Damping of Package Resonances in Microwave Integrated Circuits: a FDTD Analysis

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Abstract

In this paper, a graded mesh FDTD code running on the massive parallel computer DEC 12000 with 4K processors has been applied to analyzed various MMIC discontinuities enclosed in a metal package and fed by coaxial transitions. Observe that, in the present approach, the circuit and the package are analyzed as a whole. Moreover, also the effects of the feeding connectors have been thoroughly modeled. Since the package introduces resonances several different possibilities to choke off these resonances have been investigated. It is shown that the common practice of inserting a damping layer just below the lid is often not effective. In particular, the importance of placing damping layers also on the side walls is demonstrated.

Introduction

Many circuits, and especially MMICs, must be placed in metal packages to reduce outside electromagnetic interference, to provide isolation between different circuits and to protect the circuit from material contamination, hazardous environment, stresses, etc. However, the current trend towards the millimeter-wave applications requires the development of packages able to operate up to 40 GHz and, at these frequencies, packages are generally large enough to support resonant modes. Interaction phenomena between circuit elements and package itself have increasingly pronounced effects.

A properly designed package should reduce resonant modes by lowering the Q of the package. Conventional microwave absorbers, or resistive films, have to be placed inside the package, in properly selected locations, in such a way to choke off the resonance without affecting the circuit behavior. Therefore, because of the complexity of the structures involved, only numerical methods can be applied.

Method

The basic FDTD algorithm is well known and is not described here [1, 2]. Two particular features which have been introduced for the simulations are briefly described in the following:

Unidirectional graded mesh [3]:

The analysis domain is discretized by subdividing the mesh in many slices with different scaling factors. This allows a drastic reduction of the memory storage to be achieved.

Modeling of the coaxial feeding lines:

The feeding lines have been approximated as 50 ohm coaxial lines with square cross section. In the FDTD simulation a precomputed field distribution, corresponding to the TEM mode of the feeding line, has been used to excite the structure from the feeding coaxial lines [5]. The time dependence of the impressed field distribution is a gaussian pulse properly chosen to reduce numerical dispersion. A first order absorbing boundary condition has been implemented [6] to simulate non reflecting terminations. Observe that in this manner, not only the ABC is rigorous but also the actual physical situation is properly modeled and simulated.

Structures

The previously described algorithm has been used to analyze various microstrip discontinuities enclosed in a metal package and fed by coaxial transitions. Fig 1 shows the simulated structures, namely a single microstrip via hole, a simple 50 ohm microstrip transmission line and two microstrip via holes separated by a gap.

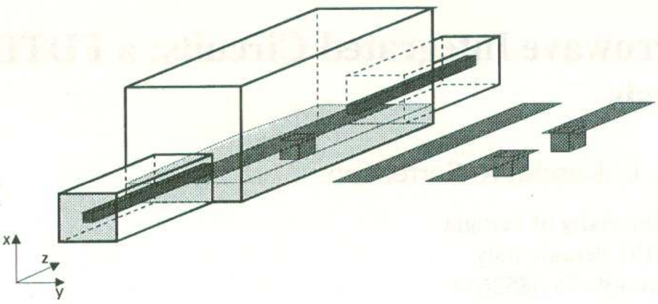

Fig. 1: Sketch of the simulated microstrip discontinuities

Fig. 2 shows the comparison between theoretical and experimental results obtained for the third structure enclosed in a package with the dimensions of 10*10*25 mm. The presence of two resonances is quite evident. Fig. 3 shows the behaviors of the transmission microstrip line both with and without the package lid. It is evident that when the lid is removed the resonances disappear and a little amount of radiative losses is present.

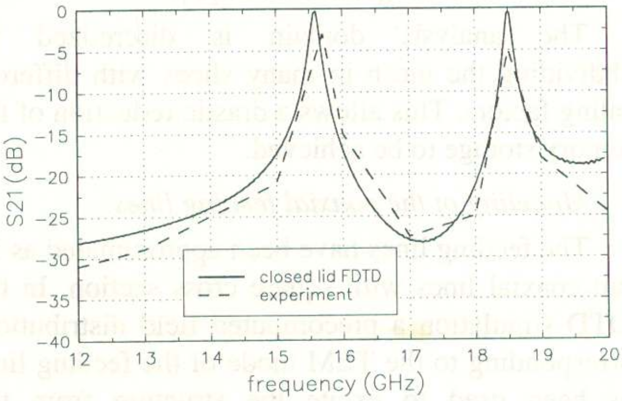

Fig. 2: Two packaged via-holes separated by a gap: theoretical and experimental results.

