EXPERT SYSTEM FOR MICROWAVE FILTER DESIGN

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ABSTRACT

An expert system for microwave filter design, "fire" (FIlteR dEsigner), has been developed to make a straightforward optimum design of edge-coupled microstripline bandpass filters. The system incorporates the design expertise and knowledge of experienced microwave-circuit design engineers as a knowledge data base, necessary design data as a microwave data base, and commercially available microwave circuit simulators. It can also generate MIC pattern layout data on MT(magnetic tape). Thus the system makes it possible even for inexperienced engineers to design bandpass filters with experienced engineers' design quality in much shorter time than conventional design procedures.

INTRODUCTION

In conventional edge-coupled bandpass-filter design, an engineer first chooses an optimum prototype filter (number of stages and g-values) satisfying given specifications and then determines even- and odd-mode impedances (Zoe's and Zoo's) of coupled microstrips. Then he has to select the type and thickness of dielectric substrate by considering specified frequency and temperature ranges, circuit size and insertion loss. An adequate selection of substrate material and thickness is important to obtain practically realizable and satisfiable design. It is much dependent on the design experience and data. For the selected substrate he then determines the width, spacing, and length (including corrections for the open-end fringing capacitances) of the coupled microstrip lines. With these data, he then carries out microwave circuit simulations using commercially available CAD softwares to check the perfomance. If the perfomance does not satisfy the requirements, he has to go back to one of the earlier steps. If the design is found good, he proceeds to determine a circuit pattern layout by taking physical constraints such as circuit size and input/output terminal positions into account, and finally obtains photomask data. If one fails to determine pattern layout, one has to return to one of the previous steps.

One of the problems of the above-mentioned conventional design procedure is that one has to take design margins for the given specifications and make trade-offs at certain design steps. To do this, an inexperienced engineer has each time to consult a design manual that fully and systematically describes engineering experience and knowledge.

The second problem is that the design procedure is piecewise or not unified, i.e. the engineer must go back and forth between his desk and a CAD terminal. Even if he is an expert engineer of microwave circuit design, he spends a lot of time to get final drawing or photomask data.

The present expert system, "fire", has been developed to solve these problems. It makes it possible even for inexperienced engineers to design bandpass filters with experienced engineers' design quality in much shorter time than by conventional design procedures.

EXPERT SYSTEM DESIGN

The process of our expert system design is as follows.

First, knowledge acquisition has been done by a KE (knowledge engineer) asking expert microwave-circuit engineers about their filter design practice and know-hows as well as their technical background information such as books [1], papers [2]-[5], and design manual or data.

As a second step (knowledge classification), the acquired knowledge has been analyzed and classified by the KE according to its type, i.e. static or dynamic knowledge, heuristic or algorithmic, rule or data and so on.

Thirdly, the flow, relation and structure of the classified knowledge have been defined by employing frame transition diagram and common knowledge list [6].

Finally, the expert system has been implemented using ASIREX which is an expert system shell supplied by Toshiba. The ASIREX belongs to a second generation AI (artifificial intelligence) tool and has both production system and frame system which are popular methods in AI.

STRUCTURE OF EXPERT SYSTEM

The structure of our expert system consists of three parts. The first part is the knowledge processing section. It includes design rules as a knowledge data base and numerical data as a microwave data base. The knowledge includes how to take design margins and choose substrate from the viewpoints of frequency, temperature, and insertion loss, how to compensate for the frequency dispersion, and how to fit MIC patterns in the specified area. The computational formulae for calculating the required number of stages, g-values, Zoe, Zoo etc. are also included in the knowledge data base.

The second part of the system is the electrical CAD section. This part operates as a microwave circuit simulator. Commercially available CAD softwares capable of UNIX procedure call can be used in this section. In our expert system, UNIX procedure calls are employed throughout to communicate with the used CAD software without any human interface.

The third part of the system is the

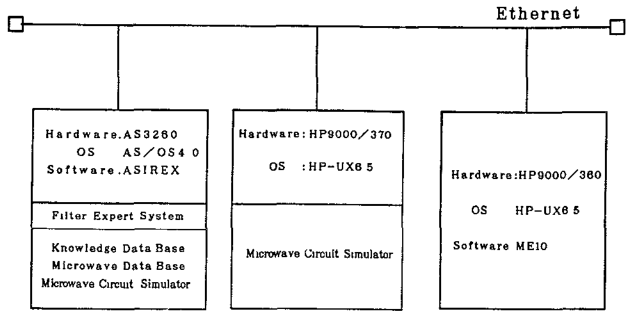

Fig.1. Environment of expert system.

