An Alternative Approach for Designing Microwave Circuits using a Personal Computer

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Abstract—A new computer-aided design program, *Puff*, for designing microwave integrated circuits will be presented. To demonstrate the various features of *Puff*, predictions for a 10 GHz patch antenna with a stub matching circuit will be compared with measurements made with an HP 8510 network analyzer.

Introduction

Puff is a computer-aided design program for the analysis and design of microwave circuits. The program runs on an IBM PC, PS/2 or compatible, and features a single interactive-graphics screen which displays all aspects of the design (Fig. 1). Circuit elements, such as transmission lines, coupled lines, and lumped elements, are selected from a parts list and drawn on the screen using cursor keys. The circuit analysis can then be performed directly from the screen drawing. *Puff* is easy to use, and has been used in microwave courses in university and industry throughout the US and the rest of the world. Since its announcement in June 1987 the authors have received over 2000 requests for *Puff*.

Apart from its ease of use, one of the main advantages of *Puff* over existing CAD programs is its openness. The models used by *Puff* and the analysis methods are thoroughly documented, and users are invited to contribute to the programs development. Feedback from users has been enthusiastic and has led to several refinements in the program. These enhancements have included more accurate modelling of losses and dispersion, improved mask-making capabilities, better hard copy facilities, and an HP 8510 network analyzer interface.

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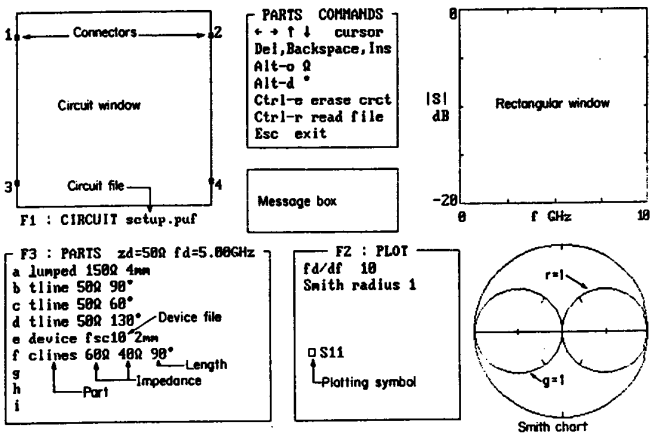

Figure 1 Screen display of Puff with the Enhanced Graphics Adaptor. The screen is divided into three main windows. Components are selected from the parts window in the bottom left are laid out on the circuit board in the top left corner. Result of the analysis are plotted on the right hand side of the screen in the plot window.

Enhancements

Using a standard dot-matrix printer, *Puff* generates a medium resolution artwork mask in as little as 30 seconds. However, some users indicated a preference for more sophisticated pattern generation. Some also required an inverse mask for compatibility with their fabrication process. In addition, precise masks are needed for fabricating circuits to verify more accurate models. For these reasons we have developed a program called *Picasso* to complement the output mask-generating capacity of *Puff*. *Picasso* is a stand alone program used to produce rubylith masks on a standard HP 7475A (or compatible) plotter, equipped with a diamond tipped cutting stylus. *Picasso* translates a list of transmission line dimensions and positions, created using *Puff*, into HP-GL (Hewlett-Packard Graphics Language) commands and sends them to the plotter via the serial port. *Puff* creates the circuit file in the Caltech Intermediate Format (CIF) [2], originally developed for use in VLSI CAD programs. In keeping with the philosophy of *Puff*, *Picasso* is also easy to use; no special commands need to be memorized.

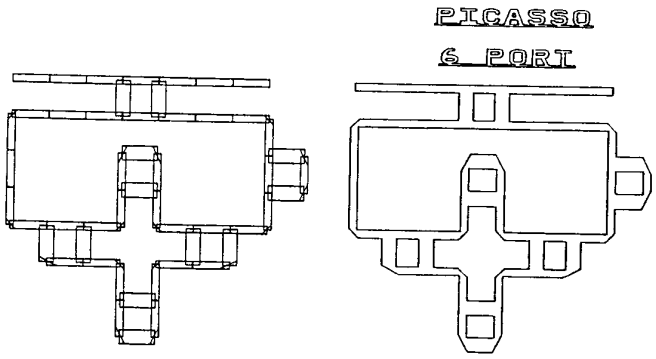

Figure 2 Artwork for a six-port network design, generated by Picasso showing the mask before and after the automatic line removal algorithm.

Picasso takes advantage of a unique algorithm which was specifically developed to eliminate all unnecessary cuts in the rubylith where parts intersect (Fig. 2). This relieves much of the tedium involved with peeling bits of rubylith away from its backing by allowing adjoining parts to be peeled off in one large strip. There is a provision for labeling the mask, and the user also has the option of changing the photographic magnification factor from within *Picasso* to enlarge or shrink the mask. Ulano RM3 (3 micron thickness) rubylith, cut out with an AP Microwave (1921 Cape Horn Drive, San Jose, CA 95133) diamond-tipped "MiCutter" stylus has yielded excellent results. The program is very fast—the entire process of designing a circuit with *Puff* to obtaining a quality rubylith mask with *Picasso* can be done in a matter of minutes.

Comparison between theory and experiment is very important for improving modelling and the accuracy of *Puff*. With this in mind, a second auxiliary program called *Iris* (messenger of the gods) was developed. *Iris* takes measurements from the HP 8510 and produces a device file that can be read by *Puff* and overlaid on circuit simulations for comparison. IBM PC to HP-IB communication is achieved using a Capital Equipment Corporation interface board. Device files can also be produced by *Elf*, a program which drives an HP 8410 network analyzer [3].

Design Example

Figure 3 shows a half-wavelength patch antenna design using *Puff*. The radiation resistance is modelled by a shunt resistor with conductance given by $G_{rad} = 2/45\,(w/\lambda_0)^2$, where w is the patch width. A single stub is used to match the reflection coefficient, and a series resistor is included to model losses in the microstrip. The patch was fabricated on Duroid (dielectric constant of 9.8) using the dot-matrix artwork mask. Superimposed on these simulations are the HP 8510 measurements generated by *Iris*, which are contained in the device file "patch".

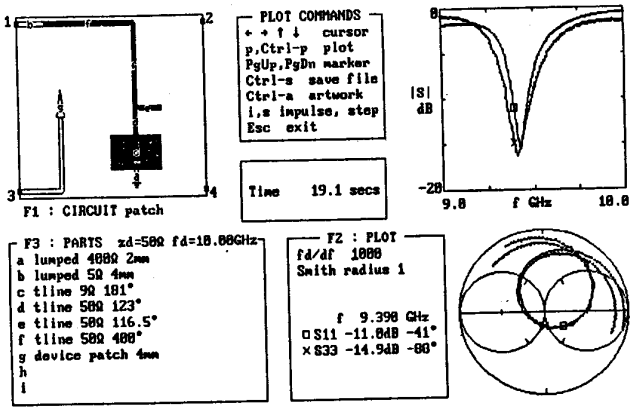

Figure 3 Screen dump of a patch antenna simulation showing Puff's predictions overlaid with measurements made on an HP 8510 interfaced to an IBM PC.

Acknowledgments

The patch antenna design is one of the laboratory experiments performed by graduate and senior students in a microwave integrated circuit class at Cornell University. The class has received generous support from the Rogers Corporation and Raytheon.

References

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