EMerge Benchmark Report
v1.3

Author: Robert Fennis

1st September 2025

Email: fennisrobert@gmail.com

Contents

1. Introduction

Engineers must be able to trust their simulation tools. EMerge its mission is to deliver accurate electromagnetic results. This document presents benchmark problems solved with EMerge and with industry-standard tools (e.g., HFSS) to demonstrate that EMerge converges to the same solutions.

Beyond implementation quality, FEM accuracy depends strongly on mesh resolution. Under a correct formulation and assembly, independent FEM solvers should converge to the same result as the mesh is refined.

Accordingly, the comparisons below are intended to show that, with appropriate meshing, EMerge converges to industry-standard results. They are not a blanket guarantee that any given EMerge result is accurate. Users should validate meshes and results and apply appropriate skepticism and verification practices.

1.1. Models used

The models in this report are not intended to represent full, production-ready geometries. Instead, they are deliberately simplified test cases designed to isolate and expose differences between solvers in a controlled way. The aim is to include enough geometric and electromagnetic detail to make the comparison meaningful, while avoiding excessive complexity that would make results overly sensitive to mesh convergence as would be the case with very thin micro-strip lines for example.

2. WR90 with two irises

This benchmark considers a straight rectangular WR90 waveguide section equipped with two internal irises. The structure is analysed with EMerge and independently simulated with CST Microwave Studio for cross-validation of the electromagnetic response. The model geometry is fully defined by the following parameters:

- Waveguide width = 22.86mm
- Waveguide height = 10.16mm
- Waveguide length = 50.0mm
- Iris width = 5mm
- Iris thickness = 1mm
- Iris locations: z=20mm and z=35mm

