Letters

Comments on "Finite-Element Analysis of Waveguide Modes: A Novel Approach That Eliminates Spurious Modes"

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One of the drawbacks of the finite-element analysis of waveguiding structures is that it often yields nonphysical solutions, which are called spurious modes. In the above paper[1] a novel formulation of the finite element method is presented which allows one to readily identify proper modes. The approach is based on the variational expression of the propagation constant involving transverse electric and magnetic field components. The following generalized eigenvalue problem is obtained from the stationary condition:

$$\underline{\underline{Q}}\,\underline{\Phi} = \frac{1}{\beta}\underline{\underline{P}}\,\underline{\Phi}. \tag{1}$$

The eigenvalues $1/\beta$ of the above problem are the reciprocals of the propagation constants of the modes supported by the structure under investigation. In general, the eigenvalues of problem (1) can be complex numbers. To identify guided modes only real eigenvalues are selected. All eigenvalues equal to zero and those having nonzero imaginary parts are attributed by the authors (see subsection IV-A) to "definitely nonphysical spurious-mode solutions." This conclusion cannot fully be accepted because a nonzero imaginary part of the propagation constant does not necessarily mean that the eigensolution is nonphysical.

1) In addition to guided modes, each guide may support an infinite number of higher order cutoff modes which have purely imaginary propagation constants. At least some of the solutions referred to by the authors as nonphysical could in fact have been cutoff waves.
2) Guides containing anisotropic or inhomogeneous isotropic media may support, even in the lossless case, complex waves [1], i.e., modes with complex propagation constants. Complex waves are physically admissible solutions and their omission in the discontinuity analysis may lead to serious errors [2]. Incidently, for a rectangular guide with one-dimensional inhomogeneity discussed in subsection IV-A of the paper, no complex waves are allowed. Thus for this case the solutions with complex eigenvalues might have actually been spurious, but one has to bear in mind that eigenvalues with a small real part compared with the imaginary part (type 3 in Table I in the paper in question) could also be due to round-off errors, especially in ill-conditioned problems. Problem (1) is ill-conditioned as matrix $\underline{\underline{Q}}$ is singular.

Concluding, the formulation proposed in the paper seems to enable one to identify guided modes with real propagation constants but care has to be taken when attributing the eigenvalues having a nonzero imaginary part to spurious modes.

Manuscript received August 22, 1990.
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IEEE Log Number 9041940.
[1]T. Angkaew, M. Matsuhara, and N. Kumagai, *IEEE Trans. Microwave Theory Tech.*, vol. MTT-35, pp. 117–123, Feb. 1987.

Reply[2] by Tuptim Angkaew, Masanori Matsuhara, and Nobuaki Kumagai[3]

Using the variational method, we derived equation (15) in our paper on the assumptions that the permittivity and permeability tensors are Hermite tensors and that the propagation constant β is real. Therefore, any solution to (15) with a nonreal propagation constant does not conform to these assumptions, and we select only solutions with real propagation constants.

However using the Galerkin method or weak formulation, (15) may be derived without the assumptions made in our paper. In this case, certain solutions with nonreal propagation constants correspond to the evanescent modes and the modes with loss or gain. These are reported in [3].

References

[1] P. J. B. Clarricoats and K. R. Slinn, "Complex modes of propagation in dielectric-loaded circular waveguide," *Electron. Lett.*, vol. 1, pp. 145–146, July 1965.
[2] A. S. Omar and K. F. Schünemann, "Effect of complex modes at finline discontinuities," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-34, pp. 1508–1514, Dec. 1986.
[3] M. Matsuhara and T. Angkaew, "Analysis of the waveguide with loss or gain by the finite-element method," *Trans. IEICE*, vol. J71-C, pp. 1398–1403, Oct. 1988 (in Japanese).

[2]Manuscript received October 1, 1990.
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Comments on "An Exact Solution for the Nonuniform Transmission Line Problem"

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As the author of the above paper[1] points out in his introduction, this problem has been solved within certain approximations. A limitation of these methods is the fact that some parameters of the line do not vary independently. It is exactly this kind of interdependence between the impedance and admittance that limits the form of lines to which the present solution

Manuscript received August 7, 1990.
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IEEE Log Number 9041942.
[1]C. Nwoke, *IEEE Trans. Microwave Theory Tech.*, vol. 38, pp. 944–946, July 1990.