Composite Filter CAD Procedure based on Variational Approximations

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Abstract

Multi-modal variational approximations for scattering parameters of general triple-discontinuity non-ideal cavity are expressed in terms of aperture integrals. Solution is derived for different types of cavity junctions as convergent two-dimensional sums of elementary functions. The filter or diplexer is considered as number of such cavities connected by uniaxial waveguide sections with dominant mode taken into account and linked with interface by uniform waveguides, probes, loops or apertures. Design approach is based on direct optimization of composite structures compiled from pre-synthesized filters. The approach is used to create a fast running CAD tool successfully used for design of variety of filters for SATCOM and wireless applications.

Introduction

Modern technical requirements to filters and multiplexers are usually based on hard-hitting goals for pass-band performance, roll-off, harmonics rejection, high power handling and manufacturability, which often cannot be matched by conventional filters. Therefore, filter design engineers are often looking for composite design solutions using different type of scattering elements or parts of different filters integrated into a complex filter structures. However, the popular “full wave” software based on rigorous and universal numerical methods is practically not suitable for design synthesis, optimization, proposals and sensitivity analysis, requiring frequentative computations, because of slowness and awkwardness. Therefore, popular engineering design procedures are based on common equivalent circuits for discontinuities [1] connected by “long transmission lines” loaded with irises or stubs convenient for fast analysis, design proposing and design of conventional tunable hardware. However, lack of accurate equivalent circuits for waveguide discontinuities quite limit variety of applications and accuracy of cascading the discontinuities by ideal transmission lines is not adequate for cavity filters. In paper [2] a multimodal variational formulation is used for characterization of propagation in cavities of ridged evanescent-mode filters and approximations are derived for 2x2 Y-matrix expressed in terms of sums of integrals corresponding to junction apertures. Here double discontinuity model formulated in [2] is corrected by taking propagation loss into account and extended to triple discontinuity by inserting single or double E-/H-plane posts or probes. Closed form solutions are derived for Y-matrix in terms of aperture integrals corresponding to internal junctions and interface connections. Thus filter or diplexer is represented by a number of pre-calculated aperture integrals and distances between discontinuities. As the obtained expressions are based on summation of elementary functions, they can be compiled into fast running computer code, an effective design tool.

Cavity Model

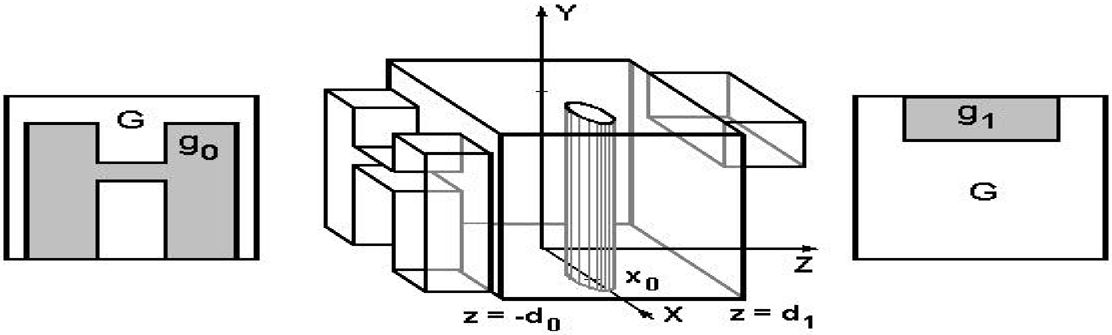

Figure 1: *A triple discontinuity as a cavity with post or probe.*

Here double discontinuity model used in [2] is generalized for case of propagation loss and extended to triple discontinuity by inserting single or double E-/H-plane posts or probes (see Figure 1). The current distribution on posts and probes is represented in terms of monopole and dipole current lines, $\vec{e}_y\left(I_0(y)\delta(x-x_0)-\frac{1}{k}I_1(y)\delta'(x-x_0)\right)\cdot\delta(z)$. Thus additional terms A_{nm} representing scattering on posts, $E^t(x,y,z)=\sum_{(n,m)=(0,0)}^{\infty}\left(C_{nm}^{+}e^{-j\beta_{nm}z}+C_{nm}^{-}e^{j\beta_{nm}z}+A_{nm}e^{-j\beta_{nm}|z|}\right)E_{nm}^{t}(x,y)$, are added into basic formulation for cavity E-field used in [2] . Analogically matching continuity of magnetic and electric fields on apertures and boundary conditions on planes of junctions, $E^t=z_s\cdot n\times H^t$, posts or probe