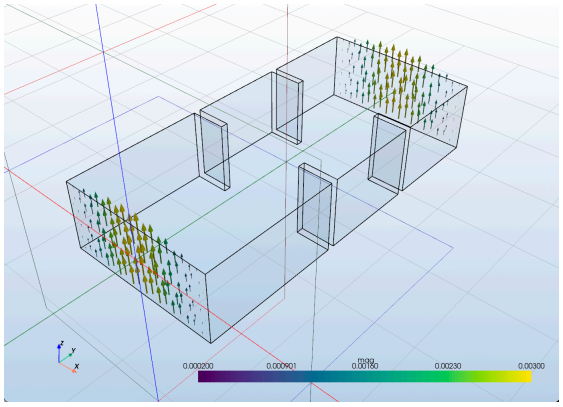

Figure 1: Geometry of the simulation model from EMerge

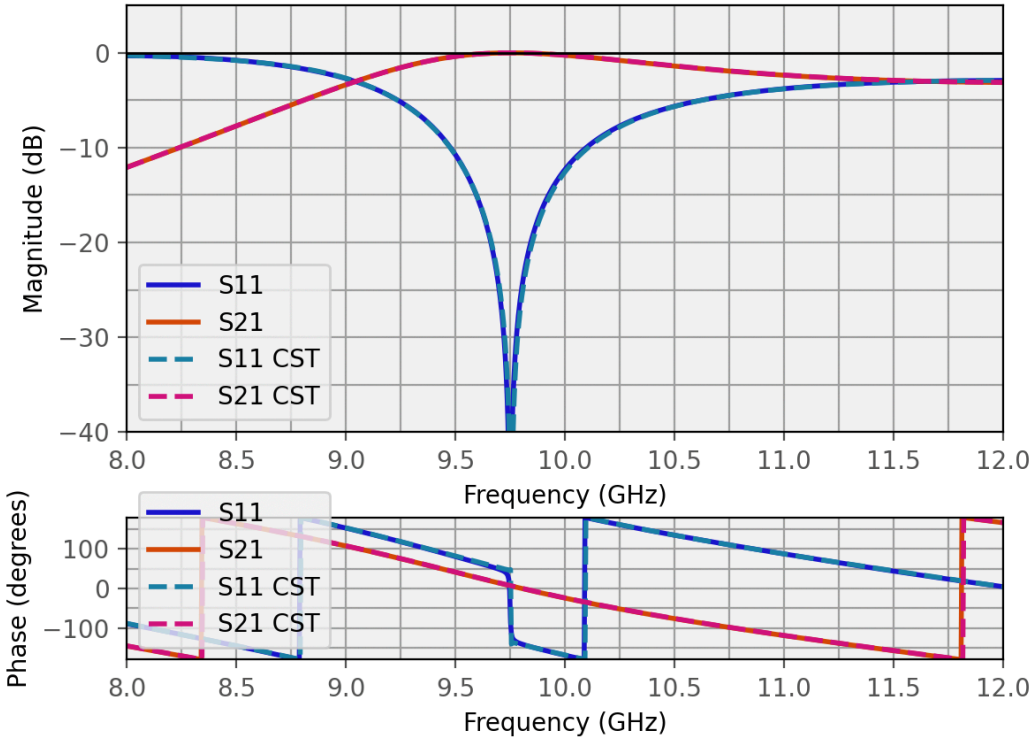

Figure 2: Comparison of EMerge S-parameters with CST Studio.

3. Patch antenna on PCB

This benchmark models a single microstrip patch antenna operating in the S-band, excited through a cylindrical lumped 50Ω feed via. The configuration is simulated with EMerge and cross-checked against results obtained from COMSOL Multiphysics. The open region surrounding the antenna is truncated using a first-order radiation (Robin) boundary condition to emulate free-space radiation while keeping the computational domain finite.

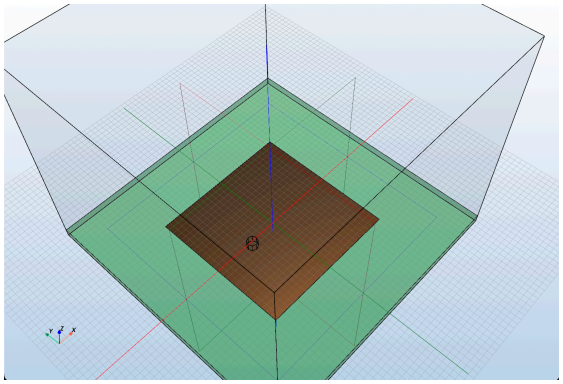

Figure 3: Geometry of the simulation model from EMerge

The geometry and material parameters are defined as follows:

- Domain width/depth = 50.0mm
- Domain height = 40.0mm
- Patch width/depth = 26.0mm
- Dielectric thickness = 1.50mm
- Via radius = 1.0mm
- Via distance from edge = 8.0 mm
- Dielectric constant = 3.55

For the EMerge results, Vector Fitting is used to refine the sample density. Some irregularities in the Comsol data are purely due to the sample density.

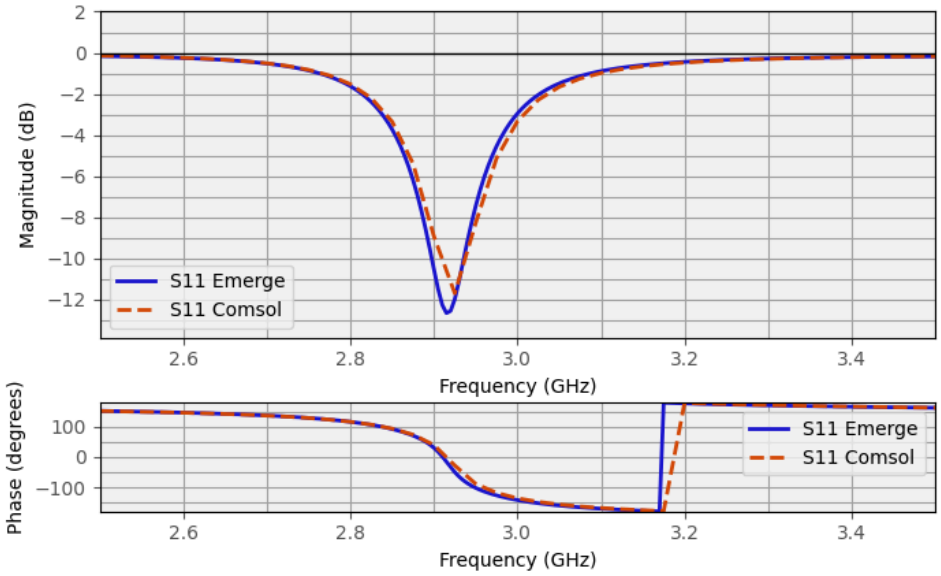

Figure 4: Comparison of EMerge S-parameters with Comsol Multi-physics.

