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Data Based Load Pull Simulation

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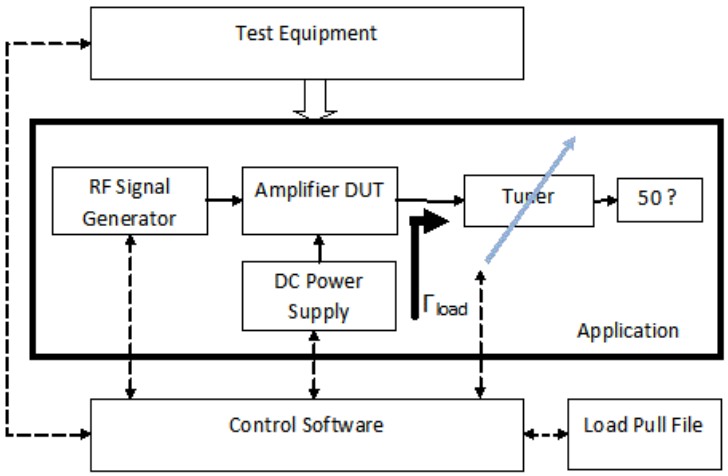
Introduction

Load Pull Concept

Load pull is the most well known form of impedance-pulling. Impedance-pulling is the process of monitoring various performance parameters while modifying the value of a specific impedance in the system. When the modified impedance is the load, the process is known as load pull. When the modified impedance is the source, the process is known as source pull.
Load pull is one of the methodologies used in designing and testing high-power RF-amplifiers. It is widely used for RF-amplifiers since the performance of a power amplifier strongly depends on the load.
Typical performance parameters monitored during a load pull process for an amplifier are output power, power added efficiency, intermodulation products, DC-power consumption. Many other parameters could also be monitored.

Load Pull Measurement

The load pull measurement requires the use of an instrument capable of precisely controlling the impedance shown as load to the device-under-test (DUT). This impedance-control instrument is the tuner.
The manufacturers of tuners typically provide complete solutions for load pull measurements: the tuner, the necessary accessories to interface with the required test equipment and the software that controls the tuner and the measurement process in general.



Various parameters other than the load can also be swept during the load pull measurement process, like operating frequency, bias, input power level, etc. This leads to a large amount of valuable information about the behavior of the DUT.
The software (usually provided by the manufacturer of the tuner) records the results of the load pull measurement in a file known as the load pull file. The file format is specific to individual manufacturers, but the information contained is usually very similar: performance parameters as a function of load-impedance value and other swept parameters. Maury Microwave Corporation is one of the well known load pull solutions providers.

Data Based Load Pull Simulation

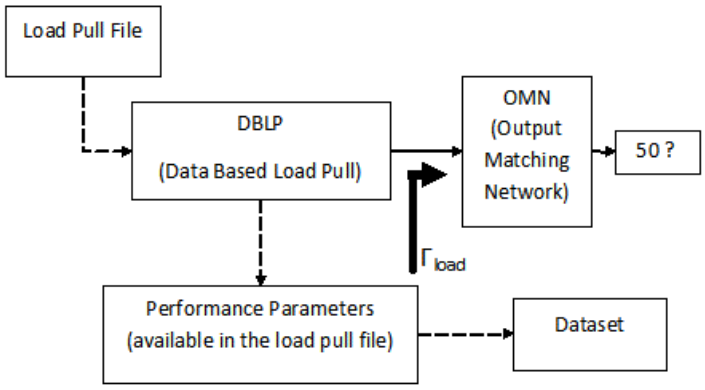
Observing the results of a load pull measurement gives valuable insight into what would the optimum load be for different performance parameters. In general, the optimum load is different for different performance parameters. For example, the optimum load for output power is different than the optimum load for power-added efficiency. It is thus the task of the designer to find the unique load value that achieves the best compromise for

all performance parameters across frequency band, power levels and other conditions that have been swept during measurement. We will refer to this impedance as the optimum impedance.

It is desirable to have the means of using the measured data in the simulation environment to design the output matching network that converts the load required by the application (typically 50 Ω) into the optimum impedance for the DUT. The data based load pull simulation is implementing this requirement. ADS currently supports only the Maury-type of load pull files in the data based load pull simulation.

About Data Based Load Pull Simulation

The data based load pull (DBLP) simulation uses the measured data available in one or more load pull files and returns the performances achieved when using specified load-impedance values. The data based load pull simulation returns only performance parameter values that are available in the original load pull files, which is the only reliable information available for the device-under-test under the specified conditions.

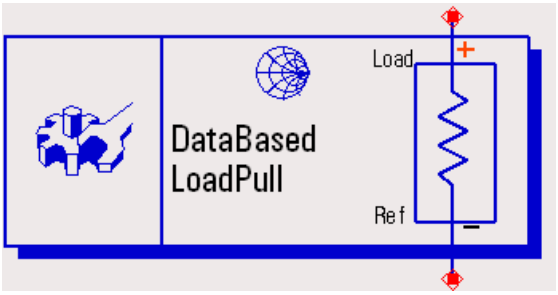


Currently, ADS data based load pull simulation only supports linear simulation. So the output matching network is required to be linear circuit. For nonlinear circuit, only small-signal behavior is analyzed through configuring the data based load pull controller (see *Allow Nonlinear Devices* (cktsimldpull)).

The data based load pull simulation can provide:

- The reflection coefficient/impedance/admittance is provided for the load.
- The scattering parameters (S-parameters) and/or the Y- and/or the Z-parameters are provided for a multi-port output matching network.
- The performance parameter values from the load pull measurement data (from the load pull file(s)) corresponding to the load provided to the device-under-test.

The Data Based Load Pull Controller



The goal of the data based load pull controller is to simplify the setup for the load pull file access and simulation. As a result, you can focus on the design of the output matching network. The data based load pull controller is a complex component that includes:

- An S-Parameter controller
- A Term component
- Pins to connect to the output matching network
- Functionality to access the load pull file(s)
- Functionality for auto-displaying results in the data display window (DDS)

The data based load pull controller has a set of parameters to support its functionality (file access, Term component, S-Parameter analysis, outputs, etc). The detailed information regarding these parameters is given in *Parameters of the Data Based Load Pull Controller*

(cktsimldpull).

The Load Pull Files

Currently, ADS data based load pull simulation only supports Maury load pull files. The supported Maury file types include:

- Sweep reflection coefficient (gamma) at fundamental(.lp).
- Sweep reflection coefficient (gamma) at second harmonic(.lp2).
- Sweep reflection coefficient (gamma) at third harmonic(.lp3).
- Sweep other parameters using Maury sweep plan (.spl).

The Data Based Load Pull Simulation Setup

The overall design setup consists of two steps:

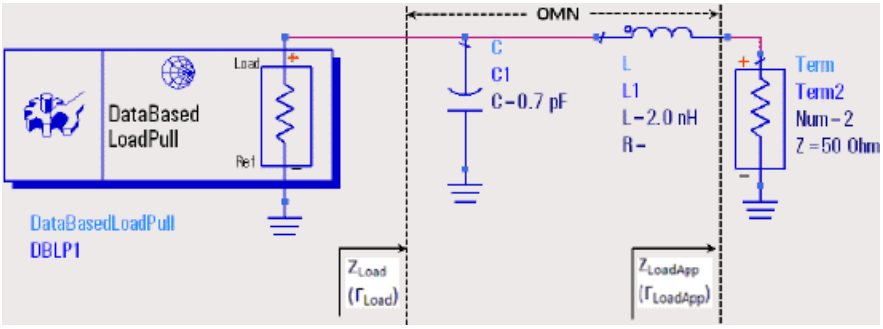
- Create the output matching network.
- Setup of the data based load pull controller. Only the setup of load pull file(s) is a required setup.

Setting up the data based load pull controller consists of:

- Setting up the load pull file(s)
  The data based load pull controller allows you to specify one more load pull files. From these load pull files, a measurement database is created and used for the simulation. The measurement data has no dimension limitations. However, the specified load pull files have to be homogeneous. Two load pull files are said to be homogeneous if:
  - They are of the same file-type
  - They contain the same variables (both independent variables and performance parameters)
- Setting up S-Parameter Simulation
- Setting up interpolation/extrapolation methods
- Setting up outputs and auto-displays
- Setting up Term component

For the detailed setup procedure, please refer *Examples of Data Based Load Pull Simulation* (cktsimldpull) and *Parameters of the Data Based Load Pull Controller* (cktsimldpull).

Overall Simulation Flow



After the design is created and the data based load pull controller is set up, the simulation starts once the **Simulate** icon is clicked. The simulation flow includes:

- Merging load pull files when multiple load pull files are used to create the scattered measurement database
- Gridding the scattered measurement database to produce the gridded measurement database if it is necessary
  Load pull file(s) contain scattered measurement data. To achieve fast interpolation,

data gridding is done on the scattered measurement data. Then the following simulation with interpolation is performed on the gridded measurement data. Data gridding is time consuming. So the data based load pull simulation tries avoiding unnecessary data gridding. After the first data gridding, the gridded measurement database is stored in dataset format. For following simulations, if the original load pull file(s) are not changed, the simulation will skip the data gridding step and directly use the gridded measurement database.

- For each frequency
  - An S-Parameter analysis will be performed to translate from $Z_{loadApp}$ to Z_{load}
  - The performances will then be obtained for Z_{load} from the gridded measurement database
  - The performances and other results will then be saved to the simulation results in the dataset format

Advanced Data Based Load Pull Simulation

The data based load pull simulation can work with advanced simulations in ADS, just like other circuit simulation controllers (eg. S_Param Controller). The advanced simulation architecture supports:

- Parameter Sweep
- Optimization
- Monte Carlo/Yield
- Design of Experiment
- BatchSim
- Sequencer

Performing a Data Based Load Pull Simulation

The data based load pull simulation embeds an S-Parameter simulation. So there are many similarities in the simulation setup. For detailed information regarding the S-Parameter simulation, refer *S-Parameter Simulation* (cktsimsp). Refer *About Data Based Load Pull Simulation* (cktsimldpull) for the simulation flow of the data based load pull simulation. The followings are general comments when you are using the data based load pull simulation.

Start by creating the output matching network, then add a data based load pull controller, connecting with the output matching network.

