WIPL-D Modeling and Results for Waveguide Filters with Printed-Circuit Inserts

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Abstract

This paper presents a three dimensional electromagnetic (3D EM) modeling of waveguide filters and the corresponding results of the full-wave simulation with WIPL-D EM Solver. The filters are designed as rectangular waveguide structures with planar resonators implemented as printed-circuit inserts. WIPL-D models of building blocks for bandpass and bandstop filters are realized.

Introduction

In the past decade, rectangular waveguide filters have been a sustainable solution for low-cost, low-loss and high power filters for modern microwave and millimeter-wave applications in satellite communications, navigation, radiometry, active and passive imaging, etc.

In this paper, we use the WR90 standard waveguide to implement the bandpass and bandstop filter components in the X-band. By employing printed-circuit inserts, we can design the resonators and inverter elements. These rectangular waveguide H-plane filters, with the printed-circuit resonator, improving compactness, maintain the low-cost and mass-producible characteristics [1], [2].

Exploring design alternatives and tuning can be very expensive and time-consuming for mass production, so CAD can provide more accurate design with less design iterations, leading to first-pass or tuneless devices. CAD will reduce the extra cost of materials and other factors necessary for developing a satisfactory laboratory prototype [3], [4].

WIPL-D is a remarkably powerful program that allows fast and accurate analysis of metallic and/or dielectric/magnetic structures (antennas, scatterers, passive microwave circuits, etc.). The analysis is performed in the frequency domain as full-wave EM simulations, which are based on the method of moments. A linear electromagnetic system is modeled by defining the geometry of its structure as combination of wires, plates, material properties, excitations, and predefined three-dimensional bodies.

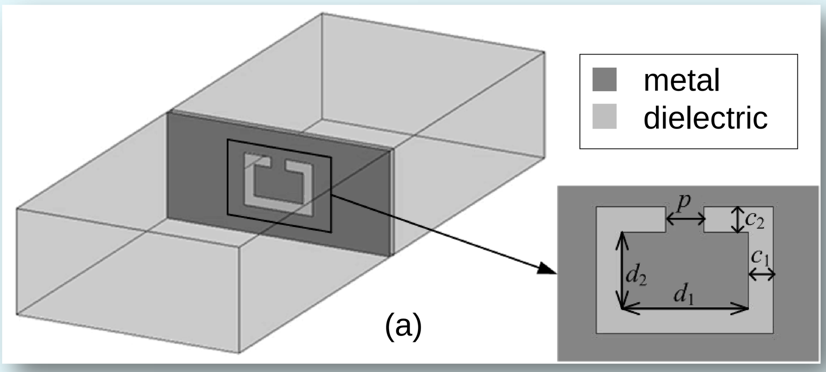
As an output, WIPL-D provides the current distribution on the structure, radiation pattern, near-field distribution, admittance, impedance, and scattering parameters. Precise current modeling is based on polynomial approximation in conjunction with the Galerkin method applied to surface integral equations, resulting in an accurate and efficient method [5]–[7].

Three dimensional electromagnetic modeling of the waveguide filters is presented, here, along with the corresponding results of the full-wave simulation with WIPL-D EM Solver. WIPL-D models of building blocks for bandpass and bandstop filters are presented as well.

Printed-circuit inserts

The rectangular waveguide bandpass building block is shown in Fig. 1.

The equivalent circuit model of this insert in the waveguide is similar to an inductor and a capacitor that are placed in parallel and inserted in a transmission line. Resonance frequency and bandwidth of the *LC* resonance circuit are adjusted by proper choice of the geometrical dimensions of printed-circuit inserts.



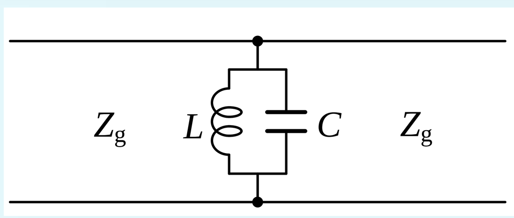


Fig. 1. Rectangular waveguide bandpass building block: (a) 3D EM model and (b) equivalent circuit model

3D EM Modeling

The 3D EM model of the bandpass building block in WIPL-D is shown in Fig. 2 and its response is shown in Fig. 3. The printed-circuit inserts are realized on RT/Duroid 5880 microstrip board with a dielectric constant of 2.2, tanδ=0.0004, a thickness of 0.8 mm, and the metallization thickness of 0.018 mm.