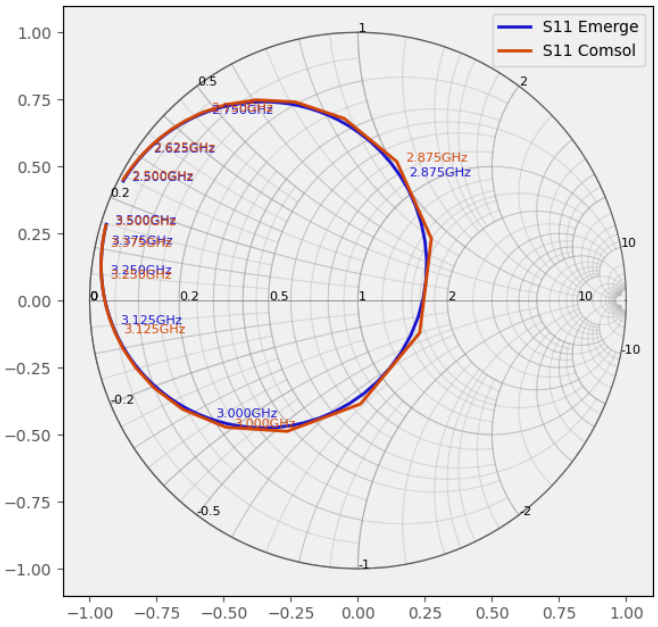

Figure 5: Comparison of EMerge S-parameters with Comsol Multi-physics.

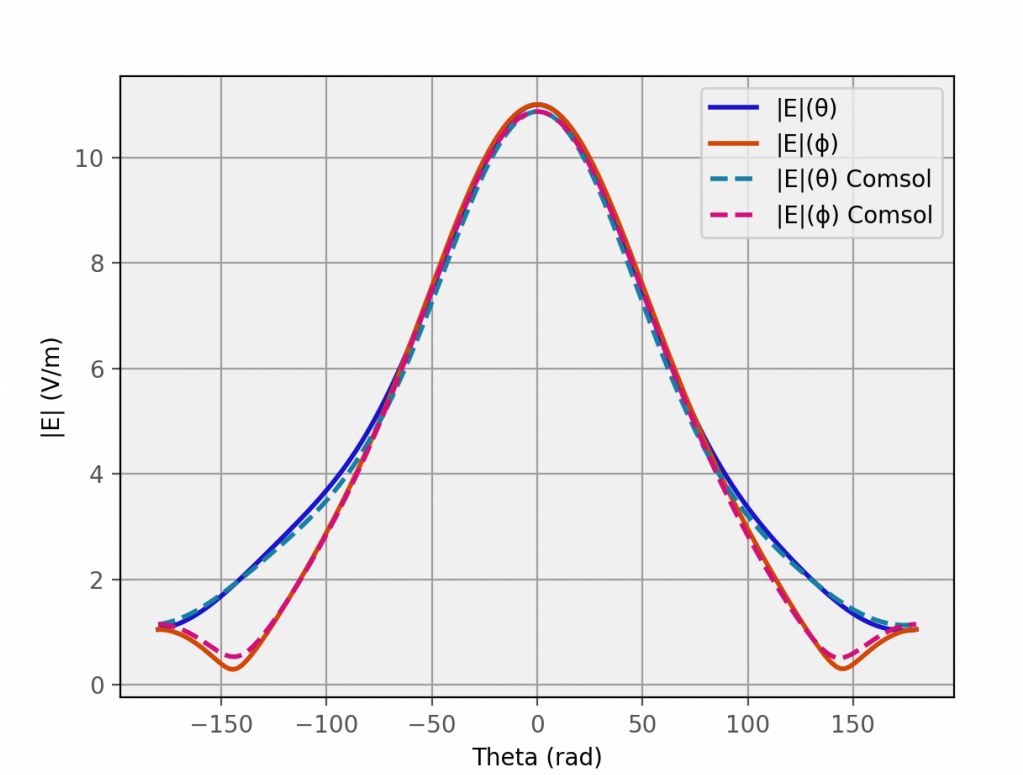

Figure 6: Comparison of the normalized E-field between EMerge with Comsol Multi-physics.

