Correspondence

Comments on "A New Model for Calculating the Input Impedance of Coax-Fed Circular Microstrip Antennas with and without Air Gaps"

Debatosh Guha

***Index Terms*—Microstrip antennas.**

In the above paper,[1] the resonance frequency of coax-fed circular microstrip antennas with and without air gaps has been modeled (in its Section III) by incorporating and rearranging some results previously reported by others. The present author, while working with the formulas of Section III noticed a discrepancy in (8) and (9)[1]. This has been investigated thoroughly and the observations are furnished below.

In (8), the static fringing capacitance, $C_{e,\mathrm{stat}}$ of the circular disk capacitor has been equated to that derived in (33) of [1] (Ref. 12 in the paper above[1]), which rather represents the total capacitance of a circular microstrip disk. It is clearly stated in [1, sec. V] that, "We have obtained an approximate formula for the capacitance of a circular microstrip disk in (33)...." Moreover, following (33), it is noted that, "We note that the first term is equal to the capacitance by ignoring the fringing fields." Hence, it is clear that the effect due to the fringing fields is accounted by the second term only and, as a result, the static fringing capacitance should be equated to the second term [1, eq. (33)] to yield the correct form of (8) in the paper above[1] as

$$C_{e,\mathrm{stat}} = (\varepsilon_0 \cdot \varepsilon_{\mathrm{re}} \cdot \pi \cdot a^2/H_T)\{(2 \cdot H_T/(\pi \cdot \varepsilon_{\mathrm{re}} \cdot a)) \times [\ln(a/(2 \cdot H_T)) + (1.41\varepsilon_{\mathrm{re}} + 1.77) + (H_T/a)(0.268\varepsilon_{\mathrm{re}} + 1.65)]\}.$$

The expression for the effective radius of circular microstrip patch in (9) can be obtained from the expression for the total static capacitance of the patch as in [1, eq. (33)]. But the statement in the last paragraph of Section III[1] in connection with the derivation of (9) misleads the reader. This can, however, be justified if the above equation replaces (8).

The theoretical calculations for the antenna parameters given in Table I[1] has been repeated after incorporating the above correction in (8) and are presented in Table I here. It is interesting to note that the theoretically computed value in the paper above[1] shows the closest agreement with the measured value, whereas the results after incorporating the above correction differs by approximately 5%. Still the model with the suggested correction can be applied for computing approximate theoretical data. However, for more accurate results some other modifications can be sought for since the model itself is based on different earlier works based on different techniques.

Manuscript received July 21, 1998.

The author is with the Institute of Radio Physics and Electronics, University of Calcutta, Calcutta 700 009, India (email: dguha@cucc.ernet.in).

Publisher Item Identifier S 0018-926X(00)04360-X.

[1]F. Abboud, J. P. Damiano, and A. Papiernik, *IEEE Trans. Antennas Propagat.*, vol. 38, pp. 1882–1885, Nov. 1990.

TABLE I
MEASURED AND THEORETICAL VALUES OF RESONANT FREQUENCIES OF CIRCULAR MICROSTRIP ANTENNAS

a mm	Measured [Table I[1]] GHz	Theoretical from [Table I[1]] GHz	Theoretical after correcting (8)[1] GHz
11.5	4.425	4.413	4.609
10.7	4.723	4.723	4.938
9.6	5.224	5.226	5.473
8.2	6.074	6.047	6.346
7.4	6.634	6.644	6.981

REFERENCES

[1] W. C. Chew and J. A. Kong, "Effects of fringing field on the capacitance of circular microstrip disk," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-28, pp. 98–104, Feb. 1980.

Authors' Reply

J. P. Damiano, J. M. Ribero, R. Staraj, and A. Papiemik

In the paper given in reference [1], we proposed a model based on the well-known cavity model, which has been modified via the introduction of the concept of dynamic permittivity in order to take into account the fringing field effects.

The critical comment contains a misinterpretation due to a lack of clarity of our explanation of (8).

The dynamic permittivity ε_{dyn} depends on the dynamic capacitance

$$\varepsilon_{dyn} = \frac{C_{dyn}(\varepsilon_r)}{C_{dyn}(\varepsilon_0)}, \quad C_{dyn} = C_{0dyn} + C_{edyn}.$$

C_{0dyn} is the main capacitance related to the static main capacitance C_{0stat}.

