Microwave Imaging for Highly-anisotropic Objects Based on Gauss-Newton Minimization Method

Bao Qi Wang, Dun Ting Zhang, and Mei Song Tong
Department of Electronic Science and Technology, Tongji University, Shanghai 201804, China

Abstract— Microwave imaging for unknown penetrable objects can be realized by solving volume integral equations (VIEs) in the integral equation approach. Based on the Born iterative method (BIM) or distorted BIM (DBIM), we alternatively solve the inverse scattering VIEs (ISVIEs) and forward scattering VIEs (FSVIEs) by alternatively assuming a known total electric/magnetic field and a known material property of the objects until the solution converges. The FSVIE can be solved by using the widely-used method of moments (MoM) in which the unknown flux density is represented with the Schaubert-Wilton-Glisson (SWG) basis function. However, the SWG basis function is defined over a pair of tetrahedral elements and requires explicit material interfaces in the geometric discretization, which are not available for unknown objects. Therefore, the MoM may not be suitable for solving inverse scattering problems.

In this work, we propose a Nyström method to solve the FSVIE for reconstructing three-dimensional (3D) highly-anisotropic dielectric objects. The method employs a point-matching procedure to transform the FSVIE into a matrix equation and the matrix elements include hypersingular integrals from the dyadic Green’s function. Although requiring to handle the hypersingularity, the method possesses some advantages that the MoM do not have and it may be more suitable to solve inverse scattering problems. When the ISVIE is transformed into a matrix equation by expanding the unknown permittivity distribution and matching the scattered fields with the measured data, the matrix equation is not directly solvable because it is inherently ill-posed. Solving the ISVIE is usually transformed into an optimization problem by defining a cost function and the Gauss-Newton minimization method (GNMM) with a regularization scheme can be used to find the best solution for the model parameters. We present a numerical example for reconstructing an highly-anisotropic dielectric sphere to illustrate the approach and good results have been obtained.