EFFICIENT EVALUATION OF THE FREQUENCY-DEPENDENT IMPEDANCE MATRIX OF FULL-PACKAGE STRUCTURES

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This work deals with the problem of the efficient extraction of the impedance matrix for a complex full-package structure. This result applies to ranges from DC to frequencies for which the skin effect is pronounced but the radiation and other full-wave effects are still negligible. The model identifies the impedance matrix by enforcing a physically consistent behavior to the resistance and reactance of the package in the low and high frequency limits.

(a) (b)

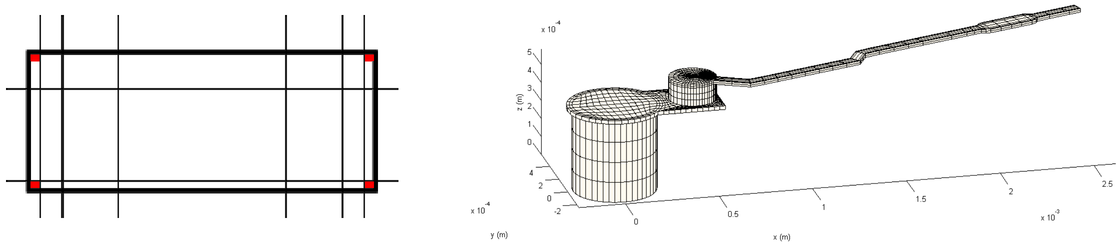

Fig.1. (a) The adopted mesh for the trace cross-section. (b) A particular of the ALE net used to compare the impedance extracted by Fasthenry and Cariddi codes (Fig.2b).

Let us consider a trace of conductivity σ, width w and height h and let us indicate with $d = \min(w, h)$. In order to check when the skin-effect should be taken into account, we compare the skin depth δ to d. On the basis of this comparison, we can define three frequency ranges: Low frequency (LF) range: $\delta \geq d$, Intermediate frequency (IF) range: $d/3 \leq \delta \leq d$, High frequency (HF) range: $\delta \leq d/3$. Let f_2 and f_4 be the frequencies corresponding to the lower and upper limits of the IF range, i.e. the frequencies for which $\delta = d$ and $\delta = d/3$, respectively. Let us define $f_1 = 0.1 f_2$, $f_3 = 0.5(f_2 + f_4)$ and $f_5 = 10 f_4$. The model is based on the evaluation of the impedance matrix at such frequencies and on the identification of the following fitting curves: in LF range

$$\mathbf{R} = \mathbf{R}_{LF}, \quad \mathbf{X} = \mathbf{X}_{LF} f \tag{1}$$

obtained from the impedance values at f_1 and f_2. In the HF range we adopt the model:

$$\mathbf{R} = \mathbf{R}_{HF} + \mathbf{K}_R \sqrt{f}\,, \ \mathbf{X} = \mathbf{K}_1 \sqrt{f} + \mathbf{K}_2 f\,, \tag{2}$$

whose parameters are identified from the values at f_3 and f_4. Finally, the values at f_2, f_3 and f_4 are used to fit the behavior of *R* and *X* in the IF range, by using cubic splines.

We have used a commercial 3D electromagnetic code (FastHenry [1]) to provide the 5 starting points and the reference values to validate the procedure. This values are compared with the results obtained with CARIDDI [2]. Benchmark tests and case-studies are carried out, confirming the accuracy of the model.

