Chapter 4
Simulation Techniques for Improving Fabrication Yield of RF–CMOS ICs

Amparo Herrera
University of Cantabria, Spain

ABSTRACT
One of the industry sectors with the largest revenue in the telecommunication field is the wireless communications field. Wireless operators compete for being the first to place their products in the market to obtain the highest revenues. Moreover, they try to offer products that fulfill the user demands in terms of price, battery life, and product quality. All these requirements must be also fulfilled by the designer of the MMIC (Microwave Monolithic Integrated Circuits) circuits that will be used in those wireless terminals, achieving a reliable design, with high performance, low cost, and if possible, in one or two foundry iterations so as to bring the product out to the market as soon as possible. Silicon based technologies are the lowest cost. The demand to use them is simply based on that fact, but their usage in these applications is limited by the ease of use for the designer, in particular, by the lack of adequate simulation models. These technologies don’t include some essential components for the design of RF circuits, which leads to measurement results quite different from those simulated. On the other hand, GaAs based technologies, more mature in the RF and microwave field, provide very accurate models, as well as additional tools to verify the design reliability (yield and sensitivity analysis), allowing good results often with only one foundry iteration. The deep study of the problems presented when designing Si-based RF circuits will convince the reader of the need to use special tools as electromagnetic simulation or coo simulation to prevent it. The chapter provides different simulation techniques that help the designer to obtain better designs with a lower cost, as foundry iterations are reduced.

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INTRODUCTION

Today’s communications circuits and systems focus on a mass market in which one of the requirements is the cost, thus pushing towards integration in Silicon technology, most particularly in CMOS technology. In addition, technology tends to associate two techniques SiP (System in Package) and SoC (System on Chip) in these systems to reduce both cost and size. The underlying effects of these requirements are (1) an increase of the circuit complexity; and (2) proximity of the functions, and so the creation of multiple coupling phenomena that are very difficult to diagnose if not known in advance.

At the same time, there is a tendency toward higher working frequencies and for that reason, libraries are very important to help rapid implementation of the functions. The library of a CMOS manufacturer usually consists of active components, MOS transistors or diodes (in which, for example, the effects of interconnecting lines between fingers are not included) and of passive elements, generally the ideal values are used at the start and after layout a parasitic RC extraction is included. Other manufacturers, for these passive components include frequency-dependent models with different levels of complexity depending on the frequency-limit for which they are defined. Moreover, GaAs or SiGe technology fabrication is more expensive but generally provides better performance, and complete active and passive libraries which include frequency-dependent models. In some cases they even provide microstrip line libraries at different levels of metallization as well as possible discontinuities, with real Layout Versus Schematic check and taking into account all of the interconnections. In this case the simulation and measurements can be very close on the first run.

To compensate for this lack of strong library in RF CMOS circuit design, this chapter will propose simulation techniques that allow the designer to take into account all the phenomena that appear due to frequency dispersion and coupling, as well as discontinuities. Initially, the typical performance of passive components is shown, including transmission lines, compared with the models provided by the manufacturer or extracted by the layout generation program. Next, typical libraries of these technologies are briefly described, for use with simulation techniques. The techniques to be used are electromagnetic simulation methods combined with circuit simulation techniques, which enable co-simulation to be carried out, taking into account electromagnetic and non-linear phenomena.

TRANSMISSION LINE THEORY

In general the books dedicated to electromagnetic signal propagation explain the complete theory of signal transmission in circuits and equipment (Wadell, 1991). All of this theory is applicable to circuits and/or distributed circuits with propagation in mind. On the other hands, circuit theory with localized components (L, C, R) are based on network analysis. For deciding when to use one or the other theory, the operation frequency and the substrate used for transmission must be taken into account.

Next, we will briefly outline one of the theories used to explain electromagnetic signal propagation.

Signal transmission in RF & Microwave circuits or systems takes place through structures that are capable of guiding waves. These structures are basically of two types: transmission lines that guide waves TEM (transverse electromagnetic) between two (or more) conductors, which can be defined and measured in each plane perpendicular to the direction of propagation by the voltage difference between the two conductors. In each transverse plane, the total current flowing through the conductors can also be defined and measured. Otherwise, and more generally, the waveguides are structures that guide electromagnetic signals which are not