A SIMPLE EIGENVALUE FORMULATION FOR THE MODE SPECTRUM ANALYSIS OF NONSTANDARD WAVEGUIDES

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ABSTRACT

Introduction: Waveguides of nonstandard cross section are frequently employed in microwave and millimeter-wave front-end systems. In order to facilitate a fast and rigorous numerical modeling and design process, the advantages of modal field-matching techniques are often utilized. However, such methods depend heavily on the knowledge of the mode spectra of the nonstandard waveguides involved. Many previous approaches to determine the mode spectrum of a nonstandard cross section relied on singular value techniques which require a more or less sophisticated search algorithm to detect the cutoff wavenumbers as the zeros of the minimum singular value. Since this procedure is not only time consuming but also prone to miss (overstep) zeros, several techniques have been proposed to formulate the task in form of a classical matrix eigenvalue problem.

Omar and Schünemann ([1] IEEE Trans. MTT, Dec. 1989) use as expansion functions the modes of a stardard waveguide; however, their formulation involving the edge condition reverts to a singular value problem. Lin, Li, Yeo and Leong ([2] IEEE Trans. MTT, June 2001) use polynomial expansions, but their constraint function required for TM modes is difficult to handle for structures entirely specified in cartesian coordinates. More general applications involve the Green's function approach of Conciauro, Bressan and Zuffada ([3] IEEE Trans. MTT, Nov. 1984) and the finite element method (e.g. [4] Jin, Wiley 2002).

Theory: In this paper, we present a combination of the first two methods referenced above. The TE modes of a nonstandard cross-section waveguide are straightforwardly expressed in terms of those of standard waveguides. The resulting eigenvalue equation is easily solved without any numerical problems, even for a large number of expansion terms. This overcomes some of the difficulties encountered in [2].

In order to enforce the boundary conditions for TM modes, we are introducing two-dimensional negative pulse functions which vanish only on the cross section of the metal insert in a standard waveguide and assume a value of unity elsewhere. Although the derivatives of such functions involve delta distributions, their influence is easily accounted for through the sifting (sampling) theorem. The resulting eigenvalue system covers a large variety of cross sections involving metal inserts in standard waveguides.

Results: The method will be demonstrated at several examples involving rectangular cross-section inserts in standard rectangular waveguides. Comparisons with other numerical techniques validate the applicability of the new approach. The CPU-time advantage compared to techniques using singular value formulations will be demonstrated. The method is currently being tested at more general cross sections, and related results will be available at the time of presentation.