COMPUTER AIDED DESIGN OF EVANESCENT MODE WAVEGUIDE BANDPASS FILTER WITH NON-TOUCHING E-PLANE FINS

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ABSTRACT

This paper presents an efficient computer aided design procedure for the evanescent mode waveguide bandpass filter with non-touching E-plane fins. The design procedure systematically utilizes a look-up table containing the scattering parameters of E-plane fins. In addition, this design procedure incorporates the correlations between each filter parameter and each characteristic of the filter into its algorithm.

INTRODUCTION

The characteristics of the evanescent mode waveguide bandpass filter with non-touching E-plane fins have been analyzed previously [1, 2]. However, the reverse process, that is, a systematic way of designing the filter with a given specification is not available. In the conventional design method, the analysis program of the filter structure is iteratively used to obtain the design parameters [1]. This trial and error approach is not efficient, and usually takes a large amount of time.

This paper introduces a new CAD algorithm for bandpass filters with non-touching E-plane fins. The parameters of the filter structure can be directly obtained from the given specifications by using this algorithm. The equivalent ladder network from the low-pass prototype is generally used for bandpass filter design [3-5]. However, this method is not appropriate for our design purpose, since there is no known relationship between equivalent circuit elements of the fin and the dimensions of the fin. Instead, an approach is established by introducing effective utilization of a look-up table, which has the scattering parameters of a single fin of specific dimensions. The techniques of selecting the E-plane fin from the look-up table and the other filter elements are presented. To verify the design algorithm, a filter was designed to obtain given specifications. The characteristics of the filter fabricated according to the design were measured, and compared with the calculated filter characteristics.

STRUCTURE

As an example, the bandpass filter structure with two E-plane fins is shown in Fig.1. This filter structure consists of discontinuities of the step junction between the larger waveguide and the smaller waveguide, intervals between the step junction discontinuity and the fin, and the interval between the two fins. The design parameters are shown in Fig. 2. In order to simplify the design problem, the symmetrical filter structure is used as shown in Fig. 2 (T1 = T3, F1=F2). WR-28 waveguide is used for the larger waveguide, and WR-12 is used for the smaller evanescent waveguide. The several design parameters of the filter structure are fixed from the selections of the larger waveguide and the smaller waveguide as shown in Fig. 2. The algorithm to determine T1, T2, W, and H in Fig.2 is the main topic of this paper.

Design Algorithm

The algorithm is briefly summarized in Fig. 3. The main idea is to achieve an optimal combination of the filter parameters with proper selections of the E-plane fins from the look-up table and the appropriate determinations of other filter structure elements (T1,T2) in order to satisfy the given filter specifications. First, the E-plane fins are selected. Then, the value of T1 and T2 are determined based on the selection of E-plane fin. If the specifications can not be achieved with the selected E-plane fin, the selection of the E-plane fin is changed. The correlations between the design parameters and the characteristics of the filter will be explained below. These correlations are incorporated into the algorithm routines.

Selection of E-plane Fins

The center frequency of the filter is the parameter most sensitive to the dimensions of the non-touching E-plane fins. The dimensions of the E-plane fin are obtained from a look-up table once the fin is selected from this look-up table. Note that the data in this look-up table are very accurate as they are based on the full-wave analysis [2]. The method of selecting an E-plane fin consists of the following steps. First, based on a full-wave analysis of the fin [2], the filter responses are calculated by varying the structural parameters. Then, from these results, the relationship between the resonant frequency of a single fin and the center frequency of the filter is obtained and is shown in Fig. 4. Next, the initial design setting value, RF, which is the resonant frequency of the E-plane fin, is found from the curve fitting equation derived from the lowest graph in Fig. 4 ;

$$RF = 0.972*CF + 1.628 \text{ (GHz)} \quad \text{-----} \quad (1)$$
(CF: desired center frequency)

When the specific value of RF is calculated by using equation (1), the E-plane fin with index (I) is selected in the look-up table such that

$$RECF\,(I-1) < RF < RECF\,(I) \qquad (2)$$

where RECF is the approximate resonant frequency of the single fin in the look-up table, and (I) is the index of the selected fin in the look-up table. This look-up table of E-plane fins with the different dimensions is constructed by the use of the full-wave analysis program for single E-plane fins [2] and shown in Table 1. Table 1 shows only the fin index, the dimensions of the fins, and the approximate resonant frequencies of each fin. However, in the actual look-up table in the computer data base, the scattering parameters of the fin are provided for the corresponding fin index at the sampling frequency points with an interval of 0.2 GHz in the frequency range from 26.0 GHz to 41.0 GHz. If the desired filter response can not be obtained with the present fin selection, the selection of the fin is varied systematically along the vertical line as shown in Fig.4.

