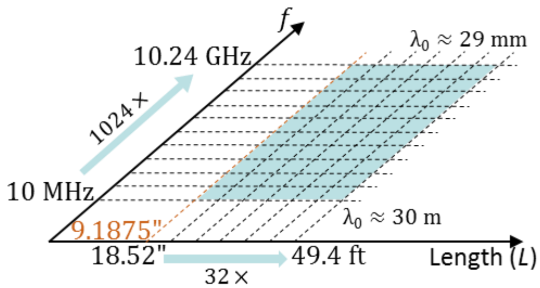
Description of Scattering Object
A perfect electrically conducting (PEC) complex aircraft model.

Length Scale and Frequency Range

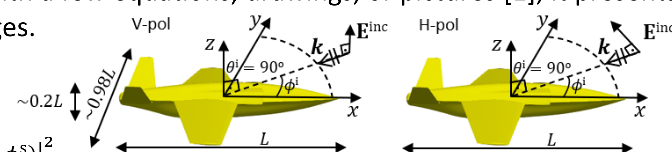


The problems of interest cover a range of ~64x in physical length scale and 1024x in frequency; the ranges are logarithmically sampled to yield 77 scattering problems. Because the aircrafts are PEC, there are only 16 + 12 unique scattering problems in Problem Set IVA. In these problems, the model sizes are in the range $0.007 \leq L/\lambda_0 \leq 514$, where λ_0 is the free-space wavelength.

Interesting Features

1. The logarithmic sampling is distorted along the size axis for the smallest model: the smallest Closed-Duct PRIME aircraft has L=9.1875'' (instead of L≈9.261''). The sampling is also distorted along the frequency axis: scattering from the smallest aircraft at frequencies $f \in$ {10, 20, 40, 80, 160, 320, 640, 1280, 2580, 5120, 7000, 10250} MHz are included in the problem set. These distortions are because of publicly available measurement data [1] and add 12 unique scattering problems to the set.

2. The model cannot be described sufficiently with a few equations, drawings, or pictures [1]; it presents modeling, meshing, and reproducibility challenges.

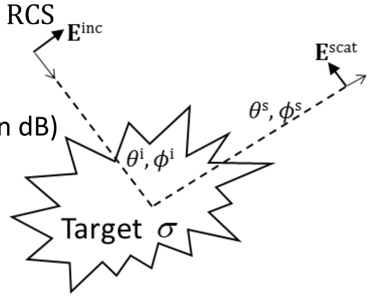


Quantities of Interest
Radar cross section (RCS) definition

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

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

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



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

Performance Measures
Error Measure: Simulation errors shall be quantified using

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

where

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

This error measure discounts errors in RCS values smaller than TH.
Cost Measure: Simulation costs shall be quantified using observed wall-clock time and peak memory/process

$$t^{\rm wall}\text{(s) and } mem^{\rm maxproc}\text{(bytes)}$$

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

$$t^{\rm total} = N_{\rm proc} \times t^{\rm wall}\text{(s) and } mem^{\rm max} = N_{\rm proc} \times mem^{\rm maxproc}\text{ (bytes)}$$

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

Study 1: Error vs. Cost Sweep

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

Case 1: *f*=10 MHz, *L*=9.1875 in Case 2: *f*=7 GHz, *L*=9.1875 in

Case 3: *f*=10 MHz, *L*≈49.4 ft (592.763 in) Case 4: *f*=320 MHz, *L*≈49.4 ft (592.763 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 aircraft dimensions and error level (proxy: mesh density). Simulate many frequencies for 4 cases:

Case 1: *L*≈18.52 in, error level 1 (coarsest mesh) Case 2: *L*≈49.4 ft, error level 1 (coarsest mesh)

Case 3: *L*≈18.52 in, error level 2 (finer mesh) Case 4: *L*≈49.4 ft, 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 sizes 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 $L \in \{9.1875, 18.524, 37.04, \ldots, 296.3815, 592.763\}$ in. It's recommended to simulate as many sizes as possible. A full size-sweep study will consist of 4x7=28 simulations.

Reference Quantities of Interest

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

8 RCS measurement results corresponding to the smallest aircraft (*L*=9.1875 in) at frequencies $f \in \{2580, 5120, 7000, 10250\}$ MHz. These measurements were made using two aircraft scale models [1]: One was of size *L*=9.1875 in and the other was scaled up 2x in all dimensions. These data are provided for ϕ^{i} sampled every 0.25^{o}.

4 RCS simulation results for the smallest aircraft at the above 4 frequencies found by using the ARCHIE-AIM code, a frequency-domain FFT-accelerated integral-equation solver developed at UT Austin [2]-[4].

References

[1] J. T. Kelley, A. Maicke, D. A. Chamulak, C. C. Courtney, and A. E. Yılmaz, "Adding a reproducible airplane model to the Austin RCS benchmark suite," in *Proc. Applied Comp. Electromagnetics Society (ACES) Symp.*, July 2020.

[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.