C_{edyn} is a dynamic fringing capacitance calculated by the static fringing capacitance C_{estat}

$$C_{estat} = \frac{\varepsilon_0 \varepsilon_{\mathrm{re}} \pi_a^2}{H_T} \cdot \left\{1 + \frac{2H_T}{\varepsilon_{\mathrm{re}} \pi_a} \left[In\left(\frac{a}{2H_T}\right) + (1.41\varepsilon_{\mathrm{re}} + 1.77) + \frac{H_T}{a}(0.268\varepsilon_{\mathrm{re}} + 1.65)\right]\right\}.$$

Manuscript received February 3, 2000.

The authors are with Laboratoire d'Electronique, Antennes et Télécommunications, UNSA-CNRS, F-06560 Valbonne, France.

Publisher Item Identifier S 0018-926X(00)04386-6.

C_{estat} is the sum of two terms, i.e., the main static classic capacitance and the term due to the fringing field effects.

Our (8) [2] is exact.

ACKNOWLEDGMENT

The authors would like to thank D. Guha for his interest for our paper.

REFERENCES

[1] F. Abboud, J. P. Damiano, and A. Papiernik, "A new model for calculating the input impedance of coax-fed circular microstrip antennas with and without air gaps," *IEEE Trans. Antennas Propagat.*, vol. 38, pp. 1882–1885, Nov. 1990.

[2] W. C. Chew and J. A. Kong, *IEEE Trans. Microwave Theory Tech.*, vol. MTT-28, pp. 98–104, Feb. 1980.

On the Link Between Top-Hat Monopole Antennas, Disk-Resonator Diode Mounts, and Coaxial-to-Waveguide Transitions

Marek E. Bialkowski

***Index Terms*—Coaxial waveguides, disk resonators, monopole antennas.**

I. INTRODUCTION

In [1] and [2] the authors present the analysis of a top-hat monopole antenna loaded with dielectric layers radiating above a conducting ground plane. In order to obtain a simplified solution to this rather complicated electromagnetic field problem, they introduce an upper ground plane that converts the original problem to the one of a monopole radiating in a parallel-plate radial guide, which is easier computationally to handle. Provided that the upper ground plane is located a sufficient distance from the lower ground plane, the currents on the monopole and consequently the input impedance are approximately the same as for the original problem (with no upper conducting plane). The authors apply a field-matching method, in terms of radial harmonics in conjunction with a method of moments, to obtain field expansion coefficients in radial regions of the parallel-plate guide structure. Subsequently, they obtain computer algorithms for calculating the input impedance of a top-hat monopole antenna in a parallel-plate waveguide.

It is interesting to mention that the problem of a top-hat monopole, as considered in [1] and [2] is very similar to the problem of a disk-resonator diode mount as well as to the problem of a coaxial-to-waveguide transition with a disk-ended probe [3]–[10]. Due to their different contexts, many antenna researchers overlooked the similarity of these problems. Hence, the purpose of this communication is to highlight this oversight.

A coaxial-to-waveguide transition with a disk-ended probe [8], [10] is a type of a top-hat monopole antenna in a parallel-plate or rectangular waveguide that is used to efficiently transfer power from a coaxial line to a parallel-plate radial or rectangular waveguide. A disk-resonator diode mount [3], [4] is also a type of top-hat monopole antenna structure used to assemble Gunn or Impatt diode oscillators or amplifiers.

It has to be noted that in order to solve the problems of disk-resonator diode mounts and coaxial-to-waveguide transitions a field matching technique in conjunction with a method of moments has been applied [3]–[10]. The methods of analysis used in [1] and [2] are very similar to the ones demonstrated in [3]–[10].

In comparison with [1] and [2], the analyses presented in [3]–[10] offer some extra features. For example, in contrast to [1] and [2], where only the excitation from a gap at the base of a monopole is considered, the analyses of [3]–[10] cover two types of excitations—one from a coaxial entry and the other in a cylindrical gap arbitrarily located along the monopole. Also, the analyses in [3]–[10] cover the cases of a rectangular waveguide and a radial cavity in addition to a parallel-plate radial guide considered in [1] and [2]. This extension is achieved by introducing equivalent impedances, which radial waves experience at the coaxial cylindrical surface enclosing the monopole antenna [3]. These impedances are calculated by assuming that the field close to the antenna is axially symmetric. This assumption produces reasonably accurate results even in considerably asymmetric waveguide environments provided that the antenna has a small diameter in comparison with a free-space wavelength [9].

