Radar Cross Section (RCS) Simulation Validations via Benchmark Objects

1. Purpose

The purpose of this white paper is to demonstrate the accuracy of the PREDICS tool in calculating the radar cross section (RCS) of objects in simulation.

2. PREDICS's Solvers

PREDICS is a fast electromagnetic (EM) simulator for the calculation of EM scattering from objects with the implementation of the shooting-and-bouncing ray (SBR) technique that combines the geometric optics (GO) theory together with the physical optics (PO) theory. For the inclusion of the EM diffraction calculations, physical theory of diffraction (PTD) technique has also been implemented within PREDICS. Therefore, PREDICS provides three solver options for calculating EM scattering and/or RCS from electrically large and complex targets at high frequencies based on their structural features.

- ***PO solver:*** If the structure supports only single bounce mechanisms such as in the case of plate or sphere, it is more convenient to select this solver.
- ***PO+SBR solver:*** If the structure supports multi-bounce mechanisms as in the case of complex platforms that may include dihedrals or trihedrals, this solver can be the right choice.
- ***PO+SBR+PTD solver:*** When the structure consists of distinct edges, wedges and/or tips as in the case of airplane wings, the contribution of diffraction fields to the total scattered electric field may be noteworthy. Then, this solver should be selected if a more accurate calculation is desired.

3. Benchmark Object Models

The PREDICS simulations have been tested using commonly used several benchmark objects that have either analytical or measured RCS values in the literature. These are:

- Rectangular Plate,
- Rectangular dihedral corner reflector (DCR),
- Rectangular trihedral corner reflector (TCR),
- Cone-sphere.

4. Simulation Results

4.1 Rectangular Plate model

The perfect electric conducting plate of 15 cm x 15 cm is considered whose CAD model is shown in Fig.1.

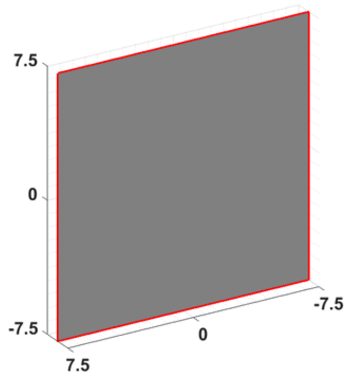

Figure 1. Rectangular Plate geometry [15 cm x 15 cm]

4.1.1 PO simulation of Rectangular Plate model

The monostatic RCS simulation of horizontal polarization at 6 GHz was carried out at for the azimuth angles from -90° to 90° for a total of 361 discrete angle points. During the simulation only physical optics (PO) solver of PREDICS was taken into account. Obtained RCS result is compared to the theoretical result of [1] as plotted in Fig. 2.

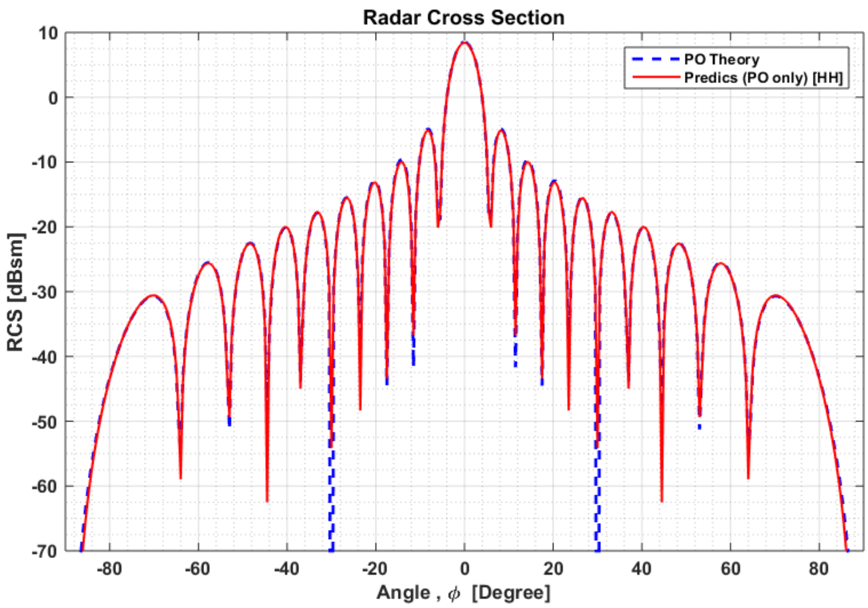

Figure 2. RCS results by PREDICS simulation [PO solver] compared to PO theory

4.1.2 PO+PTD simulation of Rectangular Plate model

The monostatic RCS simulation of horizontal polarization at 6 GHz was carried out at for the azimuth angles from -90° to 90° for a total of 361 discrete angle points. During the simulation, PO+ PTD solver of PREDICS was utilized. PREDICS's RCS result is compared to the measured one provided in [2] as presented in Fig. 3.

