A Source-Model-Based Computational Technique for Modal Analysis of Chains of Periodic Metallic Nanowires Embedded in a Half-Space Substrate

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We have developed a computational technique for analysis of wave-guiding along chains comprising electrically-small cylinders, embedded between two dielectric half-spaces. The method of solution is based on the Source-Model Technique (SMT). The SMT is an off-surface integral equation method; hence the problem is formulated in terms of fictitious sources located on mathematical surfaces inside and outside the different media boundaries. Previous works on periodic structures with the SMT have proposed a variety of case-specific periodic fictitious sources for fast computations, but they mainly dealt with scattering problems in homogeneous media. We expand upon these earlier works and offer a novel methodology for modal analysis of wave-guiding along periodic structures; the periodic elements are partially buried in a dielectric half-space, in resemblance of fabricated structures atop a supporting substrate.

The idea is to first reduce the problem to a unit-cell of the periodic structure. Complex-valued periodic boundary conditions are enforced to account for the phase shift and amplitude decay of a mode, which would propagate along the structure with a yet-to-be-determined complex propagation constant β. The SMT solution is then employed using two sets of fictitious, time-harmonic sources. Properly phase-and-amplitude modulated periodic sources, whose fields are represented in a concise analytical form as a sum of Floquet modes, are used for expanding the unit-cell fields outside the particle. Elementary sources, whose fields are known analytically, are used for expanding the fields within the particle. A search algorithm, in which the frequency is systematically scanned, is then applied, and the (β,ω) dispersion curves and corresponding modal solution of the wave-guiding structure are readily found.

This novel computational technique is efficient, reliable, and robust to the choice of material or geometric parameters. Special attention is devoted to accurate modeling of chains of metallic nanowires at optical frequencies, due to their ability to guide plasmon-type modes, but the method can be equally applied to study the modal characteristics of similar chains at other operating frequencies, such as dielectric cylinders in THz. Also, while we limit our presentation to metallic nanowires partially buried in a supporting dielectric half-space substrate, the solution can be generalized, with due modifications, to the case of particle chains against a multi-layered background.