Austin RCS Benchmark with WIPL-D Software

PEC Sphere, PEC Plate (No Thickness), PEC Plate (64 mil Thickness)

Introduction

This document will present several RCS results derived from three structures: a PEC sphere, an infinitely thin PEC plate, and a PEC plate with 64 mil thickness. The structures were simulated at several frequencies. These structures are simulated as a verification of the quality of RCS results obtained using the WIPL-D Software suite [1] by comparing the simulation results with the results from "*Austin RCS Benchmark*" [2]. In fact, The University of Texas Austin has created a computational electromagnetics benchmark suite for validating various radar cross-section (RCS) calculation methods.

The WIPL-D Software is a full wave 3D electromagnetic Method-of-Moments (MoM) based simulation tool, applying Surface Integral Equations (SIEs) and Higher Order Basis Functions (HOBFs) to ensure high computational efficiency. It will be shown that the WIPL-D Software can be used to accurately simulate selected benchmark models in a reasonable time, using an affordable computer workstation.

More details on the basics of RCS and some of the results obtained in the WIPL-D solver can be found in the document available at the following link: RCS_018_WIPL-D_Austin_RCS_Benchmark_with_WIPL-D_Software_2024.pdf.

Simulated Models

All model geometries were created in WIPL-D Pro Software according to the dimensions provided by University of Texas Austin. Examples of simulated PEC spheres and PEC plates are shown in Figure 1. All the geometries were modeled as PEC bodies.

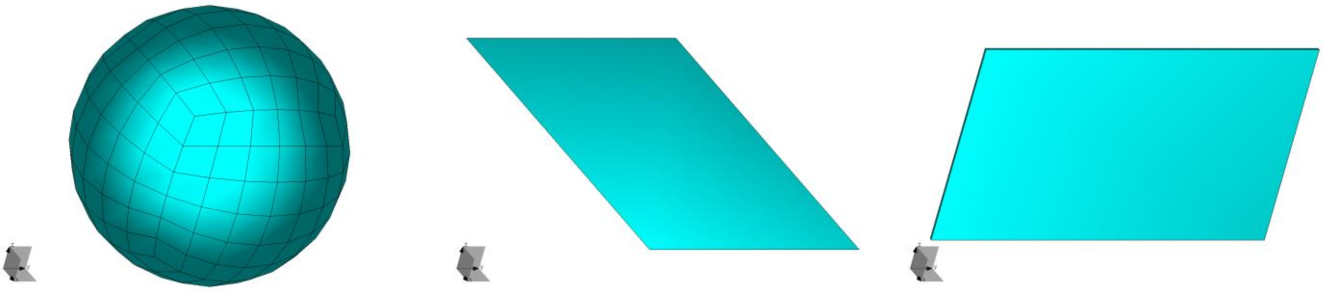


Figure 1. Examples of simulated geometries. From left to right: a PEC sphere, a PEC plate without thickness, and a PEC plate with 64 mil thickness

The model dimensions, frequencies of interest, and other settings will be described separately for each simulated geometry.

Simulations Settings and Computer Platform

Each WIPL-D simulation is performed using pure 3D EM MoM Solver. In WIPL-D, theta angle represents the elevation angle and $\theta = 0°$ points toward horizon. Besides simulation data, each set of results presented in the next chapters contains, so called, *HH Polarization* and *VV Polarization*. *HH Polarization* represents the RCS results in case where the incident wave contains only the E_ϕ component while only the scattered E_ϕ component is taken into the account. Similarly, *VV Polarization* represents the RCS results in the case where the incident wave contains only the E_θ component while only scattered E_θ component is considered.

The reference results for the PEC sphere are obtained using COMPASS-EM code. The reference results for the PEC plate without thickness are obtained using ARCHIE-AIM. Finally, the reference results for PEC plate with 64 mil thickness are obtained using ARCHIE-AIM and measurements.

Table 1 contains data about the computer platform used for running the simulations.