For a successful analysis, be sure to:

- Apply ports to all outputs. Terminate all other ports using port-impedance terminations (Term). Verify impedance. The Term component is found on the Simulation-Load Pull palette.
- Check the Num field for each port. The S-parameter port numbers are derived from these fields. Please note, the data based load pull component embedded a port. For a 2-port circuit, you would want the input labeled as Num=1 and the output as Num=2.
- Double-click the data based load pull controller to edit it. For a basic simulation, just specify the load pull files to be used.
- To calculate admittance or impedance parameters, enable the options under the Analysis->Parameters tab.

For details about each field, click *Help* from the dialog box.

For more detailed descriptions of simulation setups, refer to *Examples of Data Based Load Pull Simulation* (cktsimldpull).

For possible problems encountered during the data based load pull simulation, refer to *Troubleshooting for Data Based Load Pull Simulation* (cktsimldpull).

Examples of Data Based Load Pull Simulation

This section includes multiple examples that are intended to help you with the understanding of the usage of the data based load pull simulation. The examples provided in this section are from Using_Meas_Load_Pull_Data_wrk, which is located in the directory *$HPEESOF_DIR/examples/Tutorial*. To access this example workspace and enable simulation, open the example by choosing **File** > **Open** > **Example** > **Tutorial** > **Using_Meas_Load_Pull_Data_wrk** from the ADS Main window.

The examples covers the following topics:

- Single Data Based Load Pull Simulation
- Swept Data Based Load Pull Simulation
- Optimization with a Data Based Load Pull Simulation

Single Data Based Load Pull Simulation

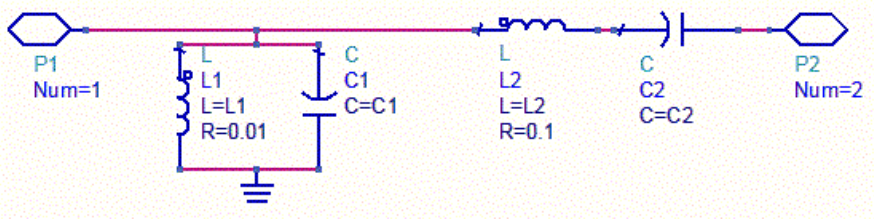
Single data based load pull simulation can have various applications. We include three cases here.

Single Data Based Load Pull Simulation: Minimum Configurations

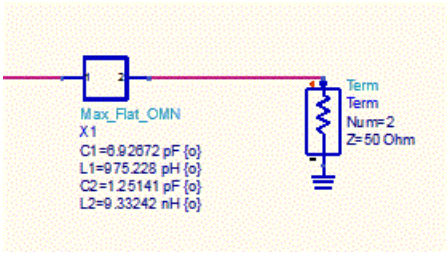
The design is called Test_Meas_LP_Data_wOMN. We will use this example to illustrate minimum setups for the data based load pull simulation.

Creating the Circuit

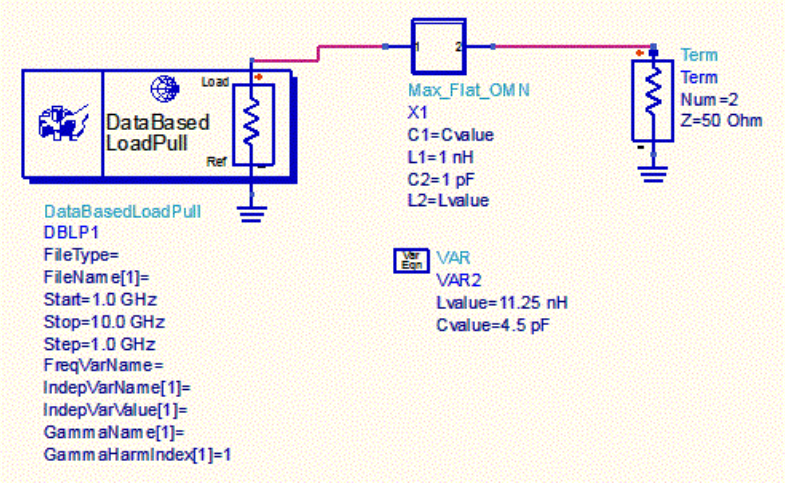
Depending on the application, you need to have the initial circuit design, for example, the output matching network design. In this example, the output matching networks design is Max_Flat_OMN.



Putting the Load and Connecting it to the Circuit

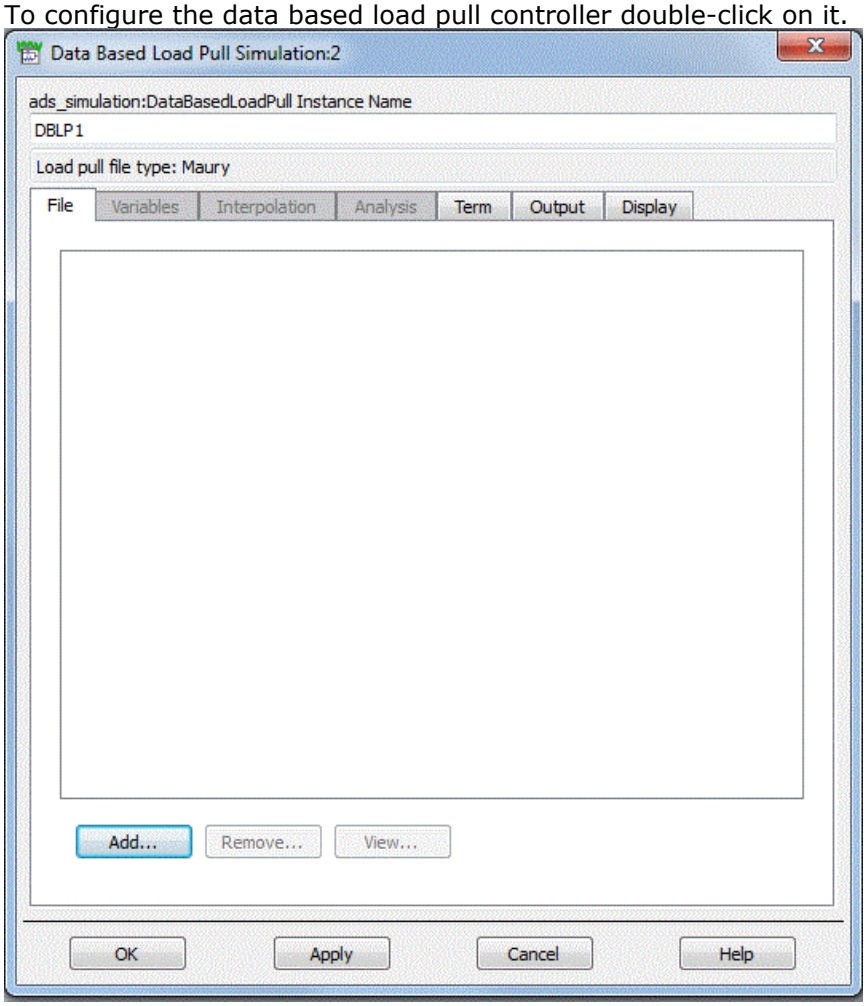


Putting the Data Based Load Pull Controller and Connecting it to the Circuit



Configuring the Data Based Load Pull Controller

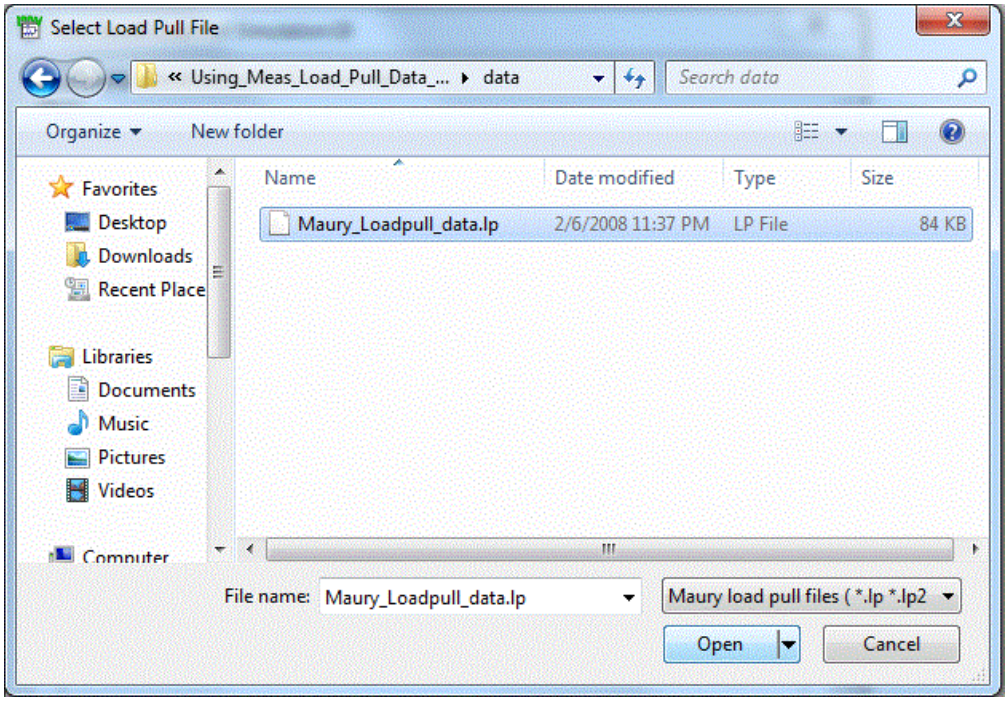
To configure the data based load pull controller double-click on it.



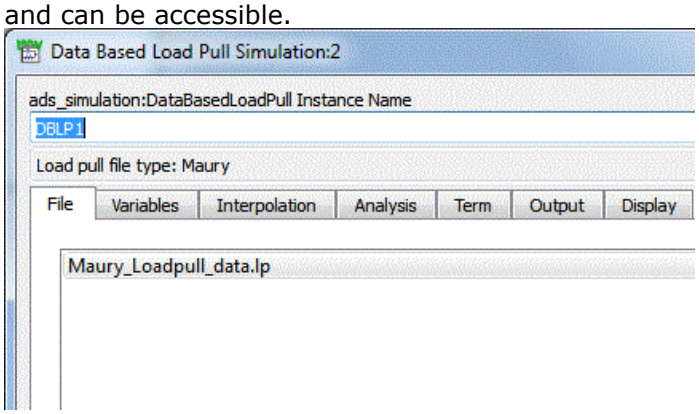
There are seven tabs for a data based load pull controller. When no load pull file is specified, *Variables*, *Interpolation*, *Analysis* Tabs are not accessible.

