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Using Sonnet in a Cadence Virtuoso Design Flow

Purpose of this document:
This document describes the Sonnet plug-in integration for the Cadence Virtuoso design flow, for silicon accurate EM modelling of passive structures.

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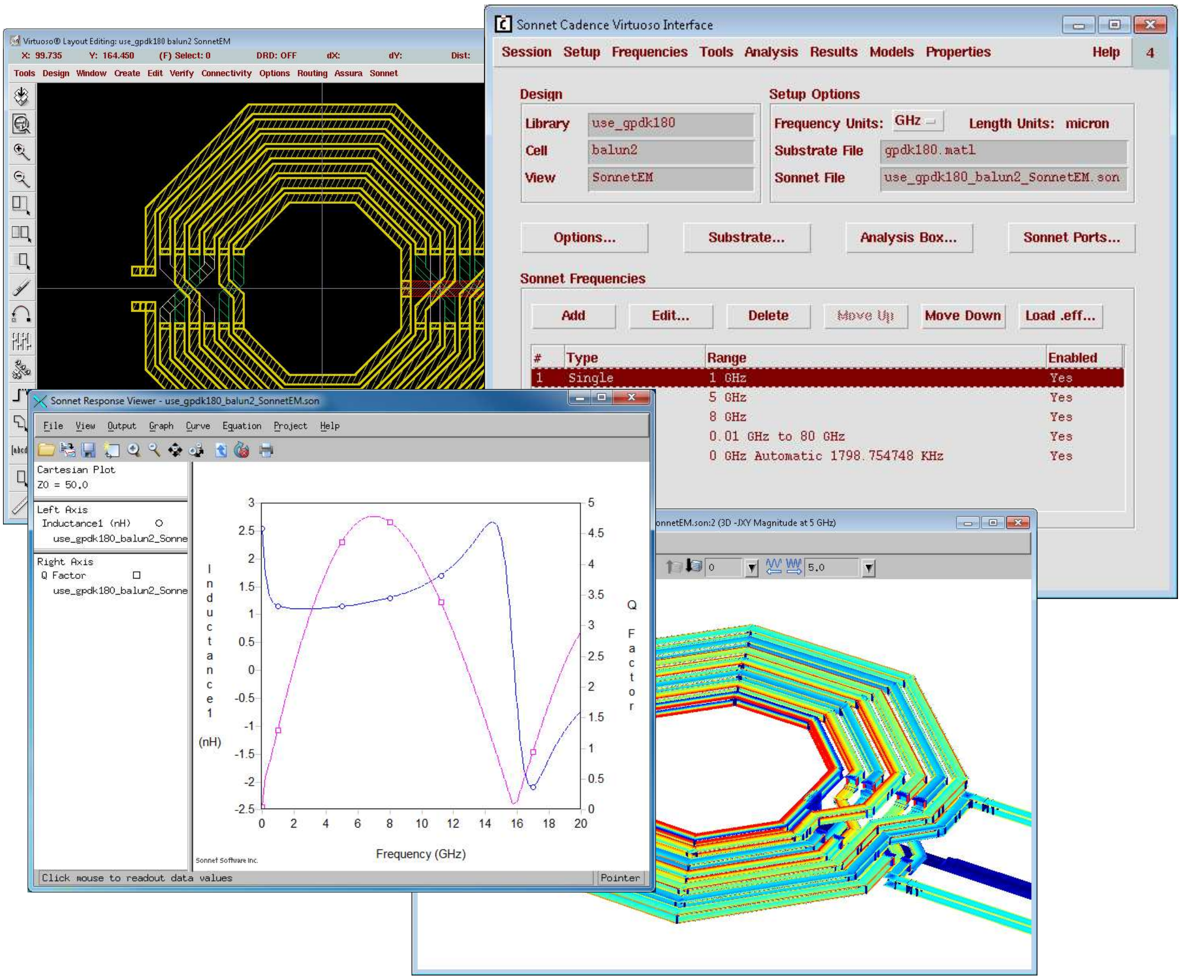
The plug-in integration of the Sonnet Professional analysis program into the Cadence Virtuoso layout environment allows Cadence users to perform accurate EM modelling on selected Virtuoso cells, for physical verification of critical components and interconnections. This plug-in solution allows designers to extract a Sonnet EM analysis cell view directly from the layout view. Simulation results can be easily back annotated to the Cadence schematic.



