Letters

Comments on "Input Impedance of Coaxial Line to Circular Waveguide Feed"

PROBIR K. BONDYOPADHYAY

The author read with interest the above paper[1] in conjunction with the correction to it [1]. While attempting to apply Harrington's well-known development for a coax/rectangular waveguide transition to the coax/circular waveguide transition case, the authors[1] arrived at results and conclusions which are highly erroneous and misleading. As explained below, (4b) and the expression for X_1 in (6), the reactance part of the input impedance, are both incorrect. Even if the expression for X_1 in (6) is corrected, the reactance series is *clearly divergent*.

First, in (4b) the authors have excluded the higher order circular waveguide TE modes with $\cos(n\varphi)$ variations in radial electric field components. These higher order TE modes are *definitely excited* by the source current J_s in (3a) and contribute to the reactance X_1. Equation (6) does not contain the contributions of these higher order TE modes and is, therefore, erroneous. Having missed the higher order TE mode contributions, the authors wrongly conclude that the reactance X_1 is always capacitive in nature. Otherwise, also, (4b) is erroneous. On the right side of (4b), the term "$2\epsilon_n$" under the square root must be replaced by "ϵ_n," and it should read correctly as [3]:

$$e^e_{np}=\sqrt{\frac{\epsilon_n}{\pi\left(x'^2_{np}-n^2\right)}}\;\frac{1}{J_n(x'_{np})}\left[\pm \boldsymbol{u}_\rho \frac{n}{\rho} J_n(x'_{np}(\rho/a))\begin{Bmatrix}\sin n\varphi\\ \cos n\varphi\end{Bmatrix} + \boldsymbol{u}_\varphi \frac{x'_{np}}{a} J'_n(x'_{np}(\rho/a))\begin{Bmatrix}\cos n\varphi\\ \sin n\varphi\end{Bmatrix}\right].$$

The authors in conclusion state, "Assumption of a curvilinear strip leads to a rapidly convergent series for jX_1." This assertion has no basis whatsoever and is misleading. The expression for X_1 is a doubly infinite series in circumferential index n and radial index p. If attention is focused on the higher order TM mode contribution to X_1, as in (6) of the paper, it is clearly seen that for a fixed "n," if "p" is increased such that x_{np} increases, then using Hankel asymptotic approximation for Bessel functions:

$$J_n(x_{np}) \underset{\substack{x_{np}\to\infty\\ n,\ \text{fixed}}}{\simeq} \sqrt{\frac{2}{\pi x_{np}}}\;\cos\left(x_{np}-\frac{\pi}{4}-\frac{n\pi}{2}\right)$$

the "np"th term in the series increases as x_{np}, and the series *diverges absolutely*. The authors' claim, "It is found that the evanescent modes with $p=1$ and $n=0,1,2,3,\cdots,12$ make a significant contribution to the reactive part of the input impedance. The contribution of the evanescent modes with higher values of "p" is found to be quite small," is, therefore, without foundation.

At this point one wonders how the authors, using an erroneous and divergent series for X_1, could calculate the imaginary part of the input impedance and get it "in close agreement between the theoretical and experimental results." It is, however, not totally surprising if one realizes that the authors have, apparently, incorporated the Finagle's constant [4] for "improving" the theory to fit the recorded experimental data.

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[1]M. D. Deshpande and B. N. Das, *IEEE Trans. Microwave Theory Tech.*, vol. MTT-25, pp. 954–957, Nov. 1977.

Reply[2] *by B. N. Das and M. D. Deshpande*[3]

The authors are fully aware of the complete expression for the modal vector function of the field distribution in a circular cylindrical waveguide. The field distribution is given by either sinusoidal or cosinusoidal distribution or a combination of both depending upon the relative orientation between the reference direction and the direction of polarization of the field generated. The effects of both TE and TM higher order modes were under consideration while carrying on the analysis. It is purely a question of examining whether TE or TM or a combination of both are generated by the radial probe used for excitation. A careful scrutiny of the mode patterns presented on page 207 of [2] makes the position clear. It is found that, for the reference frame considered in Fig. 1(b) of the paper,[1] a sinusoidal distribution function for the radial component and a cosinusoidal distribution for the circumferential component of higher order TE modal function fit exactly with the mode patterns given in [2]. It may be pointed out here that TE_{op} modes are never excited by the mechanism of excitation considered.[1] The above form of higher order TE modal function also leads to this conclusion.