(a) (b)

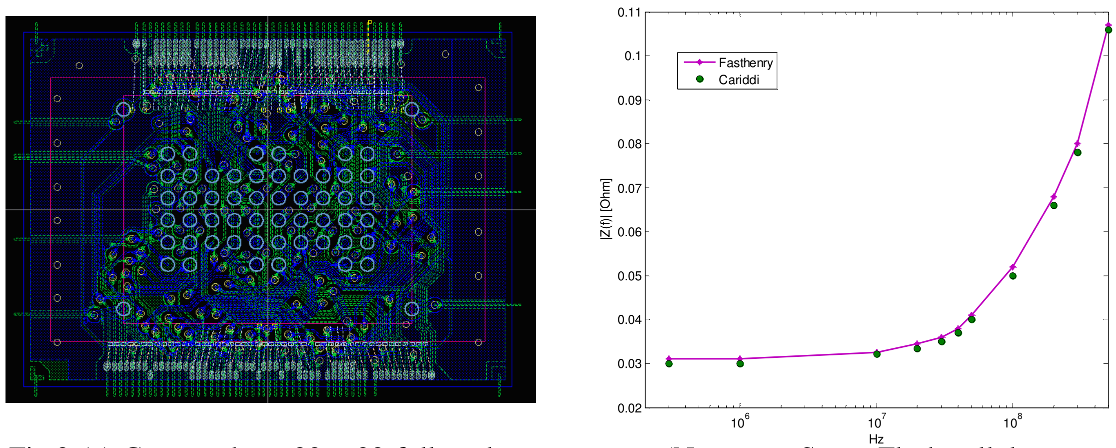

Fig.2 (a) Case study: a 92 x 92 full-package structure (Numonyx Strata Flash cellular memory) with trace width 40 µm, trace thickness 20 µm and conductivity = 5.8 10^8 S/m; (b) Absolute value of the impedance for ALE net: Fasthenry vs Cariddi.

(a) (b)

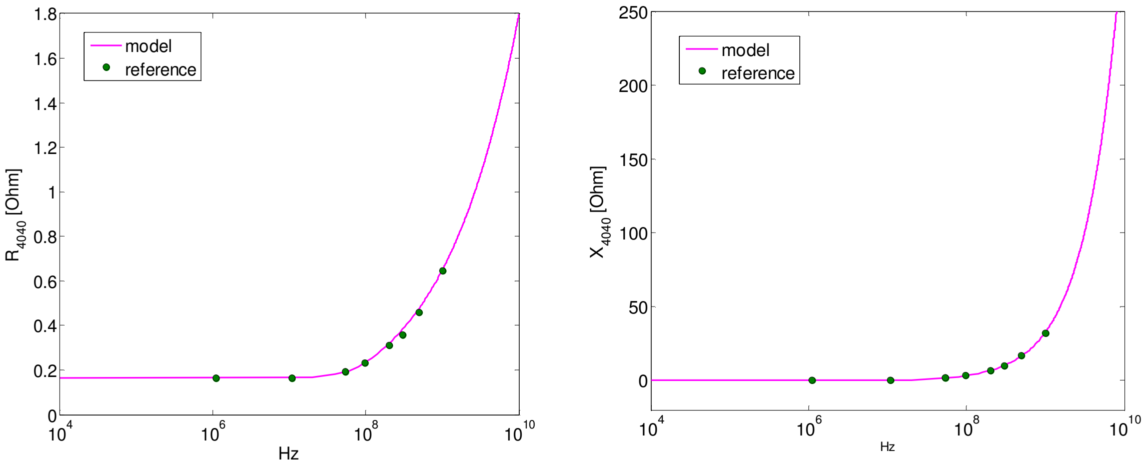

Fig.3 Case-study: resistance $R_{40,40}$ (a) and reactance $X_{40,40}$ (b) entries: model vs reference values.

Tab.1. Simulation time (on a multiprocessor SUN Workstation)

	FH Single sample (LF)	**FH** Single sample (HF)	**FH** 5 samples	**Semi-analytical model** 500 samples	**FH** 500 samples
Simulation time	~10 m	~210 m	~11 h	~11 h	~66 days

References

[1] M. Kamon, M.J. Tsuk, and J.K. White, "FASTHENRY: A Multiple-Accelerated 3-D Inductance Extraction Program," *IEEE Trans. Microwave Theory and Techniques*, (1994), pp. 1750-1758

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