Letters

Comments on "Analysis of Nonreciprocal Coupled Image Lines"

JERZY MAZUR AND MICHAŁ MROZOWSKI

In the above paper[1] an analysis based on the effective dielectric constant approach is used to investigate the coupled dielectric image lines separated by a ferrite slab magnetized in the propagation direction. According to this analysis the structure exhibits nonreciprocal dispersion properties. However, gyromagnetic waveguiding structures magnetized in the propagation direction should be reciprocal in accordance with the generalized reciprocity theorem [1], [2]. The only nonreciprocal effect allowed in this type of guide is the Faraday rotation. The results given by Sillars and Davis violate the reciprocity theorem because the analysis is based on an erroneous interpretation of the solution of the wave equation in the ferrite medium. The characteristic equation (4) is a fourth-order polynomial in k_z. Its four roots $(k_z^{(1)}, k_z^{(2)}, k_z^{(3)}, k_z^{(4)})$ define four particular solutions, corresponding to four partial waves propagating in the structure. Since the characteristic equation is biquadratic, $k_z^{(1)} = -k_z^{(3)}$ and $k_z^{(2)} = -k_z^{(4)}$, which means that there are two pairs of partial waves in this structure. One pair, with propagation constants $k_z^{(1)}$ and $k_z^{(2)}$, travels in the positive z direction and the other two waves, with propagation constants $k_z^{(3)}$ and $k_z^{(4)}$, travel in the opposite direction. Since absolute values of the propagation constants are identical for both directions, it is not possible to satisfy conditions (12) and (13) and obtain nonreciprocal coupling.

Equation (8) of the paper in question defines the propagation constants $k_z^{(1)}$ and $k_z^{(2)}$ for two partial waves traveling in the same direction, and does not, as the authors stated, "simply express the nonreciprocal propagation constant."

Owing to this error the results cannot be accepted. However, since the nonreciprocal behavior of devices using coupled guides with a longitudinally magnetized ferrite was observed experimentally, an explanation of this effect has to be given. It has recently been shown by the authors of these comments [3] that this nonreciprocity is caused by the coupling between even and odd modes existing in the structure. As the wave propagates, its energy is periodically transferred from one mode to another. This mode coupling results in an effect analogous to the Faraday rotation. A careful choice of excitation and of the electrical length of the lines allows one to obtain isolators and circulators. The mathematical model of propagation in coupled lines containing a longitudinally magnetized ferrite proposed in [3] does not violate the reciprocity theorem and enables one to explain the operating principle of experimental devices.

Manuscript received February 1, 1988.
The authors are with the Telecommunication Institute, Technical University of Gdańsk, Majakowski 11/12 Street, 80-952 Gdańsk, Poland.
IEEE Log Number 8824264

[1]D. B. Sillars and L. E. Davis, *IEEE Trans. Microwave Theory Tech.*, vol. MTT-35, pp. 629–635, July 1987

Reply[2] by D. B. Sillars and L. E. Davis[3]

We welcome the interest shown by the authors in our work on nonreciprocal effects in longitudinally magnetized ferrite components and the need for a satisfactory explanation. As indicated in the Comments in [2], we have excited the odd and even modes separately in coupled-slot finline and, over the range of conditions which we explored, we found that, unlike the even mode, the odd mode (as defined in the Comments) showed negligible nonreciprocal behavior.

Under these circumstances it was necessary to attribute nonreciprocal behavior to a pair of partial waves (our eq. (8)) although the comments about the biquadratic equation (our eq. (4)) are accepted completely in principle. The aims of our paper were to produce an approximate theory that would reproduce the experimentally observed performance and to stimulate further work on this novel and potentially useful type of coupled structure. Again, we would like to thank the authors for their constructive criticism.

References

[1] R. F. Harrington and A. T. Villeneuve, "Reciprocity relationship for gyrotropic media," *IRE Trans. Microwave Theory Tech.*, vol. MTT-6, pp. 308–310, 1958.

[2] E. Jensen, C. Schieblich, D B Sillars, and L. E. Davis, "Comments on 'Millimetric nonreciprocal coupled-slot finline components'," *IEEE Trans. Microwave Theory Tech*, vol MTT-35, pp 470–471, Apr. 1987.

[3] J. Mazur and M. Mrozowski, "On the mode coupling in longitudinally magnetized waveguiding structures," pp. 159–165, this issue.

[2]Manuscript received April 20, 1988.
[3]D. B. Sillars is with M/ACOM Ltd., Dunstable LU5 4SX, U.K. L. E. Davis is with the Department of Electrical Engineering and Electronics, University of Manchester Institute of Science and Technology, Manchester M60 1QD, U.K.
IEEE Log Number 8824265.

0018-9480/89/0100-0262$01.00 ©1989 IEEE