NASA ALMOND

This is an EMCC benchmark target referenced in:

> Alex C. Woo, Helen T. G. Wang, Michael J. Schuh, and Michael L. Sanders, "Benchmark Radar Targets for the Validation of Computational Electromagnetic Programs" IEEE Antennas and Propagation Magazine Vol. 35, No. 1 February 1993.

The Efield MLFMM was used to compute the RCS of the almond. Two different length of the almond was used in the simulations. Two different material cases was studied, a PEC case and a coated case.

Definition of geometry

Two different geometrical configurations was used in the simulation of RCS. The definition of the geometry is shown in Figure 2.

- Length: d = 9.936 inch
- Length: d = 2.5 m

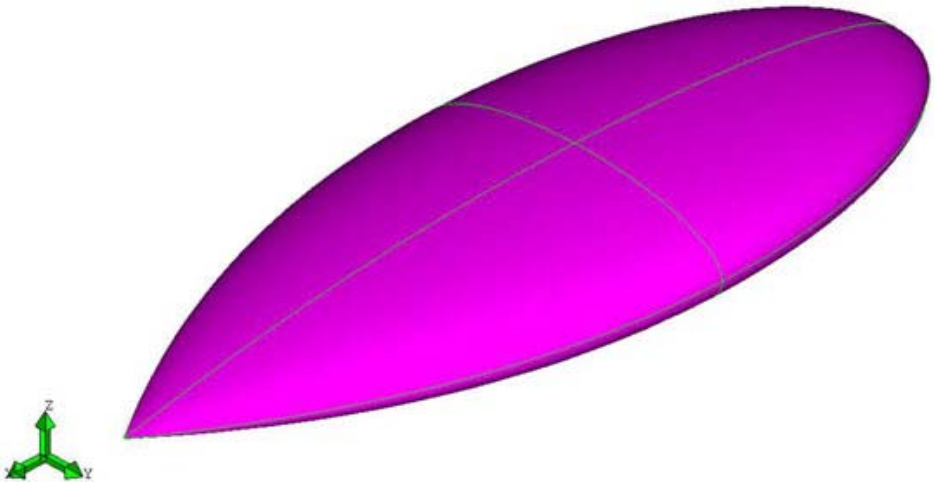

Figure 1: The NASA almond

Half ellipsoid : for -0.416667 < t < 0 and $-\pi < \psi < \pi$	Half elliptic ogive : for 0 < t < 0.583333 and $-\pi < \psi < \pi$
$x = dt$	$x = dt$
$y = 0.193333d\left(\sqrt{1-\left(\frac{t}{0.416667}\right)^2}\right)\cos\psi$	$y = 4.833450d\left(\sqrt{1-\left(\frac{t}{2.083350}\right)^2}-0.96\right)\cos\psi$
$z = 0.06444d\left(\sqrt{1-\left(\frac{t}{0.416667}\right)^2}\right)\sin\psi$	$z = 1.611148d\left(\sqrt{1-\left(\frac{t}{2.083350}\right)^2}-0.96\right)\sin\psi$

Figure 2: Definition of geometry of NASA almond

Simulation with efield

Four different cinfigurations was studied:

- 9 inch PEC case
- 9 inch coated case
- 2.5m PEC case
- 2.5m coated case

The 9 inch cases can be solved using Efield MoM solver but here we use the Efield MLFMM solver. The 2.5m cases are electrically large and was solved using Efield MLFMM solver. The Efield MLFMM solver can handle both PEC cases and mixed PEC, dielectric and magnetic materials such as in the coated case.

9-inch PEC case

Model and simulation data:

- 9 inch PEC case
- Monostatic RCS at 7 GHZ in azimuth plane (x-y-plane)
- CFIE is used with alpha = 0.5
- 10020 elements
- 15030 unknowns

In Figure 3 and Figure 4 the monostatic RCS are shown and compared with measurement results. In Figure 5 the surface currents are shown.

