A Functional Genome Optimization Method for CPW Filters Design

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Abstract—**This paper presents a functional genome optimization method to design CPW bandpass and lowpass filters. Due to the difficulty of modeling CPW structures by lumped elements in high frequency, this design provides a method based on full wave CPW models. Then GA is used to optimize the placement of structures that meet desired specification. A band-pass and a low-pass filters designed in X-band (10GHz) are fabricated and measured. The theoretical and experimental performance shows good agreement, therefore proves the applicability of this method.**

I. INTRODUCTION

The coplanar waveguide (CPW) has gained increasing interest in recent years, since it has several advantages over the microstrip line, such as less dispersion, easier integration with solid-state active devices, and the possibility of connecting series and shunt elements to the active devices without the need of via holes through the substrate; however the parasitic effects are inevitable. The equivalent lumped circuits for CPW elements have been demonstrated in literatures [1]-[4], but could not model the corresponding frequency response over a wide frequency band owing to the parasitic effects. Therefore it is not easy to design a wideband CPW filter with these elements by the insertion loss method.

The GA is first proposed by J. Holland in 1975, and some applications for optimization of electromagnetics have been proposed [5]. It is a global optimization technique and possesses versatile capabilities for both continuous and discrete problems. In combinatorial optimization problem, the GA is more suitable over other optimization methods.

In this study, the solution space in the GA consists of different types of basic CPW elements shown in the literature [1]-[3]. Their S parameters are simulated by full wave solver Ansoft Ensemble 8.0 and stored as a database. The GA is applied to search for the optimal combination of cascaded CPW elements so as to best fit the design specifications, which could be quite arbitrary.

II. FUNCATION GENOME OPTIMIZATION METHOD

In this section, a functional genome approach for CPW filter design is demonstrated. To begin with, a library is constructed with different types of basic CPW elements, over each of which different sizes are employed. . Take structure 2 in Fig.1 as an example of the basic CPW elements, length L is changed and simulated to get various responses in designed frequency band. The results are stored into a library. For the present application, the library includes 18 categories and each of which there are 15 structures.

Owing to the finite number of feasible solutions, the nonlinear optimization process is a combinational optimization problem. The encoding representation for GA has separate consideration. First of all, all constructed structures are numbered into

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integers. In order to construct a smooth fitness landscape of GA the similar structures are encoded into the neighboring numbers. The responses for the structures of the same type have the same category name; but numbered according to the sizes. In the same category, the numbered names of structures increase as the size increase. Such an encoding scheme makes the GA to search for optimal solutions more efficiently.

Then, the selection operator of GA is implemented by the conventional tournament selection. The procedure follows the typical GA approach [5] and is briefly mentioned here. In our implementation, one-cut-point crossover is implemented with 50% crossover rate owing to the total bits of 4 for each individual. Following the crossover, the mutation operator is implemented with 1% mutation rate by migrating the selected gene to its neighborhood. The range of gene migration by mutation operation is decreasing exponentially to the next one of the genes as the generation increases. All infeasible solutions generated by mutation operator are discarded and the mutation operator is applied in the GA again to keep the original population size.

III. DESIGN of CPW BANDPASS and LOWPASS FILTER

Two optimization designs of bandpass and lowpass filters are fabricated and measured in this study. The design specifications are listed in Table. I. The design steps are described as follows.

1. Choose several types of CPW structures and simulate them in the desired frequency band. In each type the size of structure is tunable to obtain different frequency response. The number of structures should be sufficient for the solution space of the GA to achieve satisfactory performances.

2. Objective function is specified in the frequency band of interest. The detailed objective functions for the passband and stopband in our design are shown as below.

Passband: Objective function= $\mathrm{Max}\{|S_{11}(f)|$ and $|S_{22}(f)|\}$

Stopband: Objective function= $\mathrm{Max}\{|S_{21}(f)|\}$

where f is the frequency band described in Table .1.

The GA searches for the minimal objective function value in the solution space. In our design approach, it is easy to design filters with arbitrary bandwidth and cutoff rate, only if the passband and stopband frequency's range is changed.

