The Space Spectral Domain Technique Applied to a Finline Configuration

N. Gupta and M. Singh, *Member, IEEE*

Abstract—**The method of space spectral domain, a novel combination of the conventional method of lines and spectral domain approach, is extended to analyze a class of finline resonators. The existing SSDA procedure is simplified using the property of the diagonal matrices, which leads to stability in numerical results with less computational efforts. As an illustration the resonant frequency for the rectangular and triangular finline resonator is computed.**

I. Introduction

THE METHOD OF LINES (MOL) [1]-[4] and spectral domain analysis (SDA) [5]–[7] have been utilized frequently in the past for the full wave electromagnetic modelling. The conventional MOL combined with SDA called the space-spectral domain approach (SSDA) is used by Wu and Vahldieck [8], [9] for the analysis of the microstrip resonators and discontinuity respectively in the past. The principal steps in SSDA technique involves one-dimensional discretization in z direction and one-dimensional SDA in the x direction (Fig. 1).

The analysis presented in [8] is complicated as it involves various matrix operations like multiplications, inversion etc. to be done on matrices of large order. The computation of their inverses lead to instability in results because the matrices involved are highly illconditioned, unless some special algorithms for finding accurate inverses like singular value decomposition are being used. This, in turn, leads to increase in the CPU time. In the case of finline the problem is more severe as the final matrix equation for the Green's function requires one more inversion so that the slot field can be expanded in terms of the basis functions. Since in the case of balanced boundary condition all the submatrices involved are diagonal matrices, each of them can be treated as a single element separately and space-spectral coupled Green's functions can be found analytically using only a four by four matrix. At this stage, substituting for the values of the each element the submatrices are retrieved back and one can start the actual computation. This clearly eliminates the matrix inversion to be performed on a large matrix whose order increases tremendously for complicated structures as one has to consider large number of lines in such cases. The formulation of the problem using the approach described here is simple and more straightforward. In the present letter this approach is utilized to compute the resonant frequency of the rectangular finline resonator as an illustration.

Manuscript received September 28, 1992.

The authors are with the Department of Electronics and Electrical Communication Engineering, Indian Institute of Technology, Kharagpur 721 302, India.

IEEE Log Number 9208976.

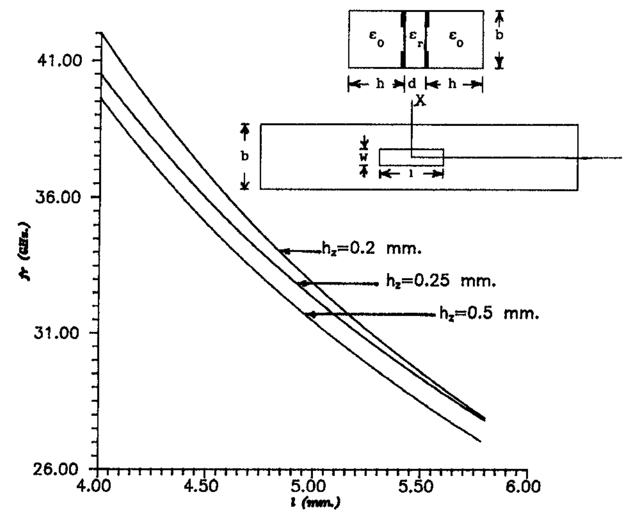

Fig. 1. Resonant frequency of a bilateral finline resonator as a function of resonator length. $a = 7.112$ mm, $b = 3.556$ mm, $w/b = 0.1$, $\epsilon_r = 2.22$, $d = 0.127$ mm.

II. Method of Analysis

The space-spectral coupled Green's function in the transformed domain for finline using the concept of chain matrix is derived. Each submatrices are treated as a single element in the beginning, because of their diagonal nature, which clearly depends only on the boundary condition and the number of discretization lines. The final algebraic matrix equation after substituting for each submatrices is written as

$$\begin{bmatrix} j\overline{J_x} \\ \overline{J_z} \end{bmatrix} = \begin{bmatrix} [\overline{Y_{xx}}] & [\overline{Y_{xz}}] \\ [\overline{Y_{zx}}] & [\overline{Y_{zz}}] \end{bmatrix} \begin{bmatrix} \overline{e_x} \\ j\overline{e_z} \end{bmatrix}. \tag{1}$$

The submatrices in (1) becomes square matrices for each spectral term $\alpha_{\cdot n}$. This is due to the balanced boundary conditions i.e., the Neumann–Dirichlet (ND) conditions which corresponds to an electric wall $z = L/2$ and magnetic wall at $z = 0$.

After reverse transformation of (1) back in the original domain and reducing the resultant matrix by considering only few discretization lines which pass through the slot the final matrix equation is subjected to SDA technique and the eigensolution can be obtained directly in spectral domain. This is usually done by the Galerkin's technique, which requires the choice of suitable basis functions on the slot for each