High precision electromagnetic (EM) analysis with Sonnet complements the traditional RC extraction tools. With Sonnet, simulation results include all physical effects like coupling, skin effect, proximity effect, surface waves and radiation. While traditional RC extraction tools like Cadence Assura are optimised to handle full chip extraction, Sonnet analysis is most suitable to rigorously analyze individual components, interconnects and smaller parts of a layout with very high confidence.

With Sonnet, you can replace legacy 3D finite element solvers, which are often not integrated into the Cadence design flow and require cumbersome and error prone manual modelling and data transfer.

Sonnet Professional Key Benefits

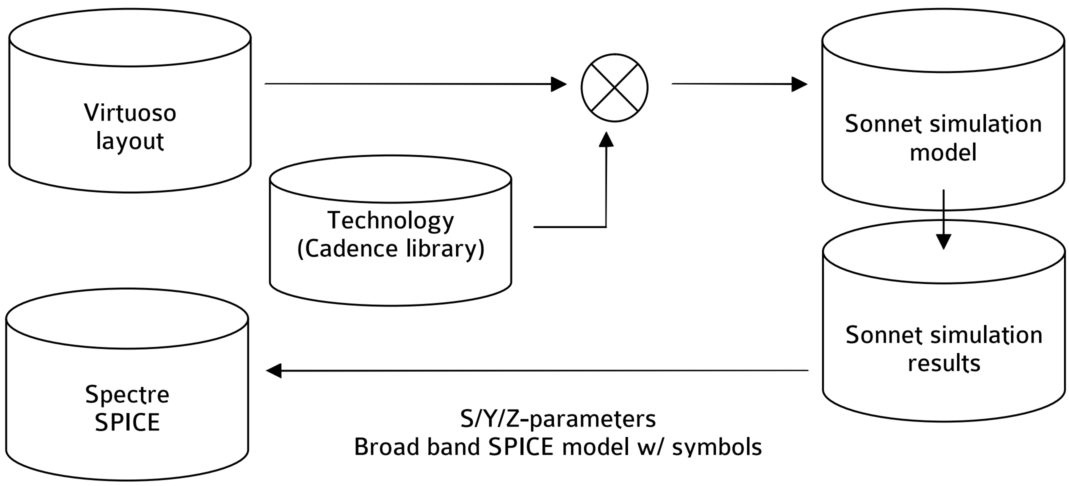
Sonnet Professional enables you to:

- Accurately model passive components (inductors, capacitors, resistors) to determine values like RLC and Q factor
- Accurately model multi layer interconnects and via structures
- Generate a technology accurate electrical model for arbitrary layout shapes
- Quantify parasitic coupling between components, interconnects and vias
- Include substrate induced effects like substrate loss
- Visualize the current flow in components, interconnects and vias

Sonnet Professional Key Features

The key features of Sonnet Professional include:

- FFT based Method of Moments analysis for ultimate reliability and accuracy
- Easy to learn, easy and efficient to use
- Only one high precision analysis engine – no need to switch between solvers
- Conformal Meshing for very efficient high accuracy meshing of curved structures
- Finite thickness modelling (including advanced n-sheet model)
- Dielectric bricks for truncated dielectric materials (e.g. MIM capacitor)
- Adaptive Band Synthesis for fast and reliable frequency sweeps with a minimum number of EM samples - more efficient than traditional approaches
- Easy to use data display for analysis results, including R, L, C, Q evaluation
- Equation capability for pre-defined or customized calculation on simulated data
- Seamless integration into the Cadence Virtuoso design environment
- All configuration and technology setup is menu / dialog based– no need to edit configuration text files
- Remote simulation capability
- Compatible with the LSF cluster and load balancing system
- Sonnet Software Inc. is a Cadence Connections partner.



When to Use Sonnet EM Analysis

The use of electromagnetic analysis with Sonnet Professional is especially valuable in the following design situations:

When parasitic coupling is present. Parasitic coupling is not always easy to predict without using electromagnetic analysis. Even elements which are "sufficiently" far apart can suffer from parasitic coupling: inductive or capacitive coupling, resonance effects due to grounding and surface waves that might propagate at the substrate boundary under certain conditions. Sonnet Professional analysis is based on the physical properties of your technology and will account for such physical effects.

