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Surface Integral Equation Formulation for Characteristic Modes of Lossy Dielectric Objects

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The theory of characteristic modes (TCM) provides excitation independent eigensolutions depending only on the material and geometrical properties of a structure. These solutions can provide important insights into the fundamental scattering and radiation properties of arbitrary structures that can be difficult and time consuming to achieve with conventional scattering analysis techniques. TCM has been found to be a particularly powerful tool in antenna design. It can enable systematic and intuitive antenna analysis with increased physical understanding and lead to antenna configurations with enhanced properties.

The theoretical background for TCM has been developed already in the 1970's [1, 2]. Indeed, most of the recent implementations and applications of TCM are based on the original electric field integral equation (EFIE) formulation for perfectly conducting (PEC) objects [3]. For penetrable (dielectric) bodies, TCM has been clearly less popular. This is because of the lack of a spurious-free surface integral equation (SIE) based TCM formulation. In particular, the TCM formulation based on the symmetrical PMCHWT equations, proposed in [4], solves for both the external (characteristic) and internal (spurious) modes, and is unusable without additional techniques [5].

The main problems in the formulation of [4] is that it mixes the internal and external integral equations, and that the operator on the right hand side of the eigenvalue equation is not related to the power radiated by an eigencurrent. As a remedy to this problem, we introduce a new SIE-TCM formulation for penetrable bodies. In this formulation the internal integral equations are used to eliminate one of the currents from the equations only, similarly as in the generalized impedance boundary condition (GIBC) formulation [6]. By properly writing the generalized eigenvalue equation in terms of the real and imaginary parts of the exterior operators, a spurious-free formulation can be obtained without requiring any additional postprocessing techniques. The obtained eigenvalues also have clear physical interpretation and show good agreement with analytical results [7] for both lossless and lossy dielectric and magneto-dielectric objects. For lossy objects, the eigenvalues are complex where the imaginary part gives the ratio of the dissipated and radiated power [7], while the real part retains its usual interpretation as in [2, 3].

References

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