Computer-Aided Synthesis of Iris-Coupled Rectangular Waveguide Filters

Jens Bornemann
Department of Electrical and Computer Engineering
University of Victoria, Victoria, B.C., Canada V8W 3P6

Jaroslaw Uher
Satellite and Communication, System Division
Spar Aerospace Ltd., Ste-Anne-de-Bellevue, Québec, Canada H9X 3R2

Theories on the analysis and design of direct-coupled waveguide filters have been extensively published since the late 1940's. Two principal strategies have evolved so far. First, equivalent circuits of waveguide discontinuities are obtained, and standard filter theory and transmission line analysis are used to design the filter component for a prescribed performance. Owing to limitations in discontinuity representation and negligence of higher-order mode interactions, considerable disagreement between specified and measured filter responses is observed, which requires post-fabrication tuning and, frequently, a new component to be manufactured.

The second strategy evolved with the availability of powerful computers. Field theory–based numerical techniques have proven to accurately predict the response of a given filter configuration. Unfortunately, such processes cannot be reversed and, therefore, are not suited for synthesis purposes. Instead, data obtained from equivalent-circuit models are used as initial values, and optimization procedures are applied until the specifications are met. For practical filter applications, however, this design strategy usually results in extensive CPU-time requirements, thus leaving the design engineer with a choice between delaying prototype fabrication or heavily investing in computer power.

Therefore, for the first time, this paper combines conventional filter theory with numerical techniques to obtain a straightforward synthesis of iris-coupled rectangular waveguide filters. Through the incorporation of field theory–based analysis methods into the design of impedance inverters known from filter theory, all problems mentioned above are completely eliminated. (Mode-matching methods are used as numerical tools in this paper. However, any other rigorous technique suitable for analyzing waveguide discontinuities with respect to scattering parameters can be applied instead.)

The computer-aided synthesis is demonstrated in the examples of standard iris-coupled filters. Comparisons with measurements demonstrate excellent agreement. Moreover, new relations derived from an unsymmetric impedance inverter allow the cross-sections of the filter resonators to differ from those of the input/output waveguides. This is especially useful for designs at the lower end of a waveguide band and for an increase of the Q factors of resonators. In order to reduce the complexity of the numerical analysis, losses are taken into account by incorporating attenuation constants derived from a power-loss method. This procedure is found to provide more realistic data than currently used in midband insertion loss predictions.

Finally, the synthesis of a wideband filter demonstrates that, contrary to common opinion, the impedance inverter approach can indeed be used for wideband applications provided that the realization of the corresponding coupling irises involves field theory–based techniques.

The main advantage of the computer-aided synthesis is its CPU-time efficiency. Using a modified TE^{x}_{mn} mode-matching approach, a complete filter synthesis including a final analysis takes less than ten minutes on a 33-MHz 486 personal computer.