



Agilent EEsof EDA

Overview on EM Accuracy with the Speed of Analytical Models

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Best of Both Worlds: New Modeling Technology Combines EM Accuracy With the Speed of Analytical Models

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Component and circuit models are a cornerstone of EDA technology. As frequencies of operation and circuit complexity increase, the accuracy of these models must keep pace. Recent progress in modeling technology now empowers designers to define the accuracy of their high frequency passive models. High frequency wireless and wireline designers no longer have to settle for pre-defined generalized passive models that only work for limited frequency ranges and process properties.

New technology from Agilent EEsof allows engineers to define the frequency range, material properties, number of parameters and desired accuracy for automatic generation of key passive models. The new Model Composer, part of the Advanced Design System 2001 (ADS 2001) linear simulator, enables generation of electromagnetic (EM) accurate parameterized passive models with the simulation speed of analytical models. With this technology, designers no longer must put up with legacy modeling techniques or invest resources in examining new ones.

The need for accurate analytical models

With wireless and wireline designs constantly increasing in complexity and operating at higher frequencies, design engineers push the limits of their EDA tool's passive analytical models. Often, these passive models are used outside their operational range, causing the EDA tool to return inaccurate simulation results. The inconsistencies of legacy modeling techniques from the 1970s and 1980s hinder the accuracy of these models when applied to different processes and frequencies. Exceeding a model's frequency limit causes errors due to the model's failure to account for higher-order propagation modes. Limitations of the equivalent circuit model, such as frequency independent inductive or capacitive elements, also lead to simulation errors. Since most EDA tools do not proactively report such errors, they propagate through the design flow and may not be discovered until a prototype fails to perform as expected.

As an example, many error-prone passive models tend to be of a discontinuous nature (i.e. microstrip or stripline cross, step, bend, open, gap, etc.) where multimode propagation is common. To avoid errors, full-wave EM simulation is required to fully characterize the structure and produce an accurate S-parameter model of the discontinuity that is then used by the circuit simulator.

This brings us to the topic of developing new models that overcome these technical issues. Developing new models is not a trivial task! To model a single parameter over a range of values, several sample points are required. Since the model can be a function of many parameters (line width, length, metal thickness, dielectric constant, substrate thickness, loss tangent, etc.) there is an exponential growth in the number of samples as

the number of those parameters increases. Also, developing a new model usually requires a highly skilled person working for an extended period—several weeks or even months—to build, test and produce the desired analytical model. If the requirement is for a complete library of models, the total effort is multiplied by the number of models sought. This task needs to be weighed against measurement-based or EM-based modeling on a case-by-case basis.

Previous modeling techniques

Some common approaches to modeling issues have limiting factors. Methods using pre-calculations of equivalent circuits, using a variety of look-up tables, fitting equations and interpolation techniques can have a limited number of samples and have insufficient interpolation methods. One clear example where the dependability of these techniques comes into question is with high-Q resonant circuits such as those used in narrow band filters. Using discrete data grids and interpolation techniques with such circuits might cause the generated model to suffer from either “oversampling” or “undersampling.” With oversampling, too many data samples are collected and model generation is inefficient; on the other hand, with undersampling, too few data samples are collected and the model is not completely defined.

As an alternative to building classic analytical models, engineers can utilize a full-wave EM modeling tool to fully characterize a given passive component. This method permits accurate characterization of the actual passive structure to be used, accounting for higher-order mode propagation, dispersion and other parasitic effects. However, the calculation time required for full-wave EM simulation of a given component makes real-time circuit tuning impossible.

This model accuracy dilemma has been addressed by a new model generation technology in ADS 2001. The new ADS Model Composer combines the speed of analytical models and the accuracy of full-wave EM simulation in one compact parameterized passive model (Figure 1).

