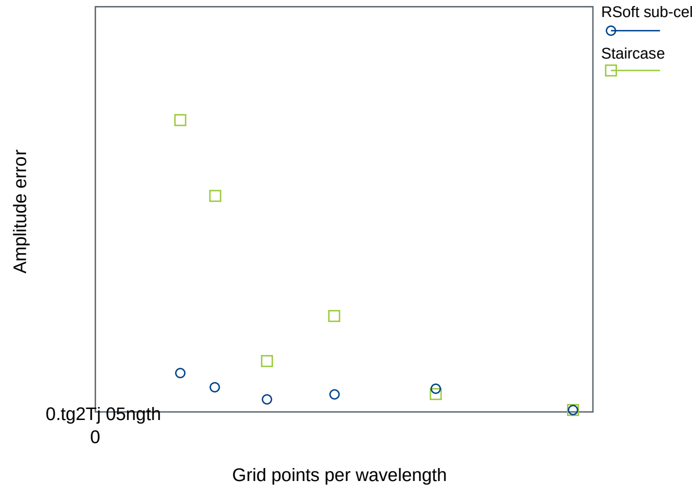
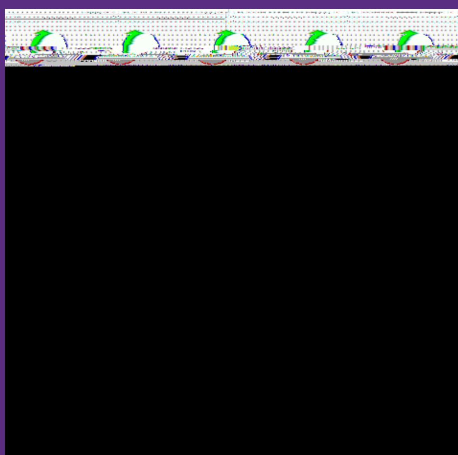
The finite-difference time-domain (FDTD) method is an advanced, rigorous solution to Maxwell's equations that does not have any approximations or theoretical restrictions. It is a full-vectorial method that yields all electric and magnetic field components and can account for omni-directional propagation and scattering. Moreover, the FDTD method can include the effects of material dispersion, anisotropy and nonlinearities. Because of its generic nature, broadband aspects and massive parallelizability, the FDTD method is a widely used propagation solution for a variety of integrated photonics applications. A major limitation is that it can require a large amount of memory storage and extremely long computation times to obtain accurate, converged results. Moreover, standard FDTD introduces staircasing when mapping material interfaces onto a Cartesian grid that can degrade accuracy from second order to first order and lead to slower convergence, especially for curved interfaces.

Several techniques have been proposed in the literature for enhancing accuracy and improving convergence [1,2]. All RSoft™ simulation tools, including the FullWAVE™ [3] tool, use a proprietary sub-cell meshing technology (also called conformal meshing) when the simulation grid does not conform to the actual shape of the geometry. The RSoft sub-cell meshing technology builds on the techniques from the literature and includes proprietary enhancements. The RSoft proprietary technology provides significantly higher accuracy and smoother convergence when compared to commonly used staircase approximations. In this white


RSoft sub-cell
Staircase
Amplitude error
0.tg2Tj 05ngth
0
Grid points per wavelength

Photonic crystals can be seen as the optical analog of semiconductors; that is, photonic band gap (PBG) materials display gaps in their photon density of states. 2D and 3D photonic crystals at optical frequencies have been fabricated over the past decade. Several optical device applications have been proposed and demonstrated, including efficient waveguiding, transmitting light around sharp corners with relatively small losses and resonant microcavities that can be used to efficiently couple light into PBG-based waveguides. These applications can potentially lead to the design of new compact integrated optoelectronic and photonic integrated circuits.



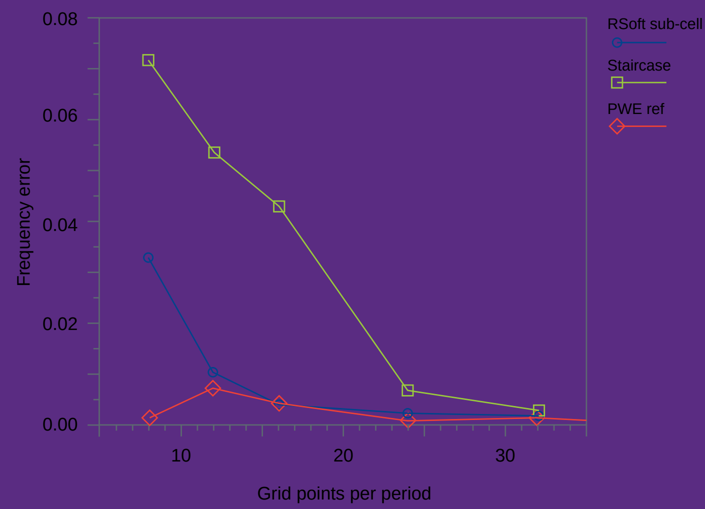


Figure 5(b) shows the convergence versus grid size of the frequency error in the photonic band calculation and compares three different numerical approaches. The blue line shows the results obtained with RSoft SCM; the green line shows the results obtained with a staircase meshing scheme; and the red line shows the frequency error calculated using the RSoft BandSolve™ tool based on the Plane Wave Expansion (PWE) technique, which is useful for analyzing PBG applications. As can be seen, the results obtained with RSoft SCM show a significantly smaller error compared to the staircase meshing scheme. In addition, RSoft SCM achieves similar accuracy to the PWE technique, but much quicker than the staircase meshing scheme. For example, to obtain a frequency error smaller than 0.015, the staircase meshing scheme would require 24 grid points per wavelength, whereas RSoft SCM requires 12 grid points per wavelength, which translates to a time savings of ~8x in 2D and ~16x in 3D with RSoft SCM.

Because of the computationally intensive nature of the FDTD method, improved accuracy and convergence are critical for its practical use as a design algorithm in applications where numerous design variants need to be explored. In this white paper, four case studies are presented that demonstrate significantly higher accuracy and smoother convergence obtained with the RSoft proprietary sub-cell meshing (SCM) technique, also called conformal meshing, when compared to the commonly used staircase meshing approach.

[1] Wenhua Yu ; R. Mittra, "A conformal finite difference time domain technique for modeling curved dielectric surfaces," IEEE Microwave and Wireless Components Letters Vol 11, 25-27 (2001).

[2] Ardavan F. Oskooi, Chris Kottke, and Steven G. Johnson, "Accurate finite-difference time-domain simulation of anisotropic media by subpixel smoothing," Opt. Lett 34, 2778-2780 (2009).

[3]