Table 1. Computer platform used for running the simulations

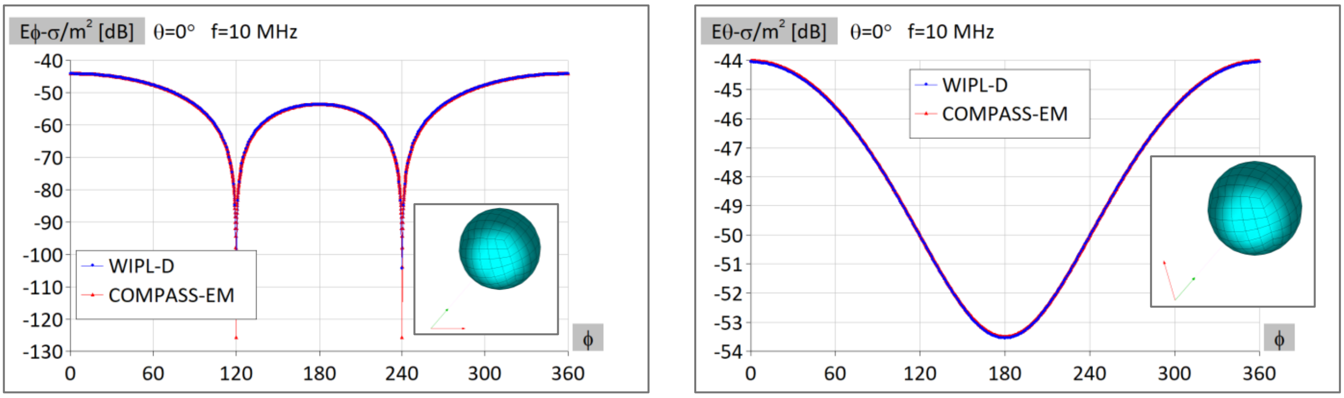
Hardware	Description
Processor	Intel® Core™ i7-7700 CPU @ 3.60GHz 3.60 GHz
RAM	64 GB

RCS Results and Simulation Data – PEC Spheres

PEC spheres [3] with diameters of 0.6 m and 19.2 m were simulated at 10 MHz and 320 MHz. The bistatic RCS is computed with incident wave direction angle defined as $\theta_i = 0°$ and $\phi_i = 0°$ (as explained earlier, $\theta_i = 0°$ points toward horizon). The scattering was computed at the angles $\theta_s = 0°$ and $0° \leq \phi_s \leq 360°$. In order to illustrate possible reduction in the simulation time and computational resources, the sphere was modeled in several ways including the full model of the sphere, the half model of the sphere involving a symmetry plane, the quarter model of the sphere involving two symmetry planes, and one eight model of the sphere involving three symmetry planes.

Computed RCS results and simulation data for PEC spheres are displayed in Figures 2-5 and Tables 2-5. Presented data are:

- RCS bistatic results for *HH Polarizations* compared between WIPL-D and COMPASS-EM results (left side of the figures)
- RCS bistatic results for *VV Polarizations* compared between WIPL-D and COMPASS-EM results (right side of the figures)
- A table with WIPL-D simulation data and number of phi angle directions

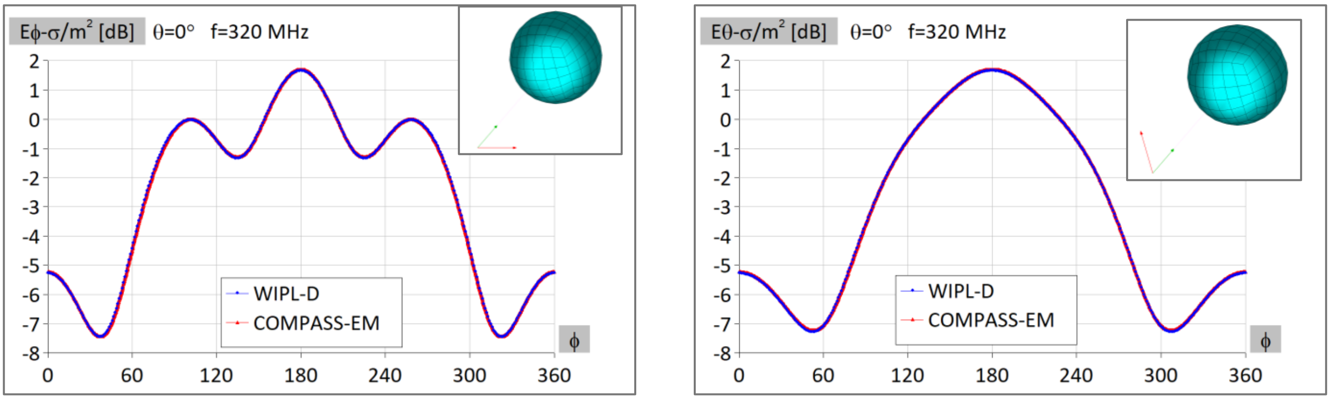


HH Polarization **VV Polarization**

Figure 2. RCS results for 0.6 m diameter PEC sphere at frequency of 10 MHz

Table 2. Simulation data

Model	Number of elements	Number of unknowns	Number of phi angle directions	Total simulation time [sec]
Sphere, 0.6 m, 10 MHz, HH	216	432	361	0.5
Sphere, 0.6 m, 10 MHz, VV	216	432	361	0.5

