Agilent Technologies

Advanced Model Composer

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Chapter 1: Advanced Model Composer

This document describes how Advanced Model Composer is used to create multi-dimensional, parameterized, passive planar models for arbitrary-shaped and user-defined parameterized layout components on custom substrates. These models can then be added to a schematic or to a design kit. Troubleshooting information is also included.

Introduction to AMC

AMC combines the capabilities of the Model Composer tool with the generality of layout components. The AMC functionality is integrated in ADS Layout under the Momentum menu: *Momentum > Component > Advanced Model Composer.*

Note Advanced Model Composer and Momentum licenses are required to generate parameterized models for user-defined layout components. Once the model is generated, no license is required when using the model in a schematic environment.

Model Composer (accessible in ADS under *Tools > Model Composer)* is used to create multi-dimensional, parameterized, passive planar models for a number of standard interconnect components such as opens, stubs, bends and tees on custom substrates. For details, refer to the Model Composer manual.

Advanced Model Composer and Model Composer rely on a unique, patented, EM-(Momentum) based modeling method, thus providing EM accuracy and generality at traditional circuit simulation speed. Models are generated in an up-front model generation step and added to the model database associated with the layout component. Models generated by AMC can be recognized by their *.pml* extension.

AMC provides an option for populating the model database of a Layout component, up front, prior to using the Layout component in a schematic. Typically, the model database of a Layout component is updated with Momentum simulation data on-the-fly, while using the Layout component in a schematic.

AMC uses an adaptive rational/polynomial curve fitting algorithm, which is a multi-dimensional version of Momentum’s Adaptive Frequency Sampling (AFS) algorithm.

The *.rat* (=RATional) files generated by Momentum's AFS algorithm contain information about the rational fitting model of single Momentum simulations. There can be multiple *.rat* files in the model database for a single layout component.

The AMC algorithms combine multiple *.rat* files into one global *.pml* (Passive Model Library) file. This file contains the multi-dimensional rational/polynomial model that is used to represent the S-data in the user-defined parameter/design space.

Note Multiple *.rat* files that build up a *.pml* can be deleted. However, this is not necessary and may not be advisable as these *.rat* files can be re-used in a future AMC model generation.

Creating AMC Models

The following procedures assume that a parameterized layout component has been set up and opened in the ADS Layout window. This means that the layout parameters have been defined using the *Momentum > Component > Parameters* dialog and that the Layout component has been created using the *Momentum > Component > Create/Update* dialog. For details regarding these dialogs, refer to Chapter 8, Layout Components, in the *Momentum* manual. For details regarding parameterized layout components, refer to "Examples of Parameterized Layout Components" in the *Momentum* manual.

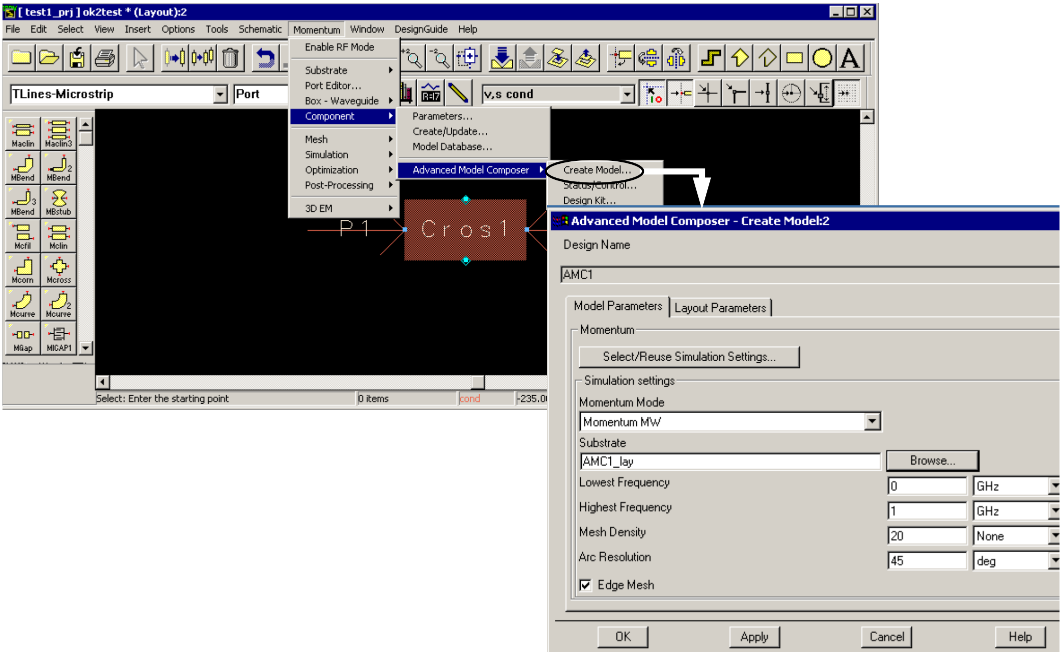
The basics for creating AMC models are:

