An electromagnetic model for post-wall waveguide building blocks
Coenen, T.J.; Bekers, D.J.; Tauritz, J.L.; Vliet, van, F.E.

Published in:
Proceedings of 2010 URSI International Symposium on Electromagnetic Theory (EMTS), 16-19 August 2010, Berlin, Germany

DOI:
10.1109/URSI-EMTS.2010.5637165

Published: 01/01/2010

Document Version
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:
• A submitted manuscript is the author's version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

Citation for published version (APA):

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.
• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal?

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Download date: 10. Nov. 2018
Abstract—During the past five years, dielectric and metallic post-wall waveguides (PWWGs) have been analyzed at TNO Defence, Security and Safety, using both an integral equation approach and a modal approach. The model developed focuses on $\text{TE}_{n0}$ modes facilitating the analysis of infinitely-long, straight PWWGs as well as finite PWWGs with arbitrary post positioning. Quite recently, we introduced an alternative approach for dealing with complex propagation constants, so that PWWG losses, and the scattering matrices of PWWG sections can be computed. These sections are represented by ‘current matrices’ that relate the ‘incoming’ electric and magnetic surface currents on predefined ports to the ‘outgoing’ surface currents. The derivation of the current matrices is based on Lorentz’s reciprocity and Love’s equivalence theorems. Both the ‘incoming’ and ‘outgoing’ surface currents are represented by rooftop bases. The scattering parameters of a PWWG section are determined by expressing waveguide modes in terms of these bases. Finally, the corresponding software code can be integrated in a circuit simulator, a familiar platform for microwave designers.

I. INTRODUCTION

Traditionally, planar transmission-line antenna-feed structures are designed by employing a microwave circuit simulator with a built-in component library. The performance of the feed structure is evaluated by first computing the matrices of the components and then by cascading these matrices. In the last decade, post-wall waveguides (PWWGs) have become a promising alternative for traditional planar transmission lines, in particular for their potential low losses at millimeter-wave frequencies, see e.g. [1], [2] and the references therein. As shown in Fig. 1, a PWWG is a waveguide embedded in a dielectric slab that is laterally bounded by rows of metallic or dielectric posts, possibly with ground plates on top and bottom. To design PWWGs antenna feed structures, we would like to have at our disposal a component library that can eventually be integrated with a circuit simulator such as Advanced Design System (ADS). A prerequisite for implementing the library is the availability of a fast numerical tool that can compute the scattering matrices of different types of components.

In [3], [4] we developed a model for the analysis of straight guides, in particular to calculate the (real part of the) propagation constant of such guides. This model is based on the infinite-array approximation in which symmetry considerations are used to reduce the analysis to a single unit cell. The main disadvantages of this approach are its inability to handle losses, or equivalently, complex propagation constants, and to handle more complex PWWG components, such as those described in [5]. In recent years [6], we have introduced an alternative approach for handling PWWG components that overcomes both limitations. In this paper we present a brief overview of this approach and we discuss preliminary simulation results.

II. ANALYSIS APPROACH

In the analysis approach discussed in [3], [4], we focus on the $\text{TE}_{n0}$ modes in PWWG for which the electric field is of the form $E = E_y(x, z)i_y$, where the unit vector $i_y$ is directed along the posts. For small to moderate substrate heights, these modes predominantly describe the electromagnetic behavior of a PWWG. To calculate this behavior, we expand the electromagnetic field of each post in terms of the eigenfunctions (of Bessel and Hankel type) of the Helmholtz equation in cylindrical coordinates. These field expansions result in a matrix equation with the expansion coefficients as unknowns.

In our alternative analysis approach, we employ the same assumption for the electric field as in [3], [4] to characterize a section of a PWWG with arbitrary positioning of the posts.
between two interfaces or ports. A top view of such a section is shown in Fig. 2. We assume that at the port planes the (tangential) fields associated to the modes that dominate the behavior of the PWWG section vanish rapidly away from the posts. Then we can limit the infinitely large planes to finite segments. At these segments, we expand the tangential electric and magnetic fields in terms of rooftop functions. We calculate the field in the PWWG section induced by a specific amplitude and phase distribution of the rooftop functions by invoking Lorentz reciprocity and Love’s equivalence theorem. This field serves as excitation field for the field-expansion approach described in [3], [4]. Thus we compute the resulting scattered field of the posts by the matrix equation mentioned above. Finally, we project the resulting total field in the PWWG section on the finite segments at the port planes and we expand tangential electric and magnetic fields in terms of the rooftop basis.

The result of our analysis is a ‘current matrix’ that relates the coefficients of the ‘incoming’ tangential electric and magnetic fields at the ports to the coefficients of the ‘outgoing’ tangential electric and magnetic fields. In order to extract the scattering parameters of the PWWG section, we determine the coefficients of the ‘incoming’ tangential fields at the ports such that they represent $\text{TE}_{10}$ modes. Next, we compute the projection of the tangential fields resulting from scattering by the posts on the same modes. To obtain the performance of a complete PWWG component or feed network we cascade the corresponding ‘current matrices’ and we compute the scattering parameters of the complete component or network by the projection on the $\text{TE}_{10}$ mode.

In summary, our analysis approach involves the following steps:

1) Generate the fields with tangential electric and magnetic currents at the ports of a PWWG section using Lorentz’s reciprocity and Love’s equivalence theorems.
2) Expand these currents in terms of rooftop functions for both ‘input’ and ‘output’.
3) Calculate the fields scattered by the posts by the field expansion approach described in [3], [4].
4) Project these fields on the rooftop functions at the ports obtaining a ‘current matrix’ that relates the expansion coefficients of output currents to input currents.
5) Cascade ‘current matrices’ of PWWG sections to obtain the performance of a complete PWWG component.
6) Calculate the scattering parameters by projecting the tangential fields at the ports onto the $\text{TE}_{10}$ mode at the ports.

III. RESULTS

The graph at the top of Fig. 3 shows the measured and simulated magnitudes of the scattering parameters for a phase-delay line, as shown in the picture at the bottom of Fig. 3. We observe that $|S_{11}|$ is below $-15$ dB and $|S_{21}|$ is above $-0.55$ dB in the 9.5–12.4 GHz range. Moreover, both the measured and the simulated results exhibit a similar trend. The difference between measurements and simulations for low values of $S_{11}$ can be explained by the measurement inaccuracy at low coupling levels.

IV. CONCLUSIONS

We developed an electromagnetic model starting from Lorentz’s reciprocity theorem that enables us to calculate the fields in (sections of) PWWGs with metallic or dielectric posts. The projection of these fields on equivalent currents defined on bounded segments of specified interfaces allows for the characterization of a PWWG with ‘current matrices’. These matrices are related to the scattering parameters, which in turn facilitate interfacing with microwave design software and determining key PWWG characteristics.
REFERENCES