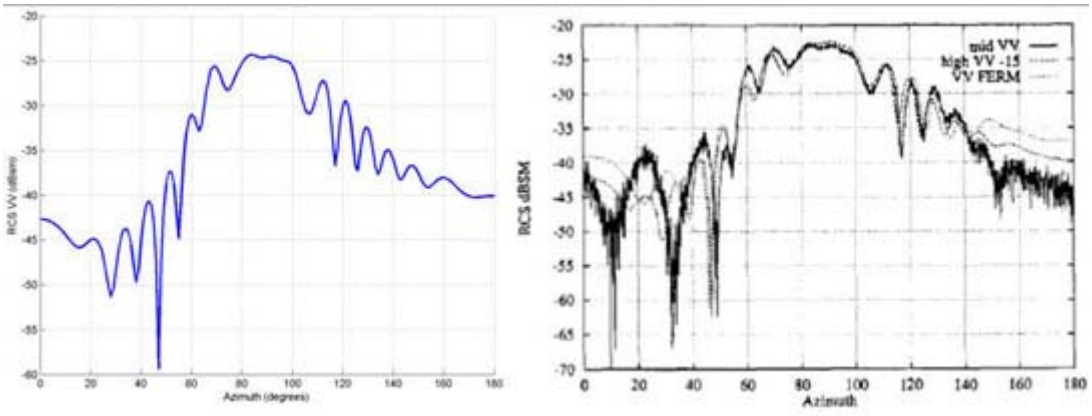

Figure 3: Monostatic RCS of 9 inch PEC NASA almond at 7 GHz in azimuth plane. Polarization VV. Computations (left) and results from Alex C. Woo, Helen T. G. Wang, Michael J. Schuh, and Michael L. Sanders (right).

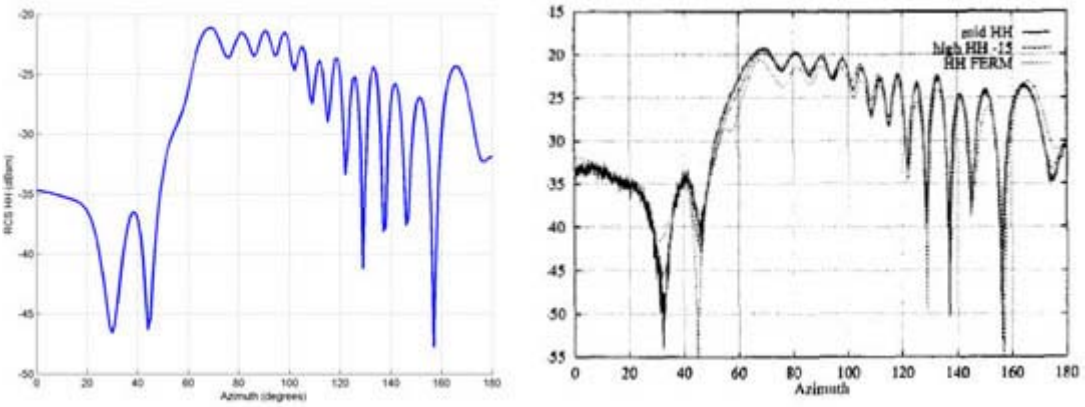

Figure 4: Monostatic RCS of 9 inch PEC NASA almond at 7 GHz in azimuth plane. Polarization HH. Computations (left) and results from Alex C. Woo, Helen T. G. Wang, Michael J. Schuh, and Michael L. Sanders (right).

