Letters

Comments on "Finite Elements for Microwave Device Simulation: Application to Microwave Dielectric Resonator Filter"

Adam Abramowicz

In the above paper[1] an application of the finite element method to the computation of scattering parameters of dielectric resonator structures is presented. Exiting possibilities of analyzing the whole filter structure (including input and output structures) seems to be the main advantage of the finite element method over other analysis methods. But presented results indicate that the accuracy of computation is the main problem in the finite element method. Two section of the paper need close scrutiny.

In Figs. 5 and 6 the results of the analysis of two transversely coupled dielectric resonators are presented. The structure is shown in Fig. 4. The resonant frequencies of the even and odd mode are too high. Lets consider the resonant frequency of the even mode, which is the resonant frequency of a half of the structure from Fig. 4 with a metal wall placed exactly in the symmetry plane. The distances between the dielectric resonator and walls are as follows: 6 mm, 6 mm, 6 mm and 3 mm. It is clear that the resonant frequency of this structure must be higher that the resonant frequency f_{c1} of the cylindrical structure with the external diameter D_{ext1} equal to $\sqrt{12^2+12^2}$ mm and lower than the resonant frequency f_{c2} of the cylindrical structure with the external diameter D_{ext2} equal to 9 mm. Computed by means of the radial mode matching method [1]–[3] resonant frequencies of the cylindrical structures are presented in Table I. The discrepancy between results is so big that dimensions given in Fig. 4 or the accuracy of the finite element method are in doubt.

In Table I The resonant frequency f_{MM} of the cylindrical resonator in the box was calculated by means of the mode matching method in which the series of radial waveguide modes is matched with the series of rectangular waveguide modes.

The second section of the paper that need to be considered describes the application of the 3-D finite element method to the computation of resonant frequencies of hybrid modes. Presented results have a little in common with the structure described in Fig. 18. In Table II the results of computation of the resonant frequencies of the structure from Fig. 18 are presented. The radial mode matching method have been used [1]–[3] to verify the accuracy of the finite element method. This time the discrepancy is so big that can be explained only as printing mistake. It is possible that a radius of the dielectric resonator stated in Fig. 18 as 17 mm in fact is equal to 11 mm (such a radius have resonators used in the filter presented in the paper). That is why in Table II there are presented results computed for two radii.

Presented results raise a question on the accuracy of the finite element method applied to the dielectric resonator structures.

Manuscript received October 23, 1992.
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[1] J. P. Cousty *et al.*, *IEEE Trans. Microwave Theory Tech.*, vol. 40, no. 5, pp. 925–932, May 1992.

TABLE I
COMPARISON BETWEEN RESULTS COMPUTED FOR THE DIELECTRIC RESONATOR PLACED IN THE CYLINDRICAL STRUCTURES AND IN THE BOX (DIMENSIONS AS IN FIG. 4)

f_{c1}	f_{c2}	f_{MM}	f_{oe} Finite Element Method
4.834 GHz	4.950 GHz	4.841 GHz	5.841 GHz

TABLE II
COMPARISON BETWEEN THE RESULTS OF THE RADIAL MODE MATCHING METHOD AND THE FINITE ELEMENT METHOD (FEM)

	Mode Matching		FEM
	$r = 17$ mm	$r = 11$ mm	$r = 17$ mm
$\text{HEM}_{11\delta}$	2.634 GHz	3.507 GHz	3.554 GHz
Second hybrid mode	3.539 GHz	4.052 GHz	4.448 GHz

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[1] Sz. Maj and M. Pospieszalski, "A composite, multilayered dielectric resonator," in *IEEE MTT-5 Int. Microwave Symp. Dig.*, San Francisco, 1984, pp. 190–192.
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[3] A. Abramowicz, Sz. Maj, and J. Krupka, "Theoretical and experimental study of the resonant modes in shielded dielectric resonators," in *Proc. Microwaves and Optronics Conf. MIOP'89,* Sindelfingen, 1989.

Reply to Comments on "Finite Elements for Microwave Device Simulation: Application to Microwave Dielectric Resonator Filters"

S. Verdeyme and P. Guillon

In the above paper [1], the Finite Element Method (FEM) has been applied to characterize different structures including dielectric resonators (DRs). The environment of the DR may be considered rigorously using this method, even the excitation components. The accuracy of our computations has been discussed on two examples.

We first notify that there was actually a printing mistake on the structure dimensions described in Fig. 18. In our paper the DR radius is equal to 11 mm (and not 17 mm), as the other ones in this paper. For this case, our FEM results differ however from mode matching method ones for the reasons presented below.