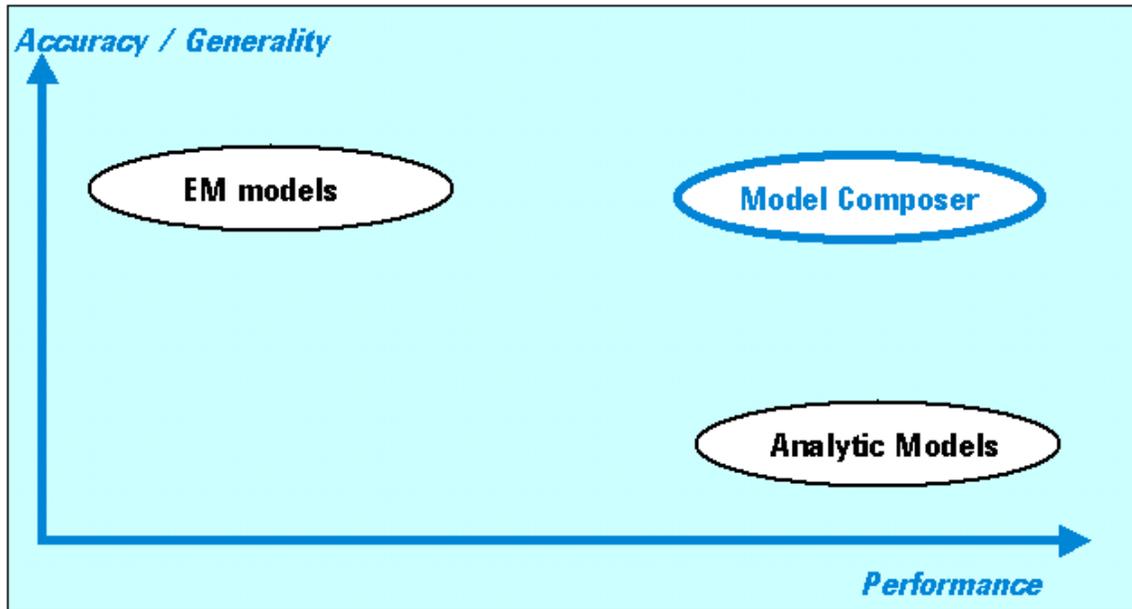


Figure 1. Model Composer combines EM-based modeling accuracy with analytical model simulation speed.

ADS Model Composer

ADS Model Composer presents a new paradigm in passive model generation. It brings the accuracy of EM simulation and the speed of analytical models into a single compact model built on specific process information, the desired frequency range and a set of pre-selected model parameters. The finished models are incorporated into ADS as part of the design kit library, accessible to all designers using the same process.

Designers no longer need to be confined to pre-built generalized passive models that only work for limited frequency ranges and substrate properties. Nor do they need to make the big investment of time and resources to independently develop their own models. Using the ADS Model Composer, designers can now generate, with minimal effort, complete passive component libraries based on the frequencies of interest and process properties. These model libraries are readily shared with colleagues and customers to allow them to achieve the same design accuracy in their contributions to the design process.

The Model Composer is wizard-driven to make it easy for users to generate models of passive elements and discontinuities. It allows users to select the model type, frequency range, process properties and the required associated parameters. Once this set of information is supplied through the wizard, the rest is done automatically. The final compact models exhibit EM accuracy while maintaining the ultra-fast simulation speeds typical of standard analytical models. This combination lets these new models' accuracy be used with design automation techniques such as real-time tuning and performance optimization.

Model Composer technology

The two key technological enablers of this new empowering tool are a new adaptive modeling technique, based on the Agilent-patented Multidimensional Adaptive Parameter Sampling (MAPS) technology, and the proven ADS Momentum full-wave EM modeling technology.

The new technique used in the Model Composer builds a global fitting model of the chosen parameters, handling frequency and geometrical dependencies separately. Multidimensional polynomial fitting techniques are used to model the geometrical dependencies, while polynomial fitting techniques are used to handle frequency dependencies. The modeling process does not require any *a priori* knowledge of the circuit under study. Different adaptive algorithms are combined to efficiently generate a parameterized fitting model that meets the predefined accuracy. This includes the adaptive selection of an optimal number of data samples along the frequency axis and in the geometrical parameter space, and adaptive selection of the optimal order of the multinomial-fitting model. The number of data points is selected to avoid oversampling and undersampling. The algorithm converges when the desired accuracy is reached. The model complexity is automatically adapted to avoid overshoot or ringing, and the model covers the whole parameter and frequency space and can easily be used for optimization purposes.

