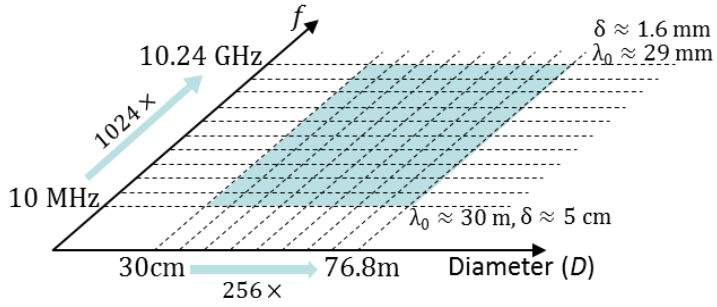
Description of Scattering Object

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

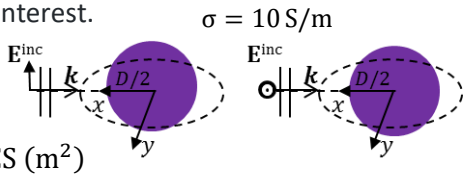
Length Scale and Frequency Range



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 $0.01 \le D/\lambda_0 \le 2624$ and $6 \le D/\delta \le 4.75 \times 10^4$, 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 Set IB.
2. Bi-static rather than mono-static RCS is used as the quantity of interest.



Quantities of Interest

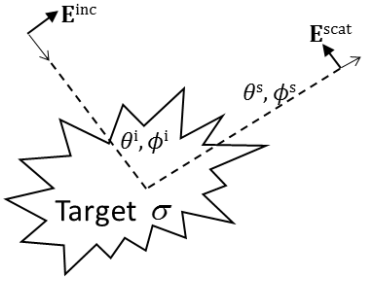
Radar cross section (RCS) definition

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

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

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

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



Performance Measures

Error Measure: Simulation errors shall be quantified using

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

where

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

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

$$t^{\text{wall}}(\text{s}) \text{ and } mem^{\text{maxproc}}(\text{bytes})$$

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

$$t^{\text{total}} = N_{\text{proc}} \times t^{\text{wall}}(\text{s}) \text{ and } mem^{\text{max}} = N_{\text{proc}} \times mem^{\text{maxproc}} \text{ (bytes)}$$

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 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 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 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