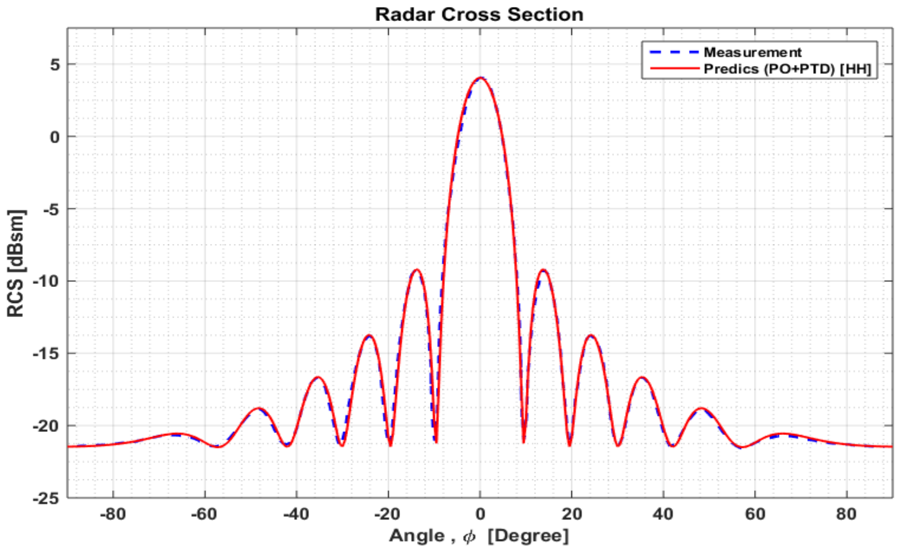

Figure 3. RCS results by PREDICS simulation [PO+PTD solver] compared to the measurement RCS provided in [2]

4.2 Rectangular DCR model

The perfectly electrical conducting rectangular DCR with square plates of lengths a = b = 17.9 cm is taken into consideration as its CAD file can be viewed in Fig. 4.

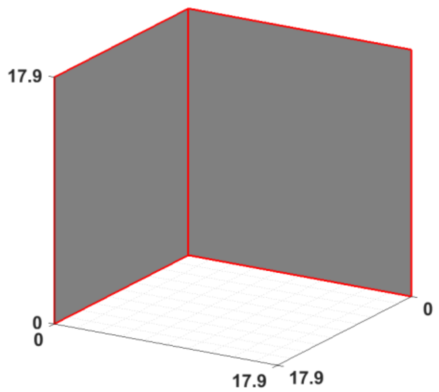

Figure 4. Rectangular DCR geometry [17.9 cm x 17.9 cm x 17.9 cm]

4.2.1 Full simulation of Rectangular DCR model

For this object, a measured monostatic RCS data are available for the whole azimuth angles (@ θ = 90°) at 9.4 GHz in [2] for vertical polarization. In the PREDICS simulation; all PO, SBR and PTD solvers have been used to calculate the backscattered RCS value. Both the measurement result of [2] and simulation results based on PREDICS simulation are presented in Fig. 5.

