Optimization of Waveguide Diplexers Using Shadow Specifications

David A. Cargill*, Timothy Dolan** and Protap Pramanick**

*University of Saskatchewan, Saskatoon, SK, S7N 5A9, Canada

** K&L Microwave Inc., Salisbury, MD, 21801, USA

Abstract — **This paper uses a new optimization technique for determining the frequency response of waveguide diplexers. The proposed technique is considerably more advantageous than the conventional waveguide filter optimization techniques. The technique uses only six variables in the penalty function irrespective of the orders of the two channel filters. This drastically reduces the chance of convergence to a local minimum as well as the computer storage and processing requirements. Two examples are presented to support the validity of this new technique. This technique will be extremely valuable in designing waveguide multiplexers.**

I. Introduction

Progress in the area of multiplexer and filter design and tuning have been hindered by the dimensionality of the problems that have to be solved in order to provide the designer with parameter values ensuring the desired frequency response. Fortunately, computer aided design techniques involving optimization have been developed to determine the optimal diplexer parameters [1]-[2]. Figure 1 shows the configuration of a H-plane T-junction diplexer with septum-coupled filters. Practical diplexer designs reported in the literature use two channels and the number of optimization variables to be adjusted depends to a large extent on the orders of the channel filters of a diplexer. Specifically, if N optimization variables are required to analyze a filter then 2N plus the variables required for the dimensions of the common junction and the tuning are needed for a diplexer. As a result the time to completion of a diplexer design and computer storage is directly related to the number of optimization variables required for the filter.

With conventional brute force optimization, the initial design of the filter is very important for fast convergence to a final solution. Traditionally, the optimization is done using the Gauss-Newton method [3]-[4] or the evolution strategy method [5]. John Bandler's space mapping method offers significant advantage over these traditional methods [6]. In the traditional approach to waveguide filter optimization the optimization variables are the resonator lengths and the dimensions of the K-inverter forming obstacles. Thus in the design of an N-pole filter of symmetrical structure, it is necessary to optimize N+1 variables. In another approach, only the K-inverters were

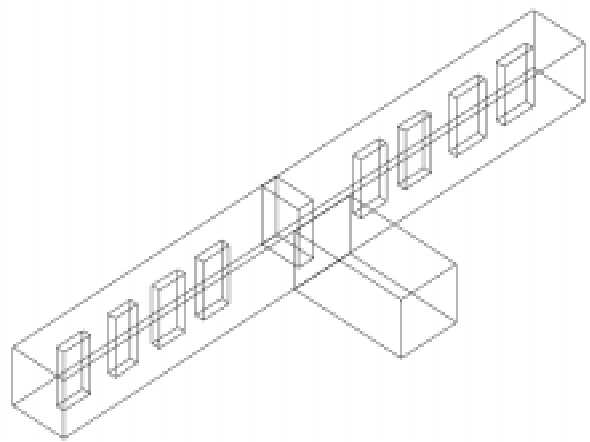

Fig 1. H-plane T-junction Diplexer with Septum-coupled Filters

used as optimization variables [7]. A sequentially coupled filter needs N+1 K-inverters, however only N/2+1 K-inverters have different values if the structure is symmetrical. Therefore we need to optimize N/2+1 variables. This approach is definitely faster than the conventional one. However, the time to optimization and computer storage are still dependent on N.

II. Diplexer Optimization Method

In general, the penalty function to be optimized in waveguide filter design is a highly complex non-linear function of the optimization variables. This requires the designer to deal with a number of local minimums of the function. The number of such local minimums depends on the number of optimization variables. We encountered this problem while attempting to optimize several high order filter ($N \geq 5$) filters. In order to alleviate this problem we proposed a new approach [8]-[9] towards filter optimization. This approach is based on the fact that no matter which optimization method is used the variables to modify are the lower cutoff frequency, upper cutoff frequency and the return loss of the filter. These three variables were used to optimize the filter where each iteration of optimization synthesized a new filter using a low accuracy but fast method.

In 1994 Morini and Rozzi [10] showed how to accurately design the common junction of a waveguide diplexer, shown in Figure 2, once the pertinent S-parameters of the channel filters are known.

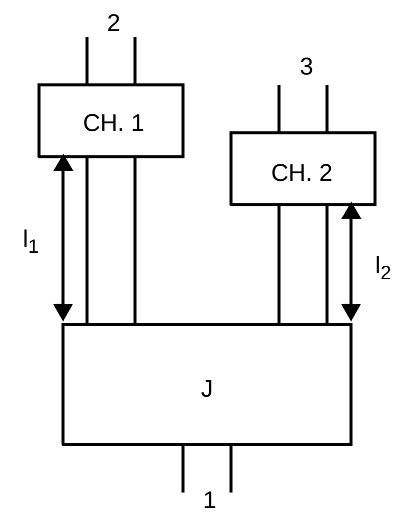

Fig 2. Block Diagram of Waveguide Diplexer (J is the common junction)