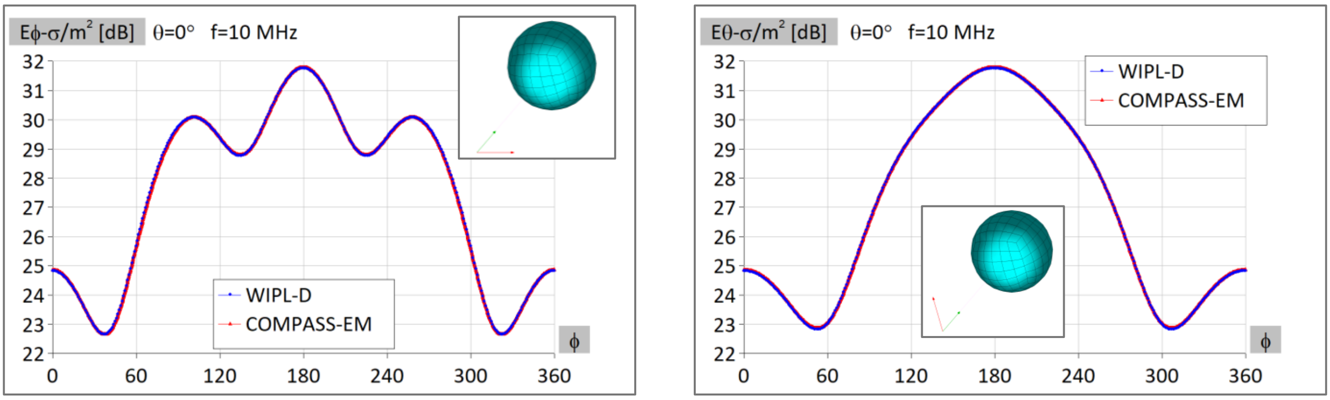


HH Polarization **VV Polarization**

Figure 3. RCS results for 0.6 m diameter PEC sphere at frequency of 320 MHz

Table 3. Simulation data

Model	Number of elements	Number of unknowns	Number of phi angle directions	Total simulation time [sec]
Sphere, 0.6 m, 320 MHz, HH	216	432	361	0.5
Sphere, 0.6 m, 320 MHz, VV	216	432	361	0.4

