

Chapter 1

Design and Optimization of Microwave Circuits and Devices with the Particle Swarm Optimizer

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ABSTRACT

In this chapter, a methodology for the unsupervised design of microwave devices, circuits, and systems is considered. More specifically, the application of the Particle Swarm Optimizer and its integration with electromagnetic simulators is discussed in the framework of the microwave circuits and devices design and optimization. The idea is to automatically modify the characteristics of the device in an unsupervised way, with the goal of improve the device performances. Such kind of CAD tool could be the solution to reduce the time to market and keep the commercial predominance, since they do not require expert microwave engineers and it can reduce the computational time typical of the standard design methodologies. To assess the potentialities of the proposed method, a selected set of examples concerning the design of microwave planar devices such as filters, splitters, and other microwave devices under various operative conditions and frequency bands are reported and discussed. The chapter also includes a brief discussion concerning different strategies, such as parallel computation, to reduce the computational burden and the elaboration time. The obtained results seem to confirm the capabilities of the proposed method as effectiveness microwave CAD tool for the unsupervised design of microwave devices, circuits, and systems. The chapter ends with some conclusions and considerations related to ideas for future works.

INTRODUCTION

The Particle Swarm Optimizer (Kennedy, Eberhart, & Shi, 2001; Robinson & Rahmat-Samii, 2004; Clerc, & Kennedy, 2002) has been successfully adopted as a powerful optimization

tools in several areas of applied electromagnetic (Grimaccia, Mussetta, & Zich, 2007; Mikki, & Kishk, 2006; Robinson & Rahmat-Samii, 2004; Mussetta, M., Selleri, S., Pirinoli, P., Zich, R.E., & Matekovits, L. 2008; Nanbo Jin, & Rahmat-Samii, Y. 2010; Yilmaz, A.E. 2010) such as microwave

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imaging (Donelli & Massa, 2005; Caorsi, Donelli, Lommi, & Massa, 2004; Huang, & Mohan, 2007; Huang, C.-H., Chen, C.-H., Chiu, C.-C., & Li C. L. 2010; Genovesi, S., Salerno, E., Monorchio, & A., Manara, G. 2009), antenna design (Robinson, Sinton, & Rahmat-Samii, 2002; Jin, & Rahmat-Samii, 2005; Migliore, Pinchera, & Schettino, 2005; Azaro, De Natale, Donelli, Massa, & Zeni, 2006a; Azaro, De Natale, Donelli, & Massa, 2006b; Azaro, Boato, Donelli, Massa, & Zeni, 2006c; Azaro, Donelli, Franceschini, Zeni, & Massa, 2006c; Fimognari, Donelli, Massa, & Azaro, 2007; Jin, & Rahmat-Samii, 2007; Donelli, Martini, & Massa, 2009; Chamaani, S., Mirtaheri, S.A., & Abrishamian, M.S. 2011; Ismail, T.H., & Hamici, Z.M. 2010; Bevelacqua, P.J., & Balanis, C.A., 2009; Lin, C., Zhang, F.-S., Zhao, G., Zhang, F., Jiao, Y.-C. 2010) and control (Boeringer, & Werner, 2004; Khodier, & Christodoulou, 2005; Boeringer, & Werner, 2005; Donelli, Azaro, De Natale, & Massa, 2006), and other interesting practical applications (Adly, & Abd-EL-Haftiz, 2006; Ho, Yang, Ni, & Wong, 2006; Genovesi, Monorchio, Mittra, & Manara, 2007; Cui, & Weile, 2006; Azaro, Donelli, Benedetti, Rocca, & Massa, 2008; Martini, Donelli, Franceschetti, & Massa, 2008). Among them, the development of CAD tools, aimed at providing the designer with an environment where a given circuit or microwave device can be characterized, investigated and also modified to obtain desired requirements, represents a significant example. As far as the modification of a given component is concerned, a key point is the development of microwave CAD environments (Azaro, De Natale, Donelli, & Massa, 2006) where the device or the circuit is modified automatically in an unsupervised way by the microwave tool itself with an improvement of performance. Such kind of CAD tools can be used to reduce the time to market of devices, and microwave circuits, and keep the commercial predominance. The unsupervised CAD tool do not require expert microwave engineers and they

are more efficient with respect to standard trial errors methodologies. Such useful automatic design tools have been the object of research since some years (Azaro, De Natale, Donelli, & Massa, 2006; Caorsi, Donelli, Massa, & Raffetto, 2002). The importance of the subject is widely recognized. In fact, it is well known that the design of new microwave devices and circuit are needed in several important areas, e.g., civil and military telecommunication systems, industrial and medical equipments. Standard microwave synthesis techniques are quite effective for the design of standard devices such as microwave filter, combiners, broad band coupler. Unfortunately, such approaches sometimes led to the development of impracticable, very expensive networks or unrealizable devices especially for very high frequencies. Moreover these techniques are not suitable when new technologies or materials such as meta-materials are considered. For these reasons, the design problem is usually recast as a global optimization problem. Formulated in such a way, the problem can be efficiently handled by the Particle Swarm Optimizer by defining a suitable cost function that represent the distance between the requirements and the obtained solution. In this framework and in recent years, many efforts have been devoted to the developments of unsupervised CAD tools for the control of smart antenna, the design and optimization of non-conventional antennas (Azaro, Donelli, Franceschini, Zeni, & Massa, 2006), and the development of passive microwave devices (Azaro, De Natale, Donelli, & Massa, 2006; Caorsi, Donelli, Massa, & Raffetto, 2002). Despite the successful results reported in scientific literature, the availability of effective CAD tools able to automatically develop microwave circuits and devices is still a challenge. In the following, Section 2, presents the solution methodology based on the use of PSO optimizer for the optimization and synthesis of microwave circuits and devices. A set of selected and representative synthesis results concerned microwave

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