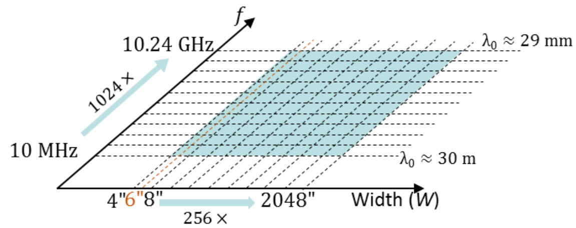
Description of Scattering Object

A perfect electrically conducting (PEC) plate of size $W \times 7W/4 \times 64$ mil.

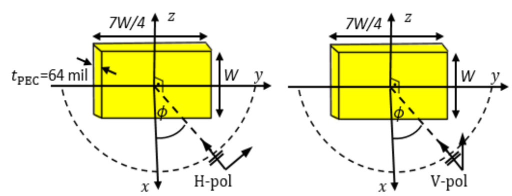
Length Scale and Frequency Range



The problems of interest cover a range of 512x in physical length scale and 1024x in frequency; the ranges are logarithmically sampled to yield 110 scattering problems. Because the plates are PEC, there are only 20 + 12 unique scattering problems in Problem Set IIB. In these problems, the plate sizes are in the range $0.0033 \leq W/\lambda_0 \leq 1776$, where λ_0 is the free-space wavelength. The dimensions were chosen to approximately match the plate targets in [1].

Interesting Features

1. The logarithmic sampling is distorted along the length axis and an extra plate of $W = 6$ in is introduced because of publicly available measurement data corresponding to this size [2]. The sampling is also distorted along the frequency axis: scattering from the plate of $W = 6$ in at frequencies $f \in \{$10, 20, 40, 80, 160, 320, 640, 1280, 2560, 5120, 7000, 10240$\}$ MHz are included in the problem set because of publicly available measurement data [2]. These distortions add 12 unique scattering problems to the set.
2. The thin side wall presents meshing and accurate integration challenges.



Quantities of Interest

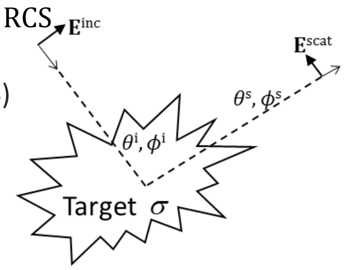
Radar cross section (RCS) definition

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

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

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

1. Set $\theta^{\mathrm{i}} = 90^{\mathrm{o}}$. Vary $0^{\mathrm{o}} \leq \phi^{\mathrm{i}} \leq 90^{\mathrm{o}}$ (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-pol RCS in dB) at $N_\phi = 181$ directions.



Performance Measures

Error Measure: Simulation errors shall be quantified using

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

where

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

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

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

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

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

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

Case 1: f=10 MHz, W=6 in Case 2: f=7 GHz, W=6 in (a measurement frequency)

Case 3: f=10 MHz, W=128 in Case 4: f=320 MHz, W=128 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 plate dimensions and error level (proxy: mesh density). Simulate many frequencies for 4 cases:

Case 1: W=6 in, error level 1 (coarsest mesh) Case 2: W=128 in, error level 1 (coarsest mesh)

Case 3: W=6 in, error level 2 (finer mesh) Case 4: W=128 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 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 $W \in \{4, 8, 16, \ldots, 1024, 2048\}$ in. It's recommended to simulate as many sizes as possible. A full size-sweep study will consist of 4x10=40 simulations.

Reference Quantities of Interest

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

4 RCS measurement results corresponding to the W=6 in plate at frequencies $f \in \{2560, 5120, 7000, 10240\}$ MHz. The HH-polarized data are the same as those plotted in Fig. 6 of [2]; they are provided for ϕ^{i} sampled every 0.25^{o}.

4 RCS simulation results for the W=6 in at the above 4 frequencies found by using the ARCHIE-AIM code, a frequency-domain FFT-accelerated integral-equation solver developed at UT Austin [3]-[5].

References

[1] A. C. Woo, H. T. G. Wang, M. J. Schuh, and M. L. Sanders, "EM programmer's notebook-benchmark plate radar targets for the validation of computational electromagnetics programs," *IEEE Ant. Propag. Mag.*, vol. 34, no. 6, pp. 52-56, Dec. 1992.

[2] J. T. Kelley, D. A. Chamulak, C. Courtney, and A. E. Yilmaz, "Increasing the material diversity in the Austin RCS Benchmark Suite using thin plates," in *Proc. Ant. Meas. Tech. Assoc. (AMTA) Symp.*, Nov. 2020.

[3] 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.

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[5] 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.