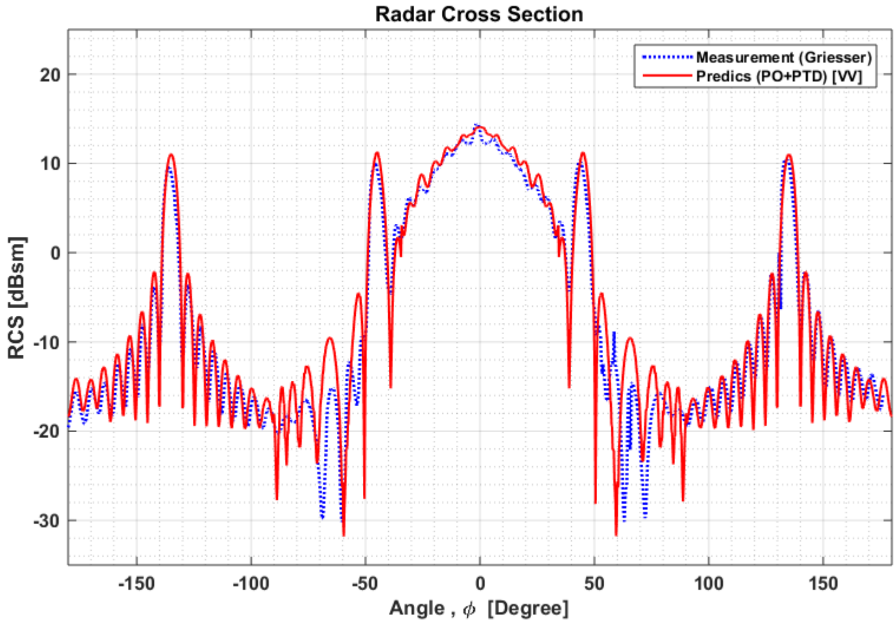

Figure 5. Angular RCS results comparison with respect to the measurement of [2] and PREDICS's simulation [PO+SBR+PTD solver]

4.3 Rectangular TCR model

The TCR model with equal corner lengths of 40 cm whose CAD file can be seen in Fig. 6 is used as another test-object for the validation of the PREDICS code over frequencies.

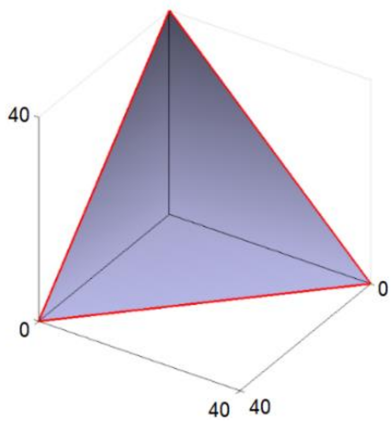

Figure 6. Rectangular TCR geometry [40 cm x 40 cm x 40 cm]

4.3.1 Full simulation of Rectangular TCR model

For this object, the backscattered RCS simulation at vertical polarization is carried out by PREDICS (SBR+PTD solver) for the frequencies between 1 GHz and 9 GHz as drawn in Fig. 7. Also, CST asymptotic solver (SBR+PTD) simulation result is also provided in Fig. 7 [5] for comparison purposes.

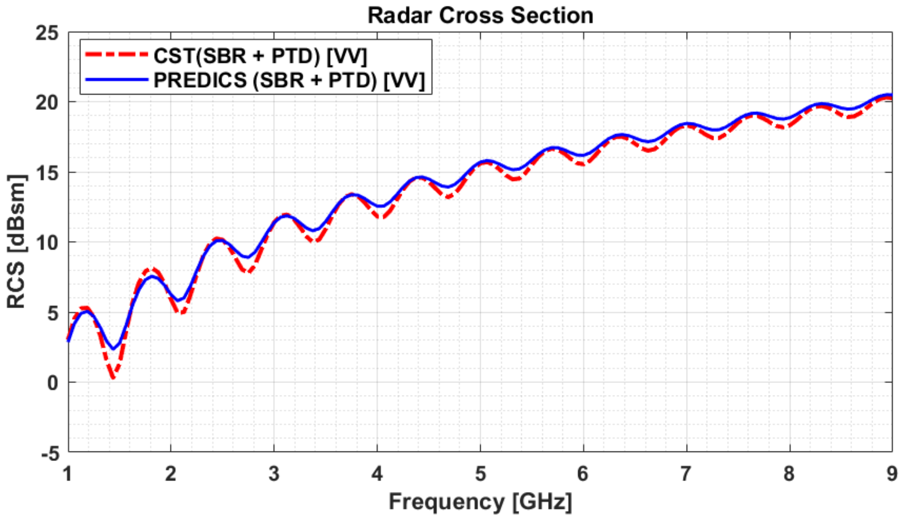

Figure 7. Comparison of spectral RCS results between PREDICS [SBR+PTD] solver, and CST asymptotic [SBR+PTD] solver for the TCR object

4.4 The cone-sphere model

The last benchmark target is the "cone-sphere" object with the sphere radius of 7.46 cm and the cone height of 60.5 cm [4] whose geometry is provided in Fig. 8.