The MAPS modeling technique follows four steps to adaptively build a model. Step One: The frequency response of the circuit is calculated at a number of discrete sample points using the Agilent Momentum full-wave EM simulator. The Adaptive Frequency Sampling (AFS) in Momentum selects a set of frequencies and builds a rational model for the S-parameters over the desired frequency range (Figure 2). Step Two: A multinomial is fitted to the S-parameter data at all frequencies (Figure 3). Step Three: This model is written as a sum of orthonormal multinomials. The coefficients preceding the orthonormal multinomials in the sum are frequency dependent (Figure 4). Step Four: Using the AFS models built in step one, the coefficients can be calculated over the whole frequency range (Figure 5). These coefficients, together with the orthonormal multinomials, are stored in a database for use during extraction afterwards.

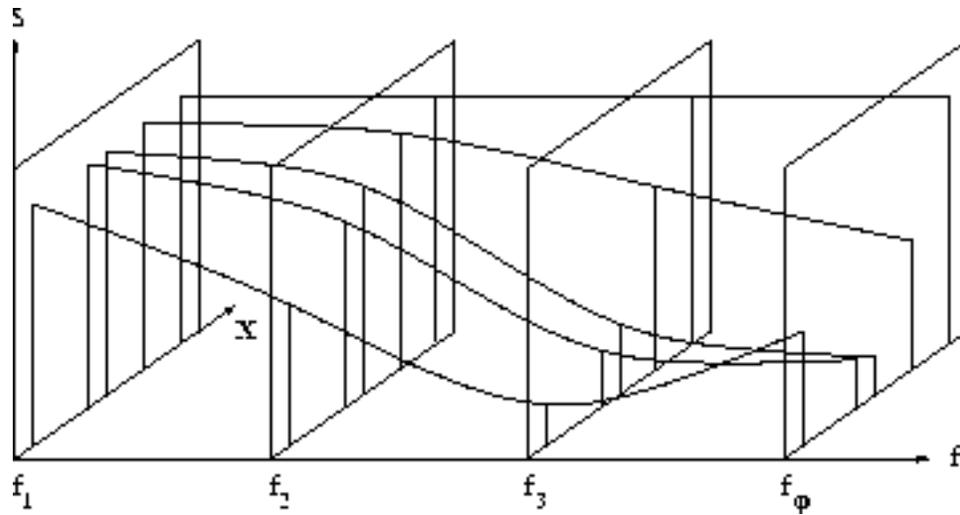


Figure 2. Step One: AFS rational models over the desired frequency range, derived from full-wave EM simulation.