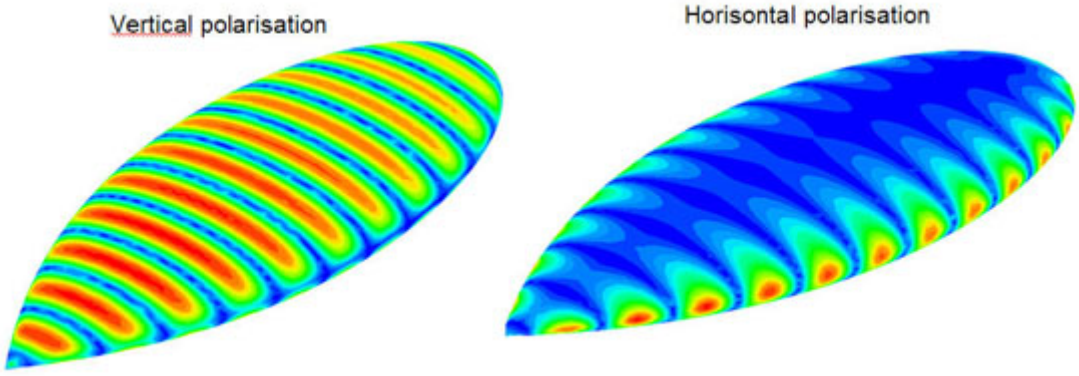

Figure 5: Surface currents of 9 inch PEC NASA almond at 7 GHz

9-inch coated case

Model and simulation data:

- 9 inch coated case
- Monostatic RCS at 3 GHZ in upper x-z-plane
- λ coating (10 mm)
- Material parameters for the coating:
    - Case 1: $\varepsilon_r = 1$, $\mu_r = 1$
    - Case 2: $\varepsilon_r = 3-2i$, $\mu_r = 2-i$

In Figure 6 the monostatic RCS is shown.

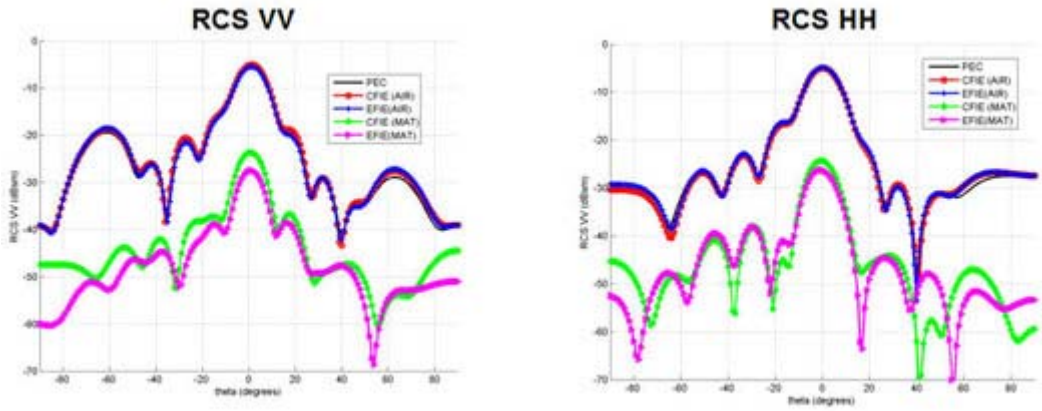

Figure 6: Monostatic RCS of 9 inch coated NASA almond at 3 GHz in upper x-z plane. In black pure PEC case, in red coated case with ε_r =1, μ_r =1 and CFIE, in blue coated case with ε_r =1, μ_r =1 and EFIE, in green coated case with ε_r =3-2i, μ_r =2-i and CFIE and in magenta coated case with ε_r =3-2i, μ_r =2-i and EFIE.

2.5m PEC case

This case was a JINA 2006 test case. Model and simulation data:

- 2.5 PEC case
- Plane wave excitation at φ=0 degrees and θ=90 degrees
- Bistatic RCS at 8 GHZ in x-y-plane and x-z-plane
- 327612 elements
- 419418 unknowns
- Efield MLFMM using CFIE with SPAI preconditioner
- Number of iterations in MLFMM:
    - θ-polarization: 27 iterations
    - φ-polarization: 29 iterations
- Total time: 3.5 hours

In Figure 7 the bistatic RCS is shown and in Figure 8 the surface currents is shown.

