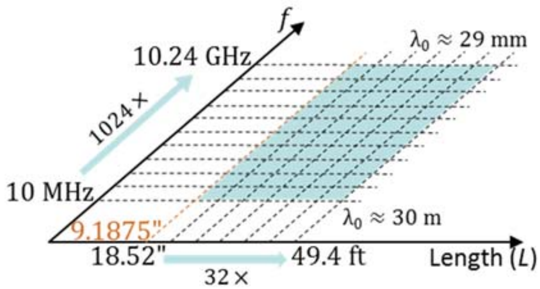
Description of Scattering Object

A perfect electrically conducting (PEC) complex aircraft model.

Length Scale and Frequency Range

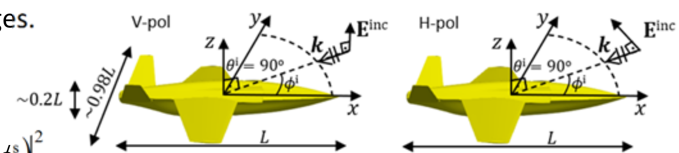


The problems of interest cover a range of ~64x in physical length scale and 1024x in frequency; the ranges are logarithmically sampled to yield 99 scattering problems. Because the aircrafts are PEC, there are only 17 + 12 unique scattering problems in Problem Set IVA. In these problems, the model sizes 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.



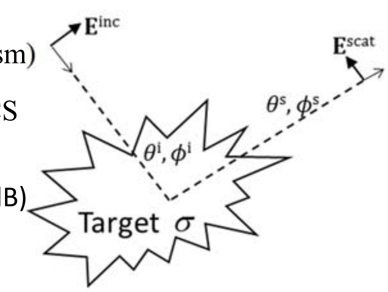
Quantities of Interest

Radar cross section (RCS) definition

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

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

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



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

Performance Measures

Error Measure: Simulation errors shall be quantified using

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

where

$$TH_{uu,\mathrm{dB}}=\max_{\phi^{\mathrm{s}}}\sigma^{\mathrm{ref}}_{uu,\mathrm{dB}}-80 \text{ (dB)}$$

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

$$t^{\mathrm{wall}}_{\mathrm{main}} \text{ (s) and } mem^{\mathrm{maxcore}}_{\mathrm{main}} \text{ (bytes)}$$

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

$$t^{\mathrm{total}}_{\mathrm{main}} = N_{\mathrm{proc}} \times t^{\mathrm{wall}}_{\mathrm{main}} \text{ (s) and } mem^{\mathrm{max}}_{\mathrm{main}} = N_{\mathrm{proc}} \times mem^{\mathrm{maxcore}}_{\mathrm{main}} \text{ (bytes)}$$

Here, N_{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_{proc}) and "Fast" (large N_{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, … , 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, … , 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=9.375 in and the other was scaled up 2x in all dimensions. These data are provided for ϕ^{i} sampled every 0.25$^{\mathrm{o}}$.

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.