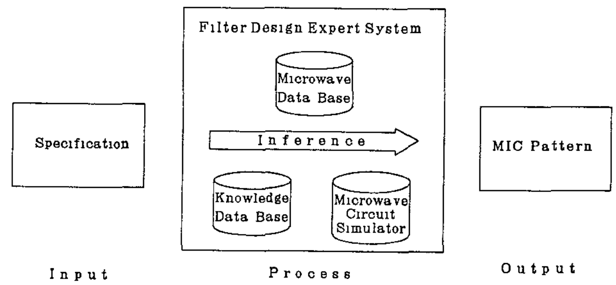

Fig.2. IPO of expert system.

mechanical CAD section. The system generates mechanical CAD data for drawing MIC patterns, writes them into UNIX files and finally sends the data file to the mechanical CAD workstation such as ME10 supplied from HP. All these three parts operate interactively on workstations.

Fig. 1 shows the expert system environment. The first part of the system is built on a TOSHIBA AS3260 workstation (equivalent to the SUN 3/260 workstation), the second part of the system is built on an HP9000/370 workstation, and the third part is built on an HP9000/360 workstation. All the workstations are networked by Ethernet.

Fig. 2 shows IPO (Input, Process and Output) of the expert system. The user inputs the filter specifications to the specification frame and commands to start inference. Then the system starts inference operations involving the knowledge data base, the microwave data base, the microwave circuit simulator and the mechanical CAD macro language translator. Finally the system generates and sends the circuit pattern layout data to the mechanical CAD workstation.

Fig. 3 shows a man-machine interface of the expert system. The window on the left half of the screen shows part of the microwave data base. The user input of specification data is seen in the

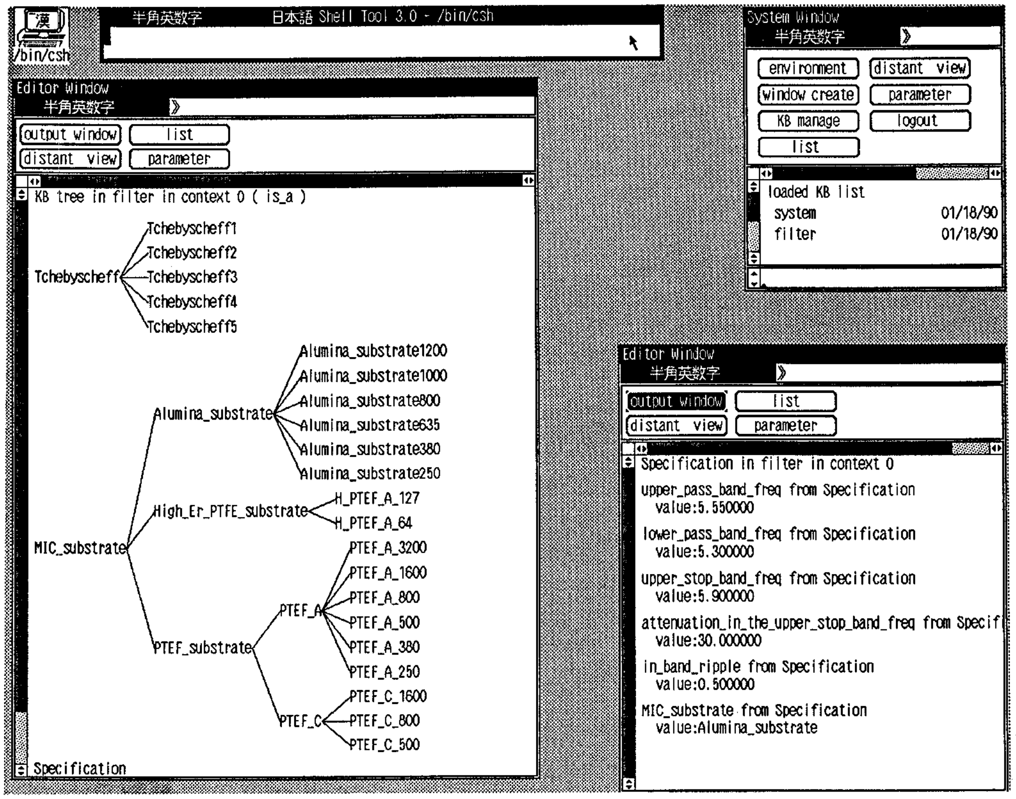

Fig.3. Display showing part of microwave data base (left) and specification frame (lower right).