4. Simplified Horn

This benchmark considers a simplified pyramidal horn antenna radiating into a finite spherical domain. The horn is excited through a rectangular waveguide section and opens into a larger aperture, allowing characterization of the radiated field in the near and transition regions. The antenna is enclosed in a hemispherical computational domain of 150 mm radius, with the curved spherical boundary terminated using a second-order absorbing boundary condition to approximate free-space radiation.

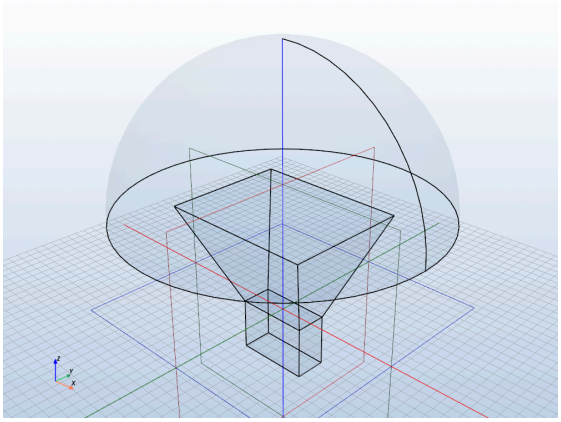

Figure 7: Geometry of the simulation model from EMerge

The geometric parameters are:

- Waveguide width: 70mm
- Waveguide height: 30mm
- Waveguide length: 50mm
- Aperture width: 150mm
- Aperture height: 120mm
- Horn length: 100mm
- Domain width: 300mm
- Sphere radius: 150mm.

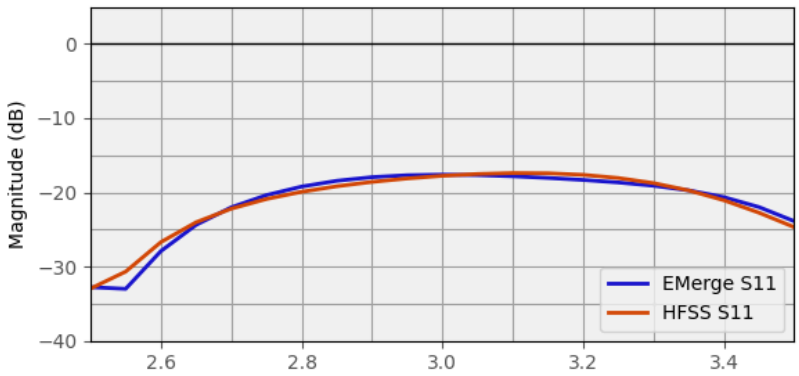

Figure 8: Comparison of EMerge reflection coefficient vs HFSS.

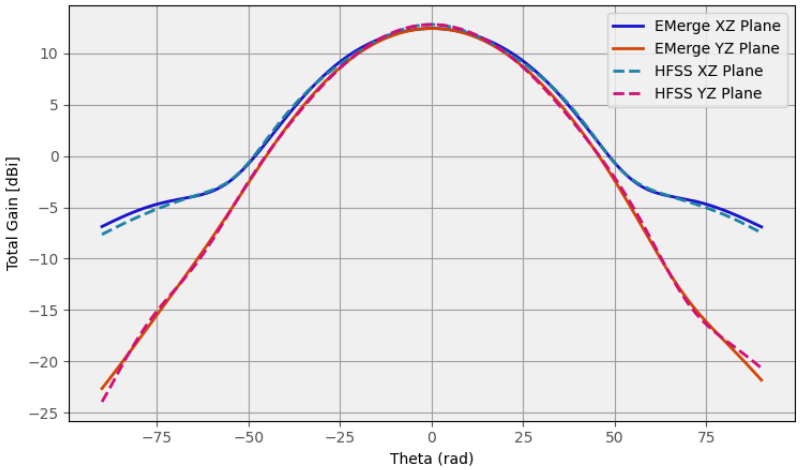

Figure 9: Comparison of the farfield patterns of EMerge vs HFSS.

