Optimum CAD Procedure For Manifold Diplexers

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Abstract

In this paper a novel Computer Aided Design (CAD) procedure is described for the manufacture of the class of manifold diplexers which is based on filters implemented with thick inductive windows in rectangular waveguide. The procedure described essentially consists of decomposing the initial design task into four simpler sub tasks with clearly identified goals. Each sub task only involves the "software" (soft) tuning of a *limited number of physical parameters* so that the complete procedure can be executed very rapidly. The procedure described allows for the manufacturing of waveguide diplexers without any tuning elements and without any experimental characterization work thus substantially reducing production time and cost.

I Introduction

The typical manifold multiplexer consists of a number of waveguide filters (the channel filters) connected to a short-circuited length of waveguide (the manifold). Although a large number of contributions can be found in the technical literature for the design of the individual (isolated) channel filters (see for instance [1]), the same is not true for manifold multiplexers. In fact, a recent publication discussing innovations in the field [2], refers to the practical tuning of multiplexers as a "... black art...". The main problem in the design of a manifold multiplexer comes from the fact that when the individual filters are assembled together in a manifold, the mutual interactions between the various constituent discontinuities of the individual filters are very strong and can completely change the behavior of the filters themselves. In practice, to recover the wanted electrical behavior, the geometrical parameters of the filters (irises dimensions, cavity lengths,...) and the manifold dimensions must be adjusted experimentally.

A few very good technical contributions can however be found describing procedures for the realization and tuning of these complex devices [3], [4]. Both contributions, however, can only give approximate results because they are based on single-mode network representations of the filters and the manifold. In a practical implementation, also the higher order modes contribute to both the filter and the manifold electrical behavior. As a result, a time-consuming manual tuning procedure is always required.

Recent publications have discussed the full wave design of the class of microwave filters which is based on thick inductive windows in rectangular waveguides [5], [7]. The results presented in [5] and [7] are based on a rigorous multimode network representation of the filter structure and allow for the rapid and accurate design and manufacture of microwave filters without tuning elements and without any preliminary experimental characterizations. A more recent contribution [6], describes the full wave modeling of rectangular waveguide T-junctions in terms of a multimode admittance matrix representation. In this paper, the results presented in [5], [7], and [6] are integrated to produce a CAD package for the full wave analysis of manifold diplexers and a coherent step-by-step procedure is described to obtain the optimum diplexer manifold and filters dimensions. Following the procedure described in this paper, a manifold diplexer can be designed and manufactured to comply with a set of given electrical specifications without any manual tuning elements or experimental characterization thus considerably reducing the development time and cost traditionally required for this type of hardware.

II Full Wave Network Representation

Although the procedure described in this paper has been developed for the design of manifold multiplexers, it has been first applied for verification to the simpler case of a diplexer. The possible geometries are shown in Fig. 1.

Each individual filter can be represented in terms of the multimode equivalent network [5]. The T-Junctions that are required for the waveguide manifold can be either H-plane or E-plane (identified as an H-type or E-type diplexer in the remainder). The resulting network representations for the diplexers in Fig. 1 are shown in Figs. 2 and 3.

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From the network representations one can easily derive a set of linear equations to be solved in order to obtain the electrical characteristics of the hardware.

III Design Procedure

The first step in the design procedure is to design two doubly terminated microwave filters that are compliant with the given elefctrical specifications. This task can be easily accomplished using the procedure described in [7]. Table 1 gives the physical dimensions of the filters thus obtained, and Fig. 4 shows their simulated electrical performance.

The second step in the design procedure is to obtain a set of reference curves from the filters designed. This is done by computing the S_{21} parameter of the first cavity of the filters in a doubly terminated configuration. One more cavity is then added and the S_{21} parameter is again computed. The procedure is repeated only for the first three cavities of each filters. It is important to note that these curves are obtained by using the actual geometrical dimensions of the filters designed in the previous step (the reference planes are located just before and just after the first and last irises).