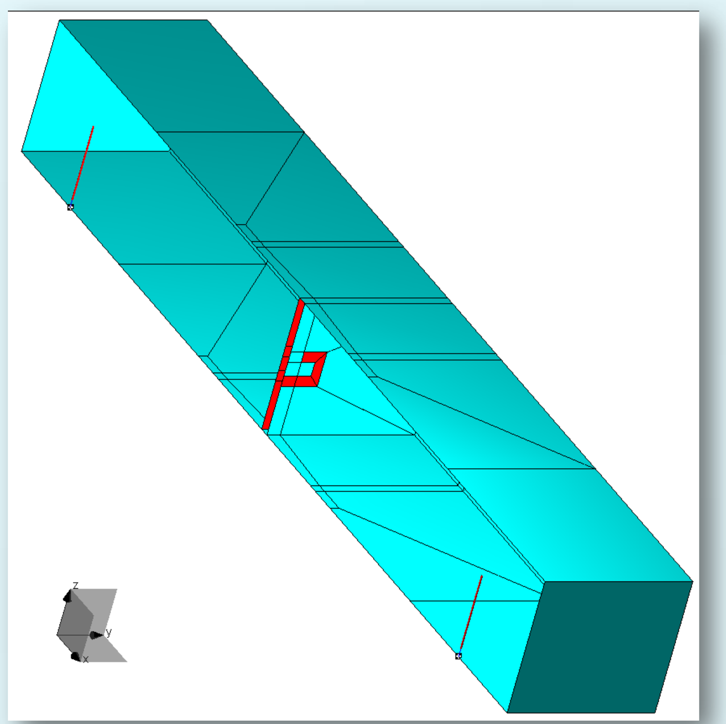
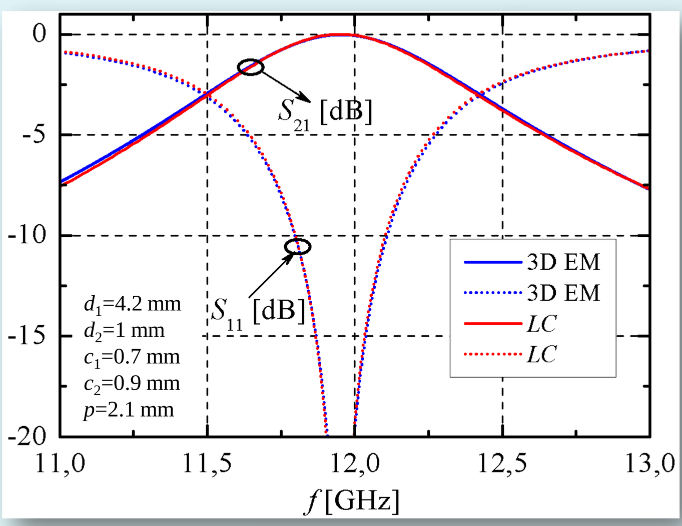


Fig. 2. 3D EM model of the bandpass building block in WIPL-D.



