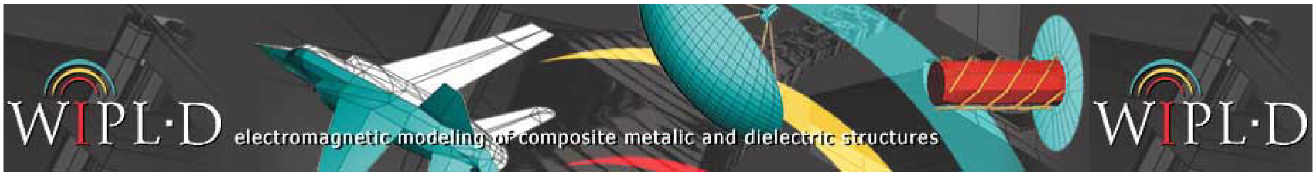

Effective Antenna Design Using EM and Circuit Co-Simulation in WIPL-D Microwave

Introduction

The EM simulation of complex antenna systems presents a challenge for modern computational software. The goal of a circuit-EM co-simulation is to alleviate the computational complexity decomposing the complete system into parts that need to be simulated using full-wave approach, and parts that would be modeled by predefined library components. Encapsulation of proven parameterized antenna models and their reuse within the same or another project is essential in rapid development of complex systems.

Co-Simulation in WIPL-D Microwave

The microwave (MW) circuit is composed of models of lumped elements, transmission lines and discontinuities which are characterized by relatively simple analytical equations based on physical and material properties of components. The circuit solver uses these models to calculate S-parameters of components, and finally S-parameters of the circuit (in reference to its ports).

Main benefit of using circuit analysis is the speed in which results are obtained. The circuit analysis is much faster than full-wave EM analysis, even if done over a wide frequency range because of simple component models. Simulation time does not depend on the size of the circuit (in wavelengths).

However, the validity range of analytical models is often small which significantly limits their applications. Besides, such a circuit model takes into account conductor and substrate losses in a typical circuit, but not radiation mechanisms. It is also difficult to include enclosure effects, since there may be box resonances or waveguide modes in our physical implementation. Furthermore, parasitic coupling between various circuit components is not accounted for.

The most significant drawback of the approach is that there is no possibility to model a device that can't be described by standard library analytical models. Therefore, there is a clear benefit from inclusion of EM simulation capabilities into the circuit simulation. EM models imported into the circuit can be parameterized and treated as any other circuit components in an optimization cycle. EM models allow investigation of wanted or unwanted radiation and coupling mechanisms. Parts of the system whose radiation or EM coupling to other parts of the system are not crucial can be modeled analytically. Moreover, measured data over a frequency range can be imported as a component. Finally, a model of any antenna or antenna component of interest can be included and electromagnetically simulated, on-the-fly, at the circuit simulation runtime. Hence, antennas can be excited in ways that are closer to how the structures are used in practice.

WIPL-D Microwave offers all the possibilities mentioned above, as well as some additional features:

1. Radiation pattern produced by all the radiating components in the circuit (Fig. 1),
2. A WIPL-D designed EM model of circuit components in the library (see Fig. 2) with de-embedded S-parameters calculation,
3. Mode-matching models of the most important rectangular waveguide discontinuities,
4. Library EM models of basic antennas and most often encountered implementation technology transitions (see Fig. 3),
5. An impedance calculator built into each component specification window (Fig. 3).

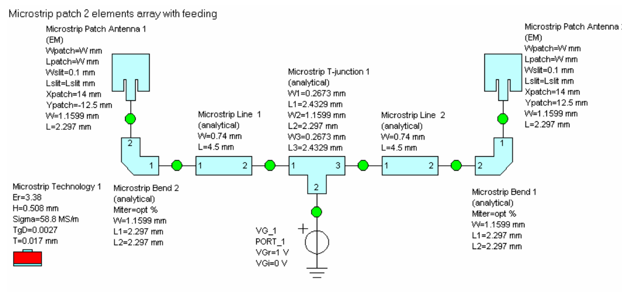

Figure 1. Microwave circuit schematic

Simulation Example

MW circuit shown in Fig. 1 is analyzed using WIPL-D Microwave. The circuit consists of two microstrip patch antennas and a feeding network: microstrip lines, microstrip T-junction and bends. All of the circuit parameters are optimized in order to achieve matching at 10 GHz. Patch antennas are physically separated by a distance which is also forwarded from the circuit, as a parameter. We specified this distance to be 25 mm along *x*-axis. We specified that the only radiating components in the circuit are patch antennas, although there was a possibility to account radiation from other components as well.

