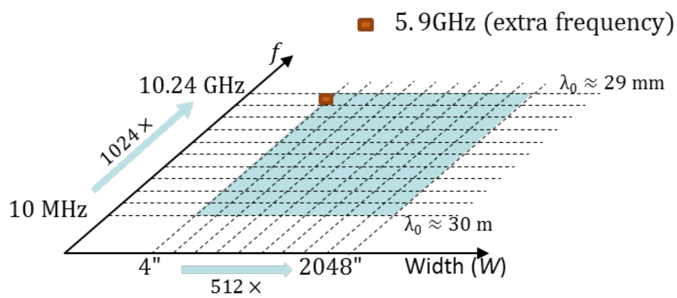
Description of Scattering Object

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

Length Scale and Frequency Range

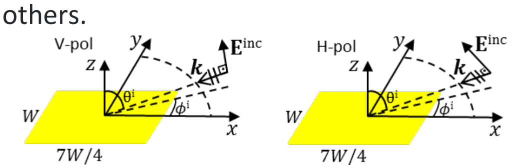


The problems of interest cover a range of 512x in physical length scale and 1024x in frequency; the ranges are logarithmically sampled to yield 120 scattering problems. Because the plates are PEC, there are only 20 + 1 unique scattering problems in Problem Set IIA. In these problems, the plate widths 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 1 size because of a publicly available measurement result [1].
2. Zero thickness prevents various formulations and exercises others.

Quantities of Interest

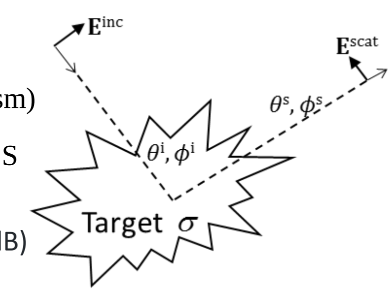


Radar cross section (RCS) definition

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

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

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



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-RCS in dB) at $N_\phi = 181$ directions.

Performance Measures

Error Measure: Simulation errors shall be quantified using

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

where

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

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

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

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

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

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

Case 1: f=10 MHz, W=4 in

Case 2: f=5.9 GHz, W=4 in (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=4in, error level 1 (coarsest mesh)

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

Case 3: W=4in, error level 2 (finer mesh)

Case 4: W=128in, 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)

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

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 [2]-[4].

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," in *IEEE Ant. Propag. Mag.*, vol. 34, no. 6, pp. 52-56, Dec 1992.

[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.