Description of Scattering Object
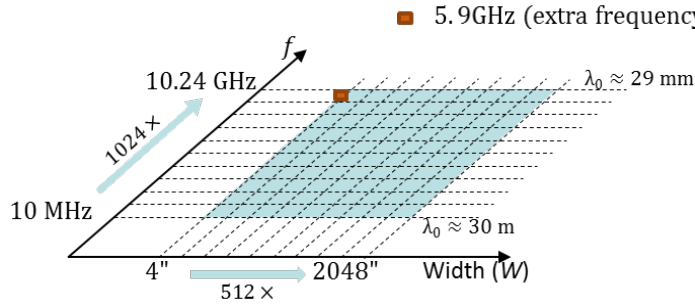A perfect electrically conducting (PEC) plate of size $W \times 7W/4 \times 31$ mil.

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 120 scattering problems. Because the plate is PEC, there are only 20 + 1 unique scattering problems in Problem IIB. In these problems, the sphere sizes are in the range $0.0034 \le W/\lambda_0 \le 1776$, 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. The thin side wall presents meshing and accurate integration challenges.
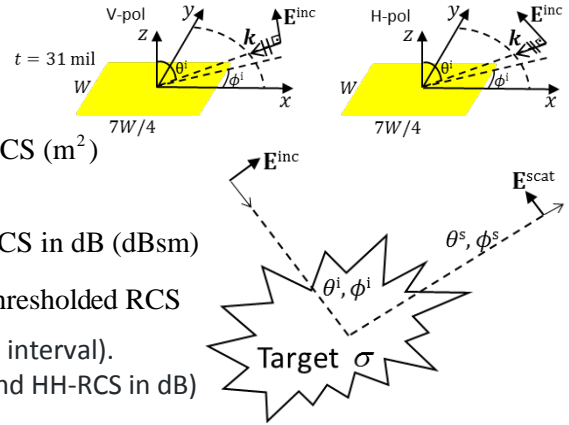
Quantities of Interest
Radar cross section (RCS) definition

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

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

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

1. Set $\theta^i = 80^o$. Vary $0^o \le \phi^i \le 90^o$ (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 $N_\phi = 181$ directions.

Performance Measures
Error Measure: Simulation errors shall be quantified using

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

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

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

$$t_{\mathrm{main}}^{\mathrm{wall}} \ (\mathrm{s})$$
$$mem_{\mathrm{main}}^{\mathrm{maxcore}} \ (\mathrm{bytes})$$

as well as the "serialized" CPU time and total memory requirement
$$t_{\mathrm{main}}^{\mathrm{total}} = N_{\mathrm{proc}} \times t_{\mathrm{main}}^{\mathrm{wall}} \ (\mathrm{s})$$
$$mem_{\mathrm{main}}^{\mathrm{max}} = N_{\mathrm{proc}} \times mem_{\mathrm{main}}^{\mathrm{maxcore}} \ (\mathrm{bytes})$$

Here, N_{proc} denote 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=5.9 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 $f \in \{10, 20, 40, \dots, 5120, 10240\}$ 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 $D \in \{4, 8, 16, \dots, 1012, 2048\}$ 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 is 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.