The next step is the connection of the *single first cavities* to the manifold. The geometrical parameters of the cavities are initially the ones obtained from the doubly terminated design. At this point the dimensions of the manifold are adjusted in order to obtain clearly identifiable resonances due to the single cavities in the frequency range of interest.

Once the dimensions of the manifold are fixed, the first and second apertures and the cavity length of the single cavities are adjusted to recover the electrical performance of the doubly terminated single cavities. This "software" (soft) tuning procedure is performed first on one cavity and then on the other. Due to the interactions, once one cavity is tuned, the other will result slightly detuned. Convergence is however obtained very rapidly.

The following step is to connect the second cavities and repeat the soft tuning procedure (involving only 5 parameters per filter) to recover the doubly terminated performance. The next step is to add the third cavities and again recover the doubly terminated performance. If the previous steps have been done carefully, at this point it is only necessary to adjust one parameter, namely the length of the third cavity. Figure 5 shows the result obtained. At this point the rest of each filter can be connected to the manifold and the final performance shown in Fig. 6 is obtained. As we can see, the electrical behavior of the isolated doubly terminated filters has been essentially recovered. Table 2 give the final dimensions of the complete diplexer.

To summarize, the steps involved in the design procedure are as follows.

1. Design isolated doubly terminated filters that meet the required electrical specifications. Compute the magnitude in Db of the S_{21} parameters of the singe first cavities of the filters designed, add the second cavities and repeat the analysis, then the third cavities and repeat the analysis again.

2. Connect only the first cavity of the filters obtained in step 1. to the waveguide manifold and soft tune the manifold dimensions to obtain clearly identifiable resonances at the approximate frequencies of interest.

3. Once the manifold is adjusted, soft tune the first aperture, second aperture, and first cavity length until the performance in step 1. is recovered. Repeat this process adding the second cavity (five parameters) and third cavities (one parameter) in sequence.

4. Connect the rest of each filter to the manifold and compute the global performance.

Figure 7, and Tab. 2, show the results of the same procedure applied to the case of E-plane T-junction. As we can see, also in this case an excellent final result is obtained.

It is important to note that in both cases, all of the soft tuning operations have been performed manually, with limited accuracy, for a demonstration purpose. Using for each step a computer algorithm would have clearly resulted in perfectly compliant final results.

IV Conclusion

In this paper, a novel procedure is described for the design of manifold diplexers that do not contain any tuning elements and that does not require any experimental (hard) tuning. The procedure is based on a very efficient and accurate software package for the full wave analysis of the structures. The procedure itself essentially consists of decomposing the complex design task into four simpler tasks. The goal of each task is clearly defined and only involves the soft tuning of *a limited number of physical parameters.* The value of the procedure described is in that it can completely replace all of the experimental development work traditionally required for the design of this type of hardware thus substantially reducing production time and cost.

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FILTER 1

Inductive window data						
	W1	W2	W3	W4	W5	W6
Width	9.868	6.400	5.660	5.660	6.400	9.868
Thick.	0.5	0.5	0.5	0.5	0.5	0.5
Connecting waveguide data						
	1-2	2-3	3-4	4-5	5-6	
Length	15.621	17.466	17.710	17.466	15.621	

FILTER 2

Inductive window data						
	W1	W2	W3	W4	W5	
Width	8.135	4.533	4.057	4.533	8.135	
Thick.	0.5	0.5	0.5	0.5	0.5	
Connecting waveguide data						
	1-2	2-3	3-4	4-5		
Length	15.425	16.744	16.744	15.425		

Tab. 1 Physical dimensions in millimeters of doubly terminated filters.

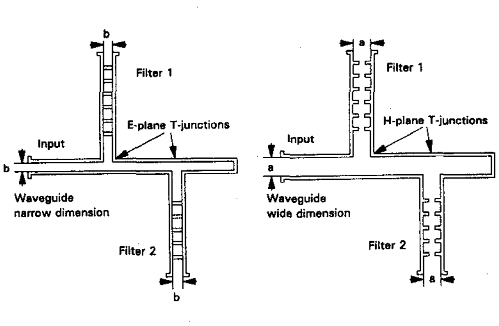

Fig. 1 Possible waveguide manifold implementations.

