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COUPLED SIMULATIONS IN THE MODELING OF COMPLETE NANOSCALE RF BLOCKS

W.H.A. SCHILDERS[*], W. SCHOENMAKER[†] AND L.M. SILVEIRA[1]

[*] NXP Semiconductors, Research
High Tech Campus 37
5656 AE Eindhoven, The Netherlands
Email: wil.schilders@nxp.com – Web page : http://www.nxp.com

[†] MAGWEL NV
Kapeldreef 60
3001 Leuven, Belgium
Email: wim.schoenmaker@magwel.com - Web page: http://www.magwel.com

[1] INESC-ID
Rua Alves Redol 9
1000-029 Lisboa, Portugal
Email: lms@inesc-id.pt - Web page: http://algos.inesc.pt/~lms/

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Summary. Next-generation nano-scale RFIC designs have an unprecedented complexity and performance that will inevitably lead to costly re-spins and loss of market opportunities. In order to cope with this, the aim of the European CHAMELEON RF project is to develop methodologies and prototype tools for a comprehensive and highly accurate analysis of complete functional IC blocks. These blocks will operate at RF frequencies of up to 60 GHz. The approach adopted for this purpose relies heavily on the ability to solve coupled problems in an efficient way. In this paper, it is described how it is envisaged to cope with these very challenging problems in the electronics industry.

1 INTRODUCTION

IC design automation tools are indispensable for RF designers in the transition to the nano-scale era. These tools are needed to develop nano-scale designs of unprecedented complexity and performance and, in addition, enable the achievement of single-pass design success to avoid costly re-spins and the loss of market opportunities.

Next generation designs will be challenged by an increased number of trouble spots, many of which negligible at lower frequencies but representing a significant limitation for future designs. These trouble spots will have to be accounted for during the design phase in order to avoid costly mishaps that can originate potential failures and additional design and silicon iterations, and must be addressed in future design automation tools.

New coupling and loss mechanisms, including EM field coupling and substrate noise as well as process-induced variability, are becoming too strong and too relevant to be neglected, whereas more traditional coupling and loss mechanisms are more difficult to describe given the wide frequency range involved and the greater variety of structures to be modeled. All this will cause extra design iterations, over-dimensioning or complete failures, unless appropriate solutions are found to resolve these design issues.

The key to the avoidance of these trouble spots is the recognition that devices can no longer be treated in isolation. Complete RF blocks must be considered as one entity. Today, it is not possible to perform such analyses of complete RF blocks. The CHAMELEON RF project will deliver the methodologies and prototype tools to make this possible. In order to achieve these goals, efficient and accurate models of the interconnect, integrated inductors, the substrate and devices, together with their mutual interactions, need to be developed.

2 GENERAL STRATEGY

The first task deals with the electromagnetic field aspects of coupling, at the component level. In this task the methods for quantitative analysis of interference are done, providing best practices for generating compact models that incorporate the coupling effects. The coupling of the front-end (active devices) with the back-end (integrated passive devices and interconnects) is studied. The presently available compact models are refined, if needed, with 'hooks' or connectors that allow the incorporation of induced field effects originating from the surroundings.

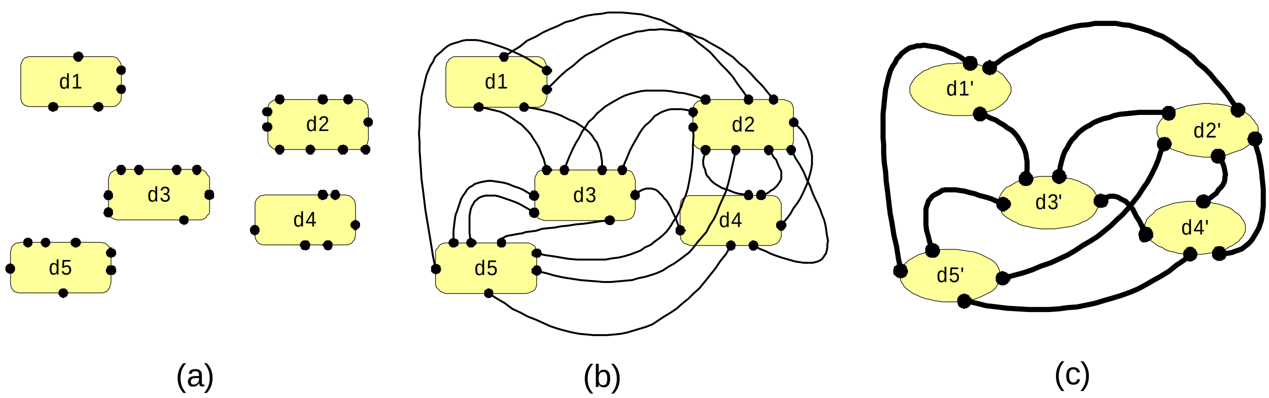

Figure 1: Illustration of our subsequent modeling and model order reduction procedures. Figure (a) shows compact models of devices, such as transistors or inductors, which are equipped with connectors to account for the interaction, which is added in (b). This model is transformed into a simpler but still accurate model using model order reduction procedures in (c).

