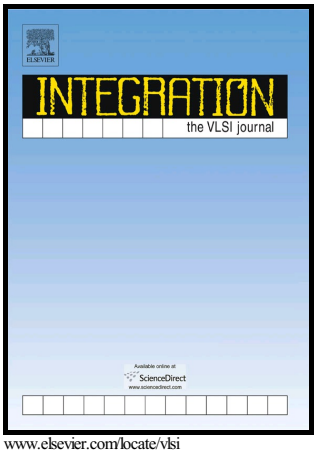

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An inductor modeling and optimization toolbox for RF Circuit Design☆

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Abstract—

This paper describes the SIDe-O toolbox and the support it can provide to the radio-frequency designer. SIDe-O is a computer-aided design toolbox developed for the design of integrated inductors based on surrogate modeling techniques and the usage of evolutionary optimization algorithms. The models used feature less than 1% error when compared to electromagnetic simulations while reducing the simulation time by several orders of magnitude. Furthermore, the tool allows the creation of S-parameter files that accurately describe the behavior of inductors for a given range of frequencies, which can later be used in SPICE-like simulations for circuit design in commercial environments. This toolbox provides a solution to the problem of accurately and efficiently optimizing inductors, which alleviates the bottleneck that these devices represent in the radio-frequency circuit design process.

Keywords—inductor design; single-objective optimization; multi-objective optimization; surrogate modeling; radio-frequency circuit design

1. Introduction

Designing a radio-frequency (RF) circuit is one of the most challenging tasks in nowadays electronics, due, partially, to its demanding specifications and convoluted trade-offs. To help managing this complexity and cut short the number of re-design cycles, an extensive effort is being made by the research community, over the past few years, to develop computer-aided design (CAD) tools that can efficiently support the RF circuit designer [1]. However, with always increasing time-to-market demands, where time consuming re-design cycles are not desired and first-pass success is a design goal [2], new CAD tools have to be proposed to assist the designer in reducing the circuit design time while meeting the ever demanding RF specifications.

One of the most difficult RF components to design is the inductor, especially at gigahertz frequencies. The inductor is one of the most used components in RF circuits [3], vastly present in circuits such as low noise amplifiers (LNAs), voltage controlled oscillators (VCOs) or power amplifiers (PAs). When the use of integrated inductors is needed, RF designers usually rely on two different methods: either libraries provided by the foundry are used (which typically have limited options) or iterative electromagnetic (EM) simulations are performed until an inductor with desired performances is obtained (which is a computationally expensive method, critically slowing down the RF design cycle).

The complexity in designing inductors comes from the peculiar features that the RF designer has to control through the geometrical parameters that characterize the inductor (topology, number of turns, inner diameter, turn width, among others). When designing inductors, there are several alternatives to achieve a given inductance. Therefore, several design decisions have to be made in order to design the inductor that meets the circuit requirements with the highest quality factor and the smallest area for a given inductance. These decisions highly depend on the expertise of the RF designer and the technology process. To overcome these difficulties, optimization-based design methodologies can assist RF designers in order to design inductors while ensuring the best trade-offs for each design.

To carry out such assistance, several simulation tools for inductor design and optimization have been reported in the literature, which are intended to reduce the simulation time. Examples of these tools are ASITIC [4] and SISP [5]. Nevertheless, these tools are based on physical/analytical models, which typically present severe accuracy issues in some areas of the design space and at higher frequencies [6]. Therefore, these tools are not suitable for proper inductor design or optimization.

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Fig. 1.Inductor geometric parameters for an octagonal asymmetric spiral inductor.

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