Letters

Comments on "A New Edge Element Analysis of Dispersive Waveguiding Structures"

F. A. Fernandez and Y. Lu

In a recent paper[1] the authors state that the methods described in [1] and [2] (their references [12] and [13]), "cannot be directly applied to transmission lines with finite thickness and finite conductivity because of the appearance of spurious modes." This is completely erroneous. No spurious modes appear when using the transverse field formulation [2] implemented with node-based or edge FE when applied to transmission lines with finite thickness and finite conductivity or indeed to any other waveguide (bounded or open-bounded).

The assertion in the above paper as a universal statement that "... node-based FEM cannot be employed in the field domain in which material property changes abruptly," is also untrue. A transverse magnetic field formulation like that in [2] (or in more details in [3]) is perfectly adequate to solve all the examples described in the above paper where only the permitivity varies abruptly and all magnetic field components remain continuous. Furthermore, as only two components per node are required for the method in [2], this procedure would be more economic than that of the authors of the above paper which needs all three field components. Admittedly, field discontinuities can pose difficulties to node-based elements and problems including discontinuities of *both* electric and magnetic field are better treated with edge elements.

References

[1] W. C. Chew and M. A. Nasir, "A variational analysis of anisotropic, inhomogeneous dielectric waveguides," *IEEE Trans. Microwave Theory Tech.,* vol. 37, no. 4, pp. 661–668, Apr. 1989.

[2] Y. Lu and F. A Fernandez, "Finite element analysis of lossy dielectric waveguides," *IEEE Trans. Magn.,* vol. 41, no. 2, pp. 1609–1612, Mar. 1993.

[3] Y. Lu and F. A. Fernandez, "An efficient finite element solution of inhomogeneous anisotropic and lossy dielectric waveguides," *IEEE Trans. Microwave Theory Tech.*, vol. 41, no. 6/7, June/July 1993, pp. 1215–1223.

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[1] J. Tan and G. Pan, *IEEE Trans. Microwave Theory Tech.,* vol. 43, no. 11, pp. 2600–2607, Nov. 1995.

Authors' Reply

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In response to the above comments, we wish to stress the following points:

1) Spurious modes in node-based finite element method (FEM) have been recognized and discussed in the literature [1]. In [4], the spurious modes are reported and analyzed in fairly good detail on pp. 204–207 and are attributed to the indefinite property of the system matrix, which is derived from the curl-curl form of the vector Helmholtz equation. In [2] and [3], the origin of spurious modes has also been further discussed. The authors of the comments did not provide any reasons why they can be sure of the positive definiteness of their system equations or why their method can be applied to problems of general conductors with finite thickness and finite conductivity without spurious modes. In their recommended paper [6] and their other publications, only an infinitesimally thick and bad "metal" of $n = 0.14 - j8.49$ was reported at a single optical frequency point.
2) We wrote in our paper: "In fact, the conventional node based FEM cannot be employed in the field domain in which material property changes abruptly [14]" ([7] of this reply). This part was quoted from [14] on p. 1580. Although this viewpoint can be further explained, it will make the correspondence too lengthy. As a result, we refer the authors to [14] for direct discussions.
3) The author's approach is clever and successful as we have elucidated in our paper: "As far as the 2-D $-\frac{1}{2}$ dielectric waveguide structure is concerned, node-based FEM has successfully been used [12], [13]" ([5] and [6] of this reply). The authors should cite a complete sentence. By cutting and pasting the context, our evaluation of their work has declined from positive to negative. As a matter of fact, by applying magnetic field formulation to electric materials and electric field formulation to magnetic materials, the authors have avoided handling field discontinuities. Consequently, they have simplified mathematical treatment greatly. Nonetheless, their approach has limitations as to what to do if the material is both electric and magnetic.
4) In the end of the letter, the authors wrote: "Admittedly, field discontinuities can pose difficulties to node-based elements, and problems including discontinuities of both electric and magnetic field are better treated with edge elements." It seems that both of us share the same idea about advantages and disadvantages of node-based and edge-based element methods. The disputes are trivial, if any.

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[7] E. Kriezis *et al.*, "Eddy currents: Theory and applications," *IEEE Trans. Proc. IEEE,* vol. 80, no. 10, pp. 1559–1589, Oct. 1992.