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A *k*-domain method for fast propagation of electromagnetic fields through graded-index media

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Abstract

Graded-index (GRIN) media are widely used to model different situations: some components are designed specifically for GRIN modulation, e.g., multi-mode fibers, optical lenses or acousto-optical modulators; on the other hand, we might also talk of undesired effects where the refractive-index variation is due to stress or heating; there are also some natural effects which exhibit GRIN behavior, e.g., air turbulence or biological tissue. Modeling of such situations is quite challenging. It may require the application of finite-difference techniques in frequency or time domain, or other rigorous solutions of Maxwell's equations, which often results in too high a numerical effort for practical application. In this work we offer a *k*-domain-based method for the fast calculation of fields propagating through GRIN media. It is potentially fast because of two reasons: (1) in the *k* domain, Maxwell's equations for GRIN media become ordinary differential equations, so that we can take advantage of Runge-Kutta-type mathematical approaches to reduce the numerical effort; (2) taking advantage of fast Fourier transform algorithms to convert the convolution-type calculation ($O(N^2)$) into a multiplication ($O(N)$). Several advantages arise when comparing this work with the famous split-step method: there is no paraxial approximation and the GRIN dependence along the main propagating direction can be accurately modeled.