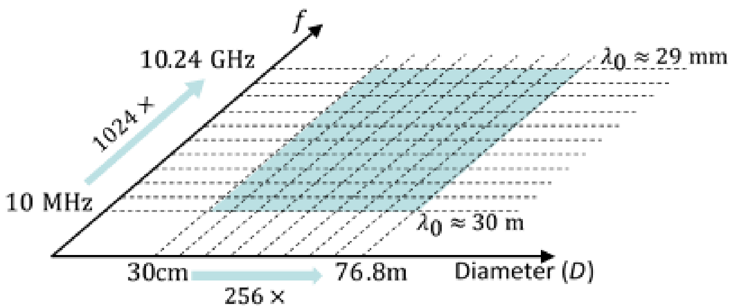
Description of Scattering Object

A perfect electrically conducting (PEC) sphere of radius $D/2$.

Length Scale and Frequency Range



The problems of interest cover a range of 256x in physical length scale and 1024x in frequency; the ranges are logarithmically sampled to yield 99 scattering problems. Because the sphere is PEC, there are only 19 unique scattering problems in Problem IA. In these problems, the sphere sizes are in the range $0.01 \leq D/\lambda_0 \leq 2624$, where λ_0 is the free-space wavelength.

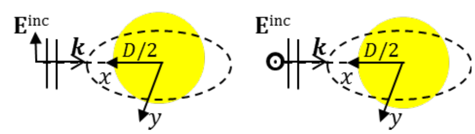
Interesting Features

1. Highly accurate, Mie-series analytical solutions are available for Problem IA.
2. Bi-static rather than mono-static RCS is used as the quantity of interest.

Quantities of Interest

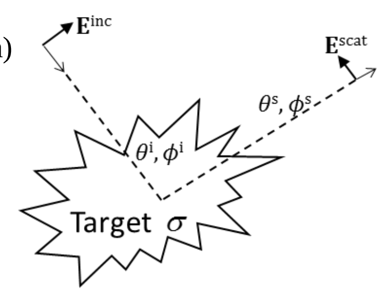
Radar cross section (RCS) definition

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



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

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



1. Set $\theta^{i} = 90^{o}$, $\phi^{i} = 0^{o}$, $\theta^{s} = 90^{o}$. Vary $0^{o} \leq \phi^{s} \leq 360^{o}$.
2. Compute both $\sigma_{\theta\theta,\text{dB}}$ and $\sigma_{\phi\phi,\text{dB}}$ (the VV and HH-RCS in dB) at $N_{\phi} = 721$ scattering directions (every 0.5^{o} in the interval $0^{o} \leq \phi^{s} \leq 360^{o}$).

Performance Measures

Error Measure: Simulation errors shall be quantified using

$$avg.err_{uu,\text{dB}}^{TH}=\frac{1}{2\pi}\int_{0}^{2\pi}\left|\sigma_{uu,\text{dB}}^{TH}\left(\phi^{s}\right)-\sigma_{uu,\text{dB}}^{\text{ref},TH}\left(\phi^{s}\right)\right|d\phi^{s}\approx\frac{1}{N_{\phi}}\sum_{n=1}^{N_{\phi}}\left|\sigma_{uu,\text{dB}}^{TH}\left(\phi^{s}\right)-\sigma_{uu,\text{dB}}^{\text{ref},TH}\left(\phi^{s}\right)\right| \quad \text{(dB) for } u\in\{\theta,\phi\}$$

where

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

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

$$t_{\text{main}}^{\text{wall}} \text{ (s)}$$

$$mem_{\text{main}}^{\text{maxcore}} \text{ (bytes)}$$

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

$$t_{\text{main}}^{\text{total}} = N_{\text{proc}} \times t_{\text{main}}^{\text{wall}} \text{ (s)}$$

$$mem_{\text{main}}^{\text{max}} = N_{\text{proc}} \times mem_{\text{main}}^{\text{maxcore}} \text{ (bytes)}$$

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 sphere diameter. Simulate many error levels (proxy: mesh densities) for 4 cases:

Case 1: f=10 MHz, D=0.6 m Case 2: f=320 MHz, D=0.6 m

Case 3: f=10 MHz, D=19.2 m Case 4: f=320 MHz, D=19.2 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 sphere diameter and error level (proxy: mesh density). Simulate many frequencies for 4 cases:

Case 1: D=0.6 m, error level 1 (coarsest mesh) Case 2: D=19.2 m, error level 1 (coarsest mesh)

Case 3: D=0.6 m, error level 2 (finer mesh) Case 4: D=19.2 m, 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 diameters 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 $D \in \{0.3, 0.6, 1.2, \dots, 38.4, 76.8\}$ m. It's recommended to simulate as many diameters 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 COMPASS-EM code [1].

References

[1] G. Kaur (2015) COMPASS-EM: Comprehensive program for analytical scattering solutions for electromagnetics. [Online]. Available: http://web.corral.tacc.utexas.edu/BioEM-Benchmarks/COMPASS-EM/index.html