We must note first of all that the results presented by A. Abramowicz using mode matching method have not been obtained on the structure presented in Fig. 18, where a DR is coupled to two coaxial probes, so it is not symmetrical. The effects of the coaxial probe

Manuscript received October 28, 1992.
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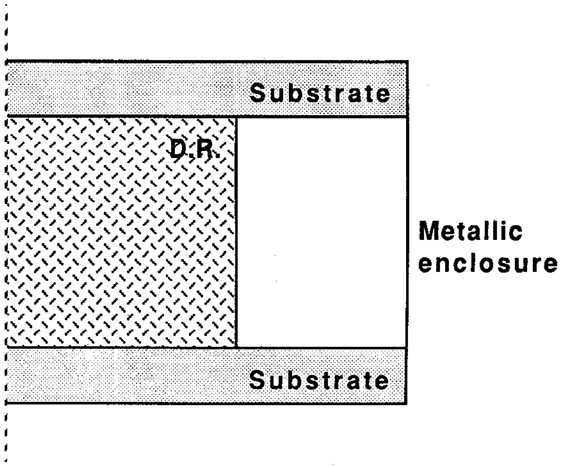

Fig. 1.

excitation (metallic perturbation) can't take into account in a two dimensional free oscillation (2-D) analysis. To our knowledge, no equivalent rigorous analysis have been published on the three dimensional (3-D) structures we have examined, and specially concerning the computed external quality factors and $[S]$ parameters. We think that in this case we can then evaluate the accuracy of these FEM results by a comparison to experimental ones. We can note that the precision on the resonant frequency is not perfect (Figs. 19 and 20), but the coupling between the DR and the coaxial probes (Figs. 19 and 20) are in good agreement. That was the purpose of these computations, as the repartition of the elements in the mesh have been chosen, to limit the computation time required, to favorise these coupling parameters determinations. Moreover, the second hybrid mode (Fig. 20) is the second mode which can be measured or computed for the probe positions shown on Fig. 18. The HEM_{12} mode (second frequency with only one azimuthal variation) can't be excited in this structure, which appears clearly applying the 3-D forced oscillations FEM, but not using 2-D analysis as the probes are not taken into account. We have considered the HEM_{21} mode.

The structure developed to study the radial coupling between two DRs (Fig. 8) is not symmetrical too, and the effects of the enclosure and substrate geometries are not considered in the 2-D analysis. Here, we can verify that the coupling coefficient between DRs agrees well with the experimental one. For time consuming requirement, the mesh was probably not enough fine to determine accurately the resonant frequencies, but it doesn't modify significantly the coupling coefficient as the computed frequencies for odd and even modes are shifted up with respect to their accurate values for about the same increment.

It is however important to establish the accuracy of the different methods, but it must be compared on the same structure. We analyze here the cylindrical structure presented on Fig. 1 and computed by A. Abramowicz. The cylindrical DR of heigth 6 mm radius 6 mm and permittivity $\varepsilon_r = 36$ is enclosed in a perfectly conducting cylindrical cavity of radius R_c and heigth 9 mm. This DR is placed between two dielectric supports ($\varepsilon_r = 2,2$). We have applied both the 2-D FEM, the Raileigh Rity Method (RRM) [2], but also the 3-D FEM, which is not required here, to compute the resonant frequency of the first TE_{01} mode of the DR structure. These results are compared with the Mode Matching Method (MMM) ones in Table I.

The 3-D FEM computations have been performed on a HP 750 workstation. The computing time required is less than 10 s.

TABLE I

	2-D FEM	MMM	RRM*	3-D FEM
$R_c = 9$ mm	4.950 GHz	4.950 GHz	4.950 GHz	4.951 GHz
$R_c = 16.97$ mm	4.838 GHz	4.839 GHz	4.835 GHz	4.836 GHz

A 2-D approach is desirable for a symmetrical structure, but we hope that these results may prove the accuracy of the 3-D FEM. This analysis, or equivalent finite difference one, is an efficient tool for real arbitrary structures engineers have to modellize. With the development of high power workstations, 3-D electromagnetic simulators seems to become desirable to analyze but also to optimize such devices.

Note: We think that there is a printing mistake in the comments of A. Abramovicz. $D_{\text{ext1}} = \sqrt{12^2 + 12^2}$ or = 9 mm represent the external radius, and not the external diameters, of the cylindrical structure.

References

[1] J. P. Cousty, S. Verdeyme, M. Aubourg, and P. Guillon, "Finite element for microwave device simulation: Application to microwave dielectric resonators filters," *IEEE Trans. Microwave Theory Tech.*, vol. 40, no. 5, pp. 925–932, May 1992.

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Corrections to "Moment Method Formulation of Thick Diaphragms in a Rectangular Waveguide"

Amlan Datta, B. N. Das, and Ajoy Chakraborty

In the above paper[1] the following corrections should be made:

1) On page 592, the revised version of (1) should be

$$H_i(e_p) = \sum_{n=1}^{\alpha} V_n \Big[\text{sinc}\{R_{np}(w_1)\}\cos\{S_{np}(c_1)\} - \text{sinc}\{T_{np}(w_1)\}\cos\{U_{np}(c_1)\}\Big]\sin\left(\frac{n\pi y}{b}\right)$$

instead of

$$H_i(e_p) = V_n \Big[\text{sinc}\{R_{np}(w_1)\}\cos\{S_{np}(c_1)\} - \text{sinc}\{T_{np}(w_1)\}\cos\{U_{np}(c_1)\}\Big]\sin\left(\frac{\pi y}{b}\right)$$

Manuscript received October 23, 1992.

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IEEE Log Number 9206322.

[1] A Datta, B. N. Das, and A. Chakraborty, *IEEE Trans. Microwave Theory Tech.*, vol. 40, no. 3, pp. 592–595, Mar. 1992.