Morini and Rozzi stated that the fundamental mode scattering matrix of the common junction should satisfy the following condition for good matching [10]

$$|S_{11}| = |S_{22}| = |S_{33}| \geq 1/3 \qquad (1)$$

at the center frequencies of the two channel filters. In addition, the two filters should be located at distances l_1 and l_2 for a perfect match, which are given by

$$l_1 = -\frac{1}{2j\beta}\ln\left(\frac{S_{22}}{\Delta S S_{33}{}^{*}\rho_{11}}\right) \text{ at } f = f_2 \text{ and} \qquad (2)$$

$$l_2 = -\frac{1}{2j\beta}\ln\left(\frac{S_{11}}{\Delta S S_{33}{}^{*}\rho_{12}}\right) \text{ at } f = f_1 . \qquad (3)$$

Where f_1 and f_2 are the center frequencies of the two channel filters, respectively, ρ_{11} and ρ_{12} are the reflection coefficients of the filters under matched condition at their center frequencies, β is the propagation constant, and ΔS is the determinant of the common junction scattering matrix.

The diplexer optimization method proposed in this paper combines the shadow specification approach in references [8]-[9] with the common junction design approach by Morini and Rozzi [10] and shows that we need only six variables to optimize a waveguide diplexer no matter what the orders of the channel filters are. Those six variables are the cutoff frequencies and the passband return losses of the two channel filters. Figure 3 shows the flow diagram of the proposed optimization scheme. The required fast channel filter synthesis scheme is based on rational function approximation of K-inverters and the associated phase shifts [8]-[9].

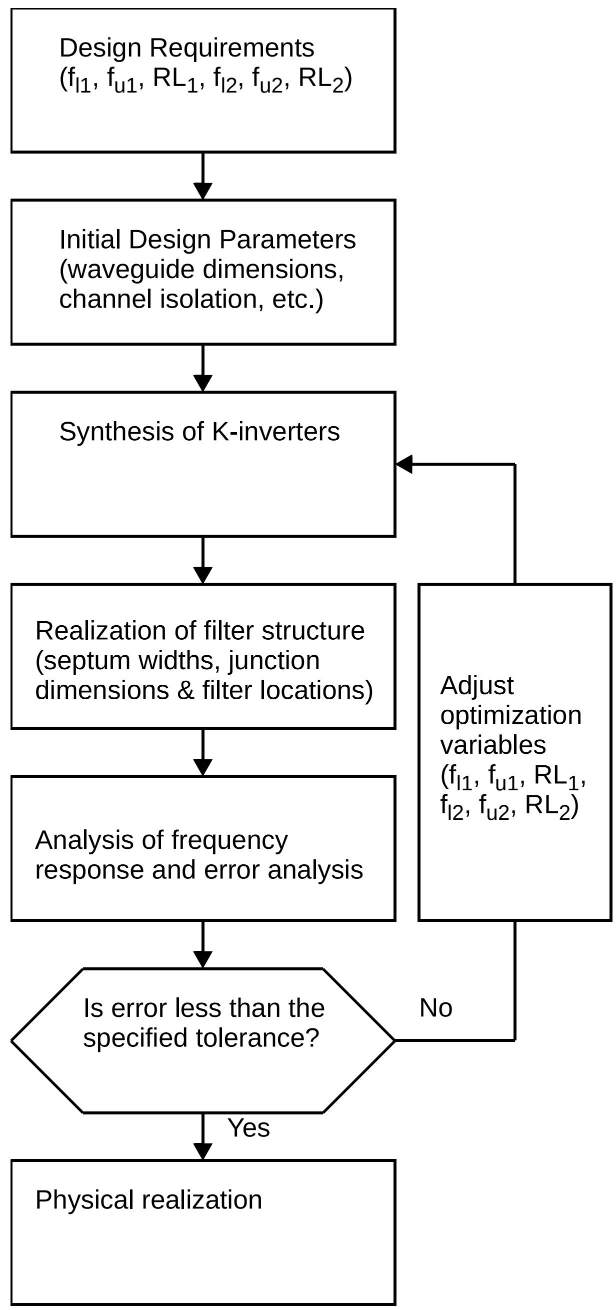

Fig 3. Optimization Flowchart with Six Variables

The shadow specification approach is simply based on the principle that if a set of input specifications do not give the desired frequency response then an alternative or "shadow" specifications can.

III. RESULTS

Figure 4 shows the computed unoptimized and optimized frequency responses of a Ka-band H-plane T-junction diplexer with 6-pole septum-coupled filters. The diplexer was designed for a 16 dB common junction return loss for channel bandwidths of 340 MHz and 380 MHz centered around 38.68 GHz and 39.37 GHz, respectively. The unoptimized response is from direct synthesis using the Morini and Rozzi [10] method. Optimization of the diplexer did not require more than 15 iterations using a direct search simplex algorithm [11]. The computation time was 18 minutes on a Pentium III 450 MHz computer with 256 MB RAM.

Figure 5 shows the computed unoptimized and optimized common junction return loss of a Ka-band H-plane T-junction diplexer with 7-pole septum-coupled filters. The diplexer was designed for a passband ripple of 0.043 dB for channel bandwidths of 500 MHz centered around 36.75 GHz and 37.75 GHz, respectively.