The Selection of T1

T1 is the interval between the step junction discontinuity and the E-plane fin as shown in Fig. 2. The value of T1 mainly affects the center frequency and the ripple. As T1 increases, higher ripples and a higher center frequency are obtained. Also, an increase of T1 narrows the bandwidth. From Fig. 4, T1 is determined by the approximate equation depending on the selected fin with the index (IU) and the desired center frequency

$$T1 = 2.127 / (RECF (IU) - 0.972 * CF - 0.5154) - 0.6121 \quad (3)$$

(CF : desired frequency (GHz))
(RECF (IU) : the resonant frequency of the selected fin)

The Selection of T2

T2 is the interval between two E-plane fins as shown in Fig. 2. This parameter controls the magnitude of the ripple and the bandwidth. As T2 increases, a smaller ripple and a narrower bandwidth are obtained. As a result, the increase of T2 gives a tradeoff between the ripple and the bandwidth. This parameter is assigned after the other design parameters are selected, and varied in discrete values in the algorithm. From the calculations using the analysis program, it has been found that there is an acceptable range of values of T2 in our operating frequency range of 26.0 GHz to 41.0 GHz. T2 is initially set at 2.0 mm and varied step by step.

Results from CAD Program

The design algorithm was tested with the desired center frequency of 33.0 GHz and 1.0 dB bandwidth of 3.0 GHz. Fig. 5 shows the changes in the filter response for a few intermediate steps in the design algorithm. In each step, different parameters are selected as shown in Fig. 5. In Step 1, the center frequency was near the desired center frequency while the bandwidth was narrower than the desired one. Next, by increasing the fin index and choosing corresponding values of T1 and T2, the bandwidth was consistently increased until it became close to the specified bandwidth. As the selected fins were changed, the possible range of bandwidth with a reasonable value of ripple was widened. Therefore, this algorithm selected new E-plane fins if the desired bandwidth was not obtainable with reasonable ripple. After a few steps, the final parameters are determined. The height of the fin is 1.20 mm, and the width of the fin is 0.68 mm. The interval between the step junction discontinuity of the waveguide and the E-plane fin is 0.259 mm. Also, the interval between the E-plane fins is 2.500 mm. Characteristics of the evanescent mode filter constructed with these parameters have been measured. The result from the design algorithm is compared and verified with the experimental result as shown in Fig.6. The calculated center frequency of the designed filter is 32.9 GHz and that of experimental result is 32.8 GHz. The calculated filter bandwidth is 2.90 GHz, and the one of the experimental result is 2.80 GHz It is observed that the given specifications are satisfied by the calculated filter characteristics, and the design is verified by the experimental results of the designed filter.

CONCLUSION

In this paper, a design algorithm for evanescent mode waveguide bandpass filters with non-touching E-plane fins has been presented. This algorithm is not a conventional optimization algorithm which depends mainly on the repetitive computation for obtaining the design parameters. This algorithm is based on the effective and systematic utilization of the look-up table of the scattering parameters of the E-plane fins calculated by a rigorous full-wave analysis. Also, it incorporates the correlations between the design parameters and the characteristics of the filter into the routines. By using this algorithm, all the filter parameters are directly obtained from the given specifications of the center frequency and the bandwidth of the filter. The designed filter response by this algorithm satisfies the given specifications, and is verified with experimental results.

ACKNOWLEDGEMENT

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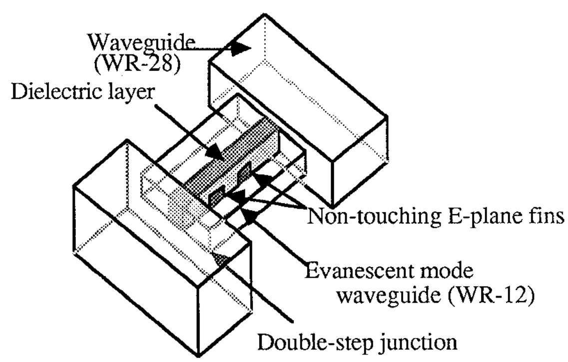


Fig.1. The structure of the filter with two non-touching E-plane fins.

