Diode Characterization in a Coaxial Mount

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ABSTRACT

A previously presented technique for experimentally characterizing packaged microwave diodes mounted in a coaxial test fixture is investigated. It is demonstrated that the fields surrounding the diode and the calibration packages are adequately developed to provide an accurate diode equivalent circuit model for use in computer-aided design. © **1993 John Wiley & Sons, Inc.**

1. INTRODUCTION

In ref. 1, a coaxial line technique was presented for characterizing packaged diodes. The calculated input impedances of three dummy diode packages with simple geometries were used to implement a standard three-termination calibration procedure and so obtain the error network up to the diode reference surface. The major consideration in establishing the integrity of the method is ensuring that the field orientation at the surfaces of the diode and dummy packages correspond to a radial mode. For this purpose, a plexiglass loaded package rather than an open circuit was used to obtain a high impedance termination and still perform the required coaxial-mode to radial-mode transformation. In this study, the performance of this diode characterization procedure is investigated by performing the deembedding procedure using various sets of dummy diodes and two different diode mounts—one enhancing the establishment of the radial mode in the vicinity of the diode.

2. DIODE EQUIVALENT CIRCUITS

At microwave frequencies the concepts of impedance and equivalent circuit refer to the field characteristics of a structure at a specific reference plane and for a particular field distribution (spatial mode) at that plane. Thus, the modeling and analysis of a mounted microwave diode, using the equivalent circuits of the diode and of the mount, requires that the interface between the two circuits be defined for a single mode and at a specific reference plane [2]. A further requirement before the two equivalent circuits are interfaced is that identical methods be used to determine equivalent voltages and currents. Fortunately, a scheme based on power equivalence is generally used [3], and is used here.

In a post-in-waveguide diode mount the fields surrounding the diode have radial mode distributions. The equivalent circuit of this mounting structure interfaces the waveguide fields to a cylindrical radial mode reference plane [4–6]. Thus, the fields at the mount–diode interface approximate a radial TEM mode field distribution. In practice, however, higher order modes are generated by axial and circumferential asymmetry in the mount and in the diode. These non-TEM radial modes at the mount reference port must not interact with the non-TEM radial modes at the diode port for a mount independent diode equivalent circuit to be developed. Fortunately, the axially and circumferentially varying modes are cut-

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off for typical gap dimensions. Thus, energy is stored in these cutoff modes provided that the radial region is of sufficient length. This energy storage is represented by reactive elements in the diode equivalent circuit.

3. RESULTS AND DISCUSSION

In ref. 1, the ordinary and enhanced coaxial line diode mounts, shown in Figure 1(a) and 1(b), respectively, were introduced. The mount in Figure 1(b) enhances the TEM radial mode in the vicinity of the diode. These mounts can be modeled as shown in Figure 2 where AA is the network analyzer measurement port, BB is a diode reference port, and CC is the diode surface. The embedding network is determined via a standard three-termination calibration procedure using three dummy packages of the types shown in Figure 3. The five different dummy packages listed in Table I were fabricated and had the calculated input impedances, obtained using radial line analysis [1], shown in Figure 4.

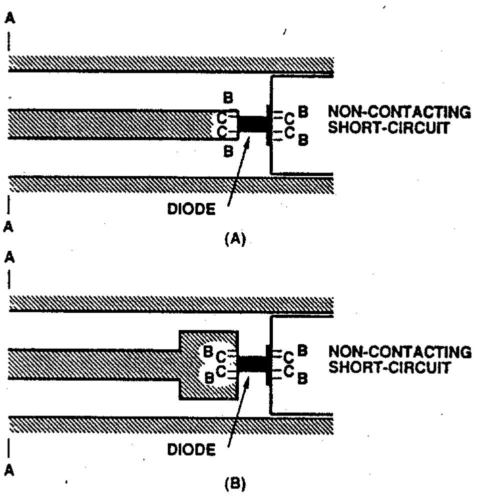

Figure 1. Coaxial line diode mount: (a) ordinary mount, (b) enhanced mount.

