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Mode Matching Method for the Analysis of Cascaded Discontinuities in a Rectangular Waveguide

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Abstract

The generalized scattering properties of cascaded H-plane discontinuity in a rectangular waveguide operating in X- band using Mode Matching Technique (MMT) is obtained from the respective field equations for two different junctions. The S-parameters obtained are cascaded to obtain the S-parameters for the whole system. The results obtained using MMT are compared with Equivalent circuit approach and 3-Dimensional (3-D) Electromagnetic (EM) simulation software package, Computer Simulation Technology Microwave Studio (CST-MWS) and High Frequency Structure Simulator (HFSS) which are based on Finite Integration Technique (FIT) and Finite Element Method (FEM) respectively, based on accuracy and simulation time.

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Keywords: Mode Matching Technique; S-parameters; Discontinuities; 3D simulation; Equivalent Circuit Technique; Susceptance; Evanescent mode; Boundary condition.

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1. INTRODUCTION

The waveguide junction plays an important role in the design of networks and integrated circuits at optical, microwave and millimetre-wave frequencies and hence it has drawn the attention of numerous researchers over the last few decades. The interest in studying the behaviour of such junctions arises from the fact that these disturbances affect the function of the components that are connected to the other end of the waveguide junctions. Examples of waveguide junctions are linear tapers, phase shifters, directional couplers, filters etc. These components are translationally symmetric along one of two transverse dimensions[1]. In this paper, H-plane discontinuities presents an incident electric field parallel to the unchanged transverse direction are analysed. It is normally used in impedance transformers, inductive windows, power divider etc.

Such a junction excited by TE_{m0} mode generates modes of the same nature[2], both propagating and evanescent; evanescent modes cannot propagate energy; they store energy and give rise to reflection problems. Also if the discontinuities are close to each other higher order modes will be generated; hence a generalized analysis is important. The generalized modal scattering matrix relates outgoing TE_{m0} modes to incoming TE_{m0} modes. Using Mode Matching Technique (MMT) [3, 4], the scattering matrix is obtained by taking into account both propagating and evanescent modes.

There are two approaches in solving electromagnetic problems: experimental and theoretical. The experimental is expensive, time consuming. Theoretical methods may be classified as analytical, semi-analytical and numerical. Numerical Techniques has the advantage that it can handle a huge variety of problems, independently of the complexity in their geometry, which is the weak point of analytical methods.

In this paper, the MMT is compared with Equivalent circuit approach[5] and with HFSS that uses Finite Element Method (FEM) and CST-MWS which is based on Finite Integration Technique (FIT). For problems with irregular geometries, the numerical methods require a lot of computer memory and CPU time. There is however some useful subclasses of problems where the variations of the field are known in one coordinate direction. Then numerical analysis can be done in two dimensions (H-plane and E-plane), which requires less memory and CPU time.

Mode Matching Technique is faster and more accurate than the typical numerical solution techniques like HFSS and CST MWS. The S-parameters obtained using MMT are compared with that of the numerical techniques in terms of time and accuracy. It was found that MMT is much accurate and the simulation time is much less than the 3D numerical simulation techniques.

2. THEORY

2.1. Mathematical Formulation of Mode Matching Technique

Waveguide structures with longitudinal discontinuities are involved in many applications. Analysis of the waveguide discontinuities is of great importance. A powerful approach is the mode matching technique (MMT) with which the fields are described by a superposition of waveguide modes, and then the boundary conditions that the tangential fields in the cross-section of the waveguide structure must be continuous are imposed at the interface between different waveguide sections. In the MMT, the structure under consideration is subdivided into simpler substructures whose modes (Eigen functions) are known or can be determined. Unknown electric and magnetic fields are approximated by a sum of Eigen modes with unknown coefficients. When these functions are orthonormal, they are referred to as the normal modes. The series expansion satisfies all the boundary conditions of the problem except for those at the interfaces between adjacent sub regions. Unknown expansion coefficients are then determined from the boundary conditions at the interfaces.

The method is most efficient when the modes of each sub region are known analytically. When the normal modes are not known, a numerical technique is first used to determine these and then the MMT can be applied. The MMT is also useful in solving the corresponding Eigen value problem when the sub region can itself be divided into sub regions whose normal modes are known. When the MMT is used to solve Eigen value problems, the method is referred to as the Field Matching Technique. When combined with the Generalized Scattering Matrix Technique (GSMT), the MMT becomes a powerful tool for analysing many composite waveguide structures.

In this approach, the generalized scattering matrices of the individual discontinuities are determined separately