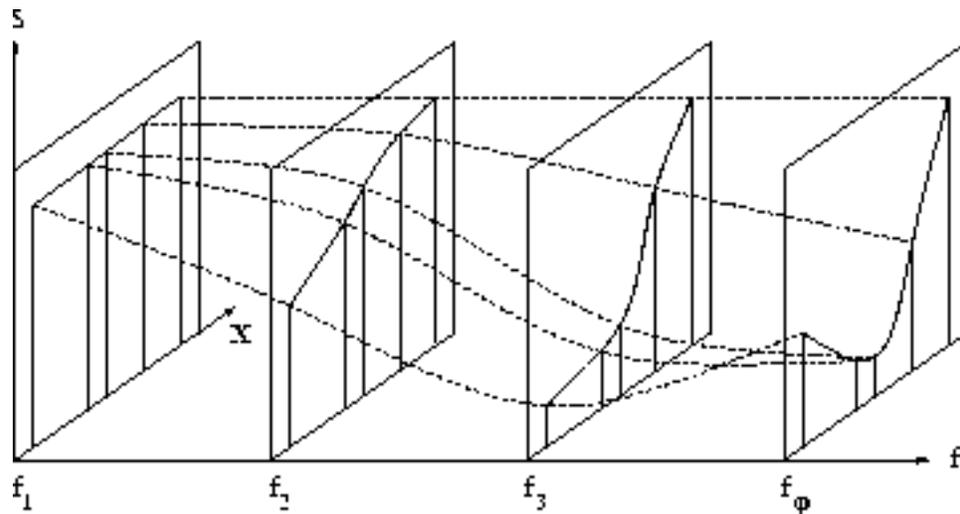


Figure 3. Step Two: Multinomial models are created at discrete frequencies.

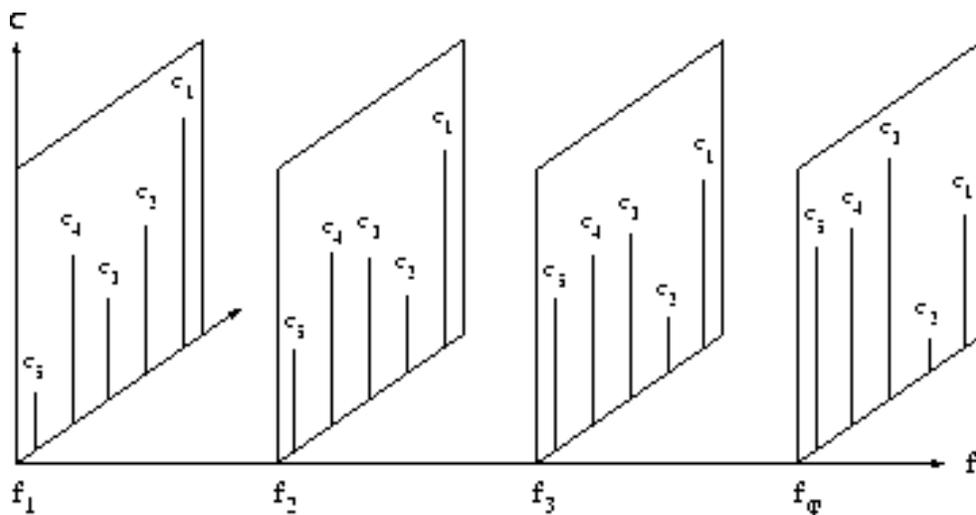


Figure 4. Step Three: Creation of the coefficients of orthogonal multinomials at discrete frequencies.