Specifying the Load Pull File(s)

This is the only required step in configuring the data based load pull controller. Click **Add** to bring up the file browser. By default, it is in current *workspace/data* directory. You can change the directory and select one or more load pull files. After you click **Open**, the file browser will be dismissed and the selected load pull file(s) are parsed.

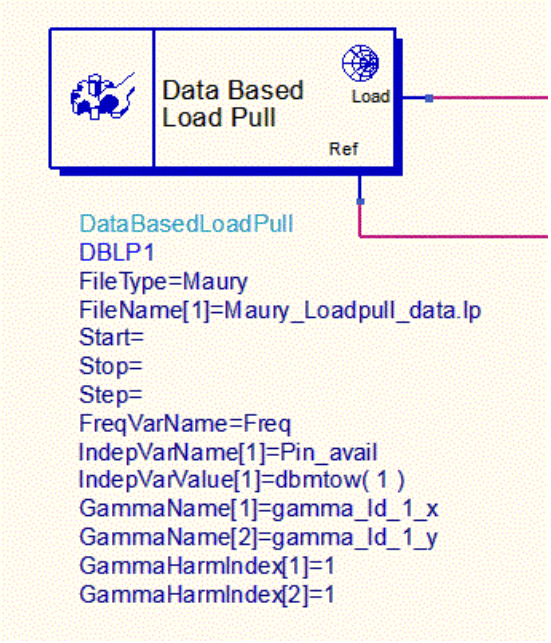


When the selected load pull file(s) are homogeneous, the data based load pull controller will be updated, using the measurement data from the files. All of the Tabs are activated and can be accessible.



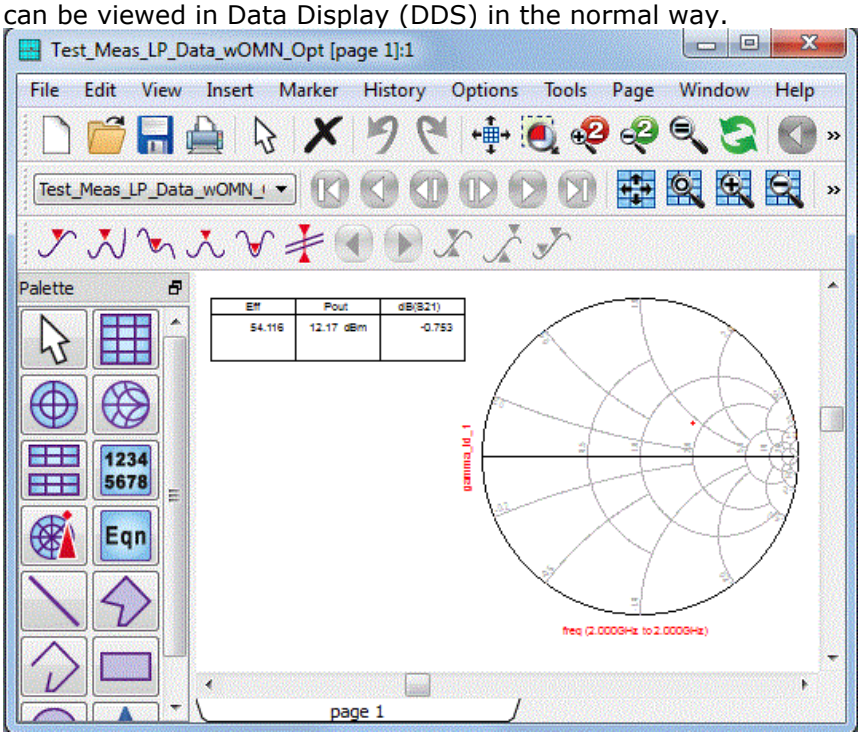
Dismissing the Data Based Load Pull Controller

All other configurations for the data based load pull controller have default values, according to the specified load pull file(s). So for the simplest case, you can ignore them and close the data based load pull controller by clicking **OK**.



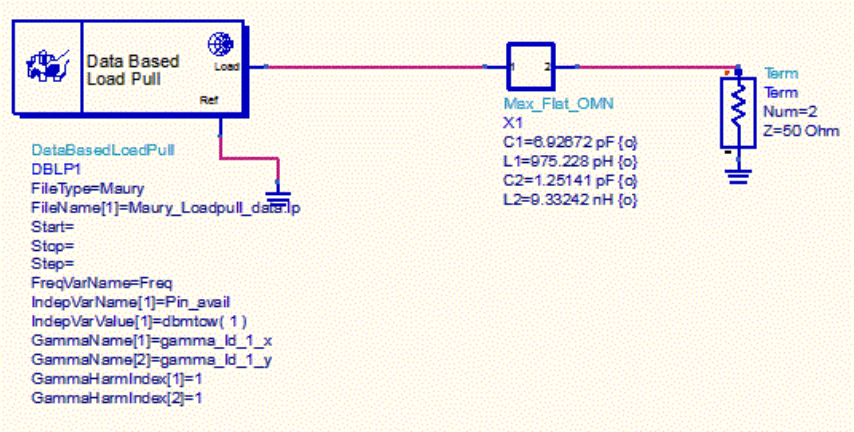
Simulating the Design

Choose **Simulate > Simulate**, or click **Simulate** icon to simulate the design. The results can be viewed in Data Display (DDS) in the normal way.



Single Data Based Load Pull Simulation: Detailed Configurations

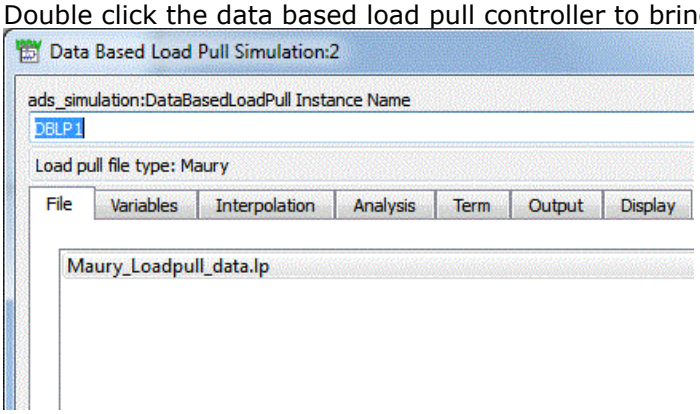
We will continue to use the same example to illustrate the detailed configurations.



For the complete descriptions for the parameters, please refer *Parameters of the Data Based Load Pull Controller* (cktsimldpull).

Modifying the Data Based Load Pull Controller

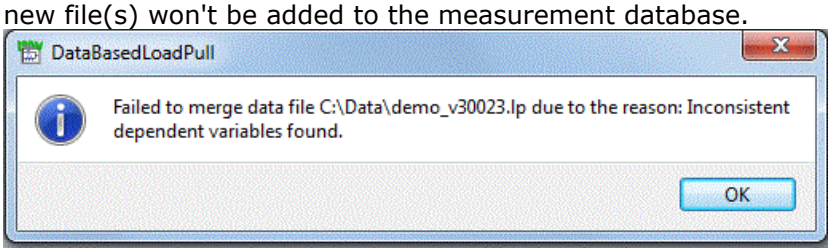
Double click the data based load pull controller to bring up the DBLP controller dialog box.



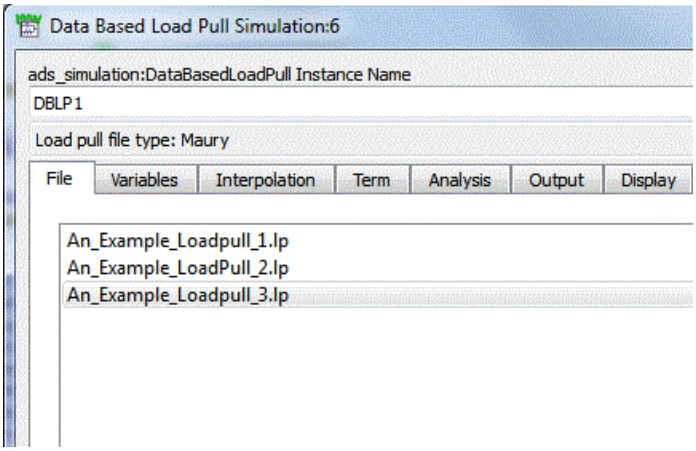
Add/Remove/View file(s)....

You can modify the selected load pull file(s), e.g., adding more load pull file(s), removing selected load pull file, or viewing the selected load pull file.

When you add more load pull file(s), the first step is to merge all of the selected load pull files. If they are not *homogeneous* (cktsimldpull), a warning message will appear, and the new file(s) won't be added to the measurement database.



We modified the load pull file(s) to have the setup as:



Set up Independent Variables

The measurement database is summarized under *Variables* tab. *Independent Variables* sub-tab gives the summary for the independent variables. The upper section is for the reflection coefficients, while the lower section is for other independent variables. When the number of points is more than one, you can specify the values for the other independent variables used in the simulation. The default value is the minimum value in the database.

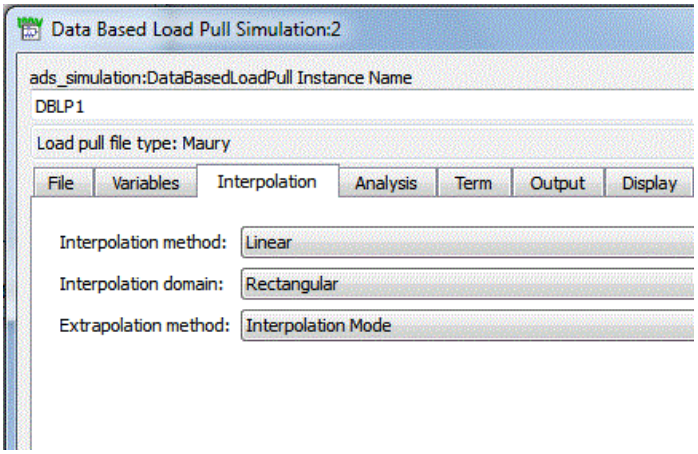
Set up Performance Parameters

The measured performance parameters are summarized in *Performance Parameters*. The table provides:

- measurement data summary: the name, the unit and the value range for each performance parameter. It can't be modified.
- simulation output control: saving and/or auto-displaying for each performance parameter. It can be modified.
  By default, all of the performance parameters are saved to the dataset without auto-displaying. When a performance parameter is marked to be auto-displayed in DDS, a plot will be automatically added in DDS when the dataset is opened. For reflection coefficients, the plots are selected as Smith Chart. For other complex performance parameters, the plots are selected as the rectangular plot for the magnitude of the complex value. For the real performance parameters, the plots are selected as the rectangular plot for the real value. If simulation results in multiple dimensions, then auto-plots will end up as the slider plots.
  Note, there is no auto-deleting function. So if you remove the auto-displaying setup for a performance parameter, the plots on the DDS won't be deleted automatically after the simulation.

