Qiang, Rui, “Numerical Analysis of Periodic Structures for Microwave and Infrared Applications with the Finite-Difference Time Domain (FDTD) Method”

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The primary emphasis of this dissertation is to develop efficient time domain based numerical algorithms to investigate the scattering and transmission behaviors of the artificial periodic structures. The discussion focuses on several difficulties in the numerical modeling research of periodic structure that cover the topics of the infrared nano-scale periodic structure analysis, periodic structure illuminated by oblique plane wave incidence and periodic structure response due to a finite-sized source excitation. Towards these subjects, several novel techniques are proposed and applied to the finite difference time domain (FDTD) method. To analyze the nano-scale periodic structure that is operating at infrared (IR) regime, a Lorentz-Drude model is incorporated into FDTD method to characterize metal film frequency-dependent electrical behavior at IR wavelength using the Z-transform technique. The predicted results are compared with measured data and good agreement is reported. A novel FDTD algorithm with simple periodic boundary condition (PBC) is developed to analyze the scattering property of general periodic structures with arbitrary incident angles. The basic idea is to fix horizontal wave numbers in the FDTD simulation. The implementation procedure is introduced and its validity has been approved through several numerical examples. A novel time-domain method, which is based on a spectral domain finite-difference time-domain (FDTD) method together with the array scanning method (ASM), is proposed in its three-dimensional representation. It is used to investigate the propagation and scattering behaviors of infinite artificial periodic arrays due to arbitrary shaped electromagnetic source illumination. Using this method, only a single periodic cell is required to be modeled in finite-difference time-domain computation. The error and convergence analysis are discussed in detail. Several periodic structures are analyzed by this proposed method to testify its computational efficiency in terms of computer memory and computing time.