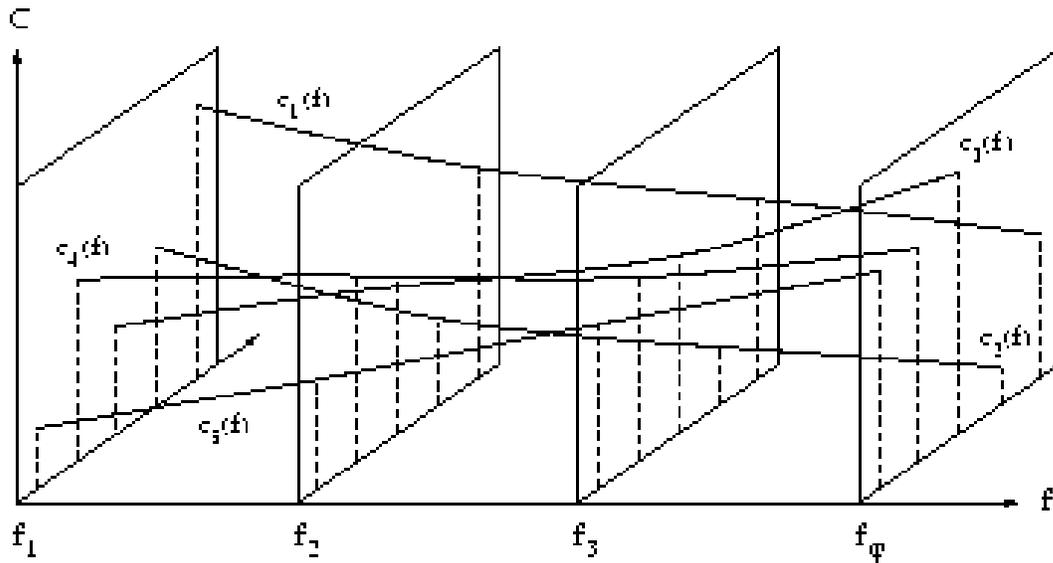


Figure 5. Step Four: Calculation of coefficients of orthogonal multinomials over the entire frequency range.

Application example

To illustrate the versatility of the ADS Model Composer, a low-pass filter (Figure 6) is simulated using ADS standard analytical models, Momentum full-wave EM simulation and, finally, a simulation using discontinuities built using Model Composer.

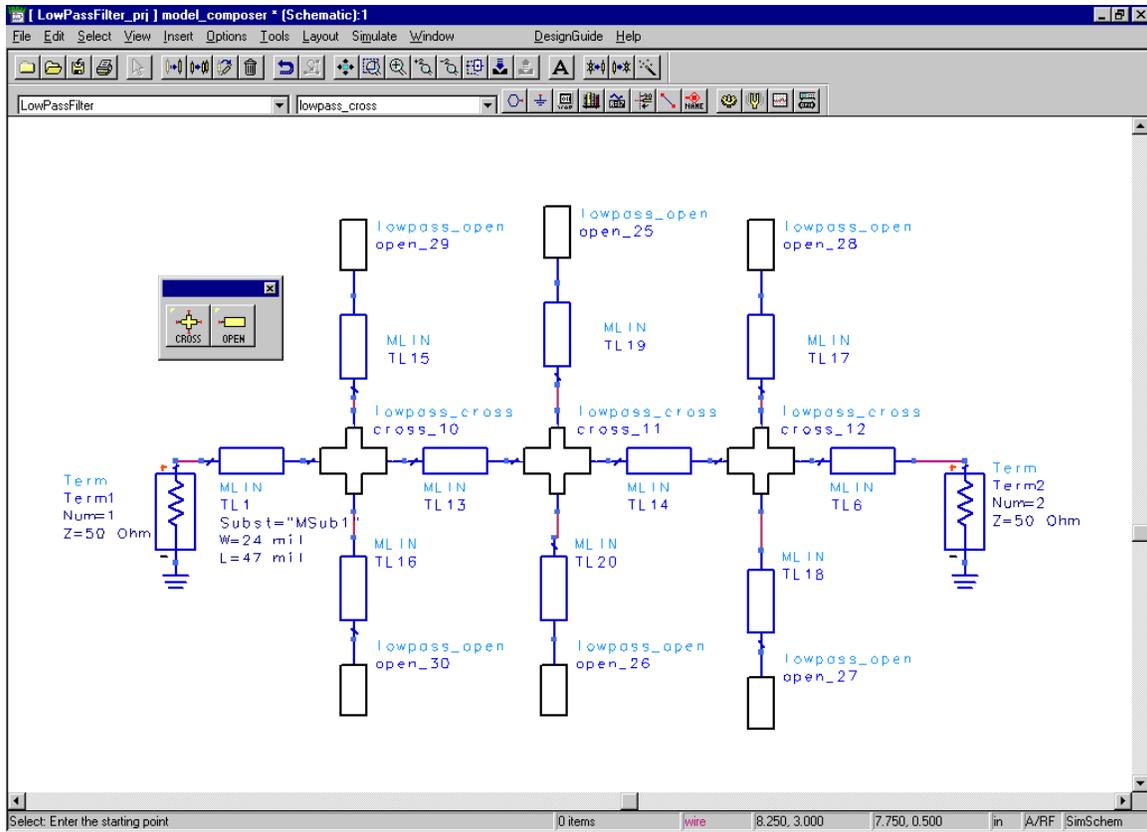


Figure 6. The lowpass filter design used in the example.