Set up Interpolation and Extrapolation

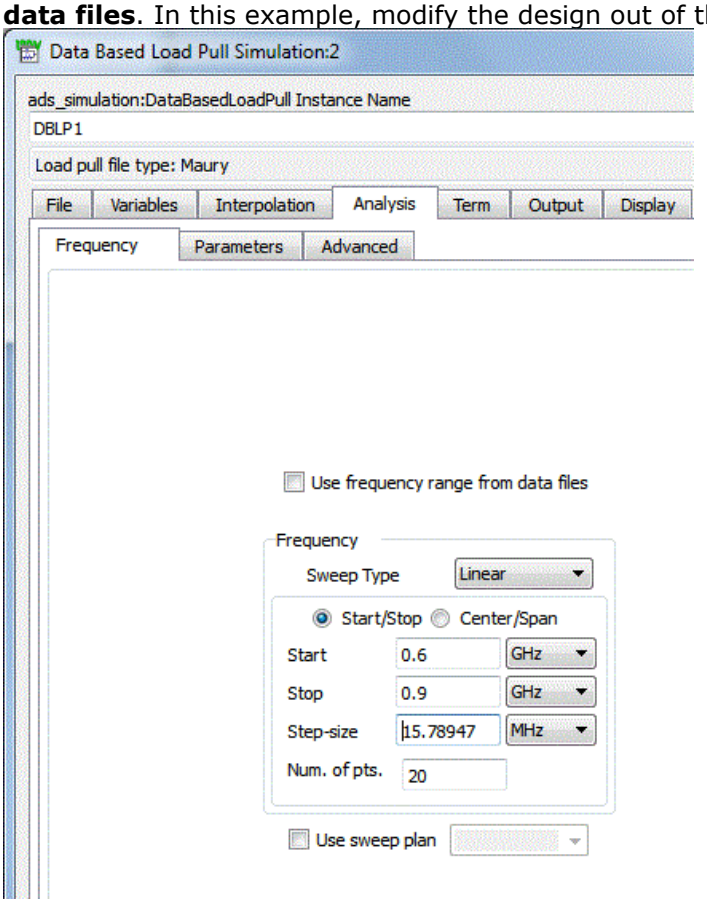
The simulation values for the performance parameters are obtained through interpolating/extrapolating the measurement database. The options for interpolation/extrapolation are accessible through *Interpolation* tab. You can select different combinations of interpolation method, interpolation domain and extrapolation method.



Set up Analysis

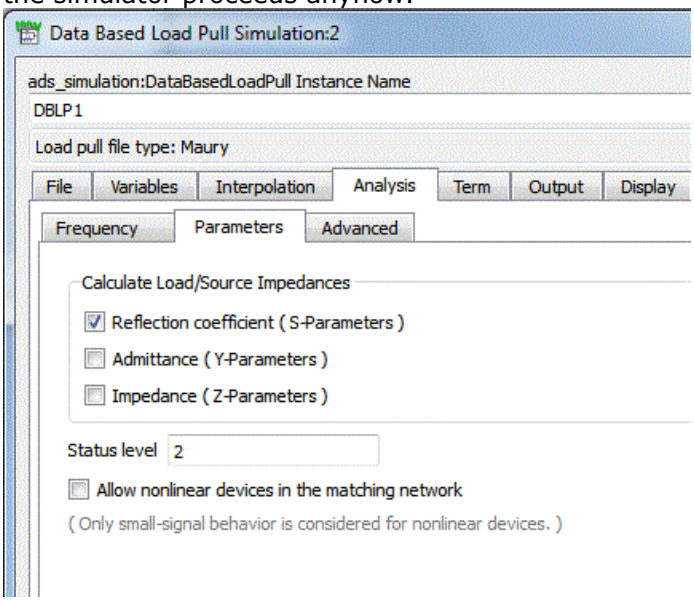
You can use the *Analysis* tab to access different configurations for the embedded S-Parameter analysis.

- Frequency Setup
  Overall the frequency set up is similar as that in S-Parameter analysis (see *Examples of S-Parameter Simulation* (cktsimsp)). Like the S-Parameter analysis, you can setup the frequency range by either using the sweep plan, or directly filling the table. Unlike the S-Parameter analysis, the default value for the frequency range is constrained by the measurement range in the load pull files. You can specify the frequency range out of that constrain by deactivating **Use frequency range from data files**. In this example, modify the design out of the measurement range.

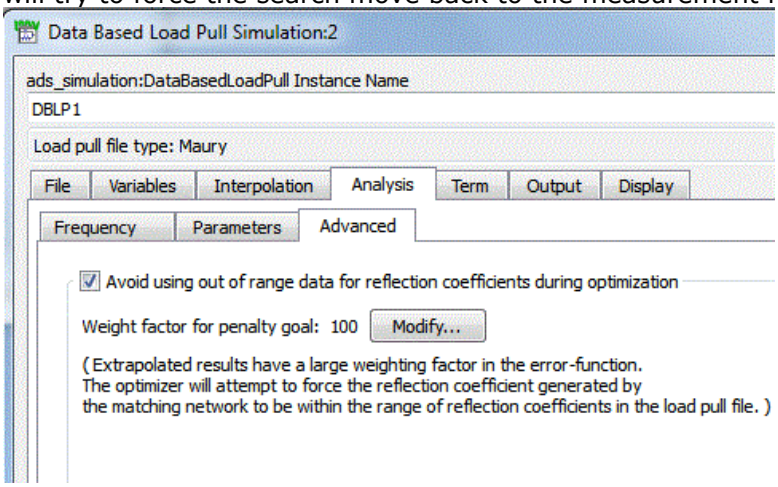


- Analysis Parameters setup
  The *Parameters* sub-tab is similar to the *Parameters* tab of S-Parameter analysis (see *S-Parameter Simulation* (cktsimsp)): you can specify the types of calculations reflection coefficient, admittance, impedance and/or S-, Y-, Z- parameters; you can

specify the status level. The new choice is, compared with S-Parameter analysis, **Allow nonlinear devices in the matching network**. When there are nonlinear devices in the matching network, by default the simulator will error out since only small-signal behavior can be considered. In this condition, if you realize the results may not be accurate but still wants to proceed, you can activate the choice so that the simulator proceeds anyhow.

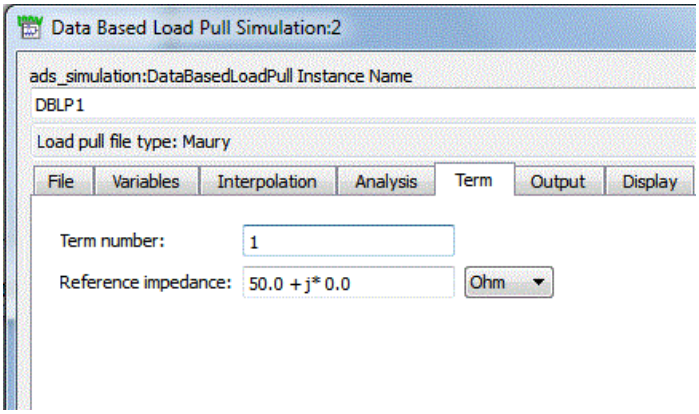


- Advanced setup
  The advanced setup is only for the optimization with the data based load pull simulation. When **Avoid using out of range data for reflection coefficients during optimization** is activated, a penalty goal will be automatically added. So during optimization search, if it is out of the measurement range, the penalty goal will try to force the search move back to the measurement range.



Set up Term

The data based load pull controller has an embedded Term component. You can modify this Term component by using the *Term* Tab and can change term number and reference impedance for it.



Set up Output Mechanism

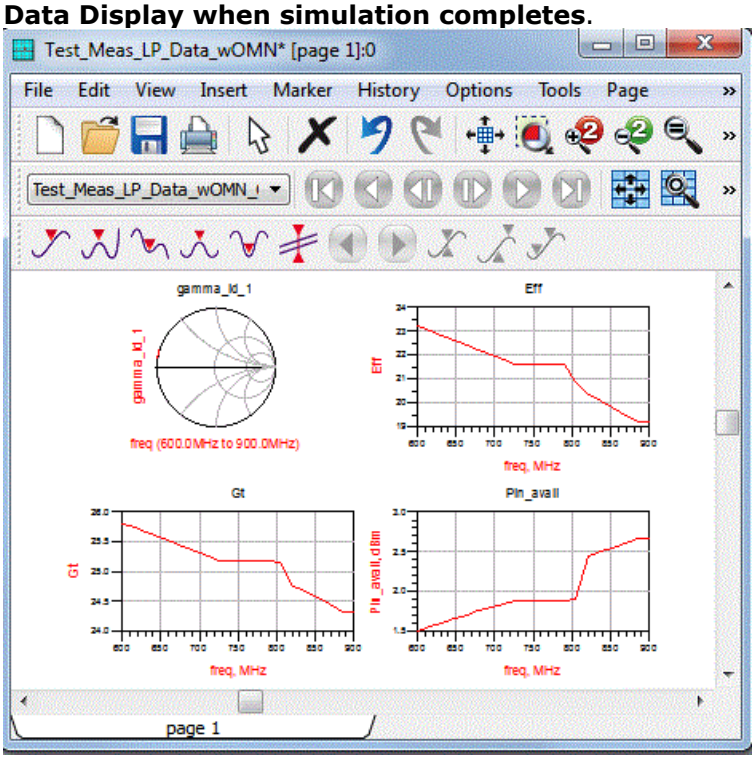
Using the *Output* tab, you can control the outputs for the measurement equations. The functionality and the use model is common for all of the analysis controllers in ADS.

