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The mimetic multiscale method for electromagnetics at a borehole with casing

A cased borehole setting is a good example of a geophysical problem that involves different length scales: metal casing (highly conductive) with a few millimeters in thickness as well as length scales of interest in meters and kilometers. This leads to a large model where including fine-scale information to an adequate level of detail comes with the risk of computationally too expensive or even intractable simulations.

The mimetic multiscale method is developed to overcome the impracticably large linear systems that result from large models and their very detailed meshes. Multiscale methods provide a framework to model features on finer scales than the simulation mesh. Mimetic methods mimic the behavior of the continuous operators in the discrete setting, for instance magnetic fields on the coarse mesh are discretely divergence-free. Thus, spurious modes are prevented and the solutions are physical. Maxwell's equations are used to interpolate between the fine mesh, where the electrical conductivity is discretized on, and a nested coarse mesh on which the fields are simulated. This yields a natural homogenization that accounts for fine-scale conductivity changes. It reduces the number of degrees of freedom enormously.

We demonstrate the effectiveness of the mimetic multiscale method at a vertical borehole with casing by simulating electric fields on the coarse mesh and comparing the results with the reference solution on the fine mesh.