(M)MIC ANALYSIS USING A HIERARCHY OF SIMULATION TOOLS CONTROLLED BY LAYOUT PATTERN RECOGNITION AND EXPERT KNOWLEDGE

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ABSTRACT

An intelligent Design Assistant has been developed connecting the layout input and the netlist level of a CAD system using a hierarchy of different simulation tools. This design utility represents a new approach based on layout pattern recognition and expert knowledge for automated choice and control of the most suitable tools.

INTRODUCTION

Today, the variety and complexity of available microwave CAD tools is increasing rapidly, so that commercial vendors have to explain to their high frequency designers which tools to apply to specific problems in the most efficient manner. An example of this is given in a recent contribution by HP EESOF outlining their different types and applications of simulators [1]. As outlined already in a recent overview by the co-author [2], this increasing complexity with which the designer has to deal, requires the use of expert systems and automation of the microwave design process in the future.

Unfortunately, this important technical field is still in a state of infancy, as a selection of recent publications reveals [3] - [7]. Recently, Brennan et al [3, 4] described an automated design environment based on an expert system in which a so-called project manager interacts with the designer and provides control of the CAD system up to the generation of layout and masks. Another system, developed by Robinson and Linton [5], addresses the routing and use of (M)MIC cells in the frame of a black box architecture. More specialized expert systems focus on a specific class of circuits like Parks and Linton [6] on microwave amplifiers and Nakamura et al [7] on microwave filters, respectively.

This contribution describes a intelligent process manager (Design Assistant) specifically developed to interpret a given layout, automatically subdivide the layout into components and substructures as well as choising the suitable simulation tools and automatically controlling the simulation process. This novel Design Assistant takes into account the fact, that a designer has to be quite knowledgeable in order to make the necessary decisions himself. In addition the automatic process control takes away from the CAD user a large amount of formulation work when preparing a simulation run in a system of different simulation tools.

DESIGN ASSISTANT

Figure 1 shows a schematic representation of the Design Assistant (dashed boundary), where the Assistant forms an intelligent layer between the layout and the interface level through which the different tools are addressed. Specifically, the described Design Assistant has been writ-

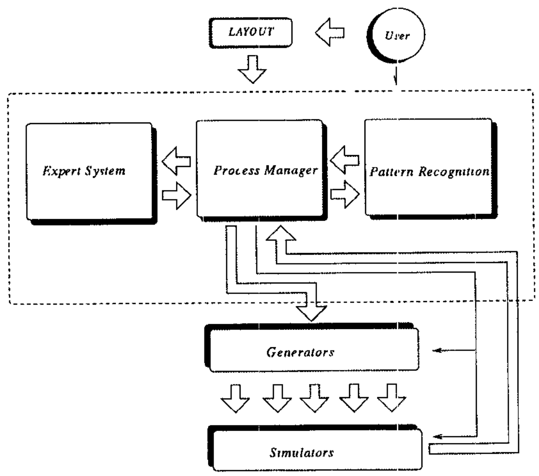

Fig. 1: Schematic visualisation of Design Assistant

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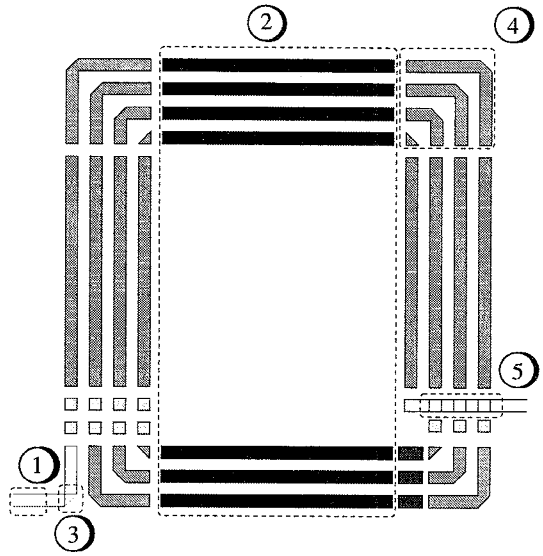
ten to provide the outlined functions between the mouse and menue driven graphics interface of an advanced commercial CAD tool [8] and a range of different netlists controlling the component modul library and various 2D, 2.5D and 3D electromagnetic simulation tools integrated within this CAD package. A brief outline of the various simulation tools addressed in this context is given in two recent publications [9, 10]. The graphics interface used allows to generate component shapes taken from a layout library and interconnect them in very much the same way as this is done by using conventional schematic capture. Independent of how a user composes a layout, the result of this process is a single or dual level metal (M)MIC layout which may even include active components in the form of black boxes (space holders). In the limit the layout generation of even a very complex geometry can, for example, be performed by using rectangular conductor shapes (strips) and just a few more elements like chamfered or unchamfered bends. The layout thus generated is then passed through a pattern recognition program, which divides the circuit into known classes of components and scans the circuit for multiple coupled conductors. This includes multiple coupled straight strips but also coupled bend structures, crossing conductors etc. In a next step, the expert system, which contains the treasured knowledge of a designer being familiar with the different simulation tools, decides which approach is used to simulate the individual parts of the circuit. Finally, the process manager generates the necessary netlists controlling the various numerical tools, generating automatically electromagnetic table data and produces the final netlist for the simulator that interconnects the selected library components and automatically generated S-parameter data.