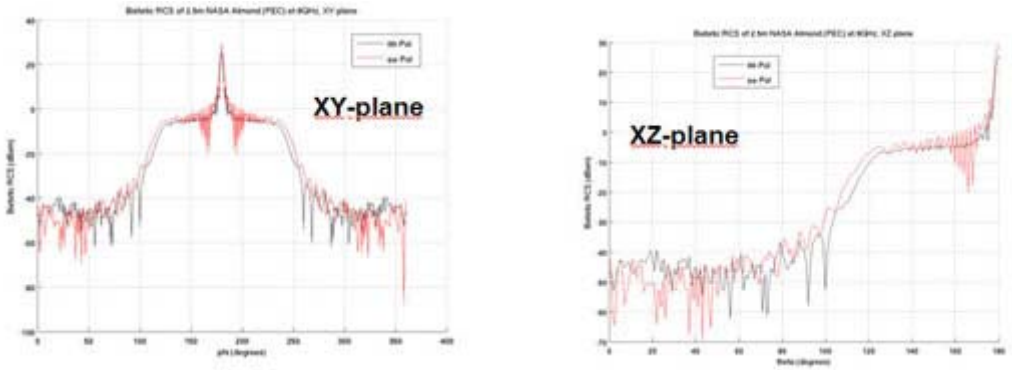

Figure 7: Bistatic RCS of 2.5m PEC NASA almond at 8 GHz in x-y-plane (left) and x-z-plane (right).

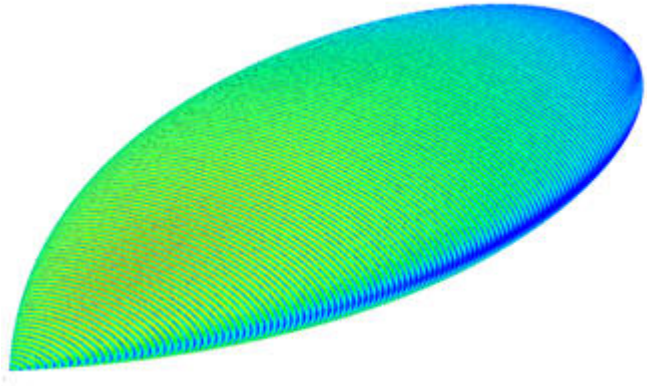

Figure 8: Surface currents of 2.5m PEC NASA almond at 8 GHz

2.5m coated case

This case was a JINA 2006 test case. Model and simulation data:

- 2.5m coated case
- 30mm coating
- Material parameters for the coating:

  ε_r =1.5-0.1i, μ_r =2.5-1.8i
- Plane wave excitation at φ=0 degrees and θ=90 degrees
- Bistatic RCS at 1 GHZ in x-y-plane
- 77692 elements
- 178464 unknowns
- Efield MLFMM using EFIE with SPAI preconditioner
- Number of iterations in MLFMM:
  - θ-polarization: 16 iterations
  - φ-polarization: 17 iterations
- Total time: 0.85 hours

In Figure 9 the bistatic RCS is shown.

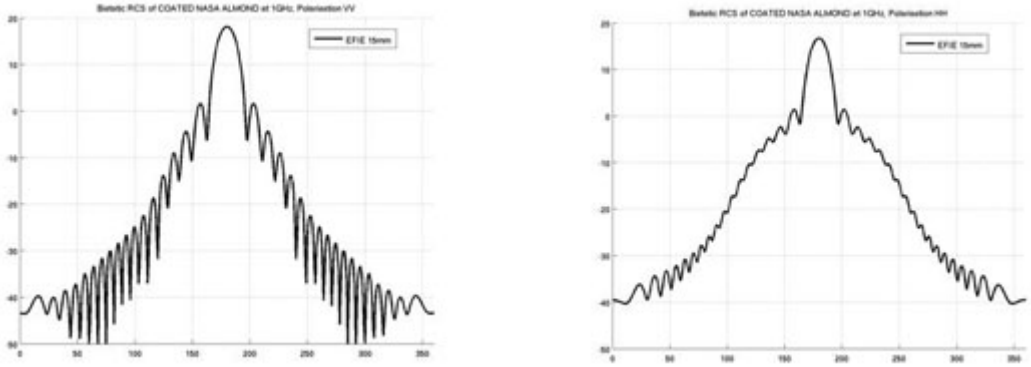

Figure 9: Bistatic RCS of 2.5m coated NASA almond at 1 GHz in x-y-plane.

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