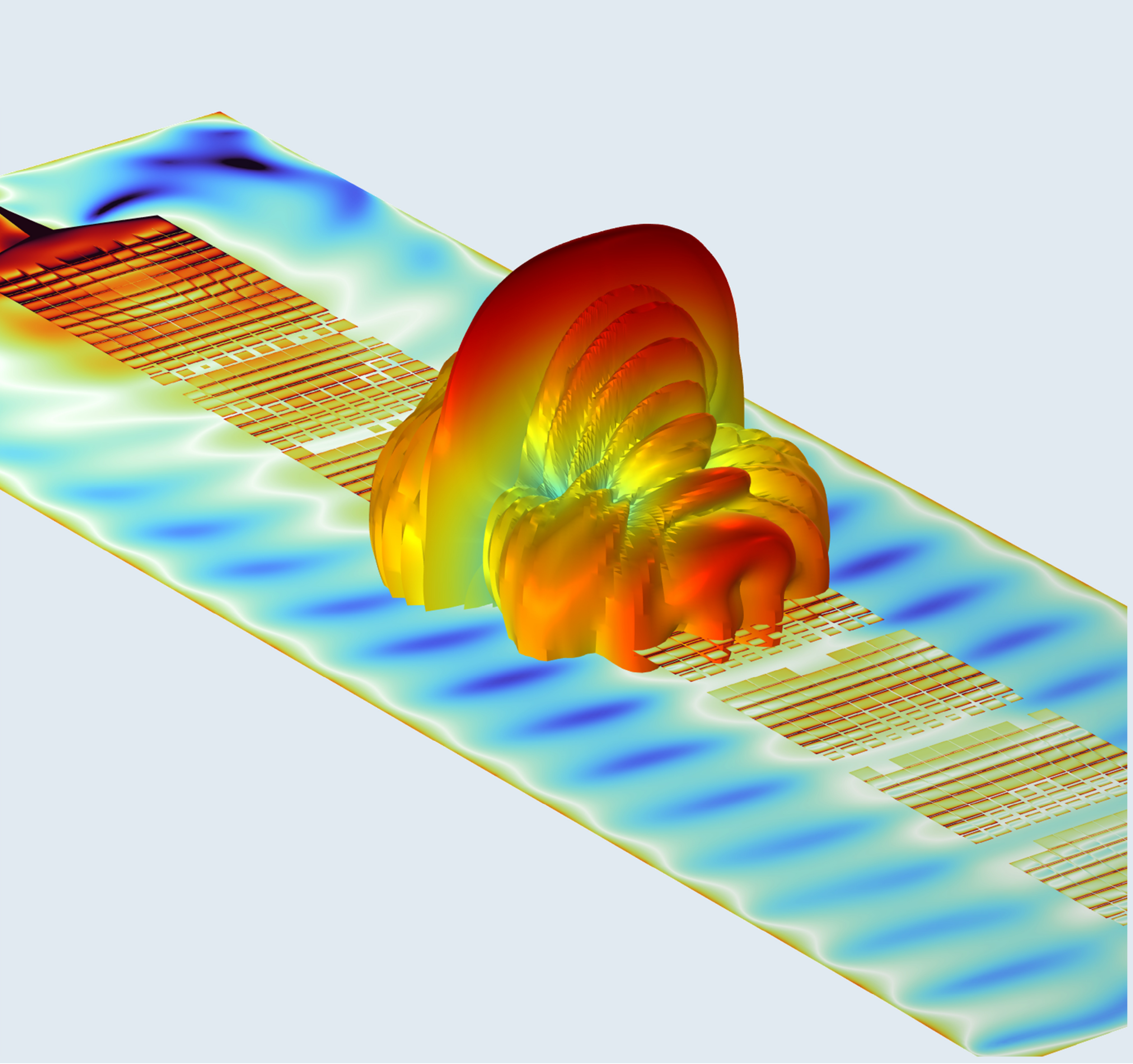

Full-Wave Validation of Broadside Radiating MTS Antennas Designed with a Current-Based Approach

Numerical validation of the performance of a Leaky-Wave Antenna (LWA) designed with a newly developed current-based numerical technique for the synthesis of metasurface antennas radiating at broadside with low side lobe level (SLL).

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Abstract

Leaky-Wave Antennas (LWAs) possess several qualities, mainly being very low-profile and having a simple feeding mechanism. However, some drawbacks characterize this kind of structures and need to be mitigated in the design process.

The open stopband at broadside is the biggest challenge for LWAs (where "open stopband" means the range of frequencies where the radiation is stopped in a particular direction) (Ref. 1). Moreover, the sidelobe level (SLL) is difficult to control.

In Ref. 2 a deterministic numerical technique for the synthesis of metasurface (MTS) antennas is applied for the first time to design a 1D broadside radiating LWA with low SLL.

COMSOL Multiphysics® is used here for the full-wave simulation of a LWA antenna designed with the proposed numerical method (Ref. 2, 3) and confirms the predicted far field with short computational times (around 30 min on a standard PC) despite the high mesh density needed to model the MTS.

