ANALYSIS OF MICROSTRIP LINES COUPLED THROUGH AN ARBITRARILY SHAPED APERTURE IN A THICK COMMON GROUND PLANE

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ABSTRACT

A flexible spectral domain analysis to characterize aperture-coupled microstrip lines with a common ground plane of finite conductor thickness is presented. In this approach, the coupling aperture is allowed to have any size, shape, and thickness. The effects of surface wave and radiation are also taken into accounts via the exact Green's function formulation in the spectral domain. Numerical results of the S-parameters generated using this method are presented for different aperture thicknesses and validated against known published data for the zero thickness case.

INTRODUCTION

This paper presents a general and flexible procedure which combines the extended spectral domain approach with the deterministic spectral domain method to accurately model microstrip lines coupled through an arbitrarily shaped aperture of any size residing in a common ground plane with finite conductor thickness. The mentioned structure is of interest in MIC, MMIC, and antenna design. Analysis of two parallel microstrip lines coupled by a small rectangular slot has been reported by Herscovici and Pozar [1], and Wakabayashi and Itoh [2] using reciprocity. However, in those analyses, the coupling slot was assumed to be rectangular and narrow. In addition, the finite thickness of the slot was not accounted for in those methods. In the present approach, an extended version of the spectral domain method [3] is utilized in conjunction with triangular subdomain basis functions to analyze thick coupling aperture of arbitrary size and shape. The discontinuities in microstrip lines at the coupling junction are characterized using the deterministic spectral domain approach [4]. As an illustration and also validation of this method, the analysis and numerical results of coupled microstrip lines via a thick rectangular slot shown in Fig. 1 will be presented.

METHOD

Assume that an incident field is launched from z = -∞ into port 1 of the structure shown in Fig. 1. To compute the scattering parameters at the four ports using the present method, the analytical procedure can be divided into three main parts: eigenvalue formulation, aperture field expression, and discontinuity scattering-parameter calculations. In the first part, the standard spectral domain method [5] is utilized to compute the propagation constants and current distributions of the uniform and infinitely long microstrip lines. These parameters will be stored and used in the last step of the analysis to express the incident, reflected, through, and coupled currents so that the scattering parameters may be computed. The second part of the present method is to express electromagnetics fields in the aperture region by the Fourier series representation using the extended spectral domain approach [3]

$$E_{x,z}^{(aperture)}(x,y,z) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} \tilde{E}_{x,z}^{(aperture)}(y,\alpha_m,\beta_n) \cdot e^{-j\alpha_m x} \cdot e^{-j\beta_n z}$$

Introduce the unknown aperture fields at the top and bottom of the aperture-dielectric interfaces and expand them in terms of triangular subdomain basis functions [6] with unknown coefficients to prepare for the next step. Finally, the deterministic spectral domain method [4] is applied to express the current distributions on the microstrip lines in the vicinity of the coupling junction as a superposition of the current distributions on a uniform and infinitely long microstrip lines and unknown perturbed current distributions. Appropriate boundary conditions and method of moments are applied in the spectral domain to generate a system of complex linear equations in which the reflection, through, coupled coefficients, and the aperture field expansion coefficients are unknowns and can be solved by any known matrix inversion methods.

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NUMERICAL RESULTS

The computed S-parameters using the present method are shown in Fig. 2 as functions of frequency for different aperture thicknesses. Results for the zero thickness slot are also compared with the computed and measured data published by Herscovici and Pozar [1] to confirm the accuracy of the proposed method. As indicated in Fig. 2, results obtained by the present approach for the zero thickness case agee very well with published data. Fig. 2 also illustrates that the conductor thickness of the common ground plane has significant effects on the S-parameters of the four ports.

CONCLUSIONS

Microstrip lines coupled through a thick aperture of arbitrary size and shape have been analyzed rigorously using the extended deterministic spectral domain method. It has been shown that the finite thickness of the coupling aperture contributes significant effects to the coupling characteristics of the structure. This paper presents a reliable analytical method to model three-dimensionally coupled structures.

