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Modeling of Electromagnetic Effects in Complete RF blocks

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Abstract

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 Framework 6 CHAMELEON RF project [1] 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.

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. At SPI 2007 the results achieved in the modeling and methodology research will be presented.

Introduction

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 these solutions is the recognition that devices, both active and passive, can no longer be treated in isolation. Complete RF blocks must be considered as one entity, and be treated as such by the design automation tools. 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.

The project has started in November 2005, and will run for a period of two and a half years. More detailed information about the CHAMELEON RF project can be found at the project website [2].

Chameleon RF objectives

The general objective of the consortium is that of developing a methodology and prototype tools that take a layout description of typical RF functional blocks that will operate at RF frequencies up to 60 GHz and transform them into sufficiently accurate, reliable electrical simulation models taking variability into account.

The main goal of the project, against which the progress of the project work will be measured, is the silicon-accurate modeling of RF functional blocks (such as a VCO or an LNA) with up to 10 transistors, 10 passive devices and implemented in 90 and 180 nano-meter technology with a maximum of 10 levels of metal for frequencies up to 60 GHz.
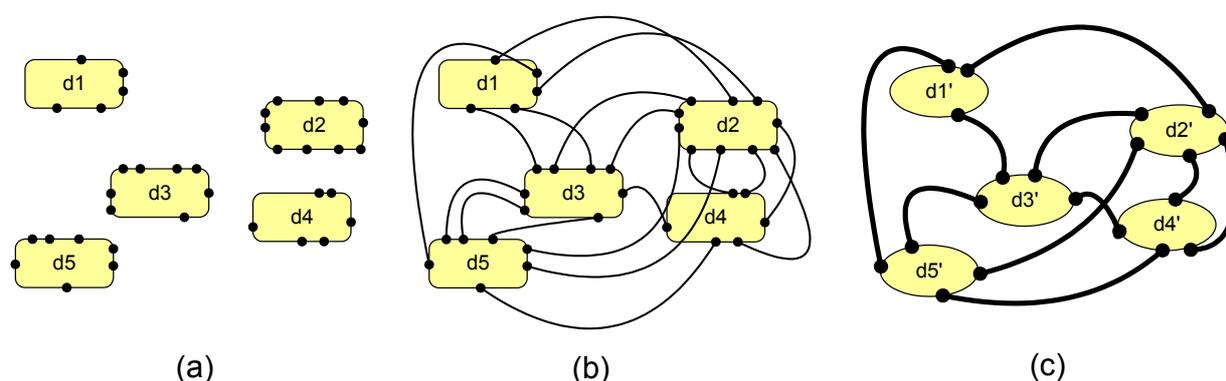

Figure 1: Illustration of our subsequent modeling and model order reduction procedures. Figure (a) shows compact models of devices, such as transistors or inductors, which are equipped with connectors to account for the interaction, which is added in (b). This model is transformed into a simpler but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

The modeling and methodology research topics

The first task deals with the electromagnetic field aspects of coupling, at the component level. In this work package the methods for quantitative analysis of interference are done. The work package provides 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 will be refined, if needed, with 'hooks' or connectors that allow the incorporation of induced field effects originating from the surrounding.
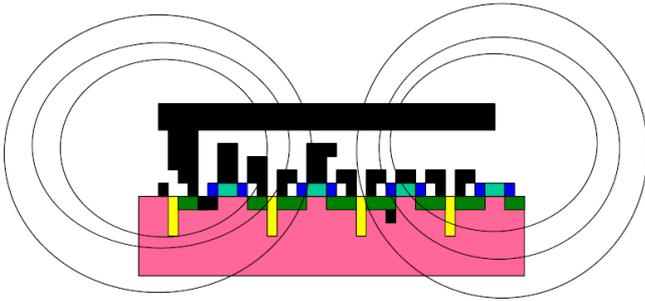

Figure 2: Active devices in an electromagnetic environment - modeling considerations.

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. 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 in this WP will attach to the specific connectors of the compact models that are the outcome of WP1. If electromagnetic analysis is necessary for the extraction of additional parameters, a hierarchical series of field problems are formulated and solved. Automatic domain decomposition is done by divide and conquer, and boundary conditions are set-up in an automatic manner. In this work package also several "on the fly" MOR techniques to improve the efficiency of EM analysis will be evaluated.
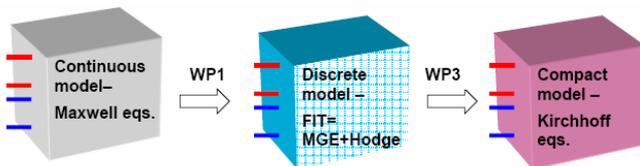

Figure 3: Different levels of abstraction for a component and their corresponding equations.

The third task therefore deals with the development of novel order reduction techniques that can take parameterized descriptions of structures into account and lead to efficient coupled analysis of active and passive devises as well as parasitics. The enabling blocks for that analysis will be reduced order models that should be described by netlists that can be directly simulated with existing or new simulation engines. In this work package we aim to develop, besides

parameterized order reduction of compact models for linear (passive) components, also new model descriptions and model order reduction techniques that enable generation of compressed representations of parameterized interconnected sets of compact models of interaction effects, active and passive devices.
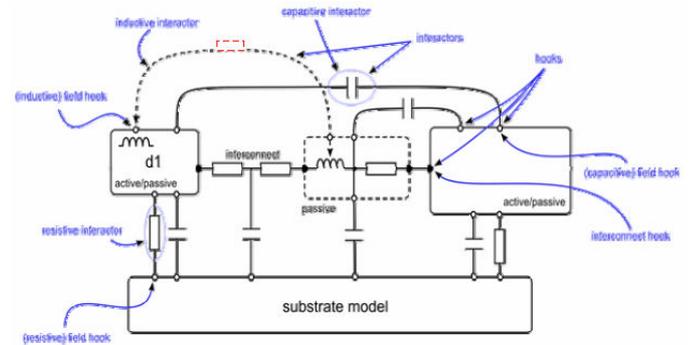

Figure 4: Example of a circuit with hooks.

For the purpose of validation of the simulation/modeling results, RF designers, the tool developers and the characterization engineer will define, design, fabricate and measure benchmark structures. State-of-the-art processes like 180nm and 90nm CMOS and SiGe BiCMOS technologies will be used for the implementation of RF circuits. The structures will be characterized using on-wafer S-parameter measurement techniques. Test structures are: substrate noise isolation structures, a series of parameterized active and passive components with particular values of parameters and for functional blocks: VCO, LNA, in 180nm and 90nm CMOS.

Then, as a final task, the software tools and modeling methodologies, developed during the project will be validated.

Results

Since the start of the Chameleon RF project signification progress has been made in the areas of:

- construction of compact/reduced order models for active and passive devices, taking the impact of the environment into account. This for both electric and magnetic effects,
- methods for interconnected / coupled sets of compact models (domain decomposition procedures, taking advantage of hierarchy),
- treatment of variability (development of parameterized MOR workbench).

At SPI 2007, an overview of these results will be presented.

References

[1] J. Niehof, H.H.J.M. Janssen, W.H.A. Schilders, "*Comprehensive High-Accuracy Modeling of ELectromagnetic Effects in cOmplete Nanoscale RF blocks: CHAMELEON RF*", 10th IEEE Workshop on Signal Propagation on Interconnects, 2006.
[2] CHAMELEON RF website: www.chameleon-rf.org.