5. Rectangular waveguide stub filter

This benchmark models a rectangular waveguide section incorporating a stub filter. The configuration is intended to represent a simple dispersive waveguide component with a localized impedance discontinuity introduced by the stub. The geometry is defined by:

- Waveguide width: 60mm
- Waveguide height: 30mm
- Waveguide length: 100mm
- Stub filter width: 193mm
- Stub filter length: 40mm

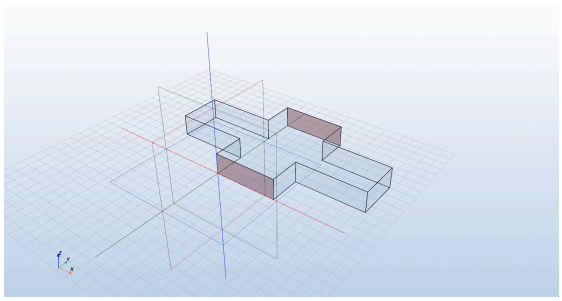

Figure 10: Geometry of the simulation model from EMerge. Selected faces are the in-port and out-port.

First mesh was resolution 0.1415 for both:

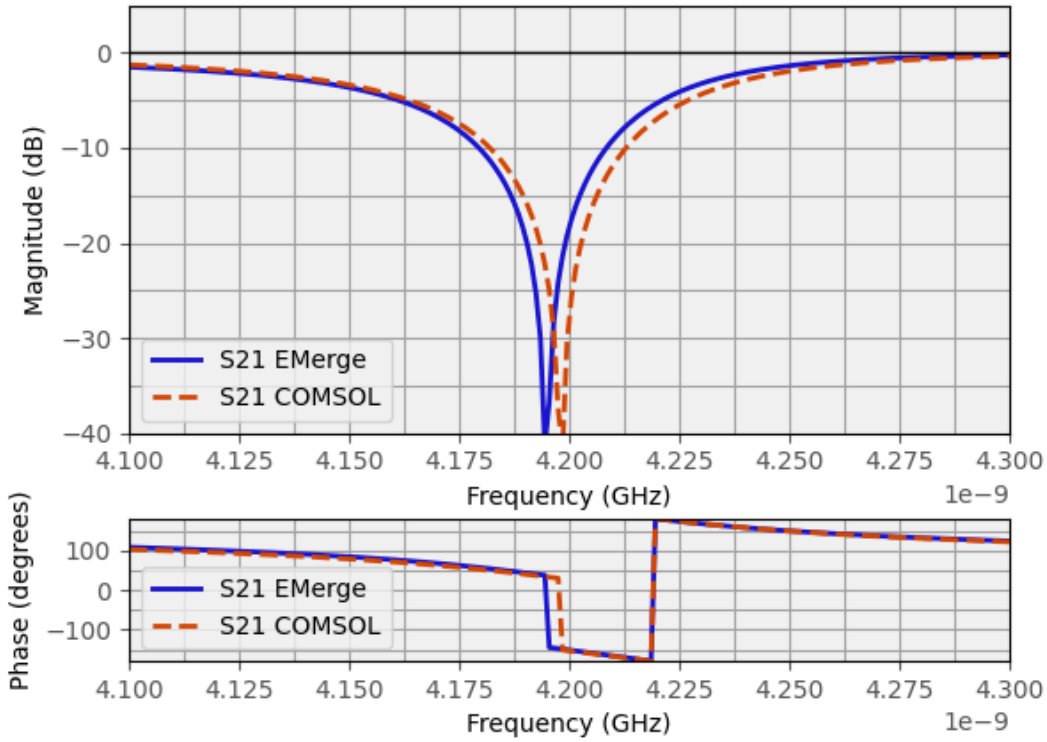

Figure 11: S21