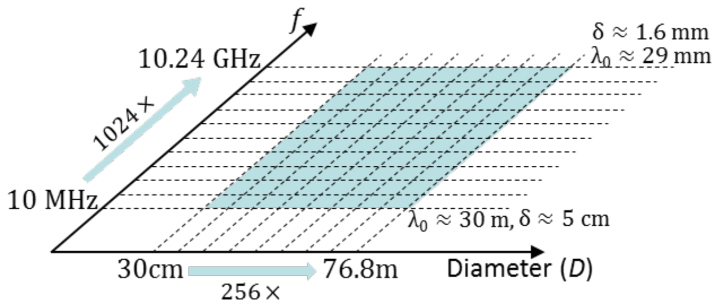
Description of Scattering Object

A semiconductor sphere of radius $D/2$ and conductivity 10 S/m.

Length Scale and Frequency Range

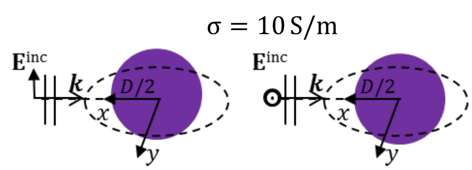


The problems of interest cover a range of 256x in physical length scale and 1024x in frequency; the ranges are logarithmically sampled to yield 99 unique scattering problems. In these problems, the sphere sizes are in the range $0.01 \leq D/\lambda_0 \leq 2624$ and $6 \leq D/\delta \leq 4.75 \times 10^4$, where λ_0 is the free-space wavelength and δ is the penetration depth in the sphere.

Interesting Features

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

Quantities of Interest

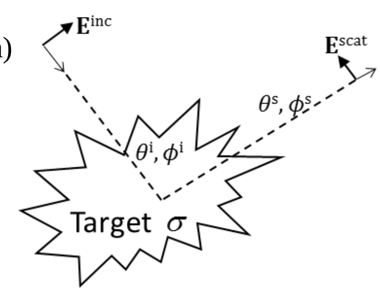


Radar cross section (RCS) definition

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

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

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



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

Performance Measures

Error Measure: Simulation errors shall be quantified using

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

where

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

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

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

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

$$t_{\mathrm{main}}^{\mathrm{total}} = N_{\mathrm{proc}} \times t_{\mathrm{main}}^{\mathrm{wall}} \text{ (s)}$$
$$mem_{\mathrm{main}}^{\mathrm{max}} = N_{\mathrm{proc}} \times mem_{\mathrm{main}}^{\mathrm{maxcore}} \text{ (bytes)}$$

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 $f \in \{10, 20, 40, \ldots, 5120, 10240\}$ 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 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 $D \in \{0.3, 0.6, 1.2, \ldots, 38.4, 76.8\}$ 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