The filter incorporates two types of microstrip discontinuities—a cross and an open—that would benefit from more robust models. The new model development process starts by using the Model Composer Wizard user interface to define the substrate information, model types, frequency range, pertinent component parameters and their desired range. The model information is displayed in Table 1.

Model	Parameter	Min.	Max.
Cross	Width1	20 mil	45 mil
	Width2	20 mil	45 mil
	Width3	20 mil	45 mil
	Width4	20 mil	45 mil
Open	Frequency	0 GHz	20 GHz
	Width	20 mil	45 mil
	Frequency	0 GHz	20 GHz

Table 1. Information used to define models to be built by the ADS Model Composer.

Once this information is entered via the model composer wizard, the rest of the process is automatic and runs in the background. The final results are two compact models of the

cross and the open, stored in the ADS design kit folder (Figure 7) with associated electrical models, palette bitmaps, schematic symbols and layout artworks. To verify the model's performance, the filter design was simulated using ADS standard microstrip analytical models, the Momentum EM simulator, and with the newly developed models from Model Composer. Results of these simulations are displayed in Figures 8a-b, along with measured results.

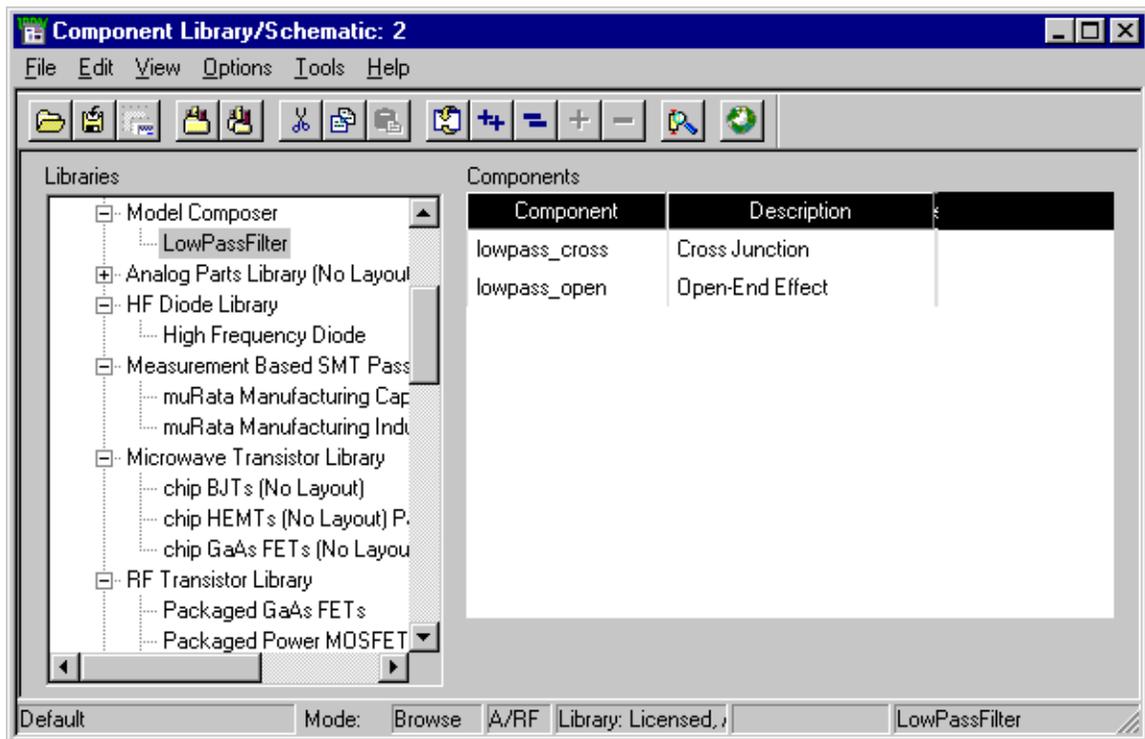


Figure 7. After model generation is complete, models are stored in the ADS Model Composer library folder.

