INVERSE SCATTERING OF GUIDED WAVES : A MODAL FORMULATION

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1 Statement of the Problem

Nonlinear inverse scattering of guided electromagnetic waves is an open topic to contribution and important one in certain areas of engineering and applied sciences, especially related to material test/measurements and fabrication of multilayered structures [1]. In this sense, we consider a three dimensional guided wave problem in which a rectangular waveguide is loaded with a non-magnetic, inhomogeneous object, D whose contrast with respect to background medium, $v(r)$ is to be determined through the use of scattered field, u_s, measured in Γ. The contrast of the object may have an arbitrary variation in spatial coordinates and is complex if the material is lossy. Given an incident field u^{inc} to excite the waveguide, the problem can be formulated as a systems of integral equations consist of the data equation

$$G_j^D[v_j u_{j,\pm m}] = u^s_{j,\pm m} \tag{1}$$

and the object equation

$$u^{inc}_{j,\pm m} = u_{j,\pm m} - G_j^O[v_j u_{j,\pm m}] \tag{2}$$

where u, j, $\pm m$ denote total electric field, index of frequencies and index of propagating modes with sign showing propagating direction, respectively. After introducing a new function $\Phi_{j,\pm m} = v_j u_{j,\pm m}$ called as contrast source, operators $G^D : L^2(D) \to L^2(\Gamma)$ and $G^O : L^2(D) \to L^2(D)$ can be given by

$$G_j^{D,O}[\Phi_{j,\pm m}] = \int_D G_j(r,r')\Phi_{j,\pm m}(r')dV, \quad r \in \Gamma, D. \tag{3}$$

Here, r, r' and $G(r,r')$ represent observation point, source point and fundamental solution of vector wave equation related to this problem, respectively.

2 Reconstruction Algorithm

In order to solve the equations (1) and (2) simultaneously, a cost functional is defined as follows

$$F(\Phi_{j,\pm m}, v_j) = \frac{\sum_{j,\pm m} \|u^s_{j,\pm m} - G_j^D[v_j u_{j,\pm m}]\|^2_{L^2(\Gamma)}}{\sum_{j,\pm m} \|u^s_{j,\pm m}\|^2_{L^2(\Gamma)}} + \frac{\sum_{j,\pm m} \|v_j u^{inc}_{j,\pm m} - \Phi_{j,\pm m} + v_j G_j^O[v_j u_{j,\pm m}]\|^2_{L^2(D)}}{\sum_{j,\pm m} \|v_j u^{inc}_{j,\pm m}\|^2_{L^2(D)}} \tag{4}$$

which corresponds to extension of the cost functional for free space problems in [2] via a modal formulation for guided wave applications. Then, the contrast source and the contrast of the object are iteratively obtained by minimizing the cost functional defined in (4). For numerical implementations, infinite dimensional operators are projected onto finite dimensional ones by following a Method of Moments technique, namely, point matching procedure. Finally, the capabilities and validation limits of the method has been demonstrated with numerical simulations.

References

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