3. Without loss of generality, two 4-element cascaded filters are demonstrated in this study. The GA is applied to search for the optimal placement of CPW elements to meet the specifications. The S parameters of two cascaded elements is shown in (1), where S' is the S parameters of element 1, S'' is element 2's S parameters [6].

$$\begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} = \begin{bmatrix} S'_{11} + kS'_{12}S'_{21}S''_{11} & kS'_{12}S''_{21} \\ kS'_{21}S''_{21} & S''_{22} + kS''_{12}S''_{21}S'_{22} \end{bmatrix} \quad \text{Where } k = \frac{1}{1 - S'_{22}S''_{11}} \qquad (1)$$

	Pass band	Stop band
LPF	DC~10GHz	11~20GHz
BPF	9.5~11GHz	5~9GHz, 11.5~20GHz

Table .I Specification of this

IV. SIMULATION and MEASUREMENT

The two types of CPW filters are fabricated on a 20-mil Duroid RO4003 substrate with $\varepsilon_r = 3.38$ and loss tangent = 0.002. The topology of CPW lowpass filter is shown in Fig.1. As indicated in this figure, four CPW elements are cascaded to assemble this filter. The simulation results of the return loss and the insertion loss for CPW LPF are shown in Figs. 2 and 3, respectively. The frequency response of the GA optimization results ranges from 5 GHz to 20 GHz owing to the frequency range of constructed full wave database. Also included in the figures are the measured results, over which the connector loss might deteriorate the performance. Other than that, the measured and simulated results show good agreement. With the present method, the lowpass filter having a very sharp cutoff rate and a wide rejection band can be readily achieved.

The bandpass filter topology is shown in Fig.4. The simulation results of the return loss and the insertion loss for CPW BPF are shown in Figs.5 and 6, respectively. After the functional genome optimization, simulation and measurement are in good agreement and both meet the specifications well. The suppression of the second harmonic band for BPF has been easily done as shown in Fig.6. It is worthy mentioning that other types of CPW filters, such as bandstop, highpass, and even filters of some special requirements, can be designed in the same approach as well.

V. CONCLUSIONS

A systematic functional genome approach to design CPW filters using GA is demonstrated in this study. It can implement different types of filters using the same design approach, as long as the number of models is sufficient. It is a very effective approach to design CPW filters of desired specifications.

VI. ACKNOWLEDGMENT

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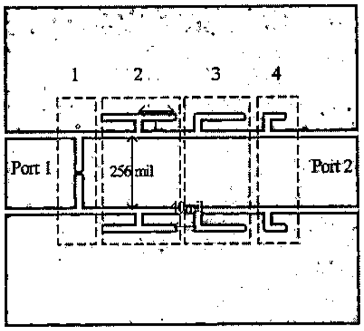

Fig.1 CPW LPF layout structure

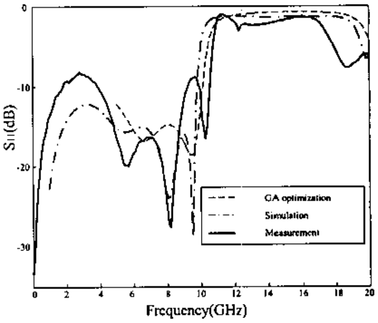

Fig.2 Return loss of LPF structure in Fig.1

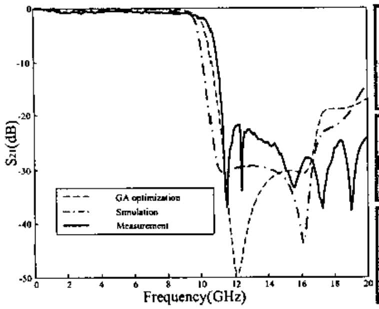

Fig.3 Insertion loss of LPF structure in Fig.1

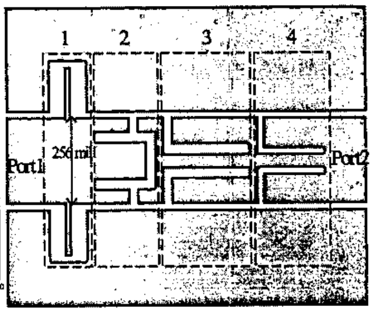

Fig.4 CPW BPF layout structure

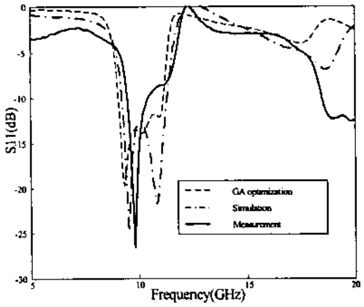

Fig.5 BPF Return loss of BPF structure in Fig.4

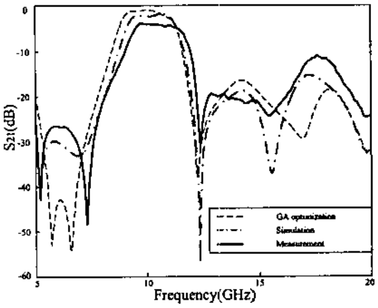

Fig.6 Insertion loss of BPF structure in Fig.4