mag(S11) ADS components
mag(S11) Momentum
mag(S11) Model Composer (cross & open)
mag(S11) Measurements

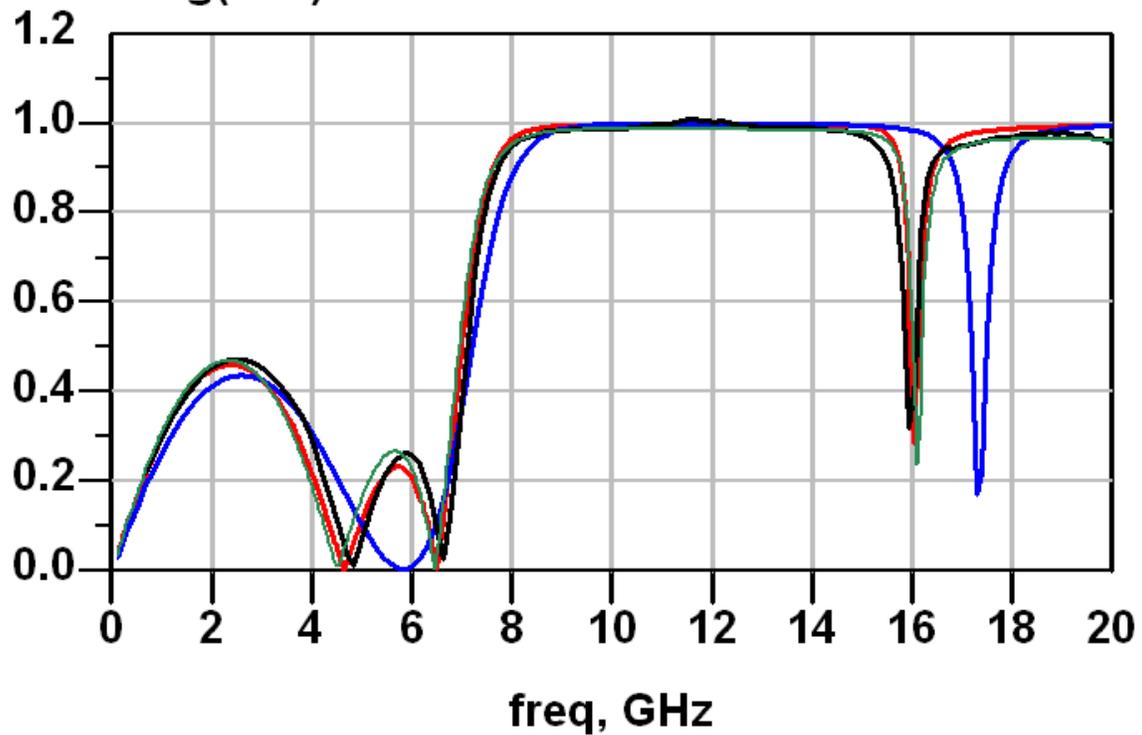


Figure 8a. Comparison of S11 simulations and measurements of the lowpass filter, showing that the use of Model Composer gives results that correspond well with EM-based simulation and measured data.