Set up Schematic Display

Using the *Display* tab, you can configure the parameters to be displayed on the schematic for the data based load pull controller. The functionality and the use model is common for all of the analysis controllers in ADS.

Simulate and Auto-Plots

Dismiss the data based load pull controller by clicking **OK**. Then choose **Simulate > Simulate** or click **Simulate** icon to start the simulation. When the simulation finishes, a DDS will automatically pop-up with the auto-plots, if the simulation setup chooses **Open Data Display when simulation completes**.

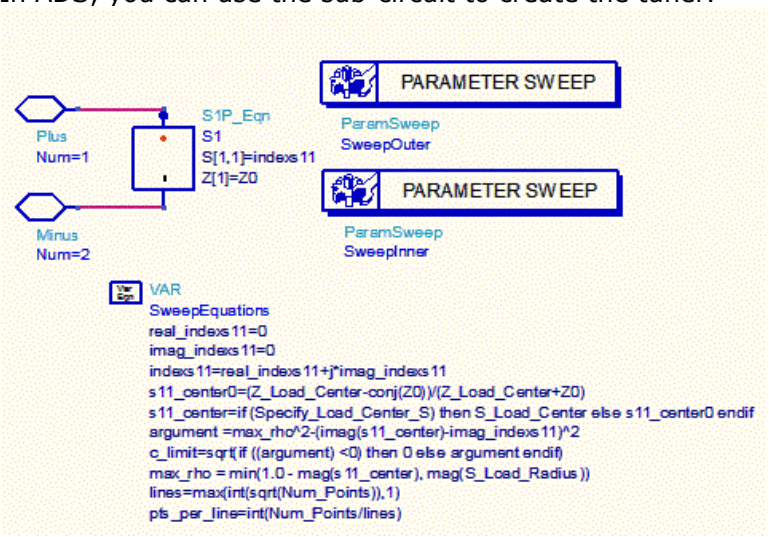


Single Data Based Load Pull Simulation with Tuner

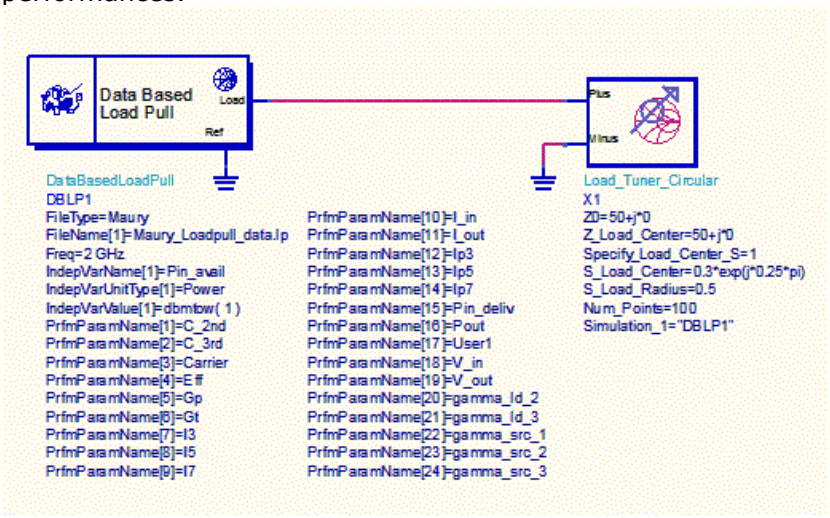
The example is called 'Test_Meas_LP_Data_wLoadPull_Circular'. It does not have any output matching network design. It illustrates how to create a tuner in ADS and how to view the contours in DDS. In this example, the simulation generates load reflection coefficients within a circular region of the Smith Chart. Various measured performances

from the load pull data file that correspond to each load reflection coefficient are output to the dataset.

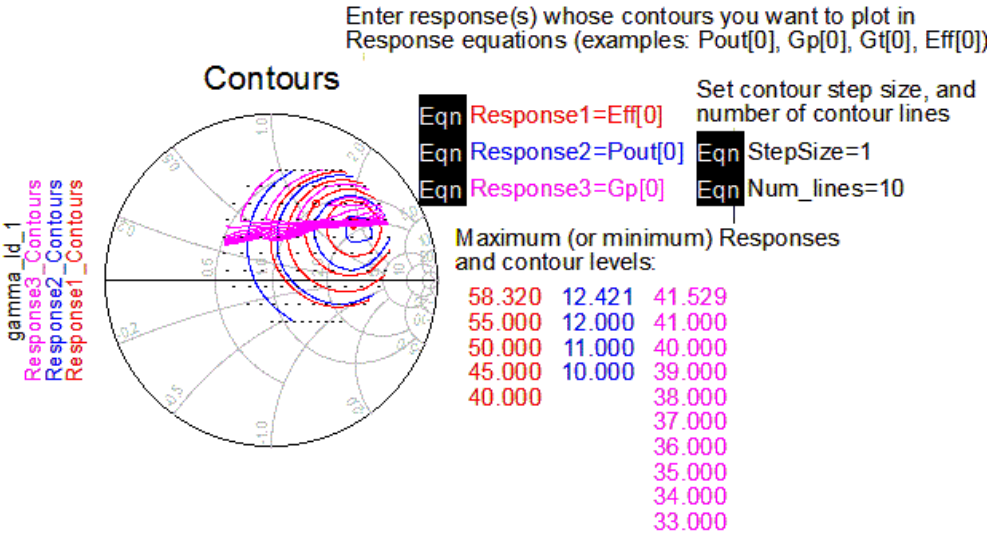
In ADS, you can use the sub-circuit to create the tuner.



Then the tuner can be used with the data based load pull component to extract the performances.



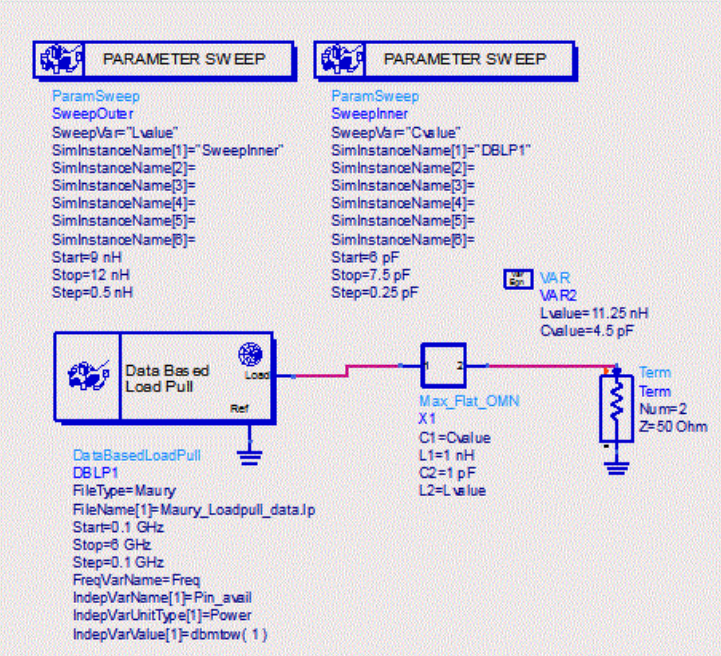
The extracted performances can be viewed in contour plots by using contour_ex() function.

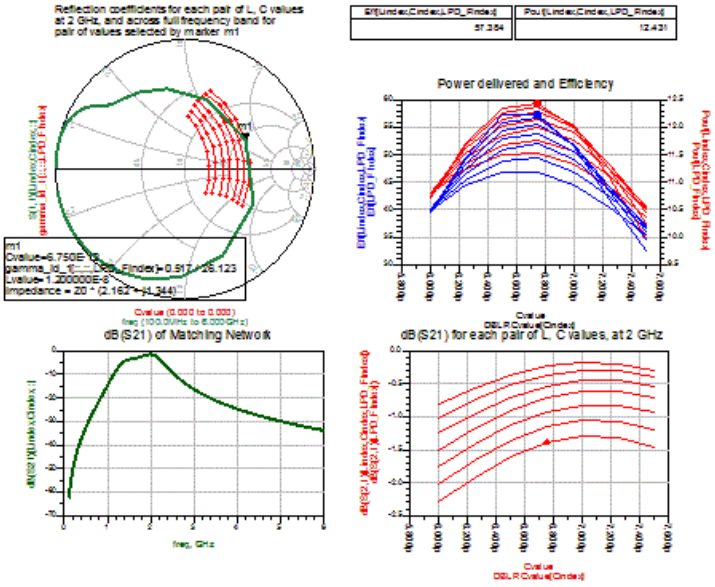


Swept Data Based Load Pull Simulation

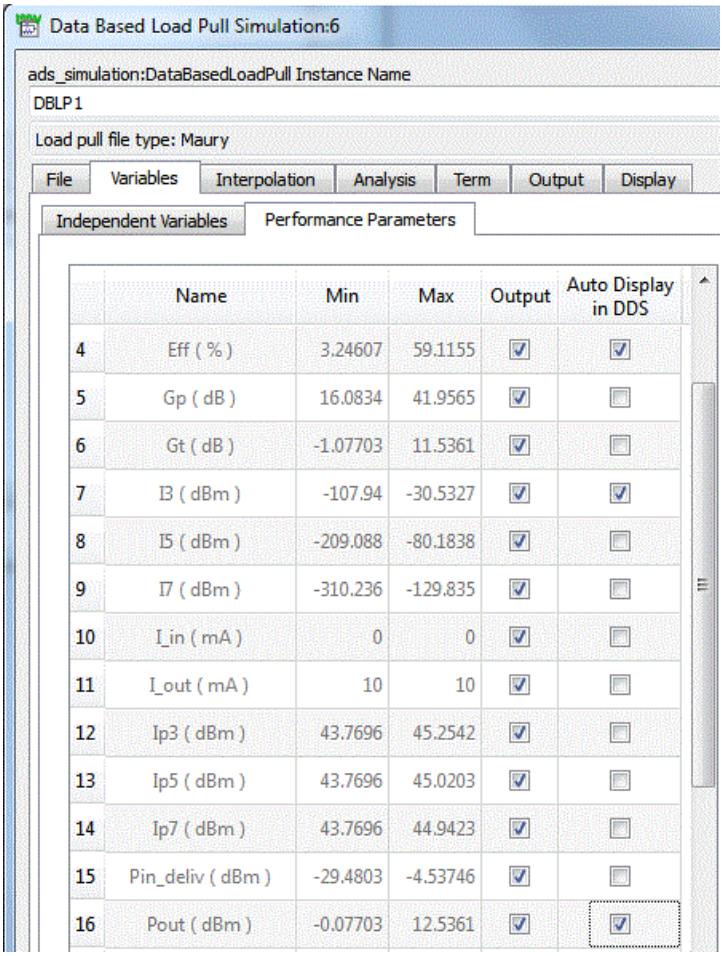
Sweep Component Parameters of the Output Matching Network