Based on the presented theories in [3]–[10], a number of computer algorithms have been developed for analysing a variety of coaxial-to-waveguide transitions and disk-resonator diode mounts. Examples of the analyzed structures are shown in Figs. 1 and 2. Fig. 1(a) shows a coaxial line driven disk-ended probe in a parallel-plate radial guide. Fig. 1(b) shows the same disk-ended probe, but fed from a gap in a post. Fig. 1(c) shows a disk-resonator diode mount, which is obtained by adding a conducting post between the disk and an upper plate of the radial guide in a gap-fed disk-ended probe of Fig. 1(b). Fig. 2 shows a coaxial line driven disk-ended probe of Fig. 1(a) but this time located in a rectangular waveguide.

Among the developed variety [3]–[10] of FORTRAN algorithms, two in particular, named CPROBE.FOR and PROBE.FOR determine the input impedance of a disk-ended probe (a top-hat monopole antenna) in three types of waveguides. Type (i) concerns a parallel-plate radial guide; type (ii) is a rectangular waveguide with one arm short circuited and the other arm match terminated; and type (iii) is a rectangular waveguide with two arms match terminated. Note that the side walls of the considered rectangular waveguides can be formed by electric or magnetic conductors. CPROBE.FOR assumes the field excitation from a coaxial entry while PROBE.FOR assumes the excitation from a gap in a post/probe. The region above the disk can be empty, filled with a dielectric material or can include a conducting post connecting the disk/top-hat to the upper guide's wall. Similarly, as in [2], while applying a field-matching method, the structure is divided into three cylindrical regions: regions I—below the disk; region II—above the disk; and region III outside the cylindrical volume containing the disk. The three regions, illustrated in Fig. 1(a)–(c) can be filled with different homogenous dielectric materials.

The principal task is to determine the input admittance (or impedance) of the probe looking from the coaxial entry or from the gap in the post. The required input admittance is given by the power-voltage relationship

$$Y_{in} = \frac{1}{V^2} \int_{S_a} (\tilde{E}_o \times \tilde{H}_o) \cdot \hat{n} \; dS \tag{1}$$

where S_a is a coaxial entry surface (for a coaxially driven probe) or a surface surrounding the gap aperture (for a gap driven probe), H_o is

Manuscript received June 15, 1999; revised February 9, 2000.

The author is with the Department of Computer Science and Electrical Engineering, The University of Queensland, Brisbane, Qld. 4072, Australia.

Publisher Item Identifier S 0018-926X(00)04365-9.

