3D MODELING AND VALIDATION OF GPR WAVE SCATTERING WITH THE SEMI-ANALYTIC MODE MATCHING (SAMM) METHOD

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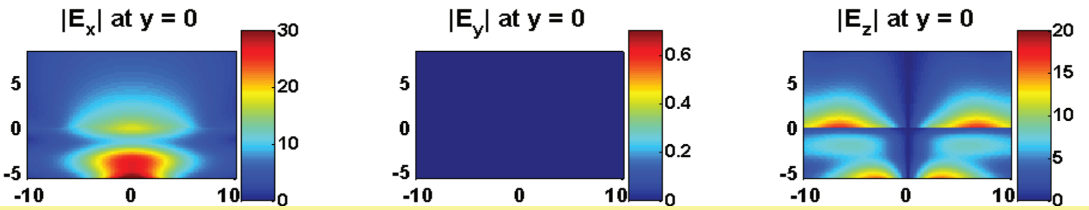
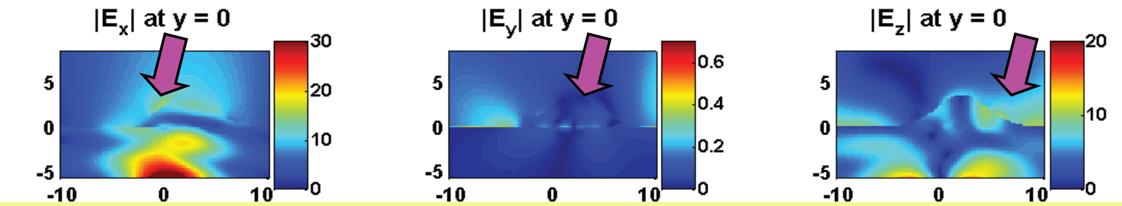
The 3D SAMM algorithm is used for the first time in simulating 3D scattering from objects below a simple rough surface, where a sample geometry of the surface and target is shown in Figure I(e). The procedure for the more complex scattering calculations begins by simulating a smooth half-space without a target or roughness as in Figure I(a), with the dipole source located outside the region of interest. The coordinate scattering centers (CSCs) are thus located along the dipole axis and higher order ($m \neq 0$) modes are unnecessary. In Figure I(b), a substantial Gaussian "bump" filled with soil has been added to the surface and the fields from Figure I(a) are used as sources for the scattering in Figure I(b). New CSCs are chosen to lie within this bump and its image, and for a given radial mode index n, all azimuthal modes $|m| \leq n$ are included. The original CSCs in I(a) are ignored. In Figure I(c), a small spherical target is added to the problem with the fields in Figure I(b) now sourcing scattering in Figure I(c). The CSCs for the target scattering are located at the center of the target sphere and at its image above ground; all other previous CSCs are ignored. By breaking the scattering problem into sub-problems, we take advantage of symmetries available in each sub-problem and reduce the number of CSCs needed. Trying to attack the entire problem at once, using all of the CSCs needed to source scattering in each region of the problem, results in longer simulation times and great difficulty in converging on the correct scattering behavior. Figure I(d) shows the point matching on either side of each of the simulation surfaces for the normal and two tangential electric field components.

Excellent agreement has been obtained between SAMM and finite difference frequency domain (FDFD) simulations for 3D models of a TNT mine-like object buried below rough ground. The 2D SAMM solution computed on a Pentium-based personal computer requires less than 1/100 the time of the FDFD simulation on a Compaq Alpha supercomputer, while the 3D calculation requires just 1/20 the time, and about 1/3 the memory.