The example is 'Test_Meas_LP_Data_wOMN'. The simulation sweeps one L and one C values to vary the load and shows how the power and efficiency performances depend on it. Although the measured load pull data is only valid at one frequency, the S-Parameters of the matching network(in a 50-Ohm system) are simulated over a broader range of frequencies to see how harmonics would be attenuated, for example:



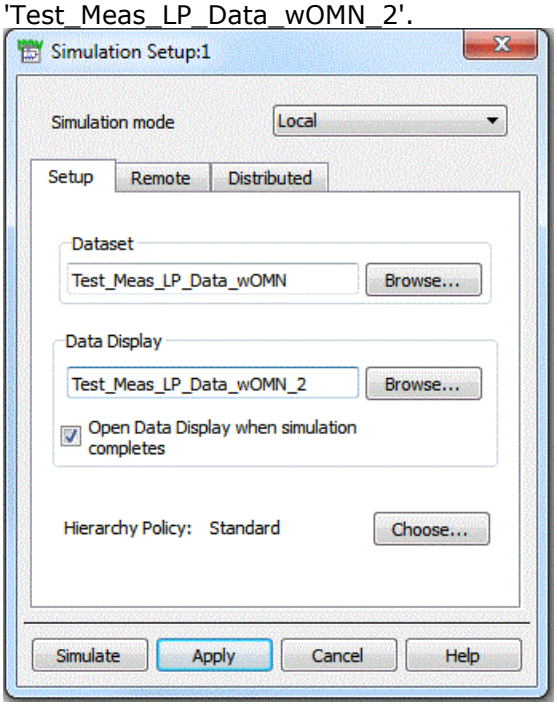


Now let's use this example to see the auto display behavior with slider plots. First, double click the data based load pull controller. From the *Variables* tab, select *Performance Parameters* sub-tab and mark **Eff**, **Ip3** and **Pout** as auto-display in DDS.

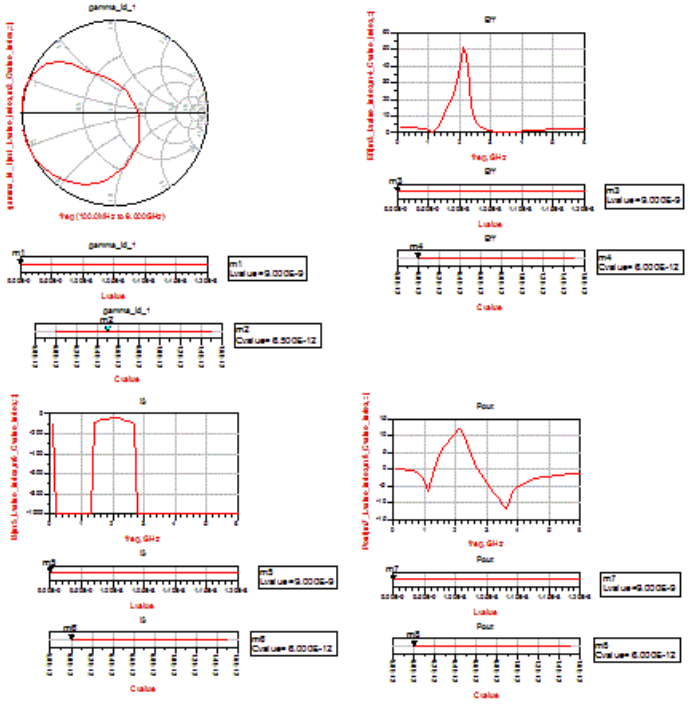


	Name	Min	Max	Output	Auto Display in DDS
4	Eff (%)	3.24607	59.1155	☑	☑
5	Gp (dB)	16.0834	41.9565	☑	☐
6	Gt (dB)	-1.07703	11.5361	☑	☐
7	I3 (dBm)	-107.94	-30.5327	☑	☑
8	I5 (dBm)	-209.088	-80.1838	☑	☐
9	I7 (dBm)	-310.236	-129.835	☑	☐
10	I_in (mA)	0	0	☑	☐
11	I_out (mA)	10	10	☑	☐
12	Ip3 (dBm)	43.7696	45.2542	☑	☐
13	Ip5 (dBm)	43.7696	45.0203	☑	☐
14	Ip7 (dBm)	43.7696	44.9423	☑	☐
15	Pin_deliv (dBm)	-29.4803	-4.53746	☑	☐
16	Pout (dBm)	-0.07703	12.5361	☑	☑

Next, modify the simulation setup to open DDS with name 'Test_Meas_LP_Data_wOMN_2'.



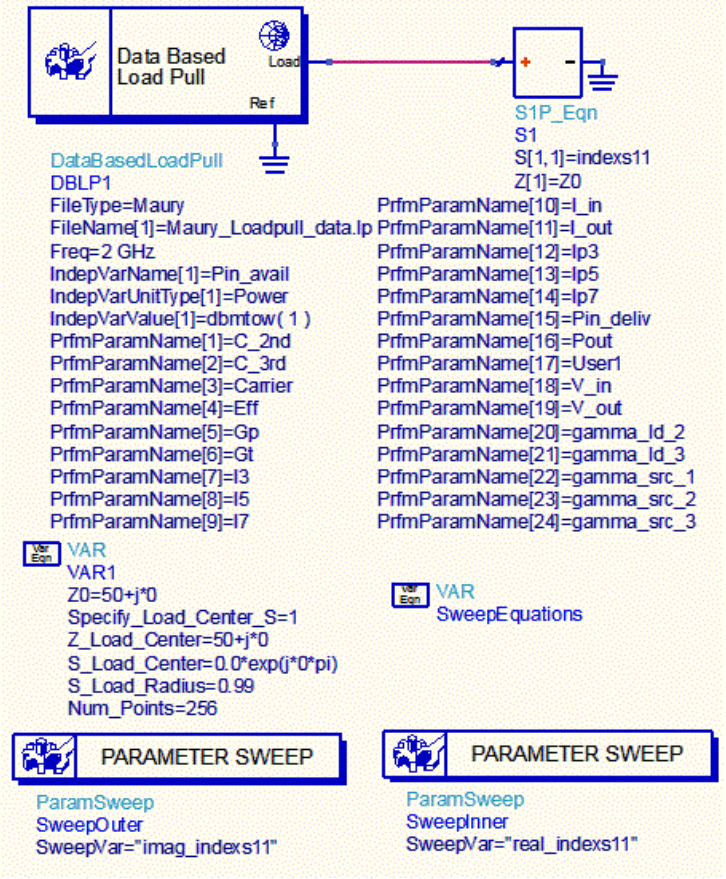
After simulation, the DDS named 'Test_Meas_LP_Data_wOMN_2' will pop up with the auto-plotted slider plots.

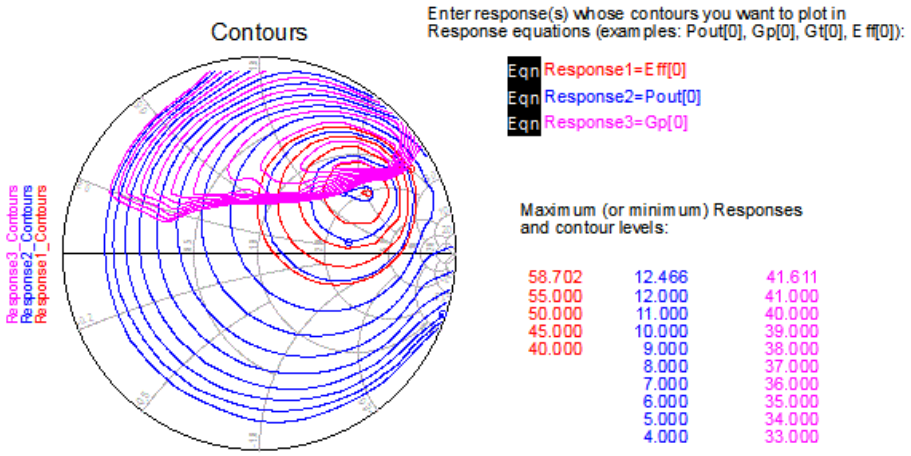


You can move the slider to see how the results changes with Lvalue and Cvalue changes.

Swept Data Based Load Pull Simulation to Produce Contours

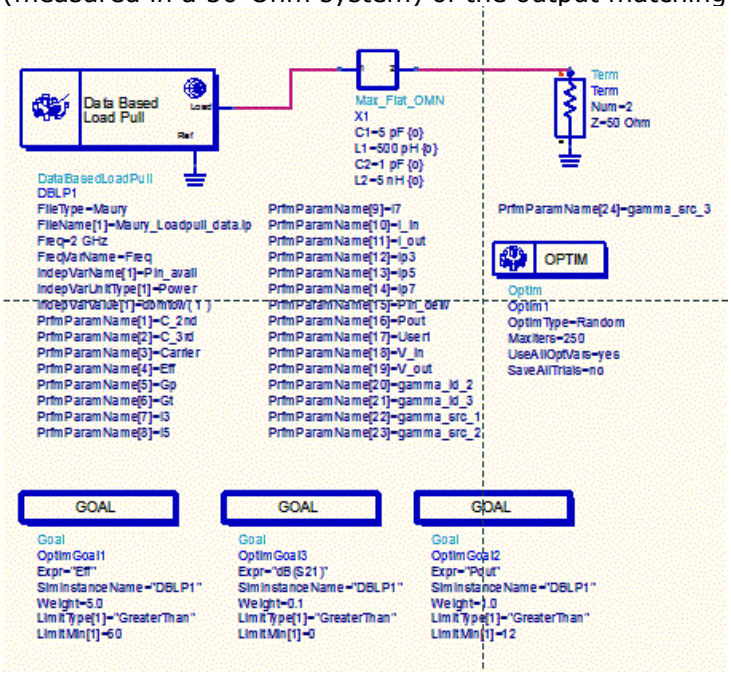
The example is called 'Test_Meas_LP_Data_wLoadPull'. The simulation generates load reflection coefficients within a circular region if the Smith Chart. Various measured performances from the load pull data file that correspond to each load reflection coefficient are output to the dataset. Equations are used to produce the contours in DDS.