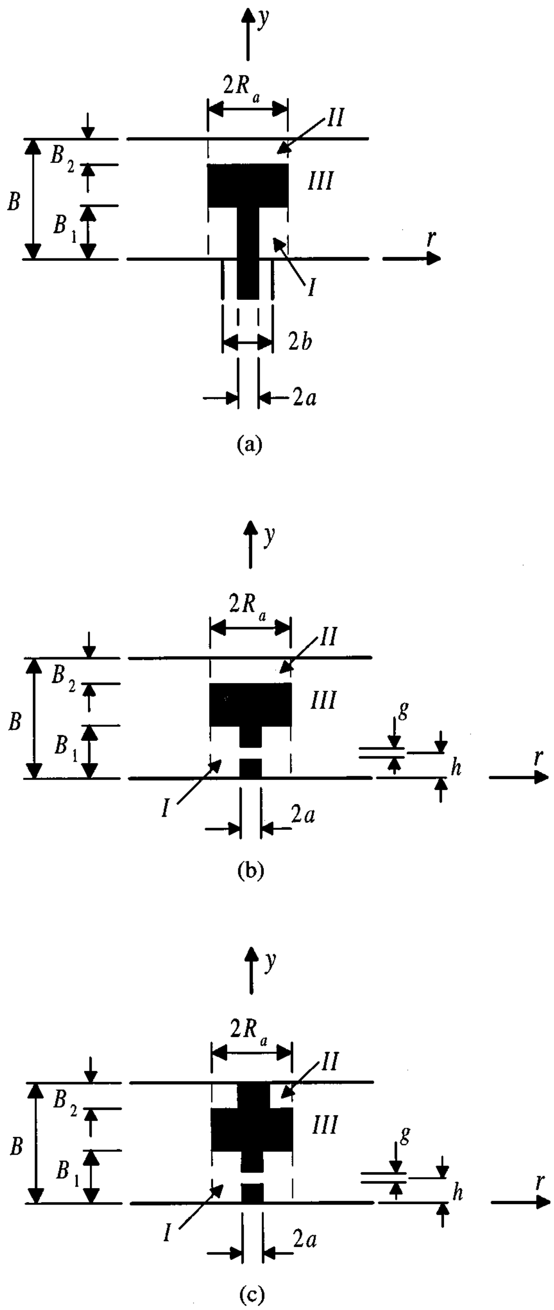

Fig. 1. Configuration of (a) a coaxial-line-fed disk-ended probe in a parallel plate radial waveguide; (b) a gap-fed disk-ended probe in a parallel-plate radial guide; and (c) a disk-resonator diode mount in a parallel-plate radial guide (note that this structure includes a conducting post connecting the disk and the upper guide's plate).

the magnetic field in the aperture and $\hat{n}$ is a unit vector normal to the aperture surface.

The accuracy of the calculated admittance is expected to be greater than that of the field expressions used to obtain it as this definition is based on variational principles.

For a gap driven probe E_o is assumed by (2)

$$\tilde{E}_o = E_y \hat{y} = \frac{-V}{g} \hat{y} \tag{2}$$

where $V e^{j\omega t}$ is the voltage applied between the ends of the gap and g is the dimension of the gap. This field is oriented in the y direction. This assumption ignores the field variation at the edges, but provides good

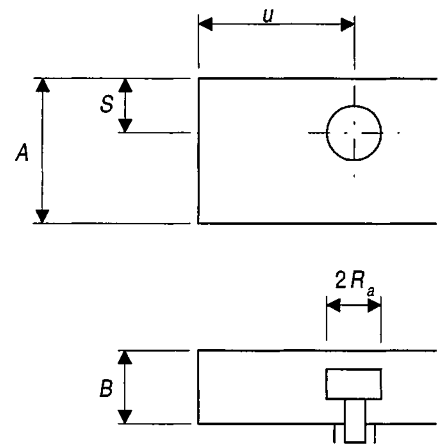

Fig. 2. Configuration of a disk-ended probe in a rectangular waveguide.

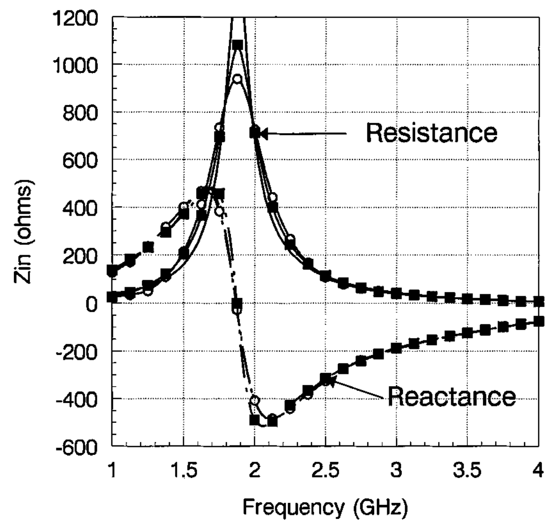

Fig. 3. Input impedance as a function of frequency for a coaxial-line-driven top-hat monopole antenna in a parallel-plate radial guide of height $B^{(1)} = 80$ mm ____, $B^{(2)} = 120$ mm ____■____, $B^{(3)} = 160$ mm ____ ∘ ____. The monopole's dimensions are as in [2].

