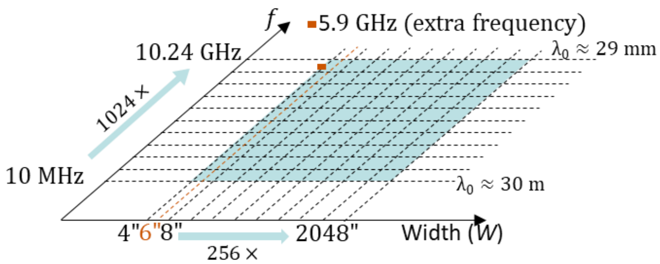
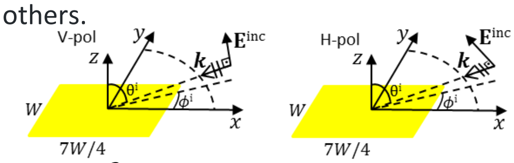
Description of Scattering Object
A perfect electrically conducting (PEC) zero-thickness plate of size $W \times 7W/4$.

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 + 1 + 12 unique scattering problems in Problem Set IIA. In these problems, the plate widths are in the range $0.0034 \leq W/\lambda_0 \leq 1776$, where λ_0 is the free-space wavelength.

Interesting Features
1. The set includes 1 extra frequency for $W = 4$ in because of publicly available measurement data [1].
2. 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 measurement data in [2]. These distortions add 12 unique scattering problems to the set. The solutions of these 12 problems can be compared to the corresponding problems in problem set IIB.
3. Zero thickness prevents various formulations and exercises others.



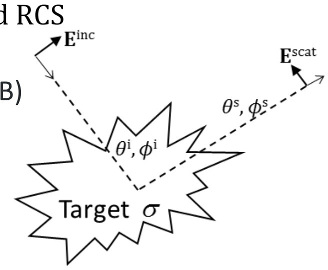
Quantities of Interest
Radar cross section (RCS) definition

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

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

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

1. Set $\theta^{\rm i} = 80^{\rm o}$. Vary $0^{\rm o} \leq \phi^{\rm i} \leq 90^{\rm o}$ (every $0.5^{\rm o}$ 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 $N_\phi = 181$ directions.



Performance Measures
Error Measure: Simulation errors shall be quantified using

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

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_{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*=4 in
Case 2: *f*=5.12 GHz, *W*=4 in
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*=4 in, error level 1 (coarsest mesh)
Case 2: *W*=128 in, error level 1 (coarsest mesh)
Case 3: *W*=4 in, error level 2 (finer mesh)
Case 4: *W*=128 in, 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)

Diameters shall be chosen as *D* ∈ {4, 8, 16, … , 1012, 2048} in. It's recommended to simulate as many sizes as possible. A full size-sweep study will consist of 4x9=36 simulations.

Study 4: Thin PEC Plate Comparison

Fix frequency and error level (proxy: mesh density). Simulate the frequencies *f* ∈ {2560, 5120, 7000, 10240} MHz for $W = 6$ in and compare the results to those from the $W = 6$ in thin PEC plate (of 64 mil thickness) in problem set II-B. For this comparison, change the zero-thickness plate's orientation so that it resides on the *z-y* plane, not the *x-y* plane. Also set $\theta^{\mathrm{i}} = 90^{\mathrm{o}}$ as in problem set II-B.

Reference Quantities of Interest

The following RCS data are 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 [3]-[5].

4 RCS results corresponding to the cases in study 4 found by using ARCHIE-AIM code [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.

[4] 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.

[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.