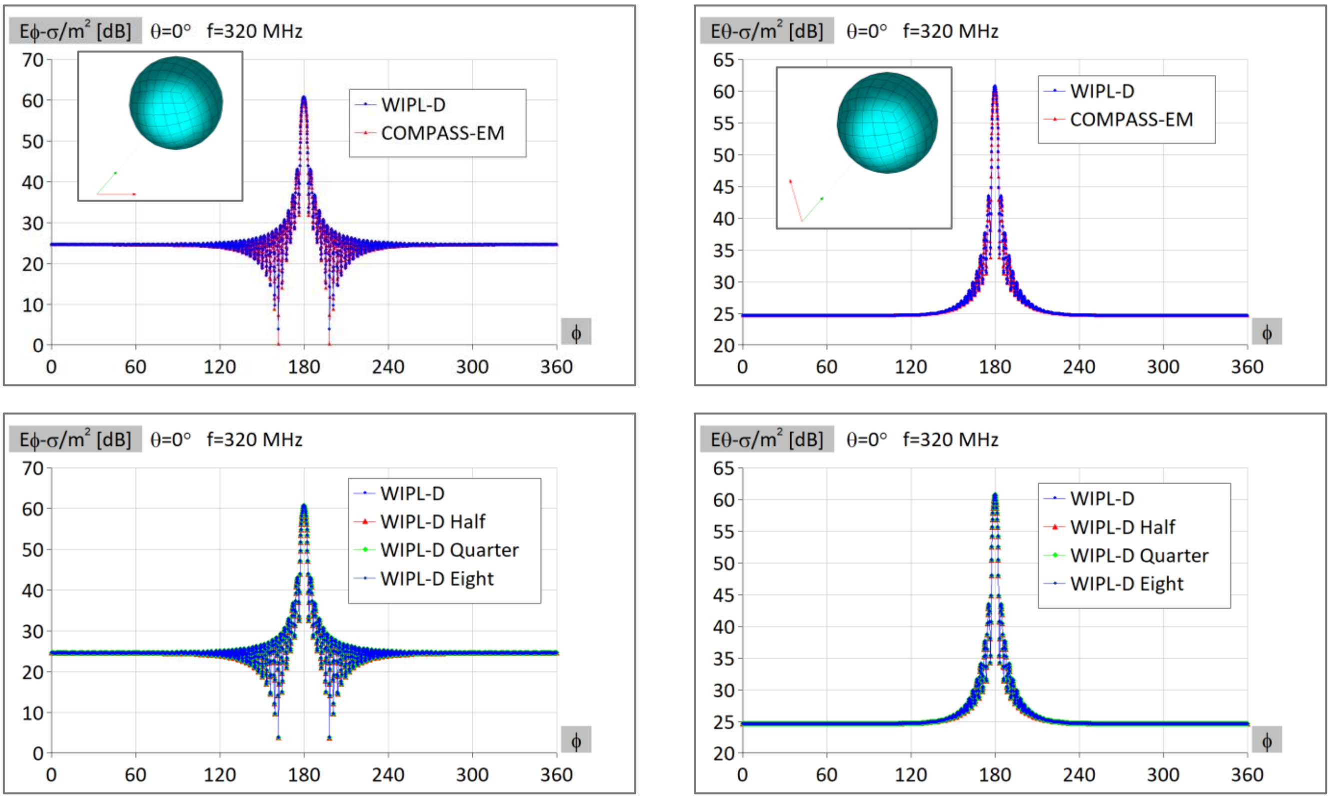


HH Polarization VV Polarization

Figure 4. RCS results for 19.2 m diameter PEC sphere at frequency of 10 MHz

Table 4. Simulation data

Model	Number of elements	Number of unknowns	Number of phi angle directions	Total simulation time [sec]
Sphere, 19.2 m, 10 MHz, HH	216	432	361	0.55
Sphere, 19.2 m, 10 MHz, VV	216	432	361	0.4



HH Polarization VV Polarization

Figure 5. RCS results for 19.2 m diameter PEC sphere at frequency of 320 MHz

Table 5. Simulation data

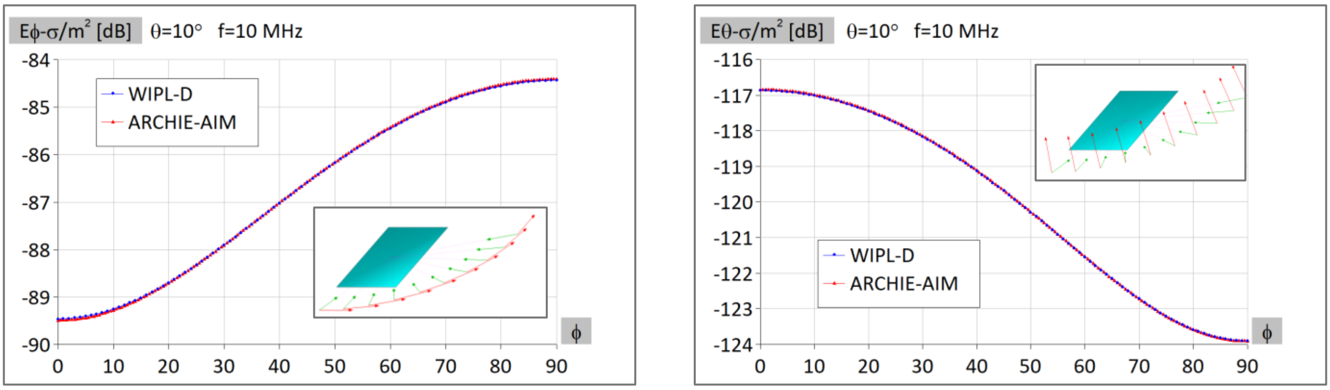
Model	Number of elements	Number of unknowns	Number of phi angle directions	Total simulation time [min]
Sphere, 19.2 m, 320 MHz, HH	7,776	62,208	1,801	34
Sphere, 19.2 m, 320 MHz, HH Half	7,776	30,960	1,801	5.5
Sphere, 19.2 m, 320 MHz, HH Quarter	7,776	15,552	1,801	1.3
Sphere, 19.2 m, 320 MHz, HH Eight	7,776	7,812	1,801	1.0
Sphere, 19.2 m, 320 MHz, VV	7,776	62,208	1,801	34
Sphere, 19.2 m, 320 MHz, VV Half	7,776	31,248	1,801	5.5
Sphere, 19.2 m, 320 MHz, VV Quarter	7,776	15,552	1,801	1.3
Sphere, 19.2 m, 320 MHz, VV Eight	7,776	7,812	1,801	1.0

RCS Results and Simulation Data – PEC Plate without Thickness

PEC plate without thickness [4] was defined with the width to length ratio of W to W*7/4, where W is either 4 in or 128 in. Plate with W = 4 in was simulated at 10 MHz and 5.12 GHz. Another plate without thickness and with W = 128 in was simulated at 10 MHz and 320 MHz. Monostatic RCS is, in these cases, computed at the angles $\theta_s = 10°$ and $0° \leq \phi_s \leq 90°$.

