Electronic design assistance tool for circuit optimization: Application to microwave power amplifiers

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***Abstract* — An electronic design automation tool is being developed to assist the designer in optimizing RF and microwave nonlinear circuits. This paper reports the first version of this software dedicated to power amplifier design. This tool does not intend to simulate nonlinear circuits because CAD tools are already available and reliable. It intends to develop an efficient and predictive design process from reusable knowledge databases (components, circuits, methodologies, etc). The reported assistance tool has been implemented into an open computing environment using the DB2 database, C^{++} programs, template files, Java interfaces and the ADS software for simulation. The design process starts off from circuit specifications. Either, the history database is explored to find already carried out circuits demonstrating performances close to specifications or the component database is explored to select appropriate active device(s) and to generate a first-cut amplifier architecture meeting the requested specifications. Then, this assistance tool guides the designer at each step by proposing suited methods and specific helps (substitute generators, matching, nonlinear stability, linearity, etc) up to yield analysis.**

I. INTRODUCTION

Today, the number of design parameters is constantly increasing so that only experienced designers are able to get nonlinear circuits to work by controlling all the technological constraints, the critical choices, and the specific design methodologies. However, even in the case of a great technical expertise, the time devoted to investigations on new methodologies and architectures is reduced since a very significant time must be devoted to explore numerous unorganized documents not readily available in electronic form (datasheet, reports, etc). Moreover, the main design choices rely on many iterative calculations using device parameters to derive initial circuit dimensions (number of stages, etc) and to estimate circuit performances (power, gain and efficiency). Unfortunately, such calculations do not make use of structured data processing tools to handle device parameters, user-defined equations, etc. In particular, all steps of design methodologies require numerous specific techniques that are not easily controlled and implemented into simulators by inexperienced designers. Everyone can notice that design re-use and experienced designers reduce the development time but at the same time, circuit re-use and design apprenticeship generally run up against the difficulty of recording and distributing experience and knowledge.

Indeed, RF and microwave system performances as well as design cycles can be greatly improved by developing suited CAD/EDA tools [1]. If reliable CAD tools are already available for nonlinear simulations, efficient EDA tools have to be developed and coupled to knowledge databases and existing CAD tools in order to facilitate the use of electronic datasheets and specific design methodologies for the various nonlinear circuits (amplifiers, oscillators, etc). Moreover, the lack of experienced designers can be significantly compensated through the use of efficient and predictive design processes.

In this paper, we report an automatic data-processing tool [2] that effectively assists the designer in optimizing power amplifiers. Organizing electronic datasheets, documents, simulation files, and user-defined calculations in an open computing environment significantly reduces the design cycle. Well-suited design methodologies for nonlinear simulations are already implemented (substitute generators [3], linearity analysis for complex stimulus [4], linear and nonlinear stability [5], etc). Specific help files are allocated to each method. In addition, the circuit re-usability and the knowledge diffusion are key points based on a design oriented database structure. The main objectives of this design assistance tool are:

- to establish a re-usable knowledge base for the design of nonlinear microwave circuits,
- to enable each designer to take advantage of specific experiences coming from other designers, since the knowledge base can be easily improved with the integration of user-defined methodologies,
- to ensure a fast implementation of design methods and suited topologies in a circuit simulator,
- to integrate documentation databases with great storage capacity and to enable a fast access to information by using query languages,

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- to propose justified design choices (device(s), circuit topology, methodologies, re-use, etc) while leaving a total control to the designer.

II. Computing Environment

The general data-processing configuration of the design assistant integrates several basic elements such as a database, template files, built-in and user-defined programs, and interactive interfaces.

1. Database

The database used for the development of this application is Universal DB2 from IBM. The key point of the database development relies on the definition of its architecture whose role is to implement well-suited information storage for device technologies, methodologies, and designs. The architecture of this database is made of three principal groups (Fig. 1) :

- The transistor group stores the available information on foundries and component technologies with their associated specifications such as device parameters, performances, measurements, simulations and models.

- The topology group (sub-circuit level) independently stores the various types of sub-circuits making up the designs (matching circuits, generic template files, etc). From their associated performances, these files can be re-used as initial sub-circuits saving time for a new design. Indeed, when starting a new design, pre-defined programs explore the database groups to select well-suited device(s), amplifier architecture and initial sub-circuits meeting the design objectives. Finally, when a sub-circuit has been modified during a design process, it becomes a new sub-circuit file stored in the topology group with its performances.

- The design group (circuit level) stores all suitable informations on a particular design such as its initial specifications, its performances (simulations /measurements), the links with the sub-circuits stored in the topology group, the reports, the name of the designer, etc. So, from its associated specifications, an entire design can be re-used at the circuit level.