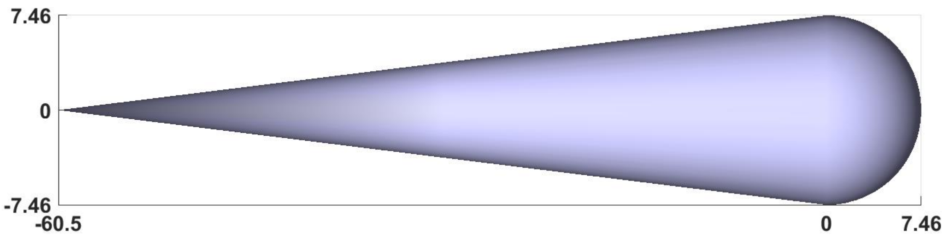

Figure 8. The cone-sphere geometry [67.96 cm x 14.92 cm x 14.92 cm]

4.4.1 Full simulation of the cone-sphere model

A monostatic vertically polarized RCS measurement data of this geometry at 9 GHz for the azimuth angles between -180° to 0° are available in [4] and plotted in Fig. 9 as blue dotted line. PREDICS's simulation result for the same simulation conditions with the PO+PTD solver is given as red solid line. Also, Altair FEKO simulation has also been carried out and the corresponding RCS result is plotted as green dashed line to provide another comparison for a typical commercial software [5].

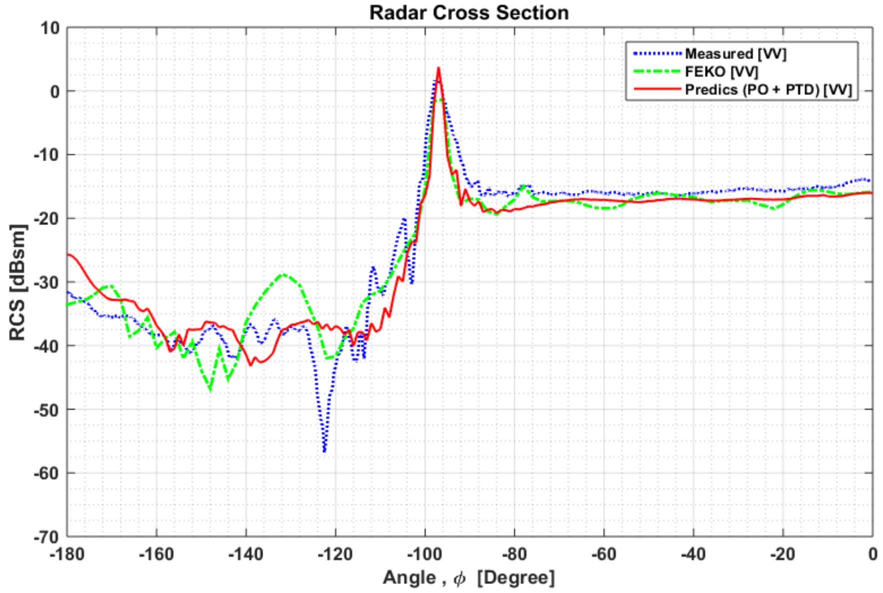

Figure 9. Angular RCS PREDICS result [PO+PTD solver] in comparison with respect to measurement of [4] and FEKO simulation

5. References

1. Balanis CA. Advanced Engineering Electromagnetics. 2nd ed. New York, NY, USA: Wiley, 2012.
2. Griesser T., Balanis C. Backscatter analysis of dihedral corner reflectors using physical optics and the physical theory of diffraction. IEEE Transactions of Antennas and Propagation 1987; 35: 1137–1147.
3. CST – Electromagnetic Simulation Software available at https://www.cst.com/
4. REMCOM - RCS Analysis of 3D Bodies. Available at https://www.remcom.com/examples/rcs-analysis-of-3d-bodies-of-revolution.html
5. Kırık Ö., Özdemir, C. An Accurate and Effective Implementation of Physical Theory of Diffraction to the Shooting and Bouncing Ray Method via PREDICS Tool, Sigma J Engineering and Natural Science 2019; 37(4): 1153-1166.