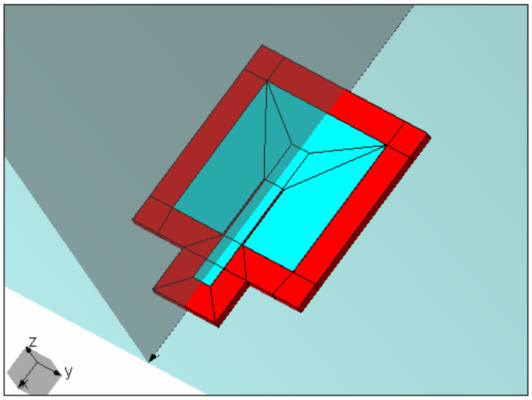

Figure 2. Full-wave microstrip patch antenna model

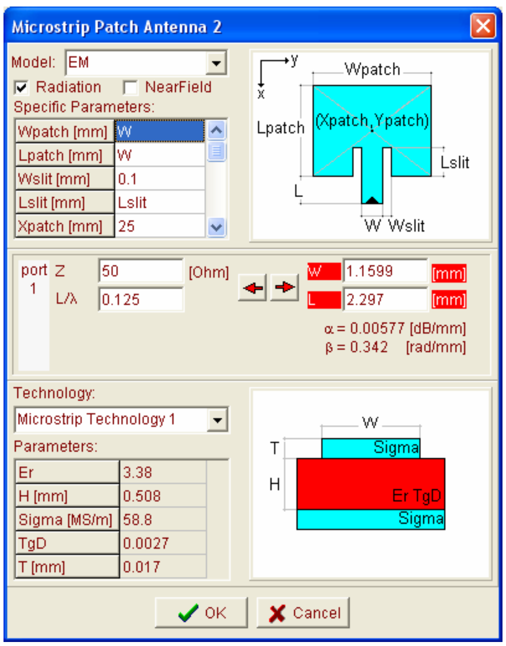

Figure 3. Library microstrip patch antenna dialog box

Full-wave model of the library patch antenna is shown in Fig. 2. Its definition dialog box is shown in Fig. 3.

The circuit is analyzed in the frequency band from 9 to 11 GHz in nine uniformly distributed points. Parameter S_{11} is calculated in order to analyze matching, and shown in Fig. 4. Gain and near field from both antennas are calculated at 10 GHz, and shown in Figs. 5 and 6. Each EM model was simulated separately so gain and near fields were obtained by superposition of these results. The simulation speed-up is significant since two simulations of individual antennas are faster then solving the whole problem at once. The more antennas in an array we have, the speed-up is larger.

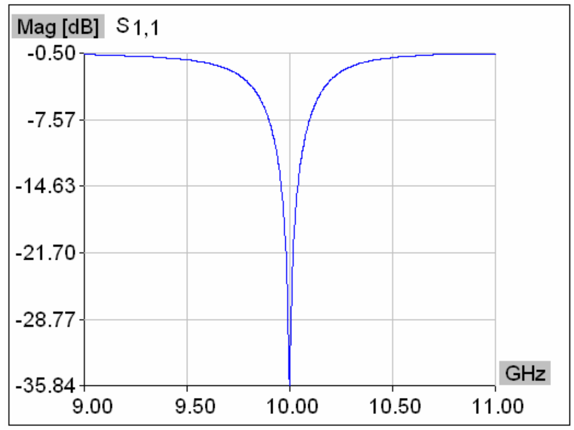

Figure 4. S11 parameter

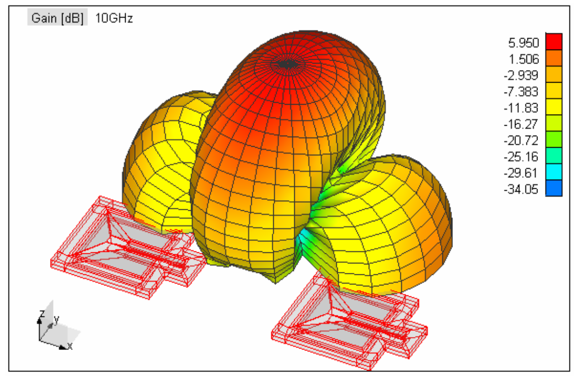

Figure 5. Gain in 3D

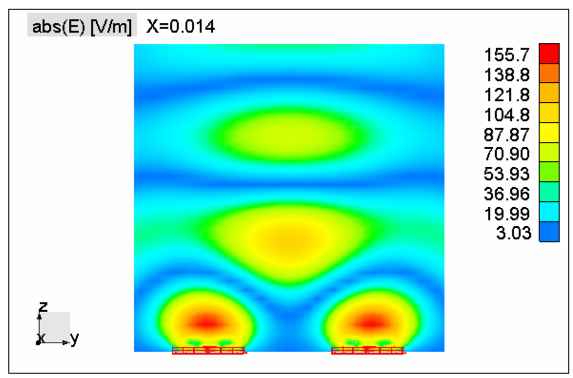

Figure 6. Near field

Conclusion

EM and circuit co-simulation offers a very effective way of designing antennas. Including antenna EM models into the circuit design environment provides greater flexibility in modeling of accompanying circuitry without decreasing the overall simulation speed. Parameterization and reuse of antenna models facilitates complex designs. Automation and optimization tools offer further increase of design productivity. The overall result is better system performance achieved in less time, at a lower cost.