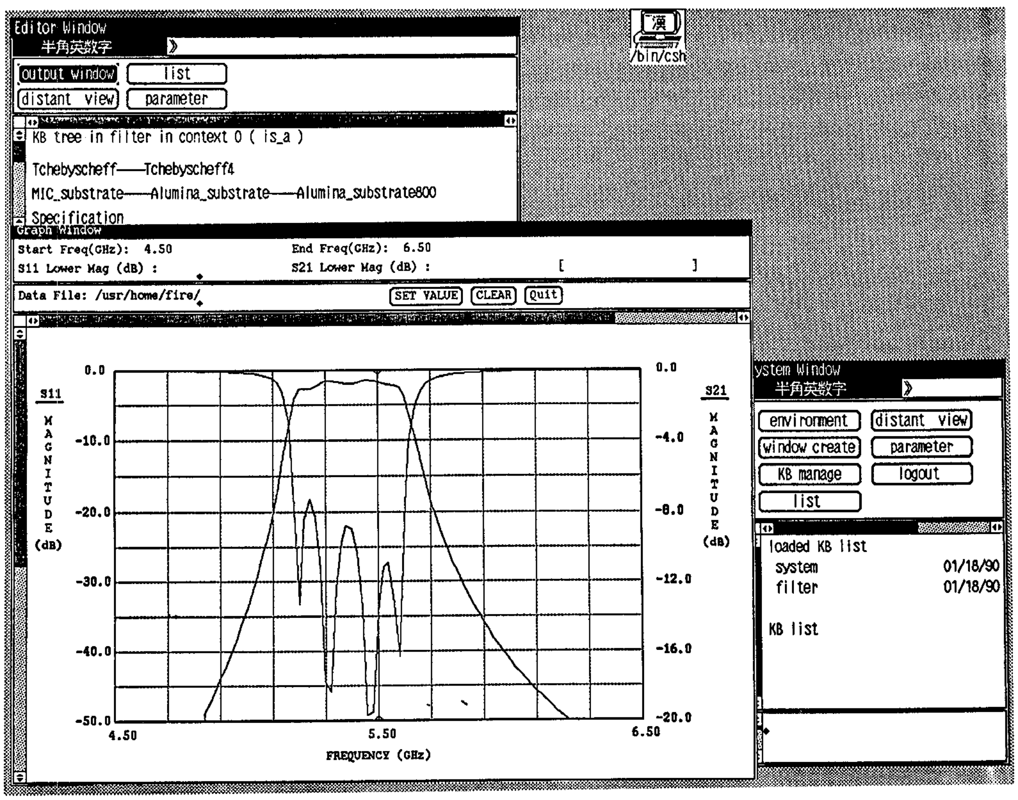

Fig.4. Example of microwave circuit simulation by expert system.

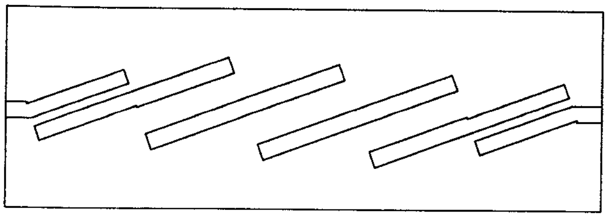

Fig.5. Example of bandpass filter pattern layout designed by expert system (output from ME-10).

specification window on the lower right of the screen.

Fig. 4 shows an example of microwave simulation for an MIC bandpass filter which has been done by the expert system. The specifications given to the expert system are the upper pass band frequence of 5.55 GHz, the lower pass band frequency of 5.3 GHz and the in band ripple of 0.5 dB as seen on the screen display shown in Fig. 3. After inference, the expert system selected a substrate with a 0.8 mm thickness and a four-stage filter, then it outputs the window in Fig. 4 indicating the simulated filter performance.

Fig. 5 shows the MIC pattern layout for the filter in Fig. 4, displayed on the screen of the mechanical CAD workstation. The workstation can also output the pattern layout data in MT for photomask generation. The expert system generates the final pattern layout data in only five minutes after it starts inference operation.

CONCLUSION

The effectiveness and usefulness of introducing expert systems into microwave CADs have been demonstrated by realizing an expert system that can perform a straightforward design of MIC bandpass filter with experienced engineers' design quality once filter specifications are given. The system can automatically output MIC pattern layout data for photomask generation. Since the system is built on three UNIX workstations networked by Ethernet and incorporates commercially available CAD softwares, microwave enginners can design efficiently in a unified computer environment. The method and concept of building such an expert system are easily applicable to other microwave circuit designs and provides a means towards the realization of intelligent microwave CAD systems.

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