Therefore, the database has been defined to store and connect each information on devices (datasheet, models), designs (devices, matching circuits, performances, simulation files, measurements, etc) and methodologies (template files, documentation, etc). Each final circuit is split into basic sub-circuits (matching and biasing circuits, etc) with associated performances (impedance levels, losses, frequency, etc) and simulation files so that re-usability is ensured at the circuit-level and also at the sub-circuit level.

2. Template files: Generic and instance files

The template files correspond to specific simulations (substitute generators, nonlinear stability, optimization, etc) or topologies (matching and biasing networks, stabilization circuits, etc). Each template file is stored in the database with its allocated specifications so that to ensure its re-usability.

The template files are made of generic files (initial state of a topology or a simulation) and instance files (new state of the generic parameters after optimization for new specifications). The generic sub-circuits are initially stored in the *Topology Group* to be used as starting points for new designs. When a generic file is modified during a design process, it becomes a new instance with its new specifications stored in the database. Thus, this new instance can be re-used as a starting point for other designs if among all the existing instance and generic files, its own specifications are closest to the required ones. The template files have been developed for the ADS simulator.

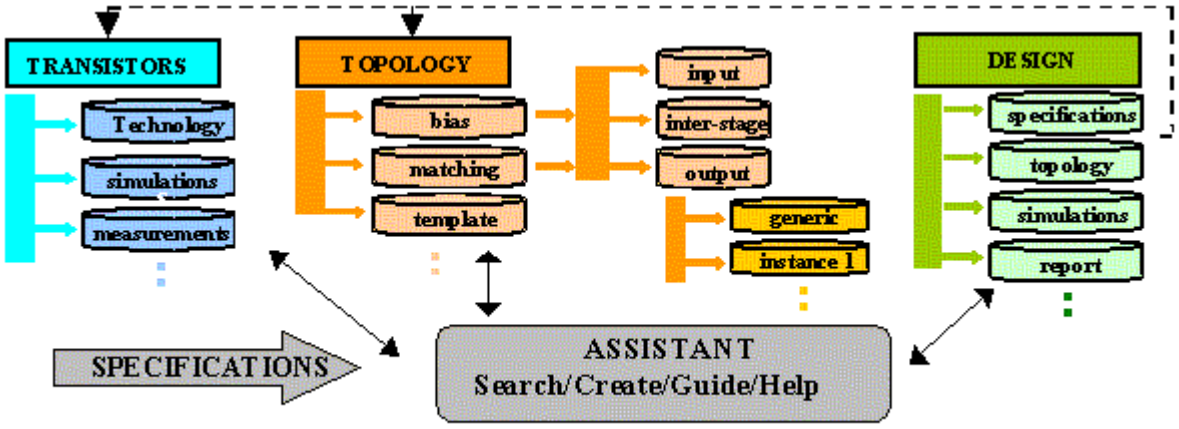

Fig 1 : General architecture of the database

3. Built-in and user-defined programs

Once the circuit specifications are assessed, a classic design process starts off with many iterative calculations to investigate and select devices (exploring all available transistors, scaling gain or power, etc) and to determine possible circuit architectures (number of stages, losses in matching circuits, number of transistors by stage, etc). Moreover, during the design process, other calculations are required such as the control of DC and large signal ratings of active and passive devices. Generally, all these calculations are time-consuming and not organized to process large amounts of data (foundry datasheets).

In order to save time and to methodically explore all possible circuit configurations, we have developed specific programs coupled to the database. These programs enable the designer to carry out fast calculations (device scaling, architectures, etc) on large amounts of data (device parameters and performances, circuit topologies, ratings, etc). From circuit specifications, pre-defined programs have already been implemented to automatically propose design choices (device(s), number of stages, bias, methodologies, etc) and also re-usable sub-circuits or circuits. Such programs are applied to the numerous datasheets stored in the database and facilitate the selection of well-suited devices and circuit configurations meeting the design specifications. Moreover, the computing environment has been structured so that the C^{++} implementation of user-defined programs is easy and fast.

4. Design guide

The design guide and its help files are readily available in electronic form (Word, Acrobat) and make use of hypertext techniques to easily link and update related information (assistance, bibliography). The design guide describes the design process as a flow chart. It proposes a step by step design from circuit specifications to final circuit layout. Each step is associated to specific methodologies and generic simulations (template files). However, all design steps are dependent so that the design guide implements multiple possible paths from one step to another (e.g. biasing circuit synthesis directly influences the stability correction). The first version of this guide is dedicated to power amplifier design.

5. Library search

For an easy selection and consultation of a given information stored in the database (textual documents, design reports, design kit, datasheets, etc), the design assistant makes use of query language capabilities. This technique enables the designers to quickly access specific information by appropriate requests. As an example, basic query processes have already been implemented and coupled to the database (selection of devices or circuits meeting a list of specifications imposed by the designer, etc). Moreover, user-defined requests can easily be implemented and coupled to the design database by using interface capabilities.