Computed RCS results and simulations data for the PEC plates with no thickness are displayed in Figures 6-9 and Tables 6-9. Presented data are:

- RCS monostatic results for *HH Polarizations* compared between WIPL-D and ARCHIE-AIM results (left side of the figures)
- RCS monostatic results for *VV Polarizations* compared between WIPL-D and ARCHIE-AIM results (right side of the figures)
- A table with WIPL-D simulation data and number of phi angle directions

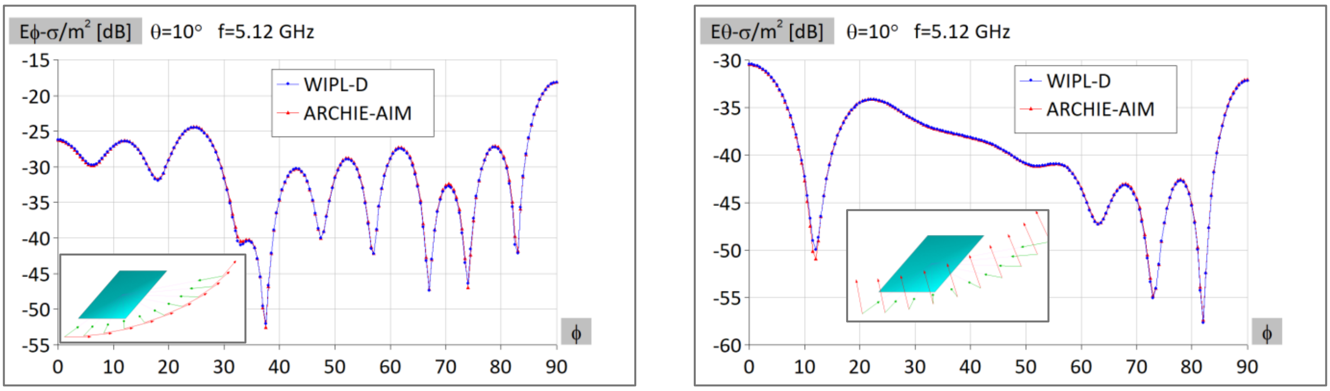


HH Polarization **VV Polarization**

Figure 6. RCS results for infinitely thin PEC plate (W = 4 in) at frequency of 10 MHz

Table 6. Simulation data

Model	Number of elements	Number of unknowns	Number of phi angle directions	Total simulation time [sec]
Plate, 4 in, 10 MHz, HH	22	100	91	0.5
Plate, 4 in, 10 MHz, VV	14	156	91	0.23

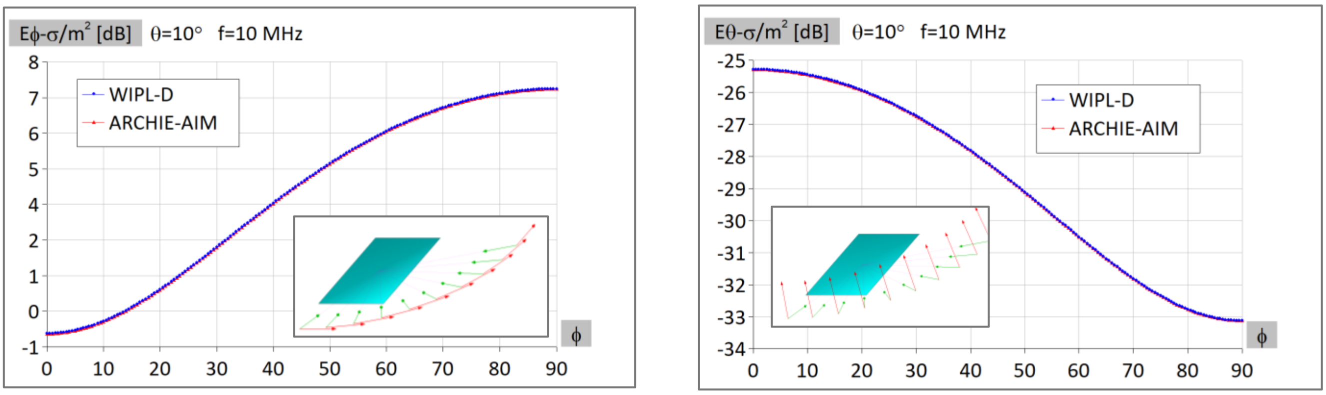


HH Polarization **VV Polarization**

Figure 7. RCS results for infinitely thin PEC plate (W = 4 in) at frequency of 5.12 GHz

Table 7. Simulation data

Model	Number of elements	Number of unknowns	Number of phi angle directions	Total simulation time [sec]
Plate, 4 in, 5.12 GHz, HH	50	685	181	0.4
Plate, 4 in, 5.12 GHz, VV	18	421	181	0.3

