Comments on "Ridged Waveguides with Inhomogeneous Dielectric-Slab Loading"

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In the above paper[1], Magerl derives dispersion equations for TE_{m0} modes of ridged waveguide with inhomogeneous dielectric-slab loading. The existence of TE modes was evidently assumed *a priori* (a seemingly natural assumption); unfortunately, true TE modes do not exist in this waveguide (with a singular exception to be noted).

Using the notation from the paper, the assumption of a TE mode, i.e., $E_z = 0$, by application of Maxwell's equations leads to

$$E_{x1} = \omega\mu_1 H_{y1}/k_z$$
$$E_{x2} = \omega\mu_2 H_{y2}/k_z$$

as shown in (1) and (2). Analysis proceeded from these starting equations. However, consideration of elementary boundary conditions at the dielectric-dielectric interface ($x=0$) immediately shows these equations are incorrect. Tangential $\vec{H}$ must be continuous, therefore $H_{y1} = H_{y2}$ at $x=0$. Normal $\vec{D}$ must be continuous, therefore $\epsilon_1 E_{x1} = \epsilon_2 E_{x2}$ at $x=0$. Since ω and k_z are constants, the only instance in which the boundary conditions are consistent with the two starting equations occurs when $\epsilon_2/\epsilon_1 = \mu_1/\mu_2$. Most dielectrics have a relative permeability $\mu_r \approx 1$; therefore, the original assumption of a TE mode is not valid. One can simply show that the above rationale holds for TM modes as well as TE modes.

Certainly TE modes exist in homogeneous ridged waveguide, and in dielectric-slab-load rectangular waveguide, the TE_{m0} mode is the LSE_{m0} mode [1]. However, in the latter case $E_x = 0$; addition of a ridge forces E_x to be nonzero which then prohibits a true TE mode. One intuitively suspects that "quasi-" TE modes exist; whether or not the analysis of the subject paper is a valid approximation to the actual modes remains to be shown.

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[1] G. Magerl, "Ridged waveguides with inhomogeneous dielectric-slab loading," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-26, pp. 413–416, June 1978.

References

[1] F. Gardiol, "Higher order modes in dielectrically loaded rectangular waveguide," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-16, pp. 919–924, Nov. 1968.

Reply[2] by Gottfried Magerl[3]

We thank Dr. Young for pointing out the error in our paper. However, we want to show that our assumption of $E_z = 0$ does lead to correct results not only for the dielectric-slab-loaded waveguide (where $E_x = 0$ applies) and for the homogeneously filled ridged guide ($\epsilon_1 = \epsilon_2, \mu_1 = \mu_2$), but also for an important special case underlying our numerical results. Rearranging (1) and (2) by expressing tangential H_y in terms of normal D_x

$$H_{yi} = \frac{k_z}{\omega\epsilon_i\mu_i} D_{xi} \quad (i = 1, 2)$$

and considering continuity of both H_y and D_x at the dielectric-dielectric interface, we get, in accordance with Young,

$$k_z/\omega\epsilon_1\mu_1 = k_z/\omega\epsilon_2\mu_2.$$

This equation will be identically fulfilled for $k_z = 0$, independent of the values of ϵ_i and μ_i. At cutoff, therefore, $E_z = 0$ leads to correct results.

This fact can additonally be explained by the transverse-resonance model. At cutoff the field pattern of the ridged-guide mode can be described as a wave propagating in x direction along a stepped parallel plate line consisting of the top and bottom walls of the ridged guide and reflected back and forth between the side walls. From the well-known field distribution of a wave guided by a parallel plate line we see that $E_z = 0$ is the only physically meaningful solution at cutoff.

Concluding, we concur with Young that our analysis based on pure TE modes remains to be shown to be a valid approximation to the actual modes for general cases, e.g., for the calculation of the dispersion. However, our numerical results concerning the cutoff frequencies and the higher order mode separation (Figs. 2 and 3 of our paper) are correct.

[2]Manuscript received August 10, 1978.
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