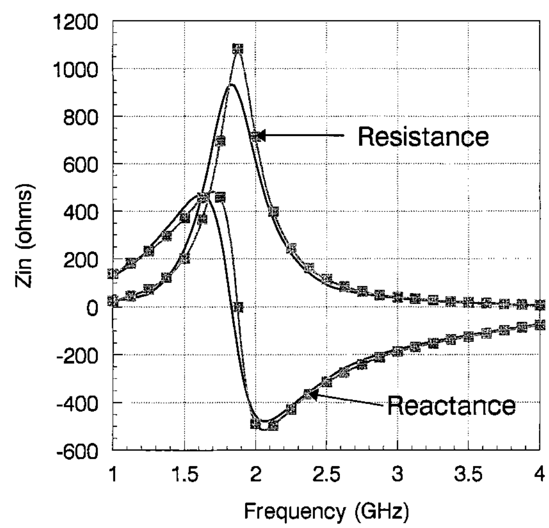

Fig. 4. Input impedance as a function of frequency of a top-hat monopole antenna in a parallel-plate radial guide of height $B^{(2)} = 120$ mm. Other dimensions are the same as for Fig. 3. Results obtained using CPROBE.FOR for a coaxial entry with $a = 1.19$ mm and $b = 3.5$ mm ____■____. Results obtained using PROBE.FOR for the excitation gap of height $g = 1$ mm ($h = 0.5$ mm) ____.

results for the input impedance as long as the gap height is sufficiently small.

The electric field at the coaxial aperture is assumed by

$$\tilde{E}_o = E_r \hat{r} = \frac{-V}{r \ln(b/a)} \hat{r} \tag{3}$$

where a and b are the inner and outer radii respectively of the coaxial line, and V is the voltage between the conductors. The field E_r is oriented in the radial (r) direction.

It was shown by Otto [11] and Williamson [12] in their analysis of straight probes in parallel-plate radial waveguide that (3) represents a good approximation in general, becoming poorer at higher frequencies when the coaxial aperture becomes a significant part of a wavelength.

Figs. 3 and 4 demonstrate the use of CPROBE.FOR and PROBE.FOR to determine the input impedance of a top-hat monopole antenna/disk-ended probe in a parallel-plate radial guide, which was considered in [2].

While using CPROBE.FOR, the following dimensions were assumed in calculations: monopole's radius $a = 1.19$ mm, disk/hat's radius $R_a = 38.7$ mm, the thickness of the disk $t = B - B_1 - B_2 = 0.8$ mm, height of region I between the bottom ground plane and the disk/hat $B_1 = 31.75$ mm. The dimensions of a coaxial line exciting the monopole: an inner radius $a = 1.19$ mm, an outer radius $b = 3.5$ mm.

The results are shown for three values of height (B) of the parallel-plate guide $B^{(1)} = 80$ mm, $B^{(2)} = 120$ mm and $B^{(3)} = 160$ mm. Note that this is in contrast to [2], where the parallel-plate guide's height is assumed constant in terms of a free-space wavelength.

Fig. 4 shows the comparison between the results for the input impedance of the same top-hat monopole antenna obtained with PROBE.FOR and CPROBE.FOR. Note that in this case, the height of the parallel-plate guide is $B = B^{(2)} = 120$ mm. While using PROBE.FOR the structure is excited from a 1-mm gap ($g = 1$ mm, $h = 0.5$ mm) at the base of the monopole [2]. Good agreement between the two sets of results is observed.

By comparing the results in Figs. 3 and 4 with those in Fig. 6 of [2], good agreement is also found. This agreement indicates that the theories developed in [3]–[10] produce results equivalent to those in [1], [2]. However, one has to note that the algorithms of [3]–[10] offer additional features such as considerations of excitation from a coaxial entry and the placement of the monopole antenna in a variety of parallel-plate waveguides.

REFERENCES

[1] L. A. Francavilla, J. S. McLean, H. D. Foltz, and G. E. Crook, "Mode-matching analysis of top-hat monopole antennas loaded with radially layered dielectric," *IEEE Trans. Antennas Propagat.*, vol. 47, pp. 179–185, Jan. 1999.

[2] M. A. Michael and F. K. Schwering, "Eigenmode analysis of dielectric loaded top-hat monopole antennas," *IEEE Trans. Antennas Propagat.*, vol. 42, pp. 54–61, Jan. 1994.

[3] M. E. Bialkowski, "Analysis of disc-type resonator mounts in parallel plate and rectangular waveguides," *AEU Int. J. Electron. Commun.*, vol. 38, no. 5, pp. 306–311, 1984.