1. Create the model; monitor the model generation progress.
2. Use the model in the schematic environment like any other ADS component.
3. Optionally, add the model to a standard ADS design kit.

The details for creating AMC models are described in the following pages.

To access AMC:

1. From an ADS Schematic window, choose *Momentum > Component > Advanced Model Composer > Create Model*. This opens the main Advanced Model Composer dialog box.

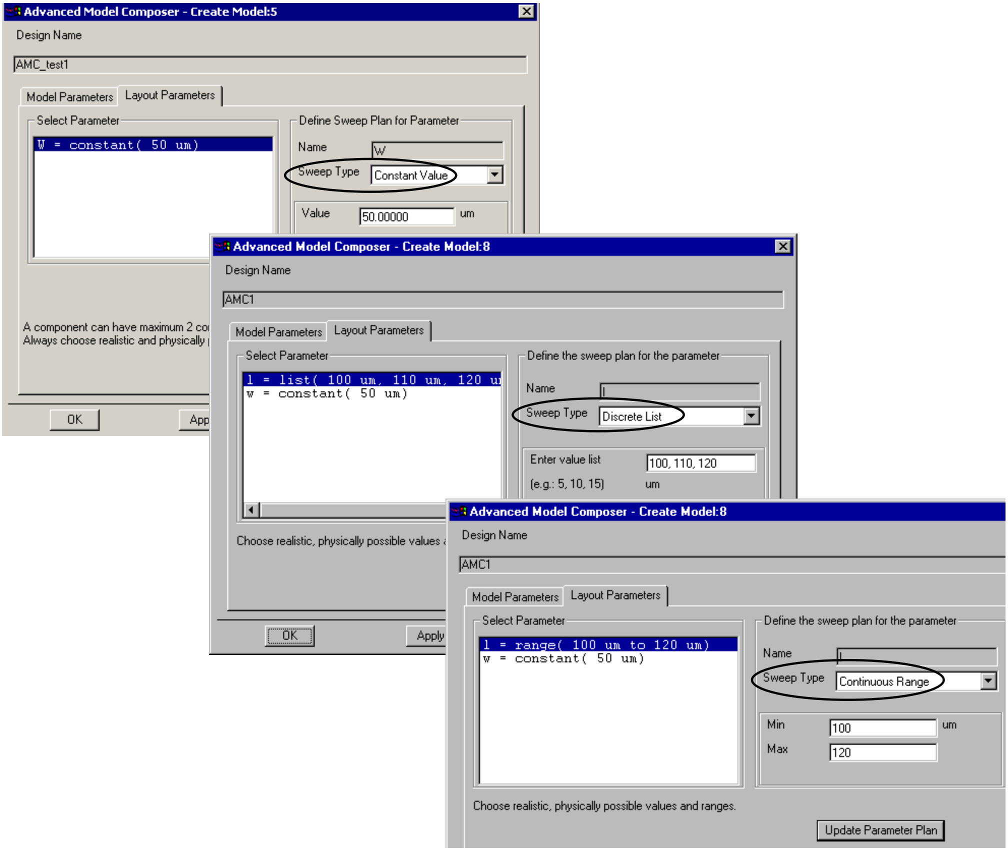


2. The *Model Parameters* tab is used to specify Momentum simulation parameters: mode (Momentum MW or Momentum RF), substrate name (*.slm* file), lowest and highest frequencies, mesh density, arc resolution, and edge mesh.