$$Ex(x_0\pm r,y,0)=\frac{z_s}{2\pi\cdot r}I_0(y)-V\delta(y),$$

can obtain expressions for elements of Y-matrix, $Y=Y_0(\alpha_0,\alpha_1)+\Delta Y(\alpha_0,\alpha_1)$, in terms of vectors of field integrals associated with the both apertures, where Y_0 is 2x2 Y-matrix of cavity [2] without post or probe with surface loss corrections and ΔY is an addition inserted by post (2x2 matrix) or probe (3x3 matrix). Additional mathematical manipulations are applied for probe models to extract irregularity associated with voltage gap [3].

Results and Comparison

The obtained expressions have been compiled into computer algorithms synthesizing initial dimensions, simulating and optimizing frequency response. Design procedure for composite filters and diplexers based on synthesis of primary filters, putting them together and optimizing over spec constrains has been developed. Although the computational approach takes only dominant mode into account between cavities, the simulation results for long filter structures with narrow gaps [4] can be even more accurate than obtained by rigorous FEM based simulators (see Figure 2). The design procedure has been applied to variety of waveguide filters, such as tapered corrugated [5], quarter-wave-coupled corrugated [4], composite asymmetric corrugated [6] (see Figure 4), H-plane iris, resonant iris and evanescent-mode ridged. It has also applied to closed surface ceramic filters (see Figure 3) and diplexers (see Figure 5) representing circular resonators as equivalent short sections of ridged or asymmetric double ridged waveguides. Accuracy of simulation is found practically acceptable in respect to production tolerances and tuning margins for majority of designs. However, the simulation time over discreet sweep of two hundred frequency points performed not longer than a second, which is about 30000 times faster than time required by HFSS, a universal FEM based simulator, installed on the same UNIX platform.

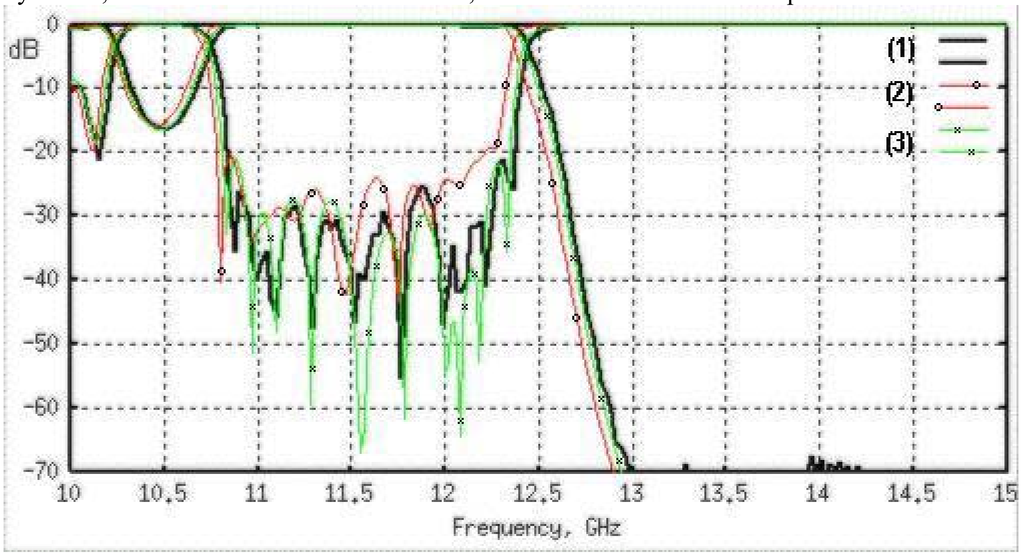

Figure 2: *Comparison between data measured (1), computed using FEM (HFSS) and presented approach (3) for a Ku-band corrugated harmonic filter (2).*

