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Two dimensional invisibility cloaking for Helmholtz equation and non-local boundary conditions

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Transformation optics constructions have allowed the design of cloaking devices that steer electromagnetic, acoustic and quantum waves around a region without penetrating it, so that this region is hidden from external observations. The material pa- rameters used to describe these devices are anisotropic, and singular at the interface between the cloaked and uncloaked regions, making physical realization a challenge. These singular material parameters correspond to singular coefficient functions in the partial differential equations modeling these constructions and the presence of these singularities causes various mathematical problems and physical effects on the interface surface. In this paper, we analyze the two dimensional cloaking for Helmholtz equation when there are sources or sinks present inside the cloaked region. In particular, we consider nonsingular approximate invisibility cloaks based on the truncation of the singular transformations. Using such truncation we analyze the limit when the approximate cloaking approaches the ideal cloaking. We show that, surprisingly, a non-local boundary condition appears on the inner cloak interface. This effect in the two dimensional (or cylindrical) invisibility cloaks, which seems to be caused by the infinite phase velocity near the interface between the cloaked and uncloaked regions, is very different from the earlier studied behavior of the solutions in the three dimensional cloaks.

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