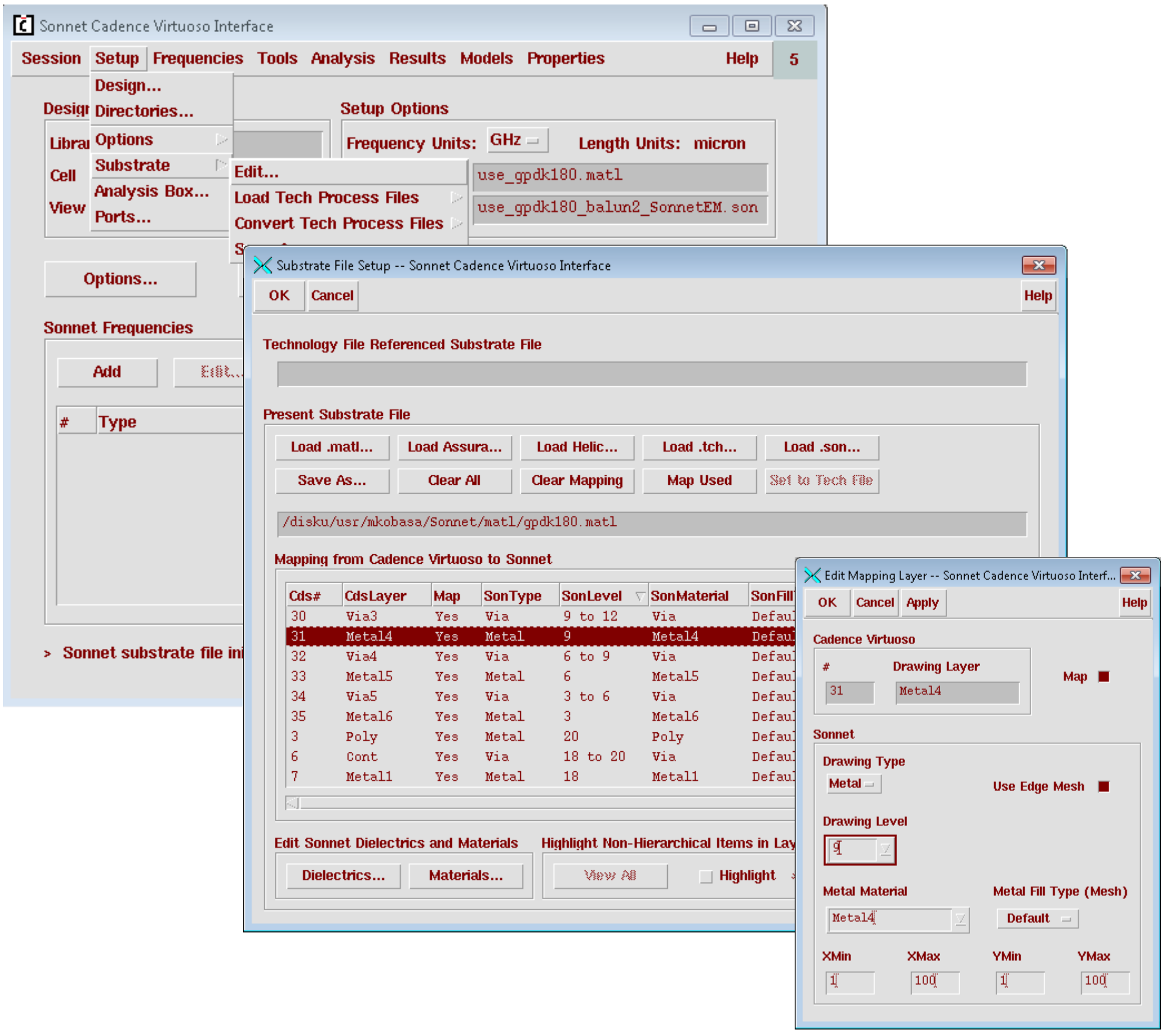
When accurate circuit models are not available or circuit model parameters are out of range. Model based circuit simulators are based on models for a specific application, with limited parameter range. For example, only selected geometries, substrate types and substrate parameters are available. It is difficult to estimate the error induced by parameter extrapolation, so using models outside their designed parameter range is not suitable for critical applications.
Whenever a layout feature cannot be described by a circuit model, due to its geometry or technology, the physics based analysis with Sonnet Professional will provide the answer. An example for this could be a special inductor, capacitor or transformer which is not included in the design kit. Sonnet can be used to analyze those components "on the fly", or generate a full library of components models with trust worth electrical results.