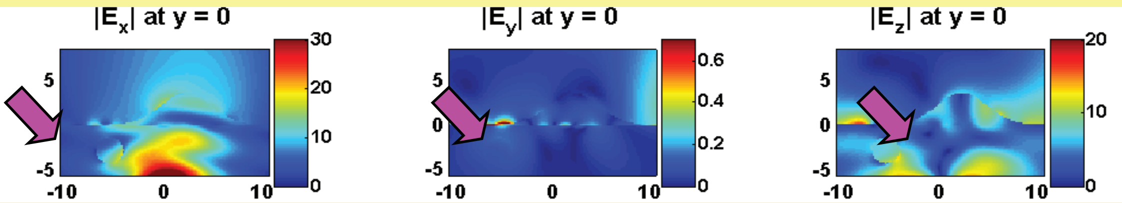
(a)



(b) Step 1: Flat ground plane, borehole dipole source, air above, Bosnian soil below



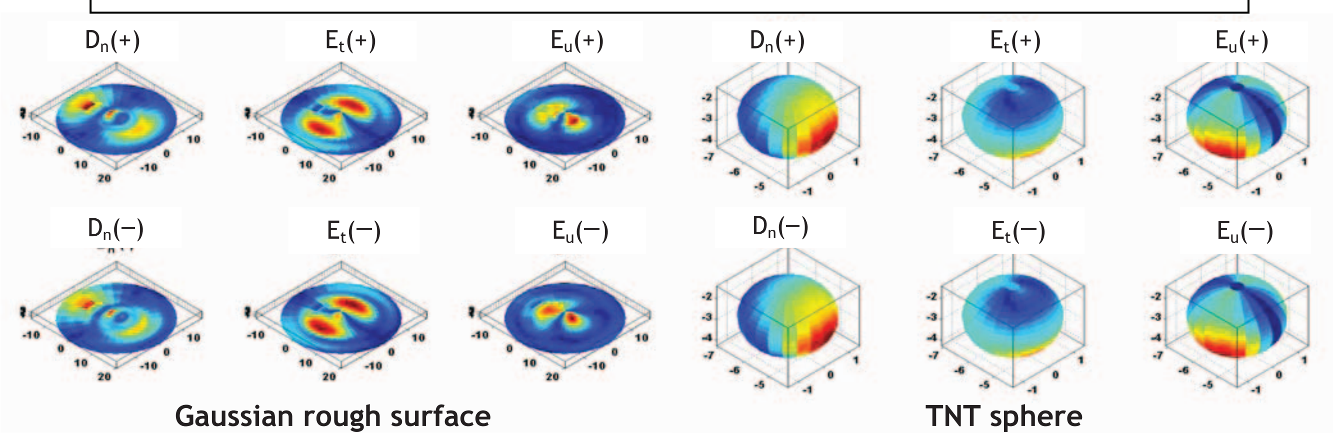
(c) Step 2: Add off-center Gaussian ground “bump”; fields in 1 source new scattering

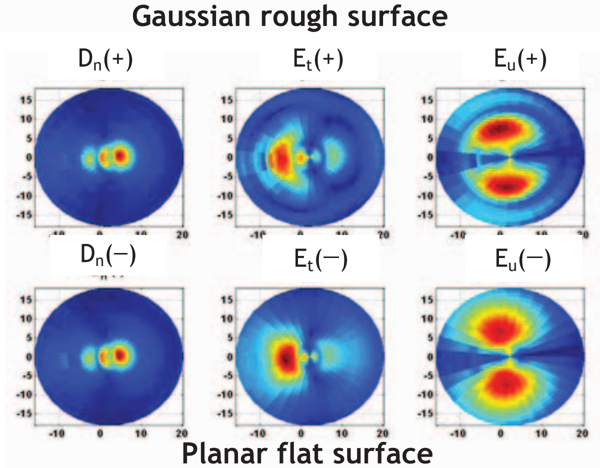


Step 3: Add TNT sphere below ground plane; fields in 2 source new scattering

(d)

- Frequency: 1.4 GHz, grid step size $h = \lambda/10 = 7.10$ mm
- x-directed dipole source located at $(0, 0, -15h)$
- Permittivity, Bosnian soil: $\varepsilon = (9.02 + 1.15\ i)\ \varepsilon_{0;}$ TNT: $\varepsilon = (2.9 + 0.0029\ i)\ \varepsilon_0$
- Gaussian “bump” located at $(3h,\ 0,\ 0)$ with height 5h and waist = $5h$
- Spherical TNT scatterer located at $(-8h,\ 0, -4h)$ with radius $2h$





(e)