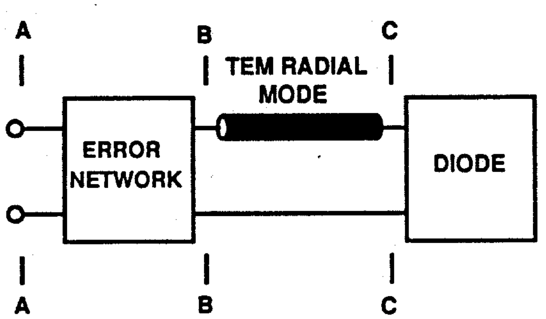

Figure 2. Components of the coaxial line diode mount.

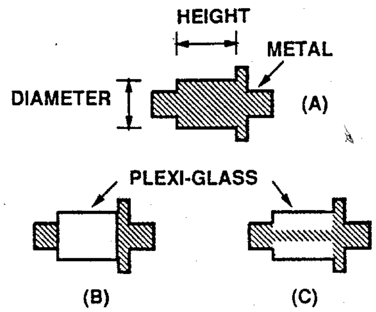

Figure 3. Reference loads: (a) brass package, (b) plexiglass package, and (c) plexiglass package with a coaxial brass pin of diameter 0.5 mm.

The radial-mode purity of the fields surrounding the diode was investigated by characterizing the diode using various sets of dummy diodes and the ordinary and enhanced mounts. For each set of three dummy diodes and one of the mounts the parameters of the equivalent circuit, shown in Figure 5, were derived. Measurements were performed using a Hewlett Packard HP8410 network analyzer specified over the range 500 MHz to 18 GHz. Packages 2, 3, and 5 present the greatest range of impedances and so these were preferred in the calibration process yielding the following optimized equivalent circuit parameters for the zero-biased diode: C_p = 0.0545 pF, L_p = 0.416 nH, $R_j > 10$ kΩ, R_S = 1.42 Ω, and $C_j + C_c$ = 0.599 pF. These parameters were obtained using a custom optimization program based on the Fletcher–Powell method. Very good agreement was obtained between the measured data and that calculated using this model (see ref. 1). The measurements were repeated for other sets of dummy packages and mounts which can be expected to establish the radial mode to various degrees. The measured data is shown in Figure 6. The closely grouped deembedded input impedances of the

TABLE 1. Dummy Diode Package Dimensions

Package	Type	Diameter
#1	a	2.40 mm
#2	a	2.01 mm
#3	b	3.11 mm
#4	a	3.09 mm
#5	c	3.06 mm
Diode		2.00 mm

All packages have a height of 1.54 mm. Package type is defined in Figure 3.

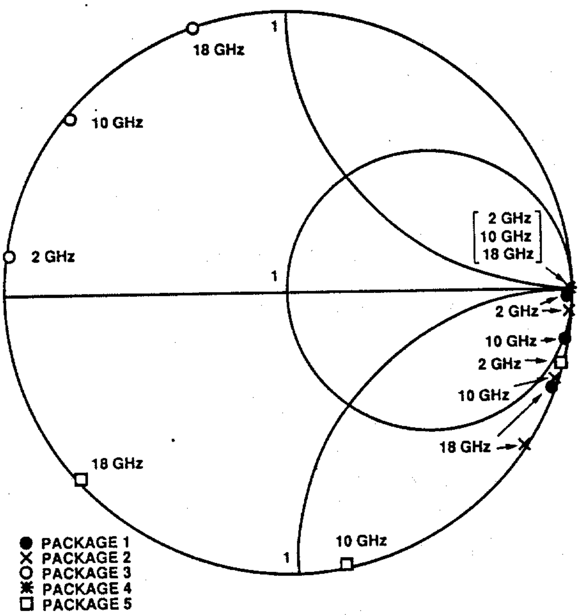

Figure 4. Smith chart plot of the dummy packages normalized to 50 Ω.

