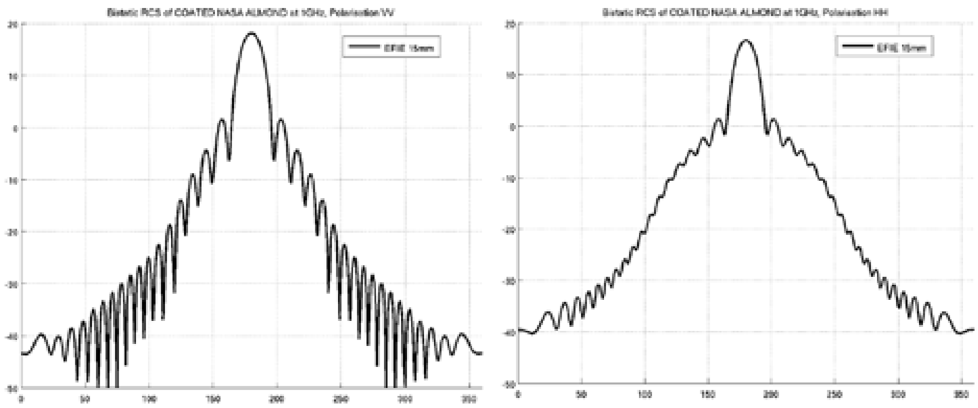
## Bistatic RCS of 2.5 m coated case at 1 GHz

This is a JINA 2006 test case. Bistatic RCS was calculated at 1 GHz in x-y-plane from φ=0-360° in steps of 1°. Model and simulation data

- Thickness of coating = 0.1λ (30mm)
- Material parameters for the coating: $\varepsilon_r = 1.5 - 0.1i$, $\mu_r = 2.5 - 1.8$
- Edge size = 15 mm. 77692 elements/178464 unknowns
- MLFMM using CFIE (α=0.5)



CAD model of the coated NASA almond



## The Efield exhibition at EuMW 2009 in Rome, Italy

### Success for Efield at Microwave Week in Rome

Efield participated as exhibitor at the European Microwave Week 2009 in Rome, Italy, between September 28 and October 2 last year. We took part in the exhibition as a member company of Microwave Road, a cluster of companies and organizations in the microwave area sharing a stand together. The exhibition was a great success for us which gave us several new and important contacts with both new and old customers and partners.

## Efield® - a complete simulation environment for 3D electromagnetics

Efield® offers software for 3D analysis of a wide range of electromagnetic applications such as:

- **Antenna design**: All kind of antennas including horn, reflector, wire and microstrip antennas as well as broadband antennas and antenna arrays.
- **Antenna integration**: Radiation pattern and coupling of installed antennas on large platforms such as aircraft or ships.
- **Microwave design**: Typical applications include design of filters, connectors and couplers.
- **EMI/EMC interaction**: Analysis of a wide range of EMC/EMI problems including shielding and coupling.
- **Scattering & radar cross-section**: RCS analysis of structures such as aircraft, ships, air-intakes and antennas.

Efield® has the solution to every stage of the analysis including:

- Integrated environment including user friendly GUI
- CAD import of all major formats
- Fixing and repair of complex CAD models
- Model building
- Efficient and high quality meshing
- Unique solver technology in both time- and frequency-domain including full wave, approximative and hybrid techniques
- Unparalleled execution performance on single PC's or parallel processing on multiprocessor computers
- Flexible and high quality post-processing including graphing of results as well as visualization of surface currents, near fields and far-fields.

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