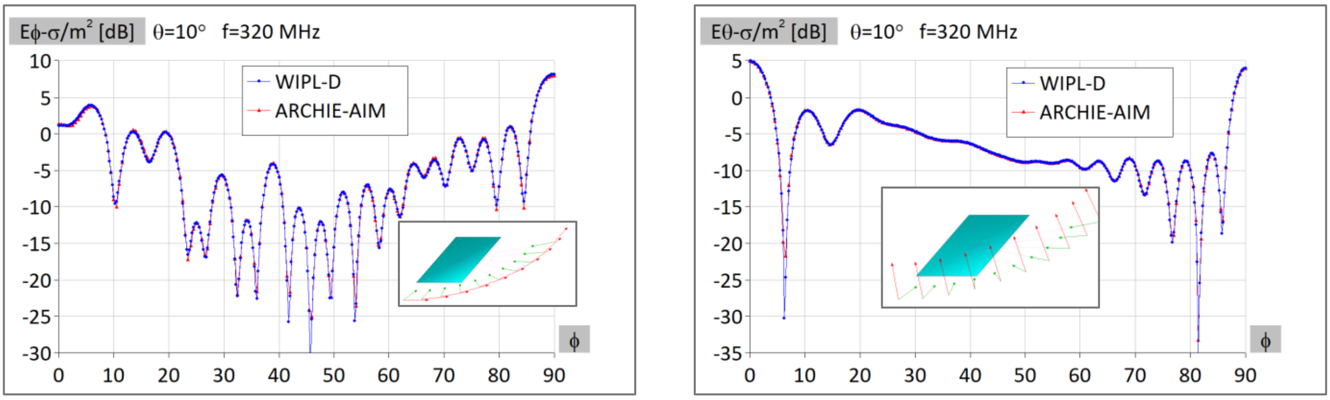


HH Polarization **VV Polarization**

Figure 8. RCS results for infinitely thin PEC plate (W = 128 in) at frequency of 10 MHz

Table 8. Simulation data

Model	Number of elements	Number of unknowns	Number of phi angle directions	Total simulation time [sec]
Plate, 128 in, 10 MHz, HH	14	185	181	0.3
Plate, 128 in, 10 MHz, VV	14	185	181	0.3



HH Polarization **VV Polarization**

Figure 9. RCS results for infinitely thin PEC plate (W = 128 in) at frequency of 320 MHz

Table 9. Simulation data

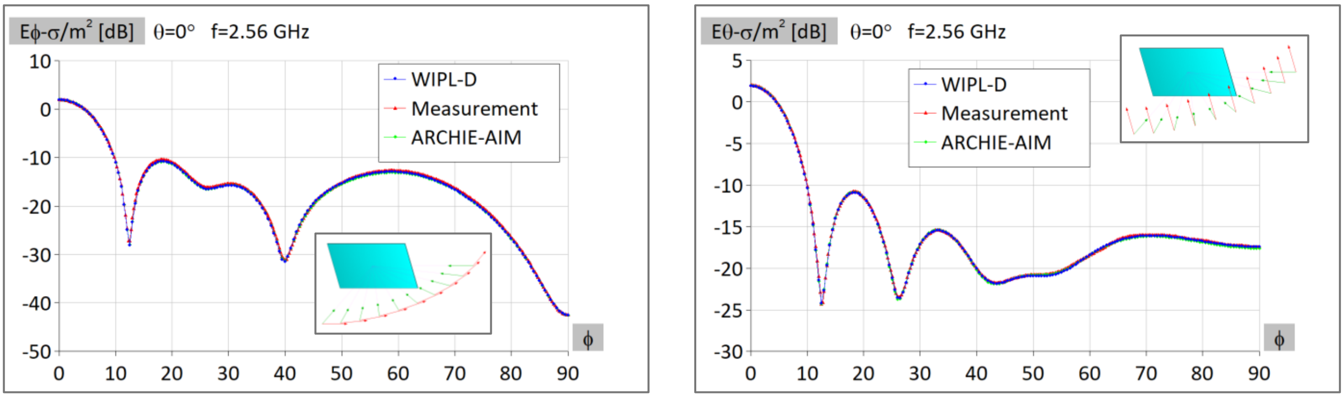
Model	Number of elements	Number of unknowns	Number of phi angle directions	Total simulation time [sec]
Plate, 128 in, 320 MHz, HH	122	1,617	361	1.3
Plate, 128 in, 320 MHz, VV	90	1,617	361	1.0

RCS Results and Simulation Data – PEC Plate with 64 mil Thickness

PEC plate with 64 mil thickness [5] was defined with the width to length ratio of W to W*7/4, where W is 6 in. The plate was simulated at 2.56 GHz, 5.12 GHz, 7 GHz, and 10.24 GHz. Monostatic RCS is, in these cases, computed at the angles $\theta_s = 0°$ and $0° \leq \phi_s \leq 90°$.