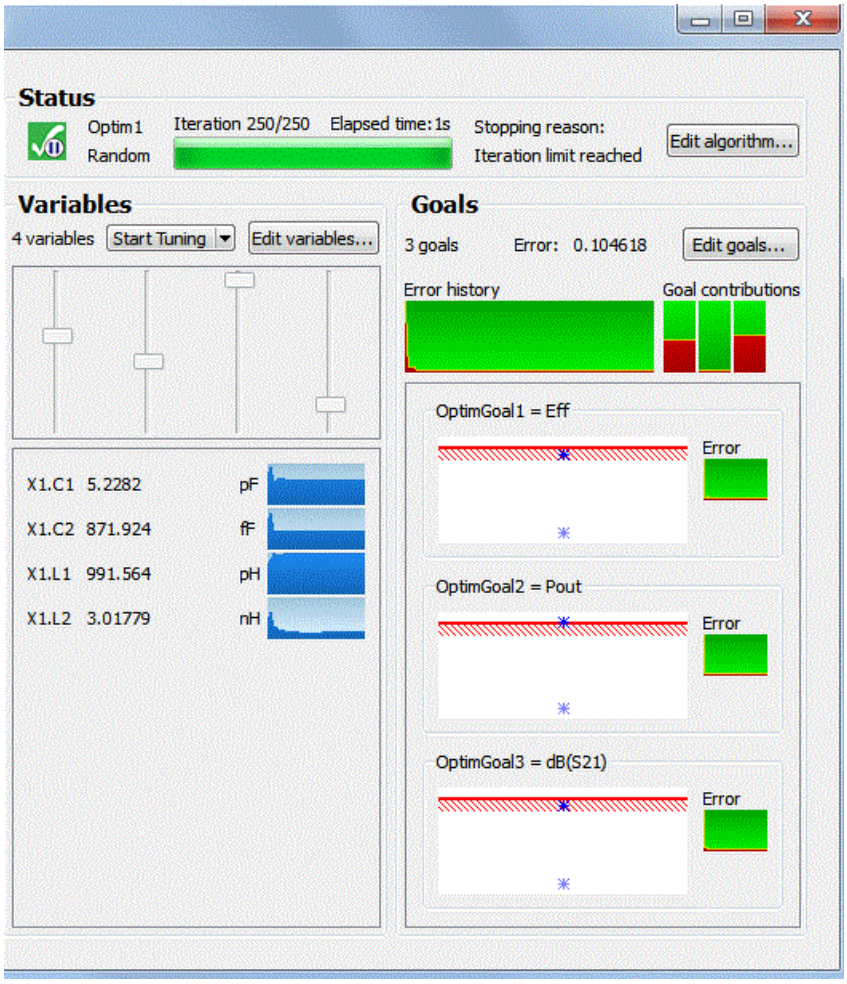


Optimization with a Data Based Load Pull Simulation

This example is called Test_Meas_LP_Data_wOMN_Opt. It optimizes the L and C values in the output matching network to maximize efficiency and power output, as well as dB(S21) (measured in a 50-Ohm system) of the output matching network.



The optimization procedure is monitored using the optimization cockpit after you choose **Simulate > Optimize** or click **Optimize** icon from the toolbar.


Status
Optim1
Random
Iteration 250/250
Elapsed time: 1s
Stopping reason:
Iteration limit reached
Edit algorithm...
Variables
4 variables
Start Tuning
Edit variables...
X1.C1 5.2282 pF
X1.C2 871.924 fF
X1.L1 991.564 pH
X1.L2 3.01779 nH
Goals
3 goals
Error: 0.104618
Edit goals...
Error history
Goal contributions
OptimGoal1 = Eff
Error
OptimGoal2 = Pout
Error
OptimGoal3 = dB(S21)
Error

Parameters of the Data Based Load Pull Controller

ADS provides access to data based load pull simulation parameters enabling you to define aspects of the simulation listed in the following table:

Tab Name	Description	For details, see...
File	Specify file access for load pull file(s)	Specify Load Pull File(s)
Variables	Summarize the scattered measurement database. Configuring variables for simulation.	Summarize and Set up Variables
Interpolation	Set up interpolation/extrapolation method.	Set up Interpolation/Extrapolation
Analysis	Set up the embedded S-Parameter analysis and the penalty goal.	Set up Analysis
Term	Set up the embedded Term instance	Set up Term
Output	Selectively save simulation data to a dataset.	*Selectively Saving and Controlling Simulation Data* (cktsim)
Display	Control the visibility of simulation parameters on the schematic.	*Displaying Simulation Parameters on the Schematic* (cktsim)

Specify Load Pull File(s)

You can use **Add**, **Remove**, and **View** buttons to access the load pull file(s). The following table describes the file parameter details:

Button Name	Description	Responds
Add	Adding one or more load pull files	The file(s) will be accepted if they are homogeneous. The scattered measurement database will be created or expanded.
Remove	Removing the selected load pull file	The selected file will be removed. The data in the selected file will be removed from the scattered measurement database.
View	Viewing the selected load pull file	A text editor will open with the selected load pull file.

Summarize and Set up Variables

After one or more load pull file(s) are specified, the scattered measurement database is summarized under *Variables* tab. The following table describes the Variables parameter details:

Tab Name	Description	For details, see...
Independent Variables	To: • Summarize the reflection coefficient(s) and the other independent variable(s) in the scattered measurement database • Set up values used for the simulation for independent variable(s) other than reflection coefficient(s)	Summarize and Set up Independent Variables
Performance Parameters	To: • Summarize the performance parameters in the scattered measurement database • Set up the outputting and auto-displaying for the performance parameters	Summarize and Set up Performance Parameters

Summarize and Set up Independent Variables

The independent variables of the scattered measurement database are summarized in *Variables* > *Independent Variables* tab. The independent variables are listed as **Reflection Coefficients** and **Other Independent Variables**.

Reflection Coefficients

The reflection coefficients are the inner-most independent variables in the scattered measurement database. The following table describes the reflection coefficient parameters:

Fields	Description	Editable
Name	The name of the reflection coefficient. Each reflection coefficient is given as a pair of independent variables. For example, gamma_ld_1 is given as (gamma_ld_1_x, gamma_ld_1_y) in real-imaginary format. Name convention: gamma_ld_harmIndex, or gamma_src_harmIndex. For example, gamma_ld_1 refers to fundamental load gamma, while gamma_src_1 refers to fundamental source gamma.	No
Type	The gamma type, either Load or Source	No
Harm	The harm index	No
Domain	The domain of the gamma, either real-imag or mag-phase	No
Min	The minimum value	No
Max	The maximum value	No
Point	The number of points	No

Other Independent Variables

The other independent variables are independent variables other than reflection coefficients. They are sweep variables outer the reflection coefficients. The following table describes the Other Independent Variables:

Fields	Description	Default Value	Editable	Valid Input
Name	The name of the other independent variables. There are two types: • Freq: Frequency. • Others: are independent variables other than reflection coefficients and frequency. For example, Pout, etc.	From files	No	None
Value	The value	Minimum value	Yes when there are more than 1 point	Real/Expression
Unit	The unit	From files	Yes when thereare more than 1 point	From files
Min	The minimum value of the other independent variable.	From files	No	None
Max	The maximum value of the other independent variable.	From files	No	None
Points	The number of points.	From files	No	None

Summarize and Set up Performance Parameters

Performance parameters are dependent parameters of the scattered measurement database. They are summarized in *Variables* > *Performance Parameters* tab. The following table describes the performance parameters:

Fields	Description	Editable	Default
Name	The name with unit of the performance parameter.	No	From files
Min	The minimum value of the performance parameter.	No	From files
Max	The maximum value of the performance parameter.	No	From files
Output	Whether saving the performance parameter in the dataset.	Yes	Checked
Auto Display in DDS	Whether auto-displaying the performance parameter in DDS when simulation finishes. A performance parameter marked as auto-displayed has to be outputted. While a performance parameter marked as outputted does not need to be auto-displayed. So, selecting the **Auto Display in DDS** will select the **Output** field. But deselecting the **Auto Display in DDS** won't affect **Output** field.	Yes	Un-checked

Additionally, there are four buttons for simplifying those setups.

Buttons	Description
Output All	Automatically selects **Output** field for all of the performance parameters.
Output None	Automatically deselects **Output** field for all of the performance parameters.
Display All	Automatically selects **Auto Display in DDS** and **Output** fields for all of the performance parameters.
Display None	Automatically deselects **Auto Display in DDS** field for all of the performance parameters.

Set up Interpolation/Extrapolation

The simulator can use the following methods to do the interpolation/extrapolation with the measurement data.

Name	Description	Default
Interpolation Method (InterpMode)	Choose amongst **Linear**, **Cubic**, and **Cubic Spline** to specify the interpolation method in each dimension (except for splines, where only the innermost variable is spline-interpolated).	Linear
Interpolation Domain (InterpDom)	Interpolation domain: **Rectangular** interpolates real and imaginary parts separately. **Polar** (arc interpolation) interpolates magnitude and angle separately.	Rectangular
Extrapolation Method (ExtrapMode)	Extrapolation mode: **Interpolation Mode**: when extrapolation occurs, the interpolation mode specified by InterpMode is used for extrapolation. **Constant Extrapolation**: when extrapolation occurs, no interpolation is performed. The value of the nearest data point is returned. An extrapolation warning is issued when an extrapolation occurs on *freq* in an S-parameter simulation. For all other analysis types, status level in the analysis controller must be set to 3 or higher to see extrapolation warnings.	Interpretation Mode

Set up Analysis

The section describes the analysis setup including **Frequency**, **Parameters** and **Advanced** setup.