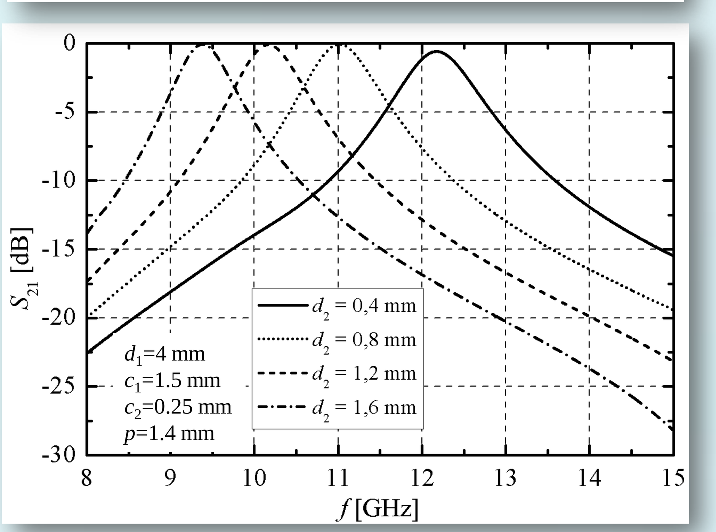


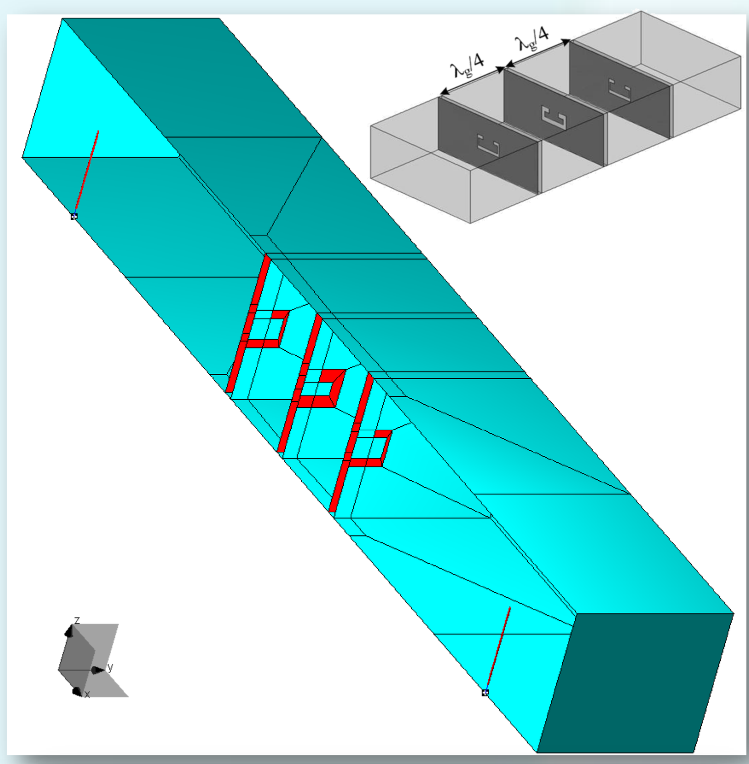
Fig. 3. Response of the building block of Fig. 2.

Bandpass Filter

The bandpass filter considered here is a third-order 0.5 dB equal-ripple Chebyshev filter, which is designed at the center frequency of 11.95 GHz with a fractional bandwidth of 4.18%.

We use the WR90 standard rectangular waveguide of width 22.86 mm and height 10.16 mm. For the dominant mode, the transverse electric TE_{10} mode of propagation, the wave impedance at the center frequency is 451 Ω.

A bandpass filter is designed by cascaded three building blocks and the WIPL-D simulated frequency response shown in Fig. 4.



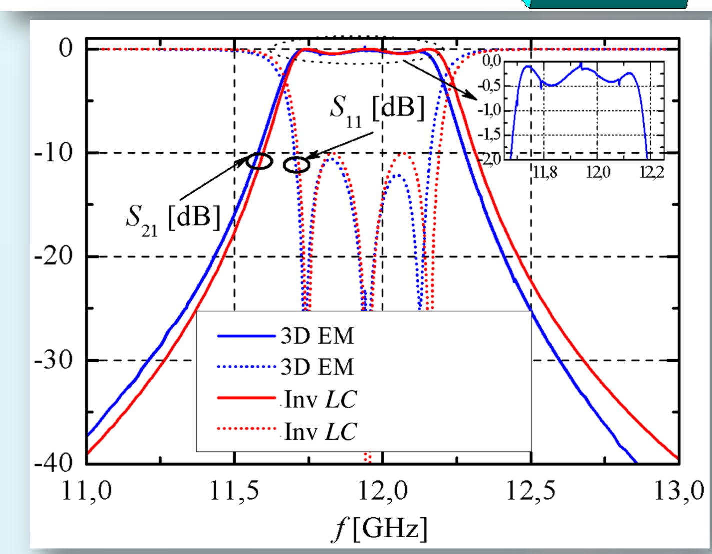


Fig. 4. Waveguide bandpass filter: (a) 3D EM model, (b) filter frequency response.

Conclusion

In this paper, we have presented a 3D EM model and simulation results for a rectangular waveguide filter with printed-circuit inserts, and its building blocks, using the electromagnetic analysis software WIPL-D. The frequency domain results from WIPL-D have been shown. Symmetry properties have been used to significantly speed up the WIPL-D analysis. The filter design underlying theory and algorithm are briefly reviewed. Finally, the performance of the filter has been demonstrated by the WIPL-D simulation results.

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