Sonnet EM Design Process

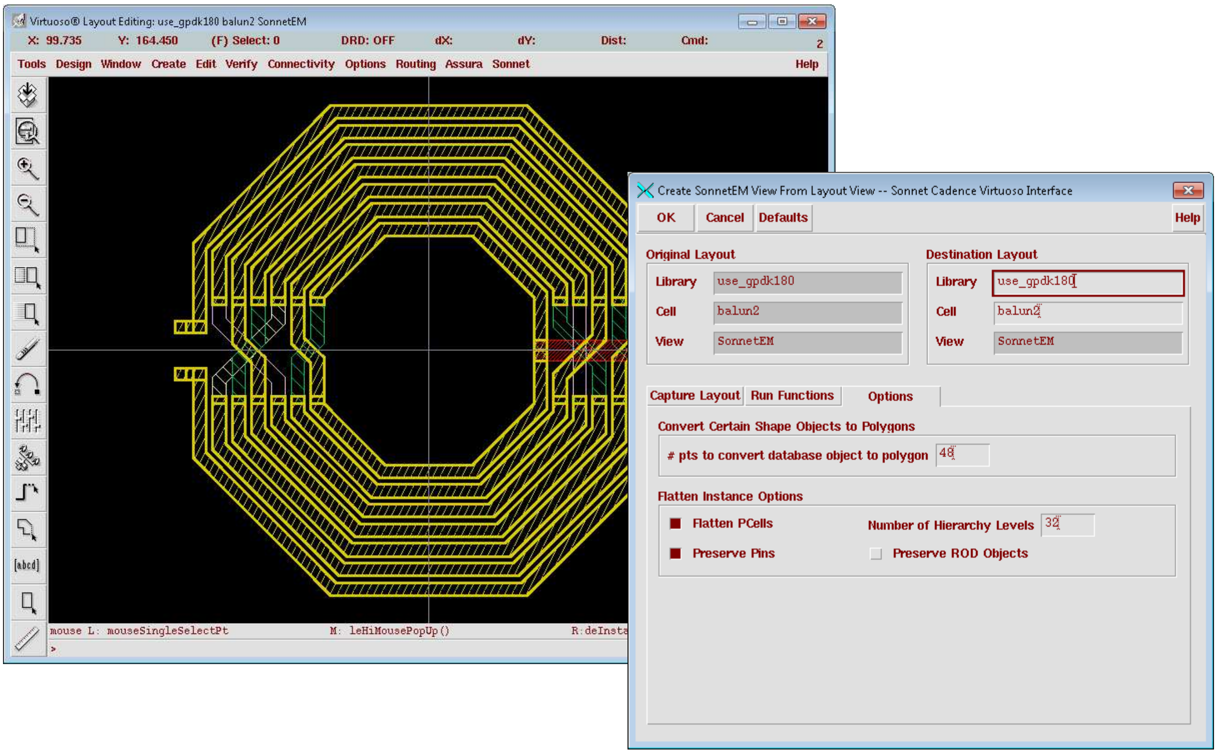
The following steps describe a typical process for creating and simulating a design with Sonnet Professional for Cadence Virtuoso.

Define the stack-up and material properties. A simulation model for Sonnet Professional contains a number of layered dielectrics, conductor levels at the interface between dielectric layers and vias to connect different conductor levels. To simulate a layout in Sonnet, these material properties and definitions ("technology") are required.
Typically, the EDA support group will define and qualify a technology file for a Cadence library and release that to the RFIC designers. This is an easy and straightforward process once the material properties are known, because that definition is fully menu and dialog driven.

When a designer creates a Sonnet simulation view of a cell, that pre-defined Sonnet technology file will be automatically loaded from the Cadence library.

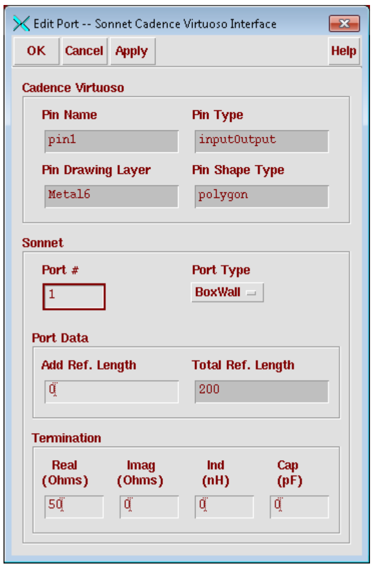


Make Sonnet View. Based on the layout view of a cell, the designer can easily create the Sonnet analysis view for that cell. If the cell layout contains hierarchy, the hierarchy will be resolved to create a flattened Sonnet EM view.