In order not to force the designer to use the automatic structure partitioning and the associated choice of simulators, the Design Assistant offers a semi-automatic mode as an alternative. If, for example, the designer decides to neglect the coupling between two parallel strips, he can mark the two conductors with the mouse buttons. When afterwards the automatic mode is switched on again, the circuit will be repartitioned under consideration of this additional information. The semi-automatic mode also offers to the designer the possibility to replace a simulator already chosen for the calculation of specific substructure, by his own choice. Again the configuration and control of that replaced simulator will also be handled then automatically by the Design Assistant. So, the Design Assistant is even suited to support the experienced engineer in partitioning a circuit and using the available simulators intelligently.

EXAMPLE

A simple example is shown in Figure 2, where the layout of a spiral inductor geometry is shown, as it has been subdivided automatically by the Design Assistant. Essentially, the subdivision was made here into multiple coupled strips, multiple coupled bends and an underpass or airbridge structure, respectively.



1) microstrip line (*2D full-wave*)

2) coupled microstrip lines (*2D full-wave*)

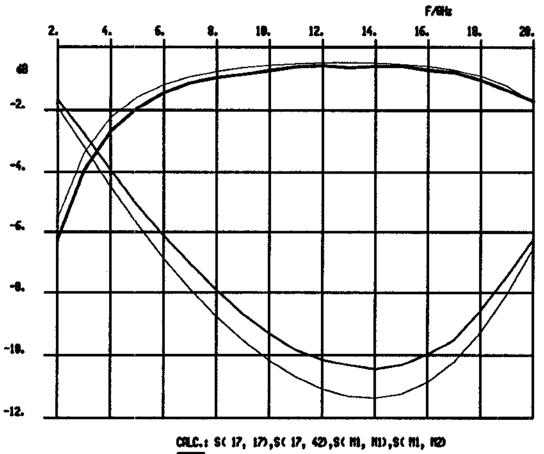
3) microstrip bend (*2D full-wave*)

4) coupled microstrip bends (*2D full-wave and 2.5D static*)

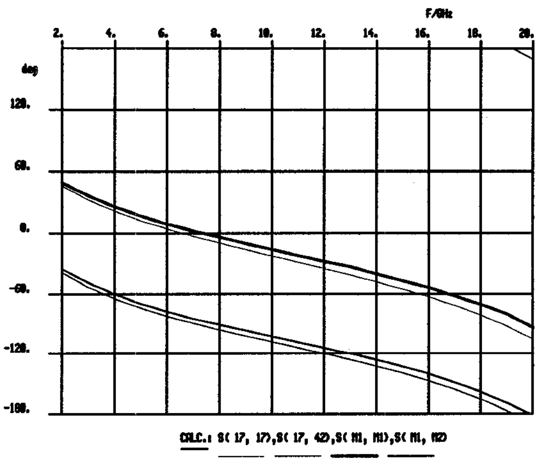
5) multiple-line crossing using underpass or airbridge (*2D full-wave and 2.5D static*)

Fig. 2: Segmentation of a spiral inductor into basic substructures

In Figure 2, the numbers attached to the partial structures as explainations indicate which components have been identified by the pattern recognition and which tools are used for their simulation. Note that the input from which Figure 2 results is a pure layout not yet making any assumptions on how this is broken up into different elements. The quality of this approach applied to the structure of Figure 2 is demonstrated in Figure 3, where a comparison between measured and simulated S-parameters is made for the spiral inductor. This has been part of a recent benchmark made under the European ESPRIT Program [11].