Calculated RCS results and simulations data for the PEC spheres are displayed in Figures 10-13 and Tables 10-13. Presented data are:

- RCS monostatic results for *HH Polarizations* compared between WIPL-D results, measurements, and ARCHIE-AIM results (left side of the figures)
- RCS monostatic results for *VV Polarizations* compared between WIPL-D results, measurements, and ARCHIE-AIM results (right side of the figures)
- A table with WIPL-D simulation data and number of phi angle directions

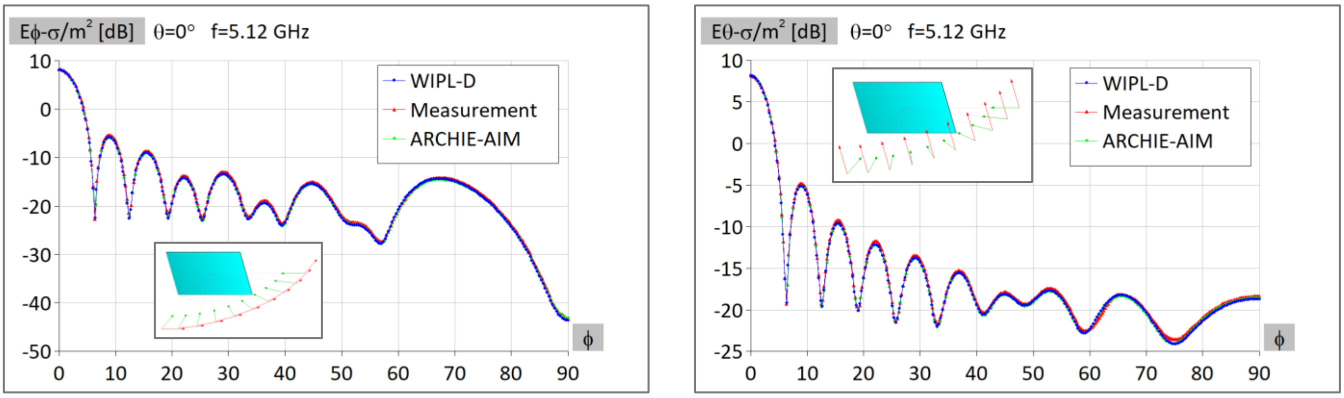


HH Polarization **VV Polarization**

Figure 10. RCS results for PEC plate with 64 mil thickness (W = 6 in) at frequency of 2.56 GHz

Table 10. Simulation data

Model	Number of elements	Number of unknowns	Number of phi angle directions	Total simulation time [sec]
Plate, Thickness, 2.56 GHz, HH	22	412	181	1.1
Plate, Thickness, 2.56 GHz, VV	22	412	181	0.7

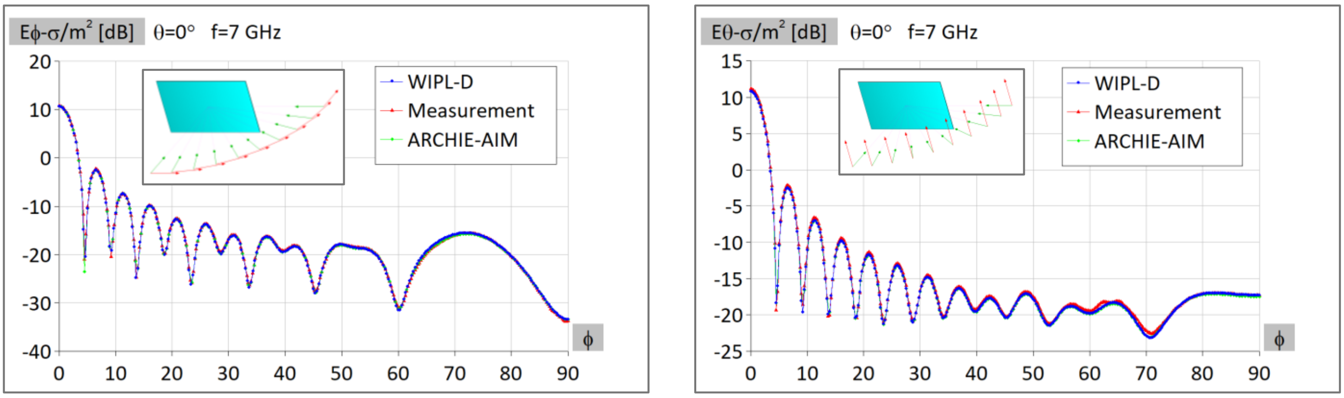


HH Polarization **VV Polarization**

Figure 11. RCS results for PEC plate with 64 mil thickness (W = 6 in) at frequency of 5.12 GHz

