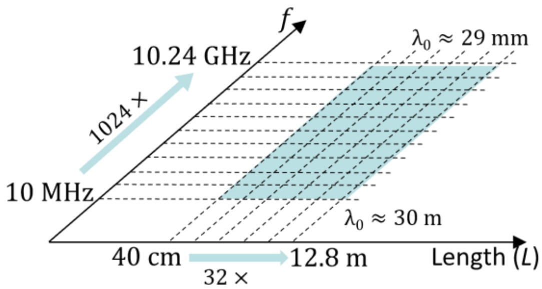
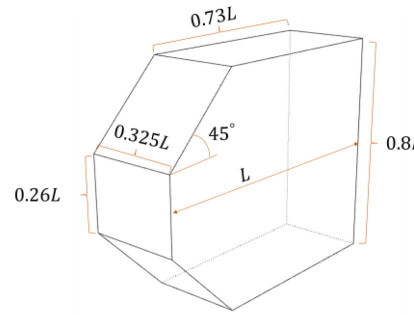
Description of Scattering Object

A perfect electrically conducting (PEC) hexagonal prism.

Length Scale and Frequency Range

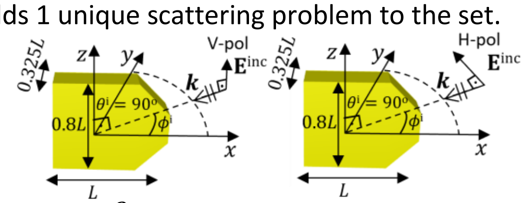


The problems of interest cover a range of 32x in physical length scale and 1024x in frequency; the ranges are logarithmically sampled to yield 66 scattering problems. Because the camera boxes are PEC, there are only 16+1 unique scattering problems in Problem Set IIISA. In these problems, the model sizes are in the range $0.013 \leq L/\lambda_0 \leq 438$, where λ_0 is the free-space wavelength.



Interesting Features

1. The camera box is designed as a host structure to enable reproducible RCS measurements of ducts. The flat-plate geometrical features of the housing promote strong backscattering in certain directions that are minimally affected by the scattering characteristics of any voids in the box [1].
2. The sampling of the frequency range is distorted for this problem: Scattering from the smallest camera box at frequencies $f \in$ {10, 20, 40, 80, 160, 320, 640, 1280, 2560, 5120, 7000, 10240} MHz are included in the problem set. This distortion is because of publicly available measurement data [1] and adds 1 unique scattering problem to the set.



Quantities of Interest

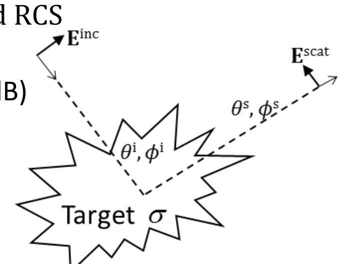
Radar cross section (RCS) definition

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

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

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

1. Set $\theta^{i} = 90^{o}$. Vary $0^{o} \leq \phi^{i} \leq 180^{o}$ (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-pol RCS in dB) at $N_{\phi} = 361$ scattering directions.



Performance Measures

Error Measure: Simulation errors shall be quantified using

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

where

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

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

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

as well as the “serialized” CPU time and total memory requirement

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

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 camera box dimensions. Simulate many error levels (proxy: mesh densities) for 4 cases:

Case 1: *f*=10 MHz, *L*=40 cm Case 2: *f*=7 GHz, *L*=40 cm
Case 3: *f*=10 MHz, *L*=6.4 m Case 4: *f*=320 MHz, *L*=6.4 m

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

Case 1: *L*=40 cm, error level 1 (coarsest mesh) Case 2: *L*=6.4 m, error level 1 (coarsest mesh)
Case 3: *L*=40 cm, error level 2 (finer mesh) Case 4: *L*=6.4 m, error level 2 (finer mesh)

Frequencies shall be chosen as *f* ∈ {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* ∈ {40, 80, 120, … , 640, 1280} cm. 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 camera box (*L*=40 cm) at frequencies *f* ∈ {2560 5120, 7000, 10240} MHz. These data are provided for ϕ^{i} sampled every 0.5^{o}. Note that the high return at $\phi^{\mathrm{i}} = 90^{\mathrm{o}}$ saturated the instrumentation radar at 10240 MHz; thus, the measured RCS values near that look angle are inaccurate. The same phenomenon can be observed in Fig. 3 in [1].

4 RCS simulation results for the smallest camera box 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] A. E. Yilmaz, E. Smith, S. Cox, B. MacKie-Mason, C. C. Courtney, and G. Burchuk, "Camera boxes: a set of complex scattering problems to test EM simulations and measurements," in *Proc. IEEE Antennas Propag. Soc. Int. Symp.*, July 2022.

[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.