   If previous Momentum simulation models are available for a Layout component defined in the Layout window, the specific Momentum settings for generating these models can be loaded using the *Select/Reuse Momentum Simulation Settings* button.

3. The *Layout Parameters* tab is used to specify values for layout parameters that will be used in the generation of the AMC model.

   You can choose the sweep type for each layout parameter:



- Constant Value   used to specify that the layout parameter does not have to be swept. A specific sweep type must be specified for each layout parameter. The *Constant Value* option can be used for fixed values.
- Discrete List   contains a set of discrete values. When you use the component on a schematic, you can set the parameter to any value in this list.
- Continuous Range   used to create a model covering a specific range with minimum and maximum values. When the component is used in a schematic, you can then select any value in this range.

  While there is no hard-coded limit to the number of continuous parameters, we recommend not using more that 2 continuous parameters. For more information, refer to “Troubleshooting” on page 1-9.

4. Click **OK** in the *Create Model* dialog to open an information window where you can view the *Parameter Sweep* plan and general information about the model generation process.

   Click **OK** in this information window to start the model generation process.

   A new (non-visual) ADS session will be launched in the background to build the model.

Note You can continue to use this ADS session for other activity (depending on memory availability). Or, you can exit this ADS session without affecting the model generation process.

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5. You can view the model generation process as described in the next section "Viewing and Controlling the Model Generation Progress" on page 1-7.
6. Once model generation is complete, the parameterized model will automatically be stored in the model database associated with this Layout component. The associated Layout component with its parameterized electrical model can be added to a schematic like any other ADS component.

   Optionally, the model can be added to a design kit as described in "Adding AMC Models to a Design Kit" on page 1-8.

Note There is an important distinction between the use of Layout components and components generated with AMC.

When using Layout components directly in the schematic environment, the Momentum engine is called on-the-fly to generate an EM model as part of the circuit simulation (EM/ckt co-simulation).

When using AMC components, the parameterized EM model is generated prior to using the components in the schematic environment, therefore running Momentum is not required during the circuit simulation.

Viewing and Controlling the Model Generation Progress

The model generation progress can be viewed and controlled from any ADS session that is running on the same computer and started by the same user. Type in the *Component* name or click *Browse* to locate the component of interest. The default location is under the *$HOME/hpeesof/amc/components* directory, the name of the model is the same as the name of the layout component.

To view the model generation progress:

1. From the Momentum menu choose *Component* > *Model Composer* > *Status/Control* to view the *Status/Control* dialog box. This dialog box:
    - Describes the status of the model generation
    - Displays any error messages or warnings
    - Enables you to stop the model generation

Adding AMC Models to a Design Kit

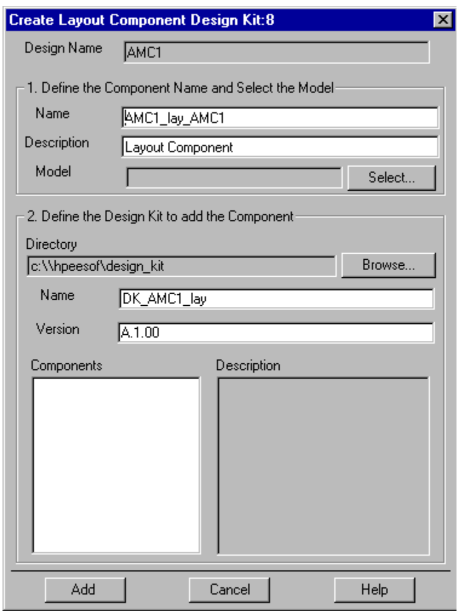
This optional feature is typically used for sharing component libraries among multiple users. An AMC-generated model can be placed directly in a schematic like any other layout component; it is not necessary to place a layout component for which an AMC model has been created into a design kit.

Note Only AMC models can be added to a design kit.