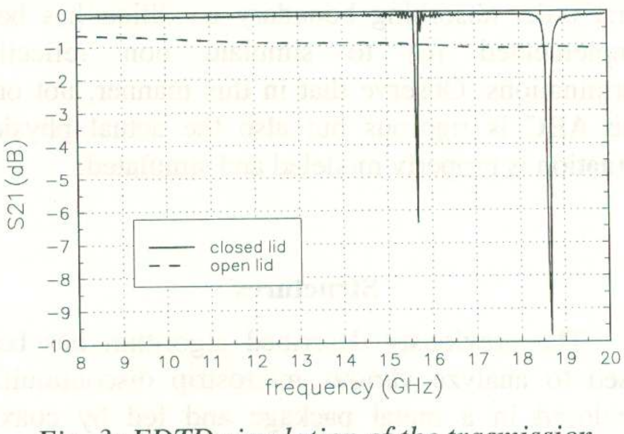

Fig. 3: FDTD simulation of the trasmission microstrip line (no via present).

Damping of the resonances

The package resonances can be lowered by inserting conventional microwave absorbers or resistive films below the lid of the package [7, 8]. Nevertheless, due to the great thickness required, this approach could not be always effective. This is clearly described in Fig. 4 where the behavior of a single packaged via-hole with several absorbing layers with different thickness is shown.

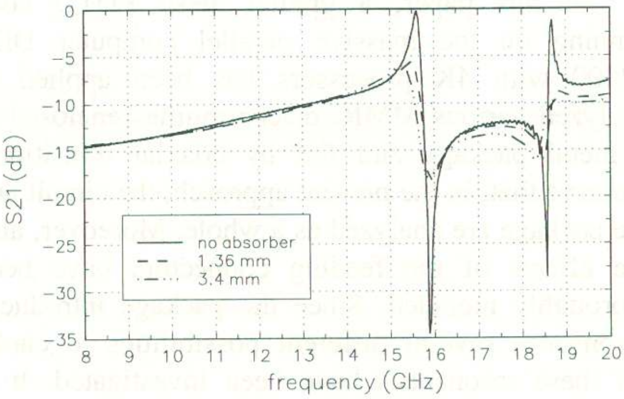

Fig. 4: behavior of different damping lids.

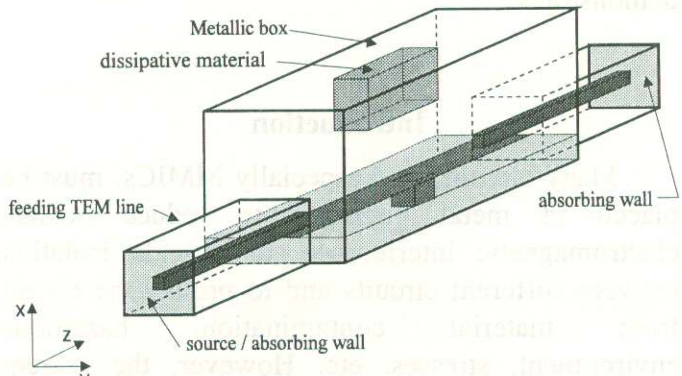

Fig. 5: Piece of absorbing material inside the package

Better results have been obtained either by placing a tiny piece of absorbing material in the center of the structure (Fig. 5). Fig. 6 shows the results related to the previously mentioned cases.

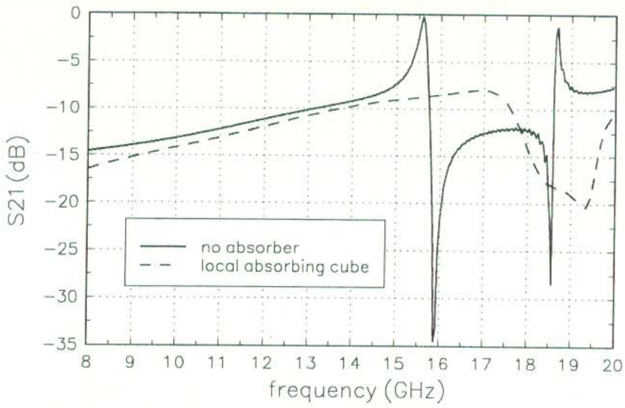

Fig. 6: comparison among several kinds of absorbers.

Conclusions

An FDTD graded mesh code, also suitable for massive parallel computers (MPCs) [4], has been used for the analysis of packaged MMICs structures. The transition between the external coaxial feeding lines and the microstrip line inside the package has also been accounted for. The latter has been rigorously modeled by suitably positioning the absorbing boundary conditions in the outer coaxial lines. Results on packaged isolated and coupled microstrip vias are shown to agree very well with experiments and, in all cases, package interaction phenomena have been fully predicted. The code can be used to achieve suppression of unwanted resonances without affecting the circuit behavior. The effect of inserting a piece of resistive material just below the top lid has also been investigated.

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