IV. CONCLUSION

Combining the shadow specification approach [8]-[9] with the common junction design approach by Morini and Rozzi [10] allows a diplexer to be optimized using only six optimization variables. Those six variables are the cutoff frequencies and the return loss of the two channel filters. With only six optimization variables the computational requirements are significantly reduced and the chances of optimizing to a local minimum are also reduced.

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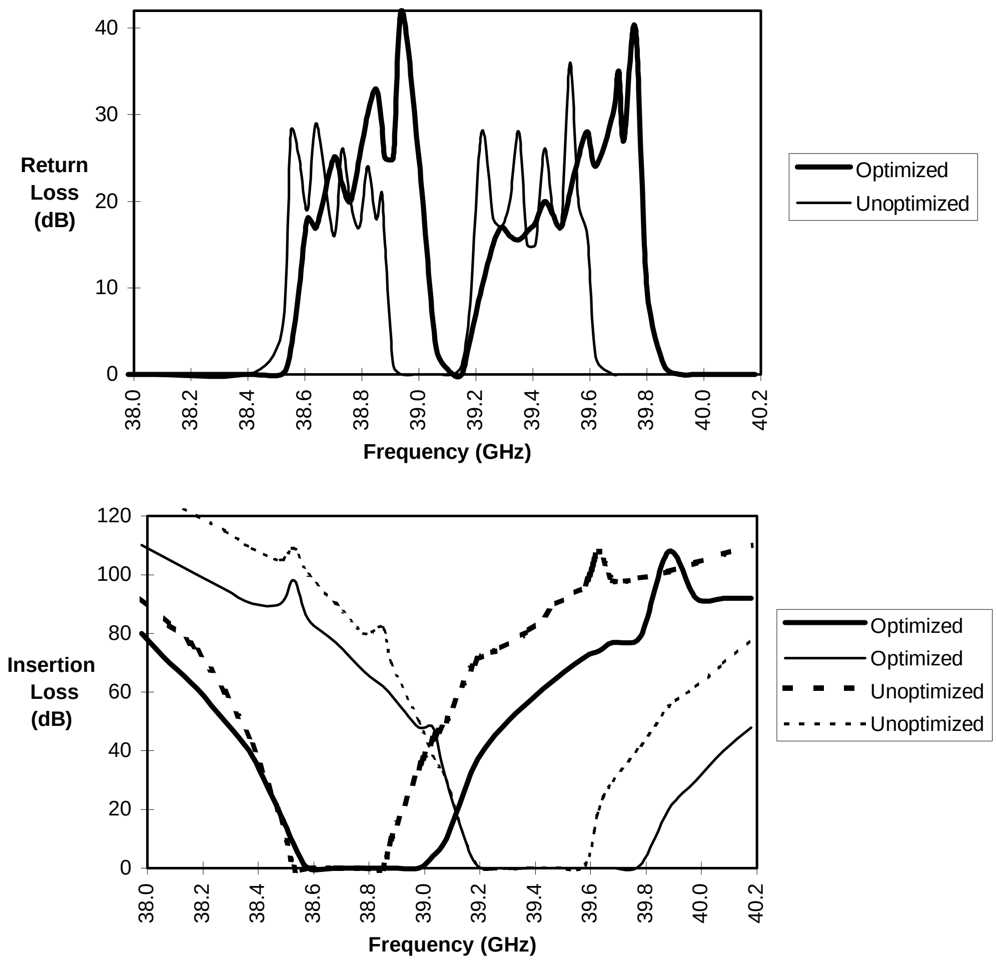

Fig. 4.Computed Frequency Responses of Unoptimized and Optimized Diplexers

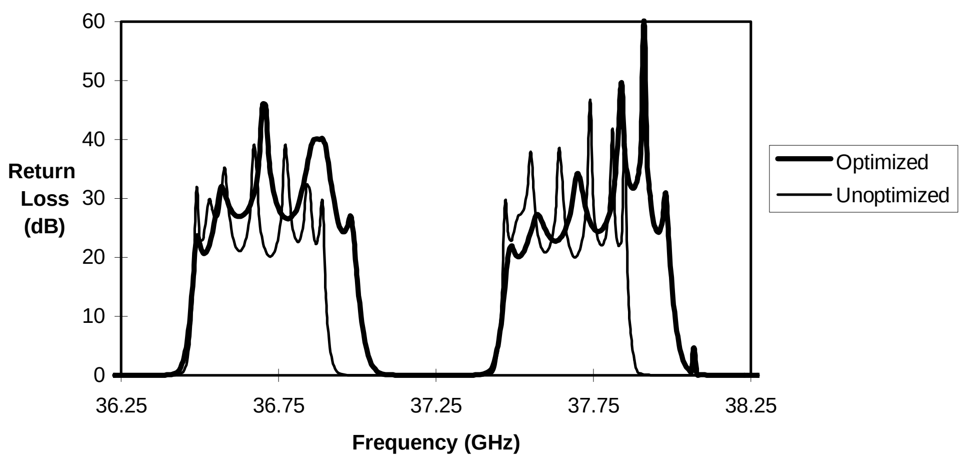

Fig. 5.Computed Frequency Responses of Unoptimized and Optimized Diplexers