To add the AMC model to an existing ADS design kit or create a new ADS design kit:

1. Select **Momentum** > **Component** > **Advanced Model Composer** > **Design Kit** to open the dialog box.

   Using this menu, the *Layout Component* defined in the layout window where the component was created can be added to a standard ADS design kit.



2. Choose the name of the component to be added to the design kit; add a description; and, select the electrical AMC model you want by selecting the appropriate *.pml* file using the *Model Select* field.

3. Specify the name of the design kit and version. A list of existing components is visible in the *Components* field. You can now add the component and the selected model to an ADS design kit; if the design kit does not already exist, a new one will be created.

4. The design kit can be shared and loaded like any other ADS design kit. For details regarding installing and enabling design kits, refer to Design Kit Installation and Setup in ADS.

Troubleshooting

This section provides troubleshooting information and describes solutions.

Errors are produced when attempting to generate an AMC model.

This can be due to a variety of problems. Typically, this is caused by non-physical combinations of:

- Substrate
- Maximum frequency
- Layout parameters

such that, the higher order modes are excited, the Momentum simulator produces non-physical results, and the AMC modeling process cannot converge.

Possible solutions are:

- Limit the frequency range
- Limit parameter ranges (for example, limit width)
- Check units (for example, m instead of µm)
- Limit the number of continuously varying parameters. The maximum is two per component, for practical reasons. Consider that the modeler uses about 5 to 10 Momentum simulations for each continuously-varying parameter. This means
  - one continuous parameter would require 5 to 10 simulations
  - two continuous parameters, 25 to 100 simulations
  - three continuous parameters would require 125 to 1000 simulations
  - four continuous parameters would require 625 to 10,000 simulations.

- Use constant values and discrete lists. Often, the line width of the metallization is limited and varies in a discrete way based on a given technology or application. If so, use discrete parameter lists that correspond to real world limitations.
- Replace a single model definition (with widely varying ranges) by multiple models of the same layout component, each valid in a subset of the original parameter space.
- Perform a worst case analysis of the library specifications (check the combination of max frequency, max width, and substrate) to make sure that no higher order modes occur. Momentum can be used to see if the simulation results (S-data) make sense.

A typical work-around is to use discrete lists and limit ranges. With wider ranges and more continuously varying parameters, longer modeling times and more Momentum simulations will be required. (Carefully consider the parameter ranges and ensure that all values are physically possible.)

It should be noted that the AMC is designed for the purpose of component modeling, (i.e., components that are small compared to the wavelength). When modeling structures with resonances, the simulation time required to generate the model can increase significantly due to the fact that more Momentum simulations must be performed to get a converged model and that each of the Momentum simulations will require more frequency points.

Note When the mesh density is set too low, mesh noise in the simulated models can influence the model generation process in such a way that the convergence of model generation is not reached within a reasonable number of samples. In this case, increase the mesh density.

It is recommended to simulate the component in the extremes of the parameter ranges prior to starting the tool; this will ensure that the Momentum model generation process for the selected simulation control options completes successfully.

AMC Model Generation Technique

AMC provides a method to build multidimensional parameterized analytical models for passive planar components. This produces highly accurate analytical models that can be used by all ADS circuit simulators. Model generation is based on EM simulation techniques, providing EM accuracy and generality at traditional circuit simulation speed.

The model generation technique, referred to as *Multidimensional Adaptive Parameter Sampling* (MAPS), selects a minimum number of EM simulations and builds a global analytical fitting model for the scattering parameters of general planar structures as a function of the geometrical parameters and of the frequency, with a predefined accuracy. Data points are selected efficiently and model complexity is automatically adapted. The algorithm consists of an adaptive modeling loop and an adaptive sample selection loop described in the following sections.