ACKNOWLEDGEMENT

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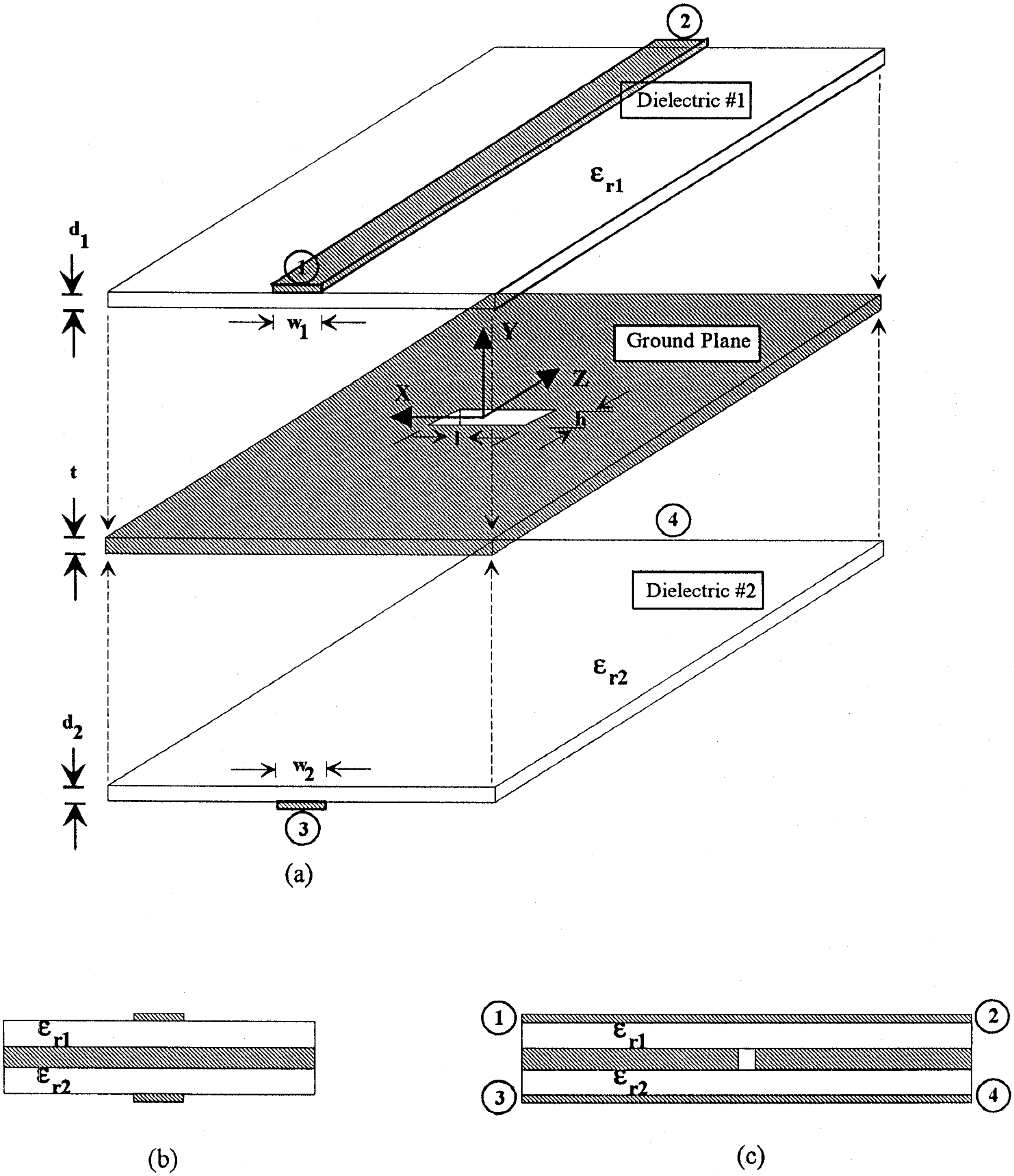
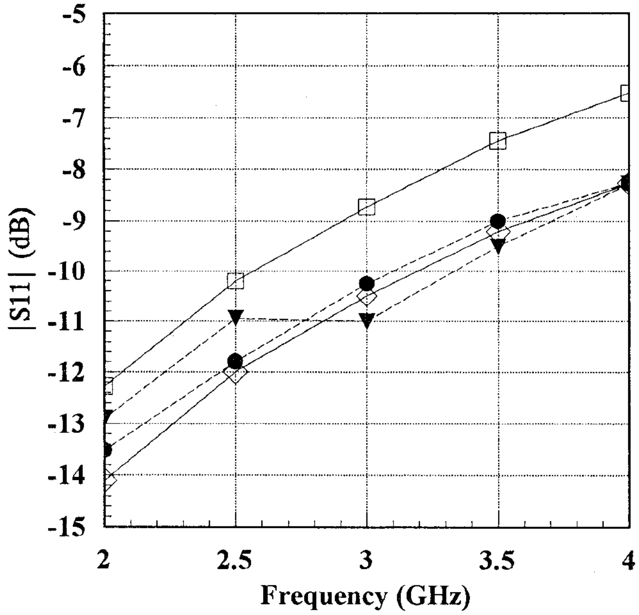
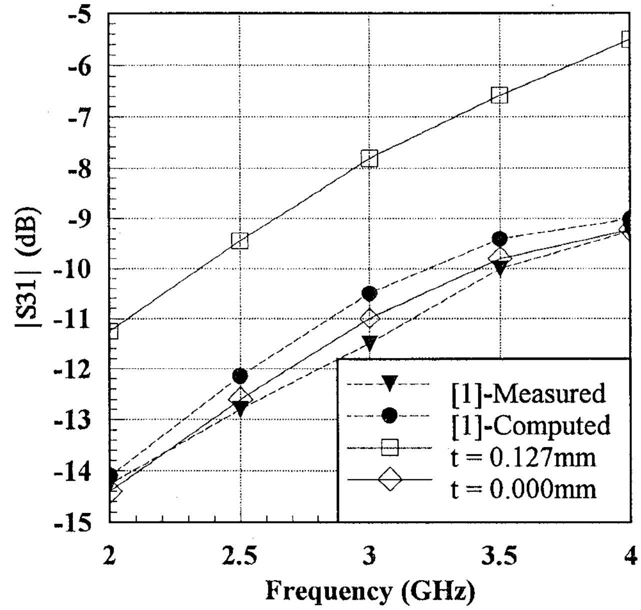


