Abstract: The design of microwave coupler is widely studied in the literature and gets adequate design for all frequency bands imposed. In this article, we present the application of the new technique recently developed and which was initiated by Bandler, the Implicit Mapping (ISM) to overcome the heavy and time-consuming task that follows the design of microwave components using a theoretical study. The application of ISM algorithm contributed to the optimization of asymmetric branch-line coupler whose theoretical development is very complex. The different phases of the simulation are also presented to demonstrate the robustness and effectiveness of this technique. The appropriate simulation software is Agilent ADS.

Key words : Branch-line Coupler, Optimization, Coarse Model, Surrogate Model, Implicit Space Mapping.

INTRODUCTION

The microstrip directional couplers have been widely used in microwave systems in mobile satellite communications, in radar systems and antennas. They are the basis of the quality and performance of all circuits due to their characteristics to be adapted to four ports. They can provide a variety of functions, such as power divider, matching between the inputs and outputs of the balanced amplifiers ensuring isolation and introducing the phase in a number of applications [1].

The four-port couplers are used with active or passive components, additional matching circuits are necessary to obtain the desired output performance. If they can be terminated in arbitrary impedances, no matching circuit is required and the total size of microwave integrated circuit can be reduced. For this purpose the first asymmetric couplers four ports were suggested by Ahn et al [2]-[5]. Compared to symmetric couplers, they have a very complex theory, their designs are very strict and their optimizations are very tedious. Due to the evolution of computer-aided design methods, optimization has become a widely used technique for the microwave circuits design. Also is it possible with the theory largely developed in the literature to design a suitable design for any application, in accordance with imposed specifications. However the most complicated and time-consuming phase is the optimization phase. Several optimization algorithms have been successfully applied to the synthesis of passive components, but their disadvantage is the time allocated to the simulation becoming very exhaustive, which has encouraged the scientific community to focus its research to adapt optimization algorithms which consume less in terms of computing time. In this paper, we present the application of one of the latest developments of optimization algorithms in microwave planar topology, called Implicit Space Mapping (ISM) [6]-[8], it is a non-linear optimization, this technique was introduced by Bandler [9]-[10]. This algorithm through its non-linear optimization achieves the objectives in minimum time. Similarly, we propose structures branch-line couplers but with different terminations, which further complicates the theory couplers developed in the literature, then this structure is optimized by the ISM technique, we present the basic concept of this technique and we describe the details of its implementation for the structure optimization using the Agilent ADS software [11].

ISM CONCEPT

ISM theory has been extensively developed in the literature [6]-[10], in this paper, the concept allows to implement the use of this technique is presented; the basic simulation tool is ADS and ADS Momentum software. The distinguishing feature that leads to the success of SM is that it allows at a complex electromagnetic model called "Fine Model" an effective optimization using an adaptation with a model based on the circuits theory called "Coarse model" with a rapid iteratively optimization. The original SM algorithm is proposed in 1994. In this algorithm a linear mapping is assumed between the space of "Coarse" and "Fine" parameters model. The least squares solution of the linear equation is used to associate the correspondence points between the two spaces [12]. The Implicit SM (ISM) algorithm is based on the idea of assigned parameters, in this method; a set of auxiliary parameters is extracted to fit the coarse model at the Fine model, while the coarse model is calibrated by the parameters and re-optimized to predict the best Fine model. ISM is a simple and effective approach SM, it integrates its mapping in the coarse model, and it automatically adjusts it in the extraction parameter process [13]-[16].

U is defined as a minimax objective function with upper and lower specifications. Figures 1 and 2 illustrate the general concept of spatial mapping technique for direct implantation of electromagnetic solvers.
RESULTS

The structure of the branch-line coupler is shown in Figure 3, the specifications for the optimization are given as follows, and the termination impedances are different values such as 30Ω, 60Ω, 40Ω and 50Ω:

For 5GHz ≤ f ≤ 5.8GHz and 6.2GHz ≤ f ≤ 7.5GHz,
-20dB ≤ S_{11} ≤ -10dB
-40dB ≤ S_{12} ≤ -35dB
-35dB ≤ S_{14} ≤ -25dB
-10dB ≤ S_{12} ≤ 0dB
-10dB ≤ S_{13} ≤ 0dB

For 5.8GHz ≤ f ≤ 6.2GHz,
-20dB ≤ S_{11} ≤ -10dB
-40dB ≤ S_{14} ≤ -35dB

For 5GHz ≤ f ≤ 7.5GHz,
-10dB ≤ S_{12} ≤ 0dB

The substrate used is FR4 with permittivity ε_r = 4.3, the height h=1.5mm, the loss angle tanθ = 0.0004 and the metal is copper, its thickness is T = 35μm.

The vector to be optimized is \( X = [W_h W_v L L_{in}] \) in mm. \( X^{(0)} = [5 5 15 15] \) in mm.

Port 1 : 30Ω
Port 2 : 60Ω
Port 3 : 40Ω
Port 4 : 50Ω

The results in Figure 4 show that the initial solution does not meet the specifications imposed above. The use band [5.8-6.2] GHz, the reflection coefficient \( S_{11} \) is around -2.5dB, the direct coupling \( S_{12} \) is attenuated at -15dB and isolation \( S_{14} \) is about -6.5dB, and except \( S_{13} \) coupling that meets the requirements of the specifications and has a value of -5.1dB. For the first ISM optimization technique, the results presented in Figure 5 occur tracking objectives during optimization.

Fig 1: the necessary resolver at ISM technical

Fig 2: Graphical representation of the ISM concept

Fig 3: Design of asymmetric coupler branch-line for the initial vector

Fig 4: Different \( S_{ij} \) coupler parameters simulated with ADS Momentum for the initial value of the vector X
CONCLUSION

The concept of implicit space mapping for design optimization was presented. ISM is intended to simplify the design process. This technique was successfully applied to model a branch-line coupler and optimizing its design parameters, with substitution the ‘Fine’ model time-consuming calculation by the ‘Surrogate’ model, which should be quick and valid in a wide range of parameters. ISM algorithm improves the efficiency of the optimization with a much reduced computation time. The conception of an asymmetric coupler showed the robustness of the ISM method.

REFERENCES