Adaptive Model Building Algorithm

The scattering parameters S are represented by a weighted sum of multidimensional orthonormal polynomials (multinomials) P_m. The multinomials only depend on the multidimensional coordinates $\bar{x}$ in the parameter space R, while the weights C_m only depend on the frequency f:

$$S(f,\bar{x}) \approx M(f,\bar{x}) = \sum_{m=1}^{M} C_m(f) P_m(\bar{x}) \qquad (1\text{-}1)$$

The weights C_m are calculated by fitting the above equation on a set of D data points $\{\bar{x}_d, S(f,\bar{x}_d)\}$ (with $d = 1, ..., D$). The number of multinomials in the sum is adaptively increased until the error function:

$$E(f,\bar{x}) = |M(f,\bar{x}) - S(f,\bar{x})| \qquad (1\text{-}2)$$

is lower than a given threshold (which is function of the desired accuracy of the model) in all the data points. For numerical stability and efficiency reasons orthonormal multinomials are used, that is. the multinomials $P_m(\bar{x})$ satisfy the condition:

$$\sum_{d=1}^{D} P_k(\bar{x}_d) P_l(\bar{x}_d) = \begin{cases} 1 & \text{for } (k = l) \\ 0 & \text{for } (k \neq l) \end{cases} \qquad (1\text{-}3)$$

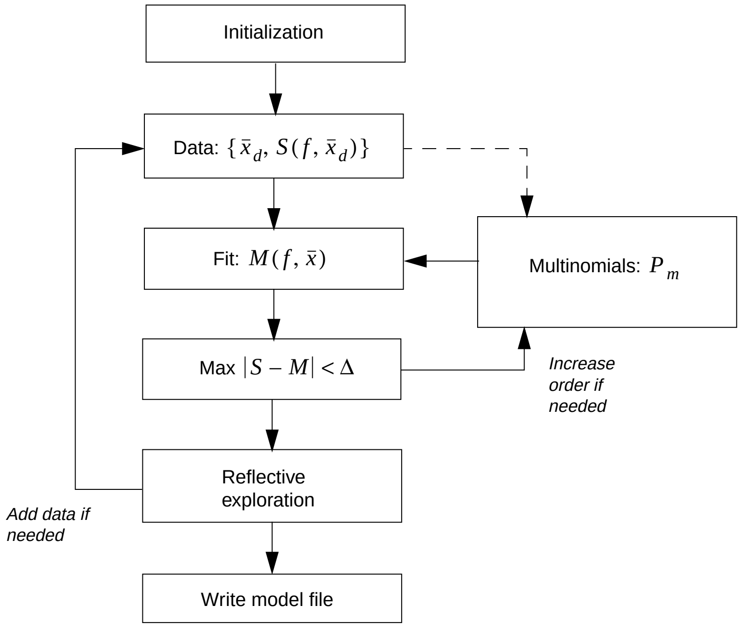
Adaptive Data Selecting Algorithm

The modeling process starts with an initial set of data points. New data points are selected adaptively in such a way that a predefined accuracy Δ for the models is guaranteed. The process of selecting data points and building models in an adaptive way is often called *reflective exploration*. Reflective exploration is useful when the process that provides the data is very costly, which is the case for full-wave electro-magnetic (EM) simulators. Reflective exploration requires *reflective functions* that are used to select a new data point. The reflective function used in the MAPS algorithm is the difference between two different models (different order M in equation (1-1)). A new data point is selected near the maximum of the reflective function. When the magnitude of the reflective function becomes smaller than Δ over the whole parameter space, no new data point is selected.

If one of the scattering parameters has a local minimum or maximum in the parameter space of interest, it is important to have at least one data point in the close vicinity of this extremum in order to get an accurate approximation. Therefore, if there is no data point close to a local maximum or minimum of $M(f,\bar{x})$, the local extremum is selected as a new data point. For resonant structures, the power loss has local maxima at the resonance frequencies. Again, to get an accurate approximation, a good knowledge of these local maxima is very important.

The scattering parameters of a linear, time-invariant, passive circuit satisfy certain physical conditions. If the model fails these physical conditions, it cannot accurately model the scattering parameters. The physical conditions act as additional reflective functions: if they are not satisfied, a new data point is chosen where the criteria are violated the most.

The algorithm flowchart is shown next.


Initialization
Data: $\{\bar{x}_d, S(f, \bar{x}_d)\}$
Fit: $M(f, \bar{x})$
Multinomials: P_m
Max $|S - M| < \Delta$
Increase order if needed
Reflective exploration
Add data if needed
Write model file

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