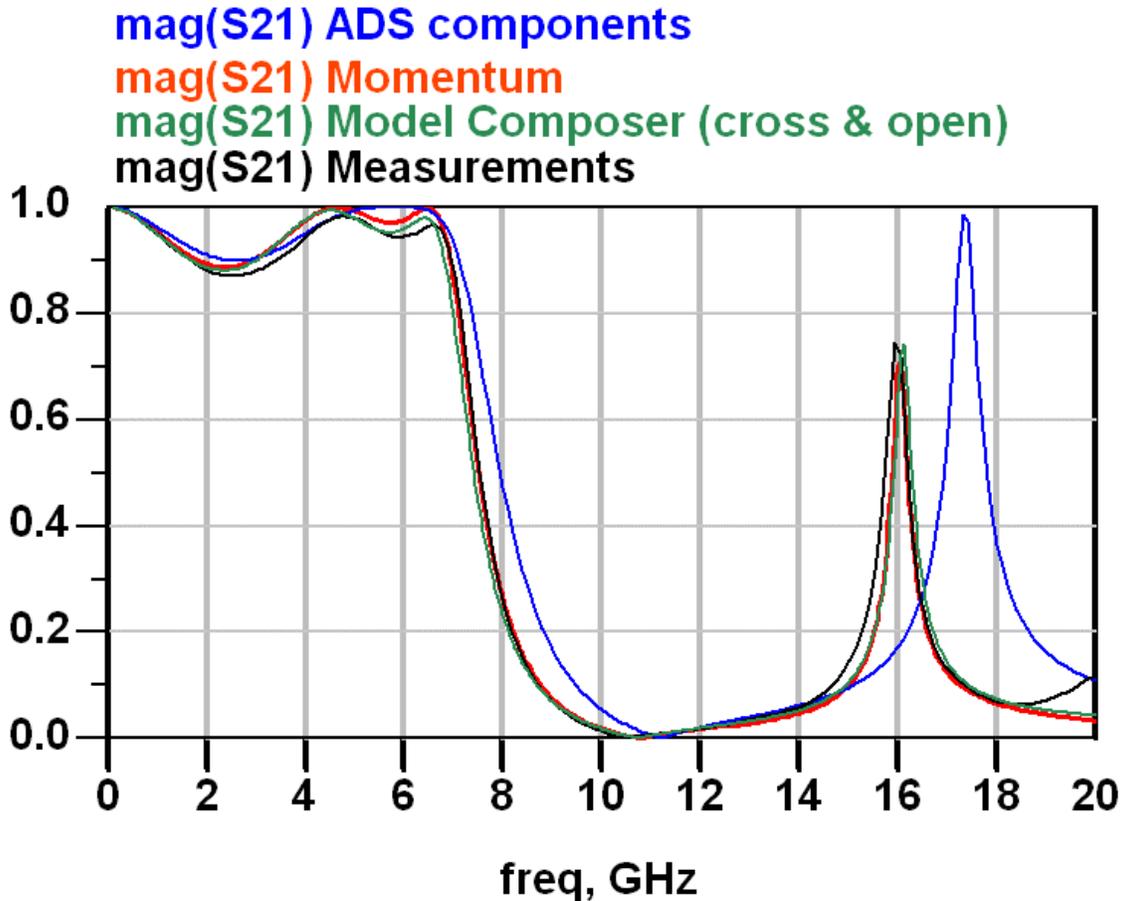


Figure 8b. Comparison of S21 simulations and measurements, clearly illustrating how standard microstrip models deviate from more accurate models (and measurements) at higher frequencies.

The simulation with Model Composer generated models has an accuracy comparable to Momentum and measured data, enabling accurate simulation with the speed of compact analytical models (Figure 9). This powerful combination of accuracy and speed provides the user with greater precision when using circuit automation techniques such as tuning and optimization.

ADS microstrip components
simulation time: 0.45 s
Model Composer: <i>cross</i>
simulation time: 0.63 s
Model Composer: <i>cross & open</i>
simulation time: 0.92 s
Momentum
simulation time: 20 m : 2 s

Figure 9. Comparison of simulation times for the example lowpass filter, using standard microstrip models, Model Composer generated models and Momentum full-wave EM simulation.

Conclusion

With the new ADS Model Composer, Agilent meets RF and microwave designers' need for EM-accurate passive models with the simulation speed of analytical models. ADS users can now develop improved models based on specific operational and material properties. The new Agilent-patented MAPS technology along with the ADS Momentum EM fullwave simulator automate the process of accurate model generation. As the low-pass filter example illustrates, simulations using models created by Model Composer maintain both the accuracy of EM simulation and the speed of analytical circuit models. The new Model Composer is part of ADS 2001's linear simulator and no additional license is required.

To learn more about Model Composer and ADS 2001 visit www.agilent.com/eesof-eda.

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