The second research task aims at efficient and accurate methods of modeling the global interactions between the physical (on-chip) realizations of the circuit elements from the schematic. These elements include the active as well as the passive devices. In Figure 2, we show the influence of a passive device, often of much larger dimensions, on the passive devices. An analysis shows that the vector potential may be assumed to be constant, thereby shifting the terminal voltages on the active devices by a constant.

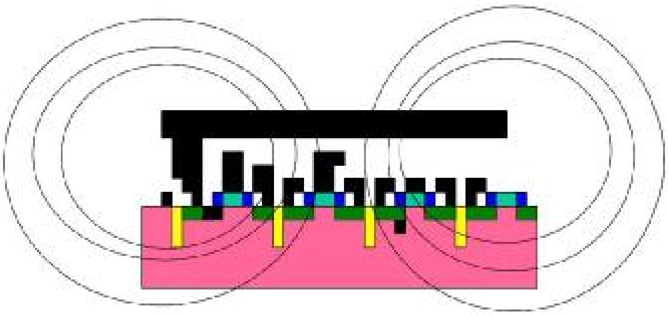

Figure 2: Active devices in an electromagnetic environment - modeling considerations.

The goal is to develop procedures for layout scanning, in order to identify the primitive components and their actual values of variable parameters. The couplings to be modeled will attach to the specific connectors of the compact models that are the outcome of the former task. If electromagnetic analysis is necessary for the extraction of additional parameters, a hierarchical series of field problems is formulated and solved. Automatic domain decomposition is done by a divide and conquer approach, and boundary conditions are set up in an automatic manner. In addition, several "on the fly" MOR techniques to improve the efficiency of EM analysis will be evaluated. In Figure 3, we show the principle in a graphical way.

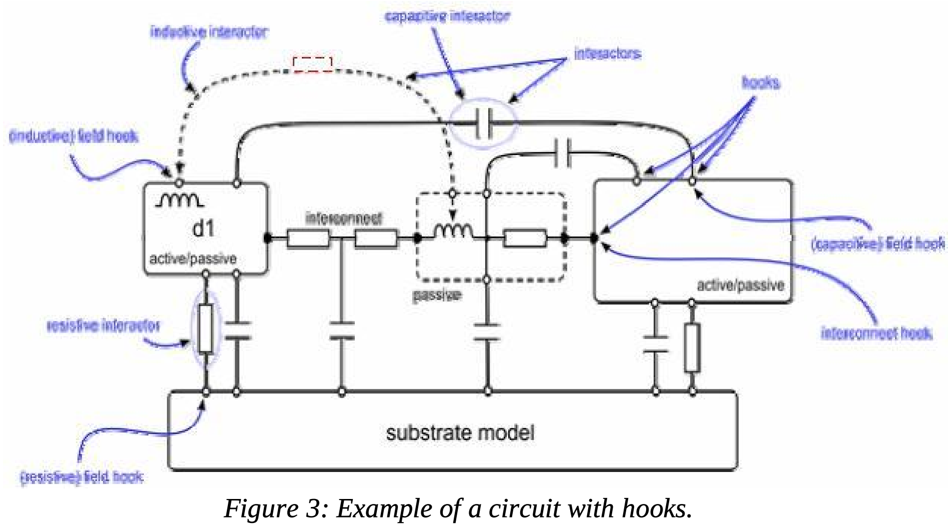

Figure 3: Example of a circuit with hooks.

3 EXAMPLES

We will present a number of results. A challenging problem is that of a coupled set of integrated inductors, shown in the figure below.

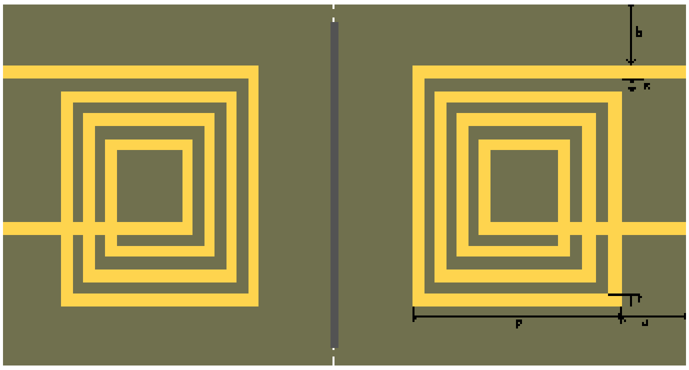

Figure 4. Coupled integrated inductors

For this problem, conventional simulation results are not in agreement with measurements, as can be seen from Figure 5. In the presentation, we will show how this discrepancy can be remedied by using the correct coupling approach.

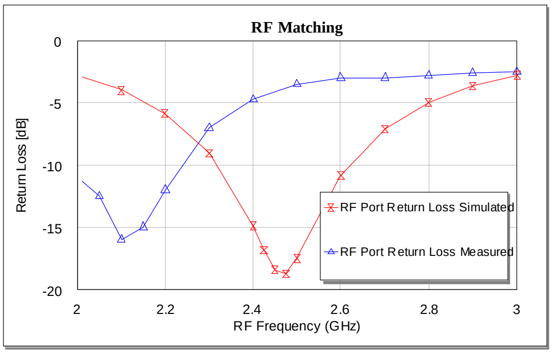

Figure 5.Comparison of measurements and simulation

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[2]CHAMELEON RF website: www.chameleon-rf.org