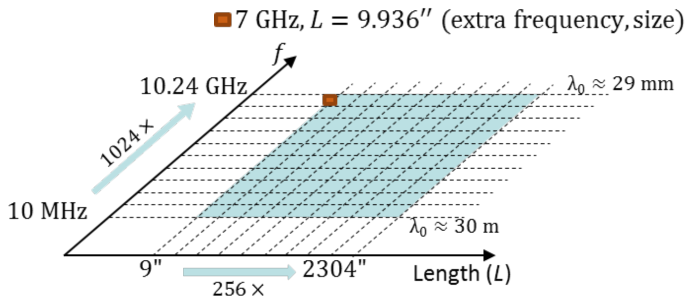
Description of Scattering Object

A perfect electrically conducting (PEC) almond proportional to the dimensions in [1].

Length Scale and Frequency Range

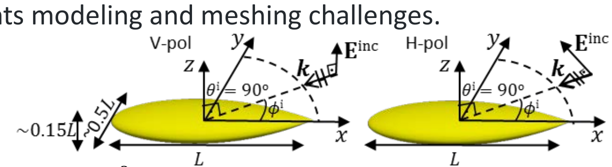


The problems of interest cover a range of 256x in physical length scale and 1024x in frequency; the ranges are logarithmically sampled to yield 99 scattering problems. Because the almond is PEC, there are only 19 + 1 unique scattering problems in Problem IIIA. In these problems, the almond sizes are in the range $0.0076 \leq L/\lambda_0 \leq 1998$, where λ_0 is the free-space wavelength.

Interesting Features

1. The set includes 1 extra frequency for 1 size because of a publicly available measurement result [1].
2. The non-trivial shape and tip of the almond presents modeling and meshing challenges.

Quantities of Interest

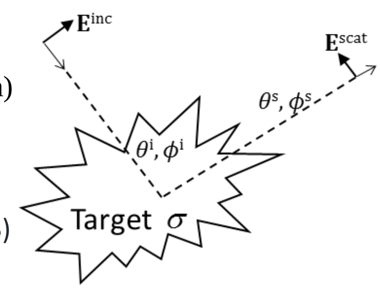


Radar cross section (RCS) definition

$$\sigma_{vu}\left(\theta^{\rm s},\phi^{\rm s},\theta^{\rm i},\phi^{\rm i}\right)=\lim_{R\to\infty}4\pi R^2\frac{\left|\hat{v}\left(\theta^{\rm s},\phi^{\rm s}\right)\bullet\mathbf{E}^{\rm scat}\left(\theta^{\rm s},\phi^{\rm s}\right)\right|^2}{\left|\hat{u}\left(\theta^{\rm i},\phi^{\rm i}\right)\bullet\mathbf{E}^{\rm inc}\left(\theta^{\rm i},\phi^{\rm i}\right)\right|^2} \quad : \text{RCS } (\text{m}^2)$$

$$\sigma_{vu,\text{dB}}\left(\theta^{\rm s},\phi^{\rm s},\theta^{\rm i},\phi^{\rm i}\right)=10\log_{10}\sigma_{vu} \quad : \text{RCS in dB (dBsm)}$$

$$\sigma_{vu,\text{dB}}^{TH}\left(\theta^{\rm s},\phi^{\rm s},\theta^{\rm i},\phi^{\rm i}\right)=\max(\sigma_{vu,\text{dB}},TH_{\text{dB}})-TH_{vu,\text{dB}} \quad : \text{Thresholded RCS}$$



1. Set $\theta^{\rm i} = 90^{\rm o}$. Vary $0^{\rm o} \leq \phi^{\rm i} \leq 180^{\rm o}$ (every $0.5^{\rm o}$ in the interval).
2. Compute back-scattered $\sigma_{\theta\theta,\text{dB}}$ and $\sigma_{\phi\phi,\text{dB}}$ (the VV and HH-RCS in dB) at $N_\phi = 361$ scattering directions.

Performance Measures

Error Measure: Simulation errors shall be quantified using

$$avg.err_{uu,\text{dB}}^{TH}=\frac{1}{2\pi}\int_0^{2\pi}\left|\sigma_{uu,\text{dB}}^{TH}\left(\phi^{\rm s}\right)-\sigma_{uu,\text{dB}}^{\text{ref},TH}\left(\phi^{\rm s}\right)\right|d\phi^{\rm s}\approx\frac{1}{N_\phi}\sum_{n=1}^{N_\phi}\left|\sigma_{uu,\text{dB}}^{TH}\left(\phi^{\rm s}\right)-\sigma_{uu,\text{dB}}^{\text{ref},TH}\left(\phi^{\rm s}\right)\right| \quad (\text{dB}) \quad \text{for } u\in\{\theta,\phi\}$$

where

$$TH_{\text{dB}}=\max_{\phi^{\rm s}}\sigma_{uu,\text{dB}}^{\text{ref}}-80 \text{ (dB)}$$

This error measure discounts errors in RCS values below TH .