[4] ——, "Disk-type resonator mount in rectangular waveguide," in *IEEE MTT-S Int. Symp. Dig.* San Francisco, CA, May 1984, pp. 196–199.

[5] ——, "Electromagnetic model of a radial-resonator waveguide diode mount," *IEEE Trans. Microwave Theory Tech.*, vol. 37, pp. 1603–1611, Oct. 1989.

[6] ——, "Analysis of a coaxial-to-waveguide adaptor incorporating a dielectric coated probe," *IEEE Microwave Guided Wave Lett.*, vol. 1, pp. 211–214, Aug. 1991.

[7] M. E. Bialkowski and V. P. Waris, "Electromagnetic model of a planar radial-waveguide divider/combiner incorporating probes," *IEEE Trans. Microwave Theory Tech.*, vol. 41, pp. 1126–1134, June/July 1993.

[8] M. E. Bialkowski, "Analysis of a coaxial-to-waveguide adaptor including a disc-ended probe and a tuning post," *IEEE Trans. Microwave Theory Tech.*, vol. 43, pp. 344–349, Feb. 1995.

[9] P. Davis and M. E. Bialkowski, "Performance of field matching and finite element methods on analysing coaxial-to-waveguide transitions," *J. Elect. Electron. Eng.—Special Issue Antennas*, vol. 15, no. 1, pp. 23–29, Mar. 1995.

[10] ——, "Experimental investigations into a linearly polarized radial slot antenna for DBS TV in Australia," *IEEE Trans. Antennas Propagat.*, vol. 45, pp. 1123–1129, July 1997.

[11] D. V. Otto, "The admittance of cylindrdical antennas driven from a coaxial line," *Radio Sci.*, vol. 2, pp. 1031–1042, 1967.

[12] A. G. Williamson, "Radial-line/coaxial-line junctions," Dept. Elect. Electron. Eng., Univ. Auckland, New Zealand, School Engrg. Rep. 332, Jan. 1984.

Authors' Reply

Felix K. Schwering and Michael A. Morgan

***Index Terms*—Antennas, cylindrical wave function modal analysis method, fictitious PEC ground screen, half-space terminations, radiation, top hat monopole antennas, waveguide feeds, waveguide transitions.**

I. INTRODUCTION

We agree with Bialkowski that the analysis methods used in his recent publications and in our cited paper [1] are somewhat related. But we would like to make the following points.

1) While all of these papers employ a cylindrical wave function modal expansion technique, the problems investigated are different. Bialkowski [8] has treated circuit elements and waveguide transitions of cylindrical symmetry, while our work addresses an antenna radiating into an infinite half-space, specifically that of a monopole extending above a ground plane, terminated in a top hat. We have shown that the modal expansion method can be used to accurately determine not only the input impedance of the antenna, but also its radiation pattern. A major innovation of our work is the introduction of a fictitious parallel ground plane sufficiently removed from the antenna to minimally perturb its currents. This phantom ground screen allows solution for currents and input impedance using multiregion cylindrical harmonics having discrete indices. Once currents and local fields are computed, the radiated fields are found via integration of physical and equivalent currents that bound the structure *in the absence of the fictitious ground screen*. Bialkowski's applications involve feeds and probes coupling to bounded waveguiding structures without need to add a ground screen or compute radiation into unbounded space.

Manuscript received October 20, 1999.

The authors are with the Department of the Army, Research, Development, and Engineering Center, Headquarters U.S. Army Communications-Electronics Command, Fort Monmouth, NJ 07703-5203 USA.

Publisher Item Identifier S 0018-926X(00)04362-3.

2) The modal analysis method has been successfully used also by other authors for the solution of problems of cylindrical symmetry, notably by Shen and MacPhie [2]–[4]. To further complete the bibliography provided by Bialkowski, we would like to add [2]–[6] listed herein. There may be others as well. All of the cited papers demonstrate the usefulness of the method for problems of cylindrical symmetry involving metal surfaces and/or dielectric interfaces that are vertical or horizontal.
3) If the priority in publication is being challenged, we would like to mention that a symposium presentation [6] was given by Schwering in June 1982, which detailed the multiregion solution procedure for the top-hat loaded monopole. This was one year before the first citation listed by Bialkowski involving this method [7].
4) We regret the lack of reference to Bialkowski's work in our two papers, [1] and [5]. Several computerized literature searches had been employed as our work progressed over several years and no citations involving Bialkowski were found. We had used keywords related to antennas, radiation and half-space terminations, rather than waveguide probes, feeds, and transitions. Had we known of Bialkowski's work, we likely would have referenced it.