Table 11. Simulation data

Model	Number of elements	Number of unknowns	Number of phi angle directions	Total simulation time [sec]
Plate, Thickness, 5.12 GHz, HH	50	1,496	271	3.8
Plate, Thickness, 5.12 GHz, VV	50	1,496	271	3.8

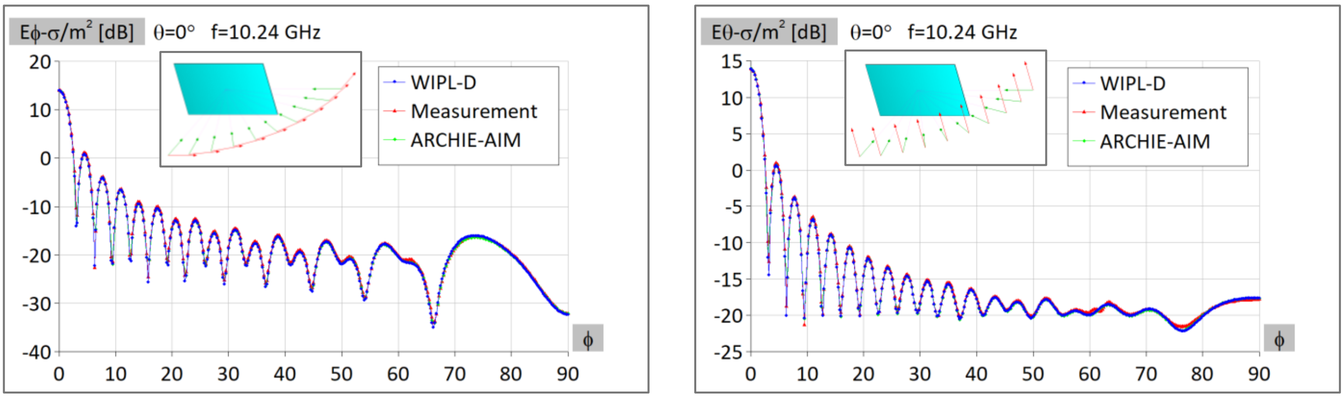


HH Polarization **VV Polarization**

Figure 12. RCS results for PEC plate with 64 mil thickness (W = 6 in) at frequency of 7.00 GHz

Table 12. Simulation data

Model	Number of elements	Number of unknowns	Number of phi angle directions	Total simulation time [sec]
Plate, Thickness, 7.00 GHz, HH	86	2,732	271	5.4
Plate, Thickness, 7.00 GHz, VV	86	2,732	361	5.5



HH Polarization **VV Polarization**

Figure 13. RCS results for PEC plate with 64 mil thickness (W = 6 in) at frequency of 10.24 GHz

Table 13. Simulation data

Model	Number of elements	Number of unknowns	Number of phi angle directions	Total simulation time [sec]
Plate, Thickness, 10.24 GHz, HH	182	6,196	361	27.1
Plate, Thickness, 10.24 GHz, VV	182	6,196	361	27.1

Conclusion

This document outlined multiple RCS results derived from three benchmark geometries simulated at different frequencies. The aim of conducting these simulations is the verification of the quality of RCS results obtained using WIPL-D Software by comparing them with the results from "*Austin RCS Benchmark*".

It was demonstrated that WIPL-D results for selected examples can be obtained very fast using an average computer workstation and without applying GPU acceleration. The results are in excellent agreement with the measurements and simulation results provided by "*Austin RCS Benchmark*".

References

[1] WIPL-D Software - Electromagnetic Simulation and EM Modeling Software | WIPL-D

[2] University of Texas Austin CEM Benchmarks - AustinCEMBenchmarks/Austin-RCS-Benchmarks at master · UTAustinCEMGroup/AustinCEMBenchmarks · GitHub

[3] PEC sphere benchmark: AustinCEMBenchmarks/Austin-RCS-Benchmarks/Problem I-Spheres/Problem IA-PEC Spheres/IA-ProblemDescription.pdf at master · UTAustinCEMGroup/AustinCEMBenchmarks · GitHub

[4] Zero thickness plate benchmark: AustinCEMBenchmarks/Austin-RCS-Benchmarks/Problem II-Plates/Problem IIA-Zero-thickness PEC Plates/IIA-ProblemDescription.pdf at master · UTAustinCEMGroup/AustinCEMBenchmarks · GitHub

[5] 64 mil thickness plate benchmark: AustinCEMBenchmarks/Austin-RCS-Benchmarks/Problem II-Plates/Problem IIB-Thin PEC Plates/IIB-ProblemDescription .pdf at master · UTAustinCEMGroup/AustinCEMBenchmarks · GitHub