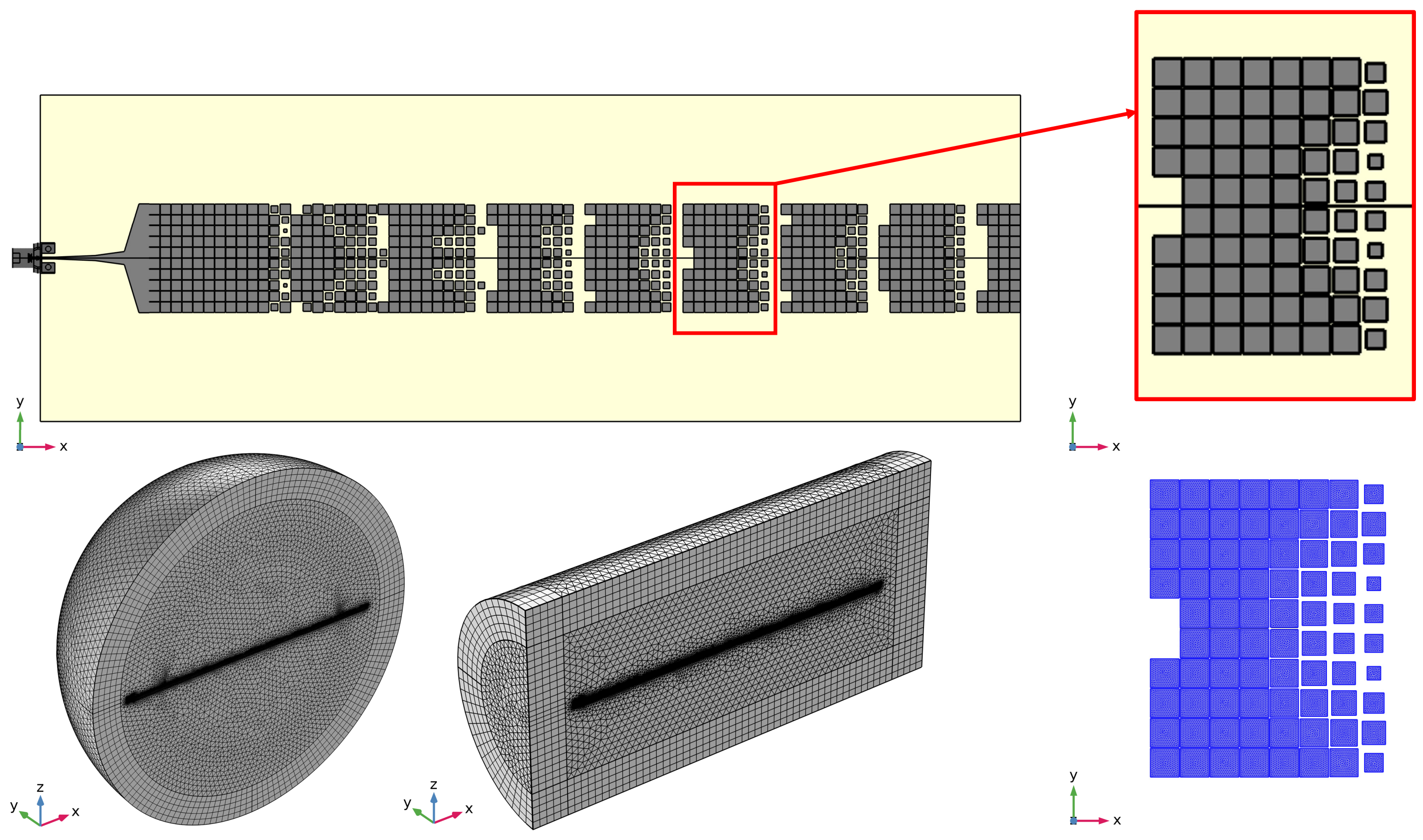


FIGURE 1. Geometry of the designed MTS antenna and different PML geometries. A PMC condition is introduced on the xz plane.

Methodology

- The method proposed in Ref. 2 involves the optimization of the metasurface (MTS) equivalent currents only and returns the surface impedance profile starting from arbitrary mask type constraints on the far field pattern.
- The incident electric field interacting with the MTS is given as input to the algorithm and extracted from full-wave simulations of the 3D coaxial feed, carried out with COMSOL Multiphysics®.
- For the design case presented in this work:
    - Working frequency: $f\ = 10$ GHz
    - Substrate: permittivity $\varepsilon_r = 2.2$ and height $h = 3.2$ mm
    - Length of the antenna: $L\ \approx 8\lambda_0$ (240 mm)
    - Mask-type constraints used: broadside (BS) radiation, SLL $=\ -10$ dB.