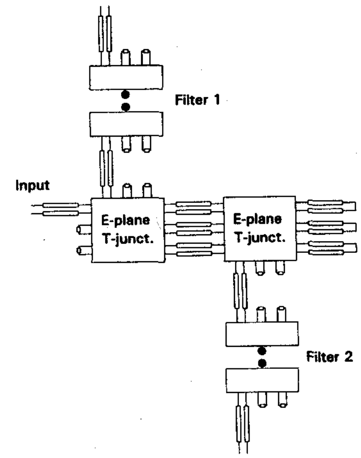

Fig. 2 Equivalent network representation of the E-type manifold diplexer in Fig. 1.

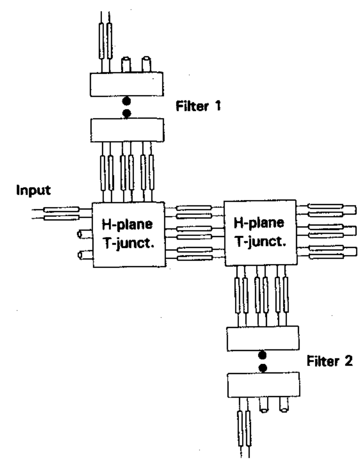

Fig. 3 Equivalent network representation of the H-type manifold diplexer in Fig. 1.

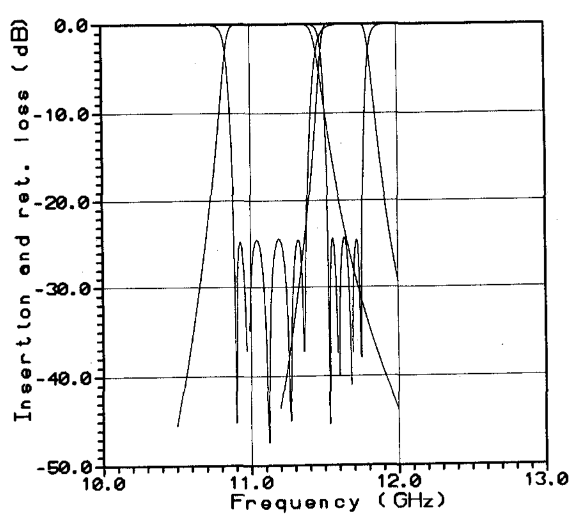

Fig. 4 Electrical performance of the filters in Tab. 1.

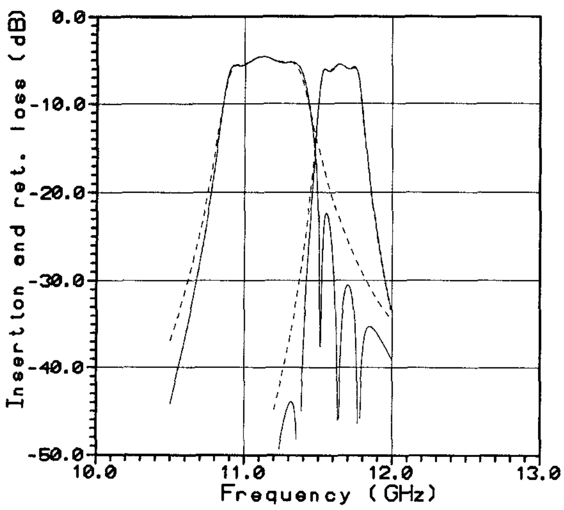

Fig. 5 Optimized electrical performance of the first three cavities for H-type diplexer.

