Analysis of Periodic Waveguides in Layered Media

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Various waveguiding structures fall into the category of being periodic along the guiding direction (1-D periodic) and existing in layered media. Examples include leaky-wave antennas such as the CRLH structure and arrays of nanoparticles on a plasmonic substrate. An efficient and accurate analysis of these general types of structures is very desirable. An approach that allows for an examination of the fundamental radiation physics of these structures is also quite attractive. In this presentation a unified approach that is accurate, efficient, and very versatile is discussed. The method also allows for the radiation physics of the structures to be directly examined, including leakage (radiation) into space and into surface waves.

The proposed method is based on the spectral-domain method in layered media, using the Mixed Potential Integral Equation (MPIE) formulation introduced by Michalski. This approach is based on the scalar and vector potentials due to current sources in layered media. This versatile method allows for the arbitrary unit cell of general structures to be represented in terms of RWG basis functions for a high-fidelity modeling of the unit cell. The approach allows for planar metallic structures to be modeled, as well as structures containing vertical current elements such as metallic vias within a substrate. Green's functions for magnetic current sources have also been implemented, allowing for the analysis of structures that include slots or dielectric objects. The Green's functions have also been extended to allow for uniaxial anisotropy in the layered medium.

The 1-D periodic MPIE Green's functions are in a form involving a spectral sum and a spectral integral. The summation is over Floquet harmonics, and for each harmonic term an integration in the complex transverse wavenumber plane is performed. The convergence of the integrals is enhanced by extracting asymptotic terms from the integrands (Kummer acceleration), corresponding to direct and quasi-image terms in homogeneous space. These extracted terms are then evaluated by using the rapidly converging Ewald method. For some potential terms these extracted quasi-image terms correspond to a 1-D array of point sources in a homogenous media. For other potential terms the extracted quasi-image terms correspond to a 1-D array of "half line sources" in homogenous media. Both are accelerated using the Ewald method.

The radiation physics of the Floquet harmonics are clearly elucidated using the proposed approach, as each spectral integral has a corresponding path of integration in the complex plane that corresponds with the type of leakage for that harmonic (leakage into space or leakage into space and surface waves).

Examples will be given to illustrate the accuracy and versatility of the proposed method.