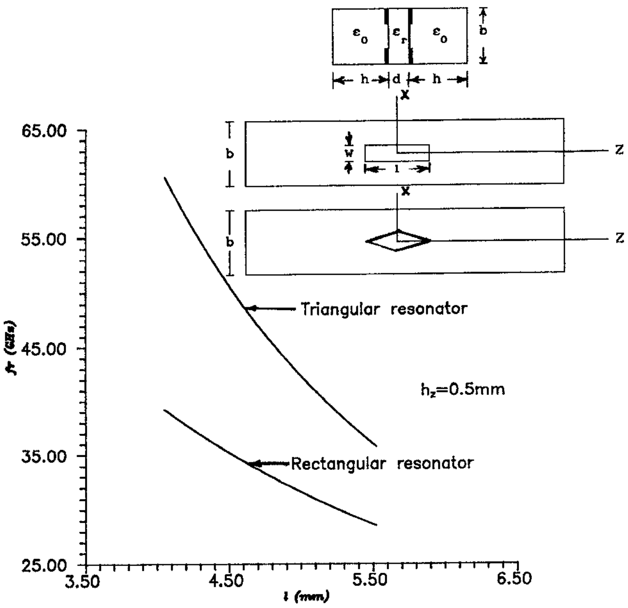

Fig. 2. Resonant frequency of a bilateral finline resonator as a fucntion of resonator length: $a = 7.112$ mm, $b = 3.556$ mm, $\epsilon_r = 2.22$, $d = 0.254$ mm, $w/b = 0.1$.

discretization line in the z direction. In our case, we have used sinusoidal basis functions. It is at this point that the actual geometry of the resonator comes into account. For irregularly shaped resonators, w and s become a function of the z direction and are therefore different for each discretization line since the circuit contours can be described by a set of coordinates.

Applying Galerkin's technique at each electric and magnetic line, the characteristic matrix equation obtained, is solved for the zeros of the determinant.

$$\begin{bmatrix} [A] & [B] \\ [C] & [D] \end{bmatrix} \begin{bmatrix} \bar{a} \\ \bar{b} \end{bmatrix} = 0. \tag{2}$$

III. Result

As an example, a rectangular and a triangular slot resonator in a Bilateral finline cavity is considered. The data obtained by using the SSDA to calculate the resonant frequencies of a rectangular bilateral finline resonator enclosed in a cavity for different resonant length was plotted for various discretization distances as shown in Fig. 1. As the discretization distance is decreased the curve approaches more towards the optimum result. The resonant frequency for rectangular as well as triangular resonator is compared in Fig. 2. As predicted the resonant frequency for a triangular resonator is more compared to the rectangular resonator. Fig. 3. shows a convergence analysis for the rectangular and triangular resonator. In the case

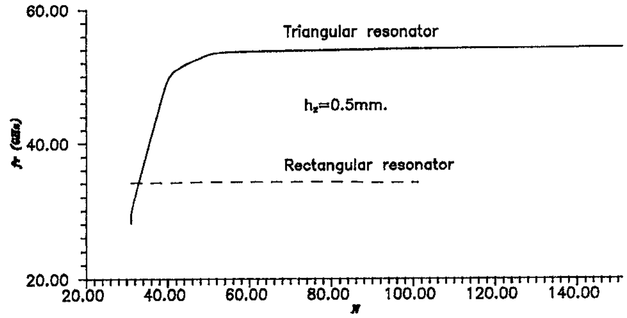

Fig. 3. Convergence analysis of a rectangular and triangular finline resonator: $a = 7.112$ mm, $b = 3.556$ mm, $w/n = 0.1$, $\epsilon_r = 2.22$, $d = 0.254$ mm.

of rectangular resonator, the convergence is achieved only with few number of spectral terms while in the case of triangular resonator more number of spectral terms are required. In the case of non rectangular structures it is advantageous to go for global convergence.

IV. Conclusion

The resonant frequency for a rectangular and triangular resonator in a bilateral finline is successfully computed using the SSDA technique. The SSDA technique applied in the present form is found to be superior to the many numerical techniques and the one illustrated in [8] in terms of the speed of computation and space required. It can even be used to compute the resonant frequency of any arbitrarily shaped 3-D circuit structures which were difficult to analyze before.

References

[1] U. Schulz and R. Pregla, "A new technique for the analysis of the dispersion characteristics of planar waveguide," *Arch. Elek. Ubertragung*, band 34, pp. 169–173, 1980.
[2] S. B. Worm and R. Pregla, "Hybrid mode analysis of arbitrarily shaped planar microwave structures by the method of lines," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-32. pp. 191–196, Feb. 1984.
[3] H. Diestel and S. B. Worm, "Analysis of hybrid field problems by the method of lines with nonequidistant discretization," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-32, pp. 633–638, June 1984.
[4] R. Pregla, "About the nature of method of lines," *Arch. Elek. Ubertragung*, vol. 41, pp. 368–370, 1987.
[5] R. H. Jansen, "The spectral domain approach for microwave integrated circuits." *IEEE Trans. Microwave Theory Tech.*, vol. MTT-33, no. 10, Oct. 1985.
[6] L. P. Schmidt and T. Itoh, "Spectral domain analysis of dominant and higher order modes in fin-lines," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-28, pp. 981–985, Sept. 1980.
[7] J. B. Davis and D. Mirshekar Syahkal, "Spectral domain solution of arbitrary coplanar transmission line with multilayer substrate," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-25, pp. 143–146, Feb. 1977.
[8] K. Wu and R. Vahldieck, "A new method of modeling three-dimensional MIC/MMIC circuits: A space spectral domain approach," *IEEE Trans. Microwave Theory Tech.*, vol. 38, no. 9, Sept. 1990.
[9] M. Yu, K. Wu, and R. Vahldieck, "A deterministic quasi-static approach to microstrip discontinuity problems in space-spectral domain," *IEEE Trans. Microwave Guided Wave Lett.*, vol. 2, no. 3, pp. 114–116, Mar. 1992.