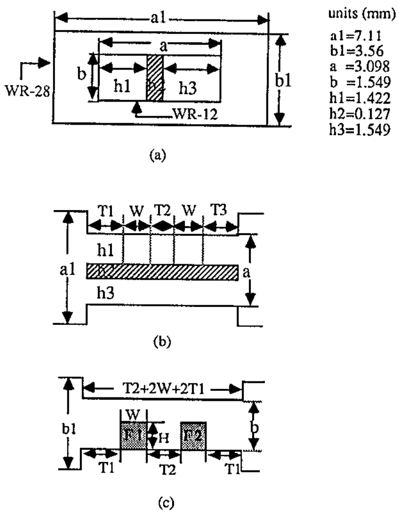
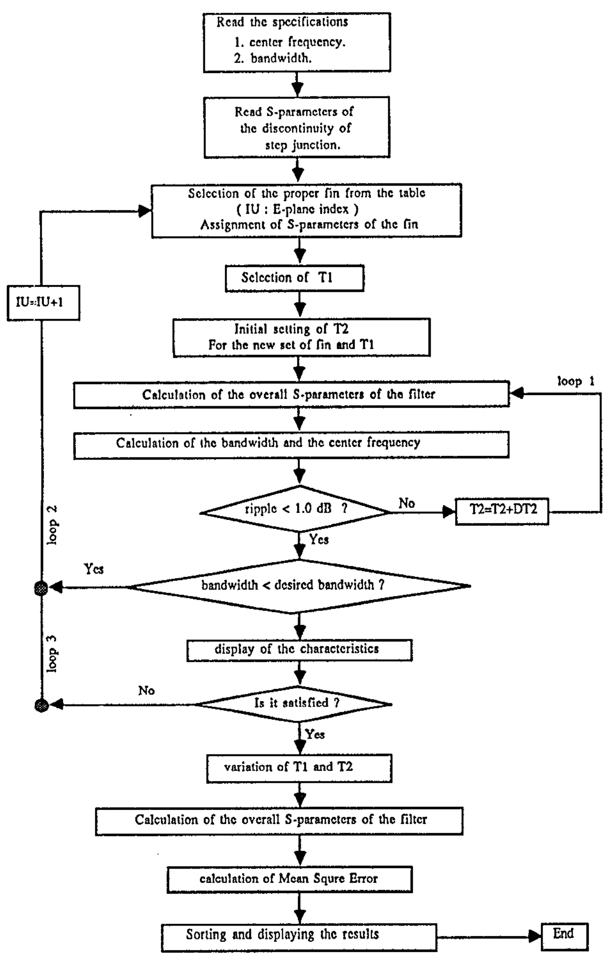


Fig. 2 Filter Structure and Parameters
a) front view
b) cross section view
c) side view

Fig. 3. DESIGN ALGORITHM



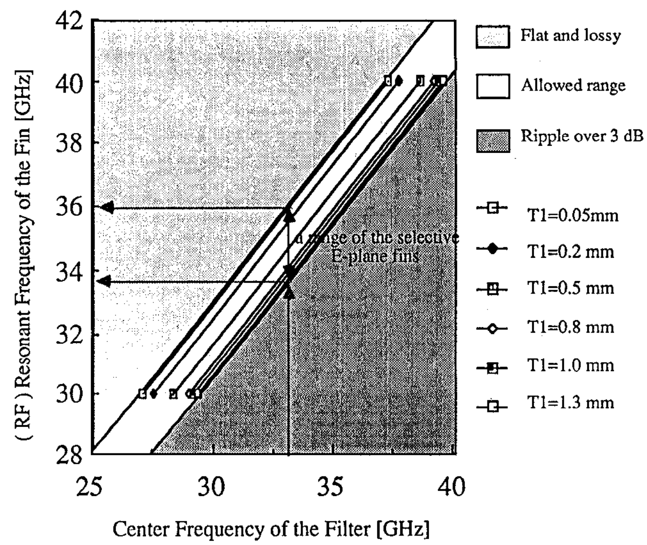
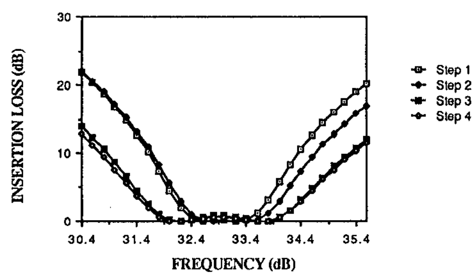
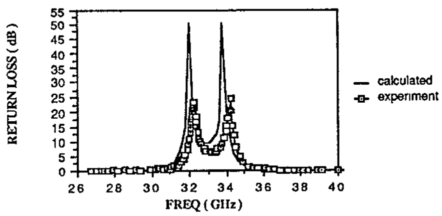


Fig. 4 Center frequency of the filter vs.
Resonant frequency of the selected E-plane fin

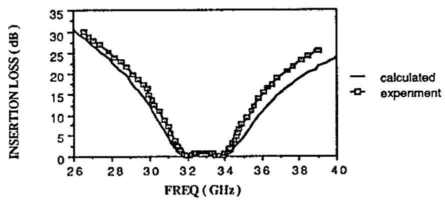


step 1) W : 0.375 H : 1.300 T1 : 0.797 T2 : 3.500
step 2) W : 0.850 H : 1.200 T1: 0.632 T2 : 3.200
step 3) W : 0.800 H : 1.200 T1: 0.452 T2 : 2.600
step 4) W : 0.775 H : 1.200 T1: 0.396 T2 : 2.600

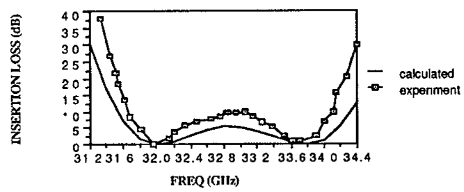
Fig. 5 Step changes of filter response and the design paramters



(a)



(b)



(c)

Fig.6 Comparison between the calculated and the experimental results of the Designed filter response
(a) Return Loss
(b) Insertion Loss
(c) Extended view of Insertion Loss