6. Interactive interfaces

The interactive interfaces between the design assistant and designers are developed in Java using the VisualAge software from IBM. The main design assistance program includes several interfaces implementing fast connections with the database, the running of specific programs, the design-level management by designers and the database-level management by a super-user (login, password, backup, datasheet input).

III. Modular Assistance for Power Amplifier Design

Initially, this investigation program was aiming to implement software tools making it possible to develop computer-aided design assistance for microwave power amplifiers. Nevertheless, the general data-processing structure has been organized to enable the addition of future assistance modules for other types of nonlinear circuit (oscillators, mixers, etc).

In this first version, the list of specifications and design methodologies for power amplifiers were defined in collaboration with the French Space Agency (CNES). In addition, it was decided that the simulation template files should be developed for the ADS software. However, it should be mentioned that these files are the only data-processing structures dependent on the simulation software so that the design assistance could be applied to any nonlinear simulator since template files can be adapted to another format.

After the designer enters his login and password, the first interface (root menu) of the design assistant is made of the following menus:

1. Administration (super-user menu)
2. New design
3. Load design
4. Built-in programs
5. User-defined programs
6. Methodology templates
7. Data search
8. Document search
9. Help

It should be noticed that the specialized design guides of electronic functions (amplifiers, oscillators, etc) appear in sub-menus of menus 2 and 3.

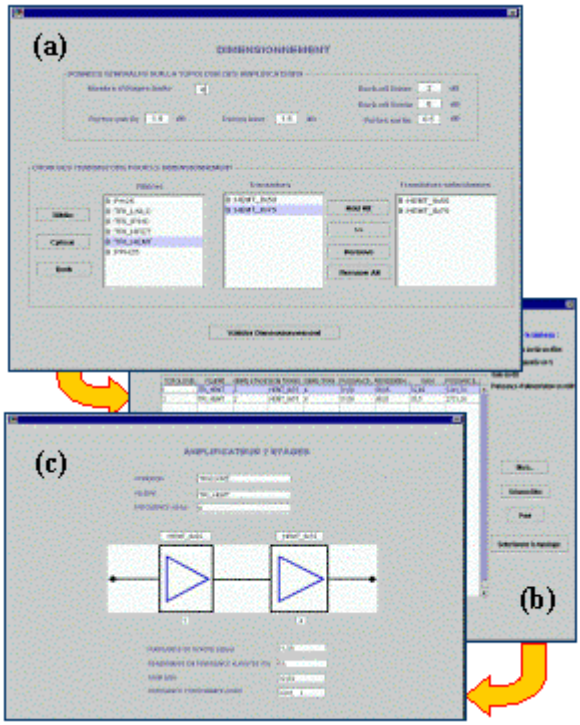

Fig 2: Assistant interfaces following specifications: (a) User-defined constraints on device selections and amplifier configurations; (b) List of possible configurations; (c) Display of selected results.

When beginning a new design, the designer will be asked to enter the circuit specifications with weighting goals related to each major objective (none, optimum, minimum, maximum, etc). Then, from these specifications, the design assistant for power amplifiers proposes several levels of assistance such as:

- Selection of suited devices and possible amplifier architectures (block-level) meeting the required specifications: The designer may ask to explore all possible configurations or only constrained configurations (device or foundry imposed, limited bias voltages, limited number of stages, etc). As an example, Figure 2 shows the three interfaces enabling the designer to run this specific design assistance and to display the configuration results. Once the designer has settled upon the amplifier configuration, other interfaces enable him to load the device models and the sub-circuit files in his working directory. Then, the design guide menu can be selected to start the design process by consulting and loading the template and help files implementing each specific methodology.
- Selection of already stored amplifier designs whose specifications are expected to meet the required ones by slight modifications of the initial sub-circuits (similar frequency, similar power, etc). This assistance level ensures the circuit re-usability to save development time.

IV. Conclusion

The combination of network-distributed data processing tools with nonlinear simulators provides an efficient way to implement design assistance. Such tools enable to efficiently manage a set of documents (datasheets, technical documents, state of the art, design rules, etc) and applications (programs, simulators, etc) in a same computing environment.

We have reported here the development of a specialized module of design assistance for power amplifiers. The main perspectives of this investigation are related to the development of future design assistance modules for other electronic functions. The next design assistance module will be devoted to free and controlled low noise oscillators.

In conclusion, it is important to point out that the design assistance must be implemented with the aim of making the designer's task easier without setting the design knowledge in a given state. With this goal, it was of primary importance to develop an open and user-friendly data processing system making it possible to easily integrate new software tools and to facilitate the description of new design knowledge.

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