Cost Measure: Simulation costs shall be quantified using observed wall-clock time and peak memory/core

$$t_{\text{main}}^{\text{wall}} \text{ (s)}$$
$$mem_{\text{main}}^{\text{maxcore}} \text{ (bytes)}$$

as well as the "serialized" CPU time and total memory requirement

$$t_{\text{main}}^{\text{total}} = N_{\text{proc}} \times t_{\text{main}}^{\text{wall}} \text{ (s)}$$
$$mem_{\text{main}}^{\text{max}} = N_{\text{proc}} \times mem_{\text{main}}^{\text{maxcore}} \text{ (bytes)}$$

Here, N_{proc} denote the number of processes used in a parallel simulation. It is expected that results will be reported for at least 2 runs: "Efficient" (small N_{proc}) and "Fast" (large N_{proc}).

Study 1: Error vs. Cost Sweep

Fix frequency and fix almond dimensions. Simulate many error levels (proxy: mesh densities) for 4 cases:

Case 1: *f*=10 MHz, *L*=9 in
Case 2: *f*=7 GHz, *W*=9.936 in (Measurement frequency)
Case 3: *f*=10 MHz, *L*=288 in
Case 4: *f*=320 MHz, *L*=288 in

It's recommended to simulate as many error levels (mesh densities) as possible. 3-5 error levels is typical. A typical error-vs.-cost study will consist of 4x3-5=12-20 simulations.

Study 2: Frequency Sweep

Fix almond dimensions and error level (proxy: mesh density). Simulate many frequencies for 4 cases:

Case 1: *L*=9 in, error level 1 (coarsest mesh)
Case 2: *L*=288 in, error level 1 (coarsest mesh)
Case 3: *L*=9 in, error level 2 (finer mesh)
Case 4: *L*=288 in, error level 2 (finer mesh)

Frequencies shall be chosen as $f \in \{10, 20, 40, \ldots, 5120, 10240\}$ MHz. It's recommended to simulate as many frequencies as possible. A full frequency-sweep study will consist of 4x11=44 simulations.

Study 3: Size Sweep

Fix frequency and error level (proxy: mesh density). Simulate many diameters for 4 cases:

Case 1: *f*=10 MHz, error level 1 (coarsest mesh)
Case 2: *f*=320 MHz, error level 1 (coarsest mesh)
Case 3: *f*=10 MHz, error level 2 (finer mesh)
Case 4: *f*=320 MHz, error level 2 (finer mesh)

Dimensions shall be chosen as $L \in \{9, 18, 36, \ldots, 1152, 2304\}$ in. It's recommended to simulate as many sizes as possible. A full size-sweep study will consist of 4x9=36 simulations.

Reference Quantities of Interest

The following RCS data is made available in the benchmark to enable participants to calibrate their simulators:

4 RCS results corresponding to the cases in study 1 found by using ARCHIE-AIM code, a frequency-domain FFT-accelerated integral-equation solver developed at UT Austin [2]-[4].

References

[1] A. C. Woo, H. T. G. Wang, M. J. Schuh and M. L. Sanders, "EM programmer's notebook-benchmark radar targets for the validation of computational electromagnetics programs," in *IEEE Ant. Propag. Mag.*, vol. 35, no. 1, pp. 84-89, Feb. 1993.

[2] M. F. Wu, G. Kaur, and A. E. Yılmaz, "A multiple-grid adaptive integral method for multi-region problems," *IEEE Trans. Antennas Propag.*, vol. 58, no. 5, pp. 1601-1613, May 2010.

[3] F. Wei and A. E. Yılmaz, "A more scalable and efficient parallelization of the adaptive integral method part I: algorithm," *IEEE Trans. Antennas Propag.*, vol. 62, no.2, pp. 714-726, Feb. 2014.

[4] J. W. Massey, V. Subramanian, C. Liu, and A. E. Yılmaz, "Analyzing UHF band antennas near humans with a fast integral-equation method," in *Proc. EUCAP*, Apr. 2016.