Figure 1. (a) 3-D View, (b) End View, (c) Side View of typical Aperture-Coupled Microstrip Lines

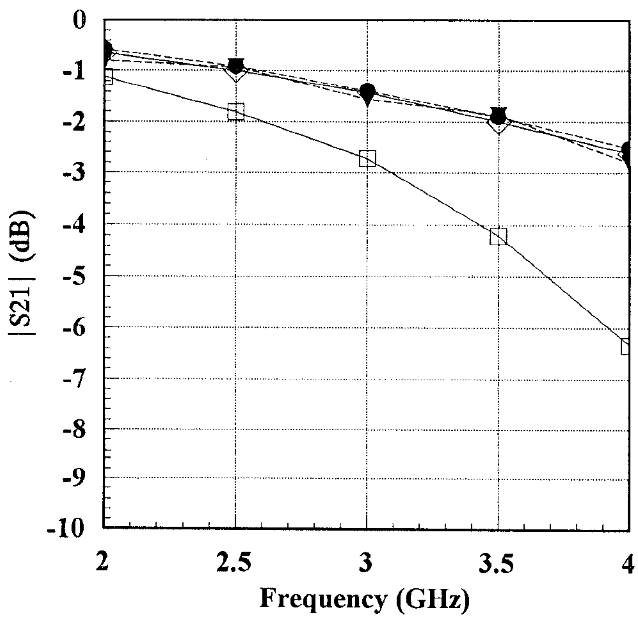


(a)



(c)

Figure 2. S-parameters for structure shown in Fig. 1 with $\varepsilon_{r1} = \varepsilon_{r2} = 2.20$, $w_1 = w_2 = 2.54$mm, $d_1 = d_2 = 0.762$mm, l = 15mm, h = 1.1mm (a) |S11|, (b) |S21|, (c) |S31|



(b)