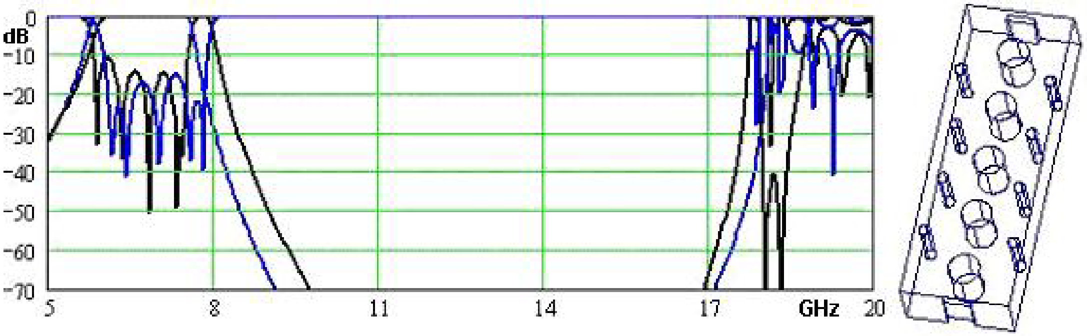

Figure 3: *Response of ceramic filter obtained by presented method and FEM (HFSS).*

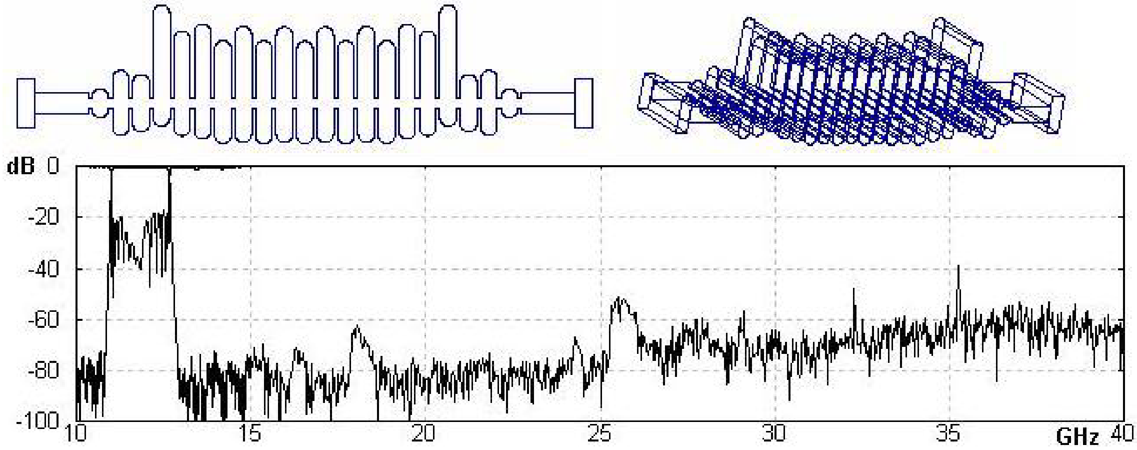

Figure 4: *Appearance and measured response of a composite corrugated filter designed using this method.*

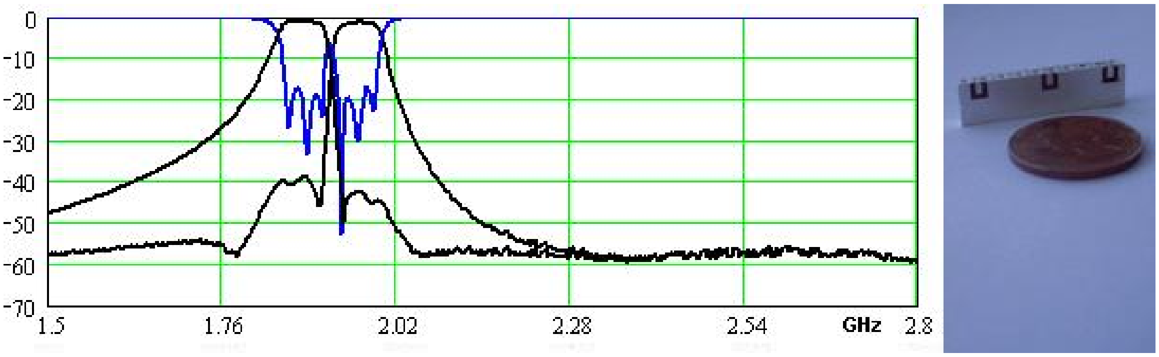

Figure 5: *Measured frequency response of a closed surface ceramic PCS diplexer designed using presented method.*

References

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