In explaining how the infinite series for X_1 diverges for a fixed n, the asymptotic approximation for Bessel function $J_n(x_{np})$ used by P. K. Bondyopadhyay is wrong. The correct form of $J_n(x_{np})$ for any value of x_{np} is

$$J_n(x_{np})=0.$$

The authors are, therefore, surprised to see how P. K. Bondyopadhyay using a wrong expression for $J_n(x_{np})$ *could prove* that series for X_1 *diverges absolutely*.

The series for X_1 is convergent, as explained below, for large values of n and p. Using an asymptotic form for Bessel function $J_n(x_{np}x)$ and $J_n(x_{np})$ and evaluating the integral

$$\int_{1-l/a}^{1} \sin ka(l/a-1+x)J_n(x_{np}x)x\,dx$$

using the asymptotic form, the expression (6) of the paper[1] for X_1 is obtained as

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$$X_1 = -\sum_{n=0}^{\infty}\sum_{p=1}^{\infty} \frac{60\epsilon_n}{\cos^2\left(x_{np}-\frac{\pi}{4}-(n+1)\frac{\pi}{2}\right)} \frac{\sqrt{(x_{np}/ka)^2-1}}{\sin^2(kl)}$$
$$\cdot\left[\frac{\sin\frac{nd'}{2a}}{nd'/2a}\right]^2 4\frac{(ka)^2}{\left[(ka)^2-x_{np}^2\right]^2}\left[\sin(kl)\sin\left(x_{np}-\frac{\pi}{4}-\frac{n\pi}{2}\right)\right.$$
$$\left.-\sqrt{1-l/a}\,\cos\left(x_{np}(1-l/a)-\frac{\pi}{4}-\frac{n\pi}{2}\right)\right]^2.$$

It is clear from the above expression that the series for X_1 is convergent.

The authors, therefore, do not understand how the correspondent arrived at wrong conclusions regarding the convergence of the series. Thus the analysis reveals that only few modes have significant contribution to the reactance. Even if effects of TE modes other than TE_{op} are considered, their contribution to the reactive part of input impedance will not be significant for reasons stated above. The same formulation can easily accommodate the effects of these TE modes, provided one is convinced of their generation by the mechanism of excitation.

The whole paper is a result of careful analysis of the problem. Regarding the last paragraph of the comments, the authors would like to state that the correspondent should have gone through the entire work thoroughly and point out clearly the stage at which manipulations as pointed out by him have been made.

Thus the authors believe that the results obtained in the paper[1] need no modification.

References

[1] M. D. Deshpande and B. N. Das, "Corrections to 'Input impedance of coaxial line to circular waveguide feed,'" *IEEE Trans. Microwave Theory Tech.*, vol. MTT-25, p. 315, Nov. 1977.
[2] R. F. Harrington, *Time Harmonic Electromagnetic Field.* New York: McGraw-Hill, 1961, ch. 8, pp. 207, 425–428.
[3] N. Marcuvitz, *Waveguide Handbook.* New York: McGraw-Hill, 1951, p. 69.
[4] "Murphy's rules for effective research and engineering," Rule 6, *IEEE Student Newsletter*, vol. 6, no. 2, p. 5, Dec. 1977.

Note on a Correction to Aperture Admittance in Waveguide Handbook

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An apparent error in the *Waveguide Handbook* [1] for the aperture admittance of a parallel plate waveguide terminated in a flange plane has been discovered. In particular, the normalized aperture susceptance we calculated[1] to be

$$B/Y_0 = -\int_0^{kb} N_0(x)\,dx + N_1(kb) + \frac{2}{\pi}\frac{1}{kb}. \tag{1}$$

This differs from the formula in the handbook (page 184, (2a)) by a minus sign in the integral term. Only if this correction is made will susceptance curve (Fig. 4.7-2 of [1]) be that of (1).

References

[1] N. Marcuvitz, Ed., *Waveguide Handbook.* New York: Dover, 1965, pp. 183–184.

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[1]The calculation is based upon an assumed constant tangential electric field.

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