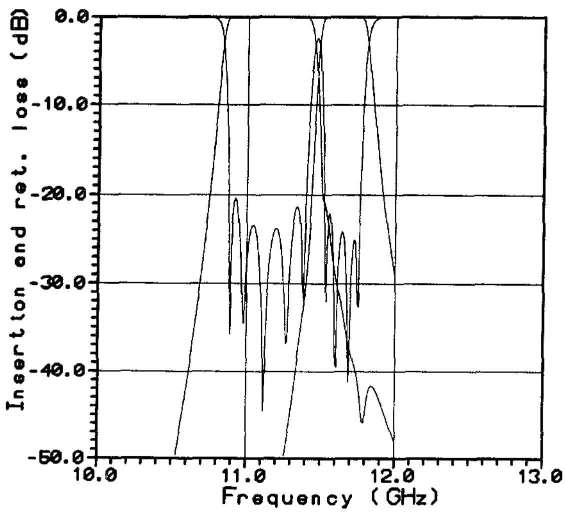

Fig. 6 Optimized electrical performance of complete H-type diplexer. The results given in Fig. 4 for the isolated filters have been essentially recovered.

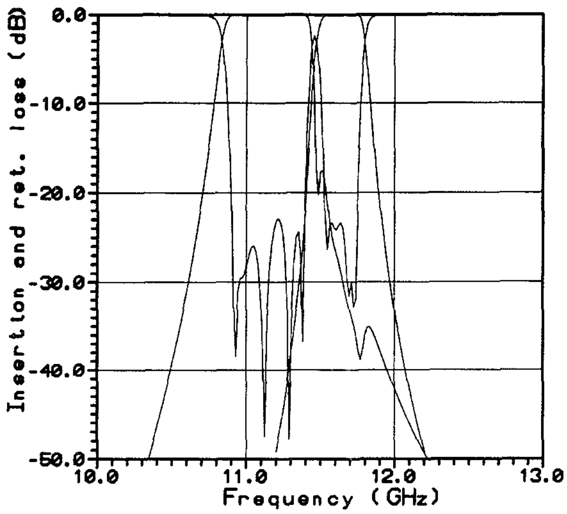

Fig. 7 Optimized electrical performance of complete E-type diplexer. The results given in Fig. 4 for the isolated filters have been essentially recovered.

H-TYPE DIPLEXER						
FILTER 1 Inductive window data						
	W1	W2	W3	W4	W5	W6
Width	10 598	6.113	6 60	5 660	6 400	9.868
Thick.	0.5	0 5	0.5	0 5	0.5	0 5
FILTER 1 Connecting waveguide data						
	1-2	2-3	3-4	4-5	5-6	
Length	15 621	17.606	17 730	17 466	15 621	
FILTER 1 Distance to T-junct 18.967						
FILTER 2 Inductive window data						
	W1	W2	W3	W4	W5	
Width	11 270	4 744	4.057	4.533	8.135	
Thick	0 5	0 5	0 5	0 5	0 5	
FILTER 2 Connecting waveguide data						
	1-2	2-3	3-4	4-5		
Length	13 245	16.674	16.744	15 425		
FILTER 2 Distance to T-junct 17 506						
Distance bet. T-Junctions	4 0					
Distance to short circuit	10 967					
Waveguide wide dim	19 05					
Waveguide narrow dim	9 525					
MANIFOLD						

E-TYPE DIPLEXER						
FILTER 1 Inductive window data						
	W1	W2	W3	W4	W5	W6
Width	12 678	7 2	5 71	5 660	6 400	9.868
Thick.	0 5	0 5	0 5	0 5	0 5	0 5
FILTER 1 Connecting waveguide data						
	1-2	2-3	3-4	4-5	5-6	
Length	13.641	17 326	17 730	17 466	15 621	
FILTER 1 Distance to T-junct 17 967						
FILTER 2 Inductive window data						
	W1	W2	W3	W4	W5	
Width	12.855	4 985	4 087	4 533	8.135	
Thick	0 5	0 5	0 5	0 5	0 5	
FILTER 2 Connecting waveguide data						
	1-2	2-3	3-4	4-5		
Length	10.845	16 684	16 744	15 425		
FILTER 2 Distance to T-junct. 12 678						
Distance bet T-Junctions	5 0					
Distance to short circuit	2 0					
Waveguide wide dim	19 05					
Waveguide narrow dim	9 525					
MANIFOLD						

Tab. 2 Physical dimensions in millimeters of the complete H-type and E-Type diplexers.