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A multigrid preconditioner for the Helmholtz equation based on a new discretization with complex coefficients

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The Helmholtz equation is widely used as model problem in many fields where indefinite partial differential equations arise, particularly wave equations. Therefore, effective preconditioners are in demand, and yet this remains a challenging task. In this work, we employ a multigrid preconditioner together with a new finite-difference discretization that employs complex coefficients and yet remains Hermitic. This approach builds on a recent development by Haber and Maclachlan (J. Comp. Phys., 2011), who employ a reformulation of the Helmholtz problem into a complex advection-diffusion-reaction equation. By applying an inverse transformation to the discretized Haber-MacLachlan problem, we obtain the new discretization of the original Helmholtz problem, resulting in several advantages demonstrated analytically and numerically.