References

[1] M. A. Morgan and F. K. Schwering, "Eigenmode analysis of dielectric loaded top-hat monopole antennas," *IEEE Trans. Antennas Propagat.*, vol. 42, pp. 179–185, Jan. 1994.

[2] Z. Shen and R. H. MacPhie, "Modeling of a monopole partially buried in a grounded dielectric substrate by the modal expansion method," *IEEE Trans. Antennas Propagat.*, vol. 44, pp. 1535–1536, Nov. 1996.

[3] ——, "Rigorous evaluation for the input impedance of a steel monopole by modal expansion method," *IEEE Trans. Antennas Propagat.*, vol. 44, pp. 1584–1591, Dec. 1996.

[4] ——, "Input admittance of a multilayer insulated monopole antenna," *IEEE Trans. Antennas Propagat.*, vol. 46, pp. 1679–1686, Nov. 1998.

[5] M. A. Morgan, R. C. Hurley, and F. K. Schwering, "Computation of monopole antenna currents using cylindrical harmonics," *IEEE Trans. Antennas Propagat.*, vol. 38, pp. 1130–1133, July 1990.

[6] F. Schwering, N. N. Puri, and A. Stravidis, "The modal expansion solution of a top-loaded monopole," in *Dig. 1982 AP/URSI Symp.* Albuquerque, NM, June 1982, pp. 584–587.

[7] M. E. Bialkowski and P. J. Kahn, "Modal analysis of a coaxial-line waveguide junction," in *Dig. 1983 Int. Microwave Symp.* Boston, MA, May 31–June 3, 1983, pp. 424–426.

[8] M. E Bialkowski, "On the link between top-hat monopole antennas, disk-resonator diode mounts, and coaxial-to-waveguide transitions," *IEEE Trans. Antennas Propagat.*, vol. 48, pp. xxx–xxx, June 2000.

Authors' Reply

L. Francavilla Bodner, J. McLean, and H. Foltz

***Index Terms*—Mode-matching monopoles.**

We would like to thank Prof. Bialkowski for his interesting remarks on the connection between diode mounts, waveguide transitions, and top-hat monopole antennas and appreciate his bringing to our attention several references that should be of interest to anyone using mode-matching methods in the analysis of cylindrical antennas.

As the title of our paper indicates, the goal of our research was to explore top-hat monopoles loaded with multiple layers of dielectric under the top hat since the single homogeneous layer case had already been investigated in [1]. We duplicated the homogeneous layer case in our work to validate our method of analysis. While Prof. Bialkowski's methods and programs could undoubtedly be extended to cover the multiple layer case as he mentions in [1] we have found that this case has been neither analyzed nor described elsewhere.

Prof. Bialkowski states in his comments that the results in Figs. 1 and 2 show that his algorithms "produce results equivalent to those in [1], [2]." For the reader's clarification, we would like to point out that this comment can only apply to our duplication of the case presented in [1] and not to the case of multiple layers of dielectric.

The reader should also note that his algorithm and ours are not identical, since in his method the top hat is given a finite thickness and a boundary condition is enforced along the edge of the top hat. In our work the thickness approaches zero, and an edge condition is satisfied indirectly through the choice of ratio of the number of modes included in the region above the hat to the number of modes included in the region below the hat. His method is of course more versatile in that it allows for a thick hat; however, it remains to be seen which method is more efficient and rapidly convergent when the top hat is thin.

A second focus in our paper was analysis of how the dielectric layers affect energy storage, which is important in understanding the factors affecting the Q of small antennas. This topic was not discussed in the comments or references given by Prof. Bialkowski, although it would seem possible that the fields computed using his methods would be equally useful in making similar energy computations.

References

[1] M. E. Bialkowski, "Analysis of a coaxial-to-waveguide adaptor incorporating a dielectric coated probe ," *Microwave Guided Wave Lett.*, vol. 1, pp. 211–214, Aug. 1991.

Manuscript received November 10, 1999.
Publisher Item Identifier S 0018-926X(00)04361-1.