Development of Numerical Techniques for Forward and Inverse Waveguide Scattering Problems

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Development of the methods and algorithms [1, 2] are considered for the numerical solution to the forward problem of the electromagnetic wave scattering by inhomogeneous dielectric inclusions in a waveguide of rectangular cross section and inverse problem of reconstructing parameters of the dielectric inclusions from the values of the transmission coefficient of the scattered electromagnetic wave. The codes are developed implementing an FDTD method that employs the PML-layer technique. Numerical modeling and simulations are performed for the analysis of the wave propagation in waveguides of rectangular cross section loaded with parallel-plane layered media (layered dielectric diaphragms) and such diaphragms containing cubic dielectric inclusions. Validation is carried out of the results of calculations using closed-form solution [3] to the canonical single-layer structure.

Progress in analytical—numerical investigations of the solutions to the forward and inverse waveguide problems are largely based on a recent discovery [4] of the singularities and extrema in the complex domain of the transmission coefficient of layered dielectric diaphragms. In fact, the knowledge of the location of singularity and extrema sets of the scattering matrix allows one to justify correct determination of real or complex permittivity of each layer of the diaphragm by specifying domains in the complex plane where the transmission coefficient is one-to-one; that is, the domains that do not contain singularities and where unique permittivity reconstruction is therefore possible. For the forward problem of the scattering of a normal waveguide mode by a single- and three-layer diaphragms with a dielectric cube, it is shown [1, 2] that variation in the values of the transmission coefficient can be up to two orders of magnitude less than that of the permittivity of the inclusion. Taking into account this result and the presence of singularities, improvements are proposed of the numerical method, algorithms and codes implementing the calculations.

The results of modeling and computations are validated by comparing with experimental and measurement data [3]. The requirements are formulated that should be imposed on the accuracy of computations and measurements necessary to reconstruct numerically permittivity of the inclusion from the amplitude and phase of the transmitted wave with the prescribed accuracy.

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