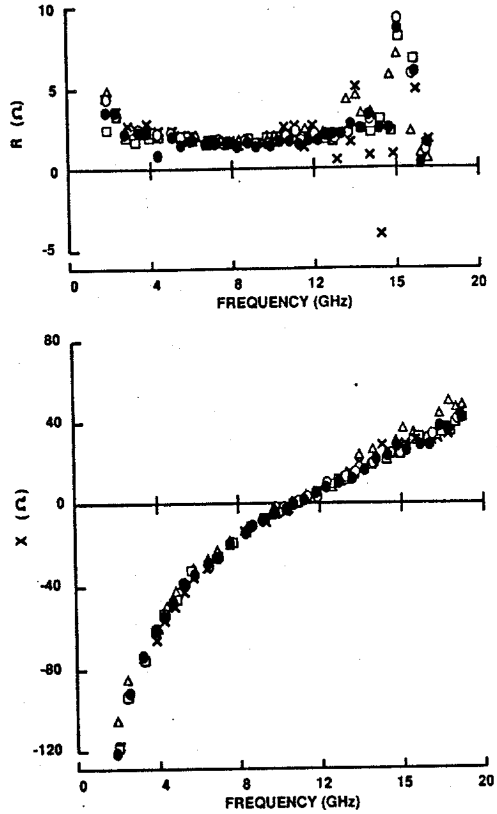

Figure 6. Measured input impedance of the diode obtained using various sets of dummy packages and the diode mounts: (□) packages 2, 3, and 5, and ordinary mount; (○) packages 1, 3, and 5, and ordinary mount; (●) packages 4, 3, and 5, and ordinary mount; (×) packages 1, 3, and 5, and enhanced mount; and (△) packages 4, 3, and 5, and enhanced mount.

diode indicate that even with the ordinary coaxial diode mount, the TEM fields are adequately developed in the vicinity of the diode. Measurements deembedded using the enhanced mount show increased scatter presumably because the large impedance discontinuity of the abrupt disc discontinuity led to reduced impedance resolution. Measurements using the ordinary mount and the preferred set of dummy packages (2, 3, and 5) showed very little reactance scatter above 12 GHz where the scatter for the other experiments is considerable. Furthermore, above 12 GHz, the resistance becomes a smaller fraction of the overall impedance so that the scatter that appears in the reactance measurements is amplified.

The results presented here demonstrate that the ordinary coaxial mount is suited to the development of mount independent diode equivalent circuits for use in computer-aided design.

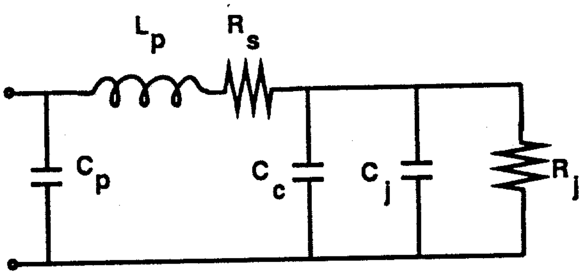

Figure 5. Diode equivalent circuit.

ACKNOWLEDGMENTS

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BIOGRAPHY

Michael B. Steer received his BE and PhD in electrical engineering from the University of Queensland, Brisbane, Australia, in 1978 and 1983, respectively. Currently he is director of the Picosecond Digital Systems Laboratory (PICOLAB), codirector of the High Frequency Electronics Laboratory, and associate professor of electrical and computer engineering at North Carolina State University. He is a 1987 Presidential Young Investigator. His research involves the experimental characterization, simulation, and computer aided design of nonlinear microwave circuits and systems, and of high speed digital systems. He is currently working on the simulation of microwave analog circuits, of high speed digital systems, characterization of multichip modules, parameter extraction, and computer-aided design of microwave circuits using simulated annealing, and millimeter-wave quasi-optical techniques. He presents a course on the National Technological University entitled "Computer Aided Circuit Analysis," which is broadcast throughout the U.S. He has published more than 70 technical journal and conference papers on nonlinear microwave circuit analysis, simulation of delta-sigma modulators, high frequency limits of transistors, microwave measurements, and equivalent circuits of diode mounts. Dr. Steer is a senior member of the Institute of Electrical and Electronic Engineers and is active in the Microwave Theory and Techniques Society and the Components Hybrids and Manufacturing Technology Society.