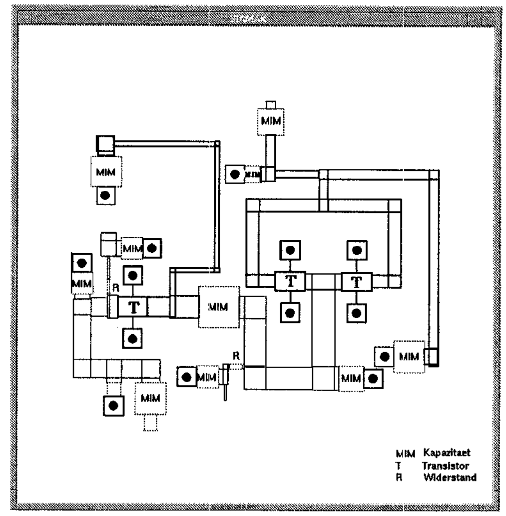
a) magnitude



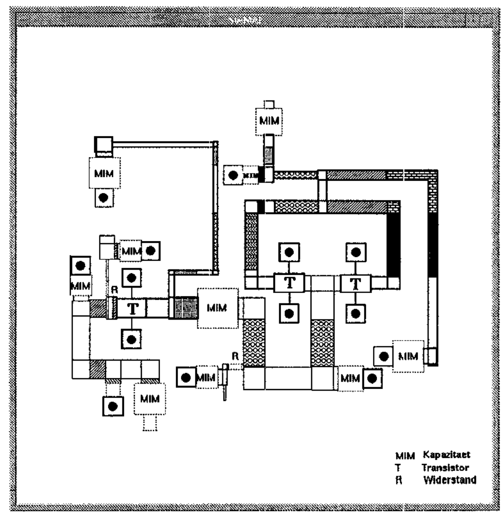
b) phase angle

Fig. 3: Simulated and measured S-parameters of a spiral inductor; simulation using the Design Assistant

As a further and more complex example, Figure 4a shows the layout of a medium power (M)MIC amplifier with some reasonable compaction already performed on the circuit. In comparison to this, Figure 4b shows the same layout with shaded conductors indicating where the Design Assistant has automatically configured the original layout and introduced conductor sections, straight and non-straight, with identified coupling. In the given layouts, the start version and the processed version, elements like the transistors (T), the MIM capacitors and the via holes are also identified. The Design Assistant can handle such structures in addition to the pure passive strip metallization. Also, this intelligent process manager chooses the most suitable process related simulation tools for such elements. A closer look of Figures 4a and 4b reveals that the conductors of the considered (M)MIC are sitting on two different metal levels. The lower level shows thin contours while the upper metal level is depicted with thick contours. In the case of Figure 4 the dielectric separation layer is polyimide.



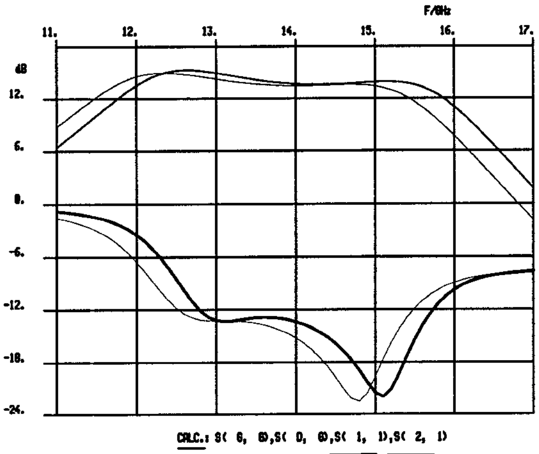
a) pure layout



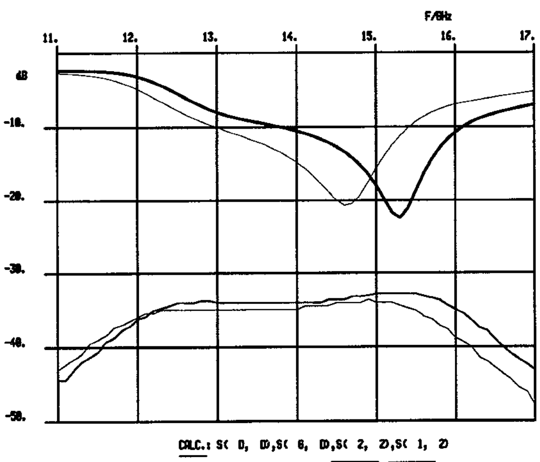
b) configured/reconfigured layout

Fig. 4: Layout of a 14.8 GHz medium power amplifier

The Design Assistant may also be used to automatically ***reconfigure*** a given layout that has been put together using (M)MIC component shapes from a library in order to account for coupling effects, that are not taken care of when putting the circuit together from isolated elements. This is well visable in Figure 4b, where coupled unequal conductors and coupled bends using different strip widths can be seen. In the latter case, the process manager selects automatically a general 2.5D full wave electromagnetic simulator, since a coupled bend module using unequal strip widths is not part of the simulator library. The effects of the reconfiguration on the simulation results are shown in Figure 5a and 5b, where the forward and backward reflexion and transmission parameters are shown, original circuit description (thin) versus simulated results after reconfiguration (thick, including parasitic coupling).



a) forward



b) backward

Fig. 5: Simulated S-parameters of amplifier; with (thick) and without (thin) using Design Assistant

CONCLUSION

The developed and described Design Assistant is believed to represent an important step towards user friedliness and design improvement for (M)MICs in a world of growing complexity and sophistication of CAD tools.

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