Set up Analysis Frequency

The frequency setup under *Frequency* tab has two modes, which is controlled by **Use frequency range from data files** option. Even though the frequency parameters are the same for both modes, the setup is somewhat different for them.

Condition	Description	Frequency Range Editable	For details, see...
Use frequency range from files option is selected	The frequency range is fixed by load pull file(s)	No	Set up Frequency Constrained by Files
Use frequency range from files is deselected	The frequency range has no limitation	Yes	Set up Frequency Unconstrained by Files

Set up Frequency Constrained by Files

When the **Use frequency range from data files** option is selected, the frequency range is constrained by the data from load pull file(s). As a result, the parameters related with the frequency range are not editable.

Parameter Name	Editable
Sweep Type	No
Use Sweep Plan	No

The following table lists whether a parameter is editable for each sweep type.

Sweep Type	Frequency	Start	Stop	Step-Size	Pts./decade	Num. of pts.
Single Point	No	No	No	No	No	No
Linear	No	No	No	Yes	No	Yes
Log	No	No	No	No	Yes	Yes

Set up Frequency Unconstrained by Files

When the **Use frequency range from files** option is deselected, the frequency range will not be constrained by the data from load pull file(s). You can follow the common use model to setup the frequency sweep. For details, see *Setting Frequency Sweep* (cktsimsp).

Set up Analysis Parameters

The analysis controllable parameters are given in *Parameters* tab. The following table describes the Analysis parameters:

Setup Dialog Name	Description	Default	Valid Inputs
Calculate Load/Source Impedance			
Reflection Coefficient (S-Parameters)	Reflection coefficient and S-Parameters	Checked	Checked/Un-checked
Admittance (Y-Parameters)	Admittance and Y-Parameters	Un-checked	Checked/Un-checked
Impedance (Z-Parameters)	Impedance and Z-Parameters	Un-checked	Checked/Un-checked
Status Level	Prints information about the simulation in the Simulation Status window. • 0 reports little or no information, depending on the simulation engine. • 1 and 2 yield more detail. • Use 3 and 4 sparingly since they increase the process size and simulation times considerably. The type of information printed may include the sum of the current errors at each circuit node, whether convergence is achieved, resource usage, and where the dataset is saved. The amount and type of information depends on the status level value and the type of simulation.	2	Integer/Expression
Allow nonlinear devices in the matching network	If the option is deselected, the simulation will give error when it detects nonlinear devices in the matching network. If the option is selected, the simulation will proceed with small-signal behavior for the nonlinear devices, with a warning information.	Un-checked	Checked/Un-checked

Set up Advanced Options

There is only one option **Avoid using out of range data for reflection coefficients during optimization** under *Advanced* tab. The default value for it is activated.

Condition	Action	Description	Limitation
Checked	a penalty goal is created.	During optimization search, if it is out of the measurement range, the penalty goal will try to force the search move back to the measurement range.	No effects if the measurement data only contains one point
Un-checked	No penalty goal is created	Optimization search may stay in the range outside the measurement data	None

When **Avoid using out of range data for reflection coefficients during optimization** option is selected, the accessible parameter for the penalty goal is the **Weight Factor**. Higher weight factor will give higher penalty and force search back to measurement range sharply.

Name	Default	Valid Inputs
Weight Factor	100	Integer/Expression

Set up Term

The embedded Term instance has the following accessible parameters:

Name	Description	Default	Valid Inputs
Term number	The term sequence number in the circuit, which should start from 1 and be successive.	1	Integer/Expression
Reference Impedance	The reference impedance.	(50 + j*0.0) Ohm	Real/Complex/Expression

Troubleshooting

This section provides general information on the data based load pull simulation that may help answer some of your questions when faced with difficulties.

Can't add a load pull file

Currently, ADS data based load pull simulation only supports Maury load pull files. It supports the following Maury load pull file:

- Sweep reflection coefficient (gamma) at fundamental(.lp).
- Sweep reflection coefficient (gamma) at second harmonic(.lp2).
- Sweep reflection coefficient (gamma) at third harmonic(.lp3).
- Sweep other parameters using Maury sweep plan (.spl).

The selected load pull files are required to be homogeneous. Two load pull files are said to be homogeneous if:

- They are of the same file-type.
- They contain the same variables (both independent variables and performance parameters).

The followings are the examples that the load pull files are not homogeneous:

- Different file types are considered as non-homogeneous.
- Files having different performance parameters are considered as non-homogeneous.
- Files with different sweep variables are considered as non-homogeneous.

Problems related with Terms

The data based load pull controller embeds a **Term** component. It is named as *DataBasedLoadPullInstName*_Term. For example, if the instance of the data based load pull component is named as **DBLP1**, then the term instance will be named as **DBLP1_Term**.
The common problem with Terms is duplicating Port or Term number. In that case, check the *Num* field for each port. The S-parameter port numbers are derived from these fields. For a 2-port circuit, you would want the input labeled as Num=1 and the output as Num=2.

Simulation terminates due to existence of nonlinear devices

By default setup, the simulation gives the following errors where it finds nonlinear devices in the circuit.

Simulation / Synthesis Messages

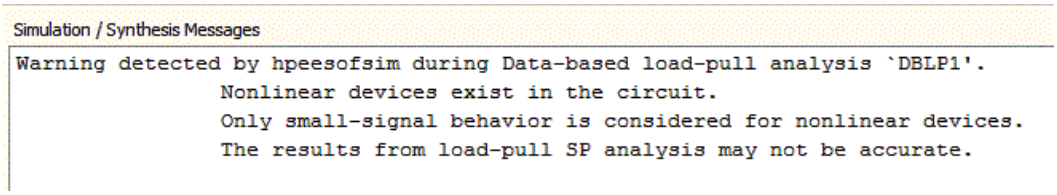
```
Error detected by hpeesofsim during Data-based load-pull analysis `DBLP1'.
                Nonlinear devices exist in the circuit.
                The loadpull SP analysis stops.
                To enable loadpull SP analysis for circuits with nonlinear devices,
                please enable 'Allow nonlinear devices in the matching network' from DataBasedLoadPull component.
```

If you want to proceed with the above design even though the results may not be accurate, you can modify the setup as described below:

1. Double click the data based load pull component
2. Select the *Analysis* tab, below the *Parameters* tab, activate **Allow nonlinear devices in the matching network** option

With this setup, the simulation will give warning information, but still proceeds the small

signal analysis.



Simulation errors out without clear information

Load pull files contain scattered measurement data. To achieve fast interpolation, data gridding is done on the scattered measurement data. Then the following simulation with interpolation is performed on the gridded measurement data.
Data gridding is time consuming. So the data based load pull simulation tries avoiding unnecessary data gridding. After the first data gridding, the gridded measurement database is stored in the dataset format. For the following simulations, if the original load pull files are not changed, the simulation will skip the data gridding step and directly use the gridded measurement database.
The data gridding will produce a .xml log file and the gridded measurement database is stored in a dataset named ADS_grid_orignalLoadPullFileName_FileExtension_uniqueId.ds (the originalLoadPullFileName will be the first load pull file name if multiple load pull files are selected). For example, if the selected load pull files are MLoadpull1.lp, MLoadpull2.lp, MLoadpull3.lp, the produced gridded dataset is named as ADS_grid_MLoadpull_lp_5666.ds.

If the simulation silently terminates, goes to current **data** directory. Clean .xml file or the gridded dataset. Then start the simulation again to see if the problem is resolved.

Interpolation/extrapolation for single point

When there is only one single point in the load pull file(s), then ADS always uses the constant interpolation/extrapolation, no matter what kind setup given from the data based load pull controller.

Penalty goal for optimization

Within the data based load pull controller, there is **Advanced** analysis setup below the *Analysis* tab. When **Avoid using out of range data for reflection coefficients during optimization** is activated, a penalty goal will be automatically added. So during optimization search, if it is out of the measurement range, the penalty goal will try to force the search move back to the measurement range. However, if the measurement data only contains one point, the interpolation and extrapolation is always constant. In that case, this option has no effects on the optimization procedure.

The only controllable parameter for the penalty goal is the weight factor. Higher weight factor will give higher penalty and force search back to measurement range sharply.

Auto display in DDS

A new concept in data based load pull simulation is the auto-displaying. When a performance parameter is marked as auto-displayed in DDS, a plot will be automatically added in DDS when the simulation finishes. For reflection coefficients, the plots are selected as Smith Chart. For other complex performance parameters, the plots are selected as the rectangular plot for the magnitude of the complex value. For the real performance parameters, the plots are selected as the rectangular plot for the real value. If the values of the performance parameters result in multiple dimensions (e.g. from parameter sweep), then the auto plots will end up as the slider plots.

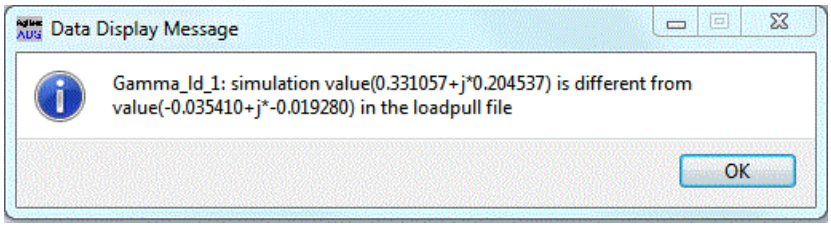
The user can manipulate the plots in the usual way. You can delete any auto-displayed performance parameter in the DDS. However, if you didn't change the configuration on

the Data Based Load Pull controller (so that the performance parameter is still marked as auto-displayed), the auto-displayed plot will be added back after the next simulation.

Be aware, there is no auto-deleting function. So if the designer removes the auto-displaying setup for a performance parameter, the plots on the DDS won't be deleted automatically after simulation.

If the DDS seems messy due to any reason, clean up DDS first to make it an empty DDS. Then run the simulation again, this will end up a clean DDS with the auto-plots.

Data Display Message



When the data based load pull simulation is performed for .lp2 or .lp3 files, it will check if the calculated reflection coefficients are the same as those from the load pull files. If the values are out of the tolerance range, then the results will store a flag to remember the case.

When Data display (DDS) set the default dataset as those dataset with this specific flag, the message will pop up to remind the designer that there are different between the calculated values and the file values.