Results

The directivity is evaluated using the following equations (Ref. 4):

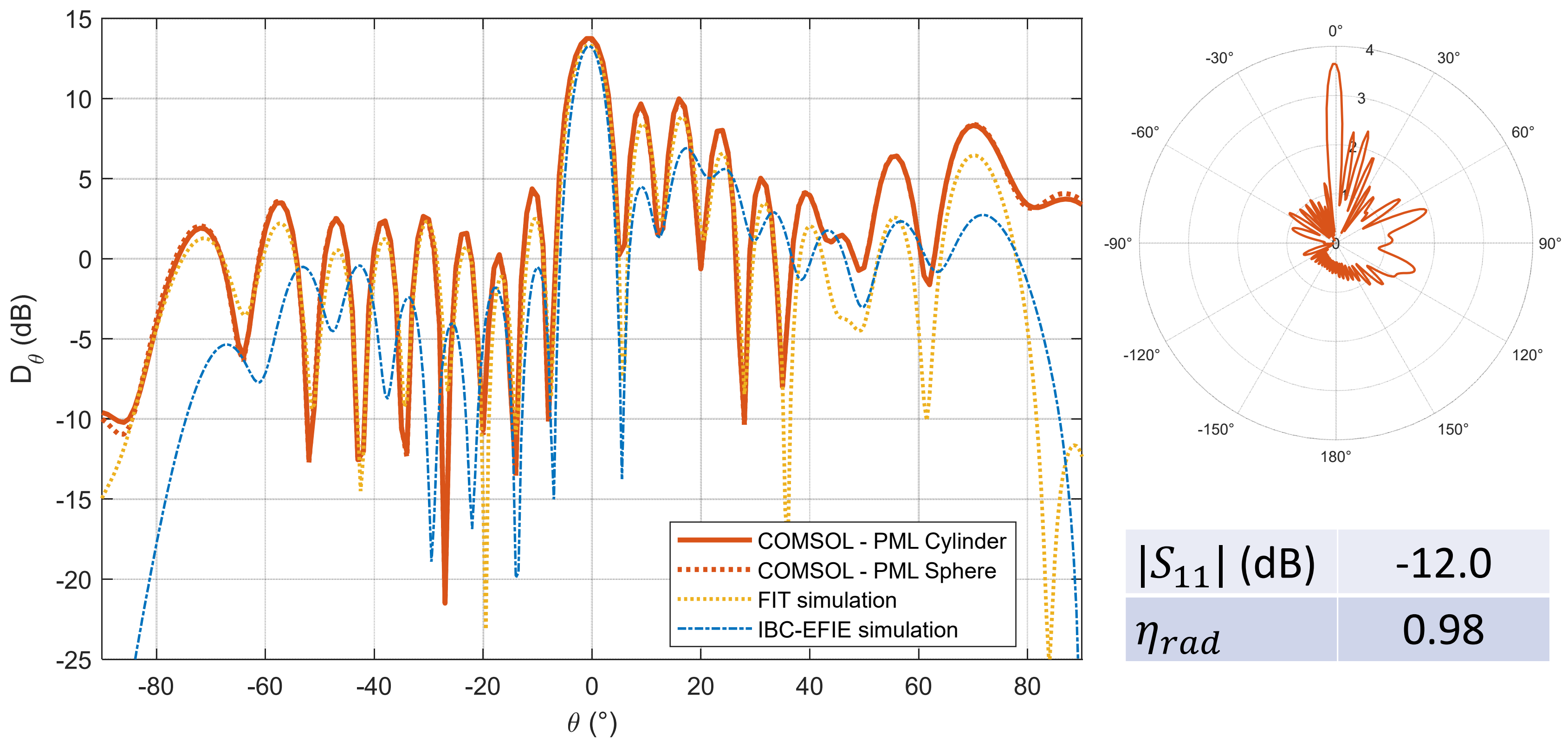
$$U(\theta,\phi) = \frac{1}{2\eta_0}\left[|F_\theta|^2 + \cancel{|F_\phi|^2}\right], \qquad P_{rad} = \iint U(\theta,\phi)\, d\Omega$$

$$D(\theta,\phi) = \frac{4\pi}{P_{rad}} U(\theta,\phi), \qquad D_\theta(\theta,\phi) \approx \frac{|F_\theta|^2}{60\, P_{rad}}$$

being F_θ and F_ϕ (negligible) the θ- and ϕ- far-field components provided by COMSOL® and η_0 the impedance of free space.

BS radiation and an excellent agreement between COMSOL® and other numerical methods is observed in Figure 2.

The radiation efficiency is evaluated using the following relation:
$\eta_{tot} = \eta_{rad}\, \eta_{mis} = \eta_{rad}\, (1 - |S_{11}|^2) = P_{rad}/P_{in}$



$\|S_{11}\|$ (dB)	-12.0
η_{rad}	0.98

FIT: Finite Integration Technique
IBC-EFIE: Impedance Boundary Condition Electric Field Integral Equation

FIGURE 2. Directivity of the simulated antenna at $f\ = 10$ GHz on the plane $\phi\ = 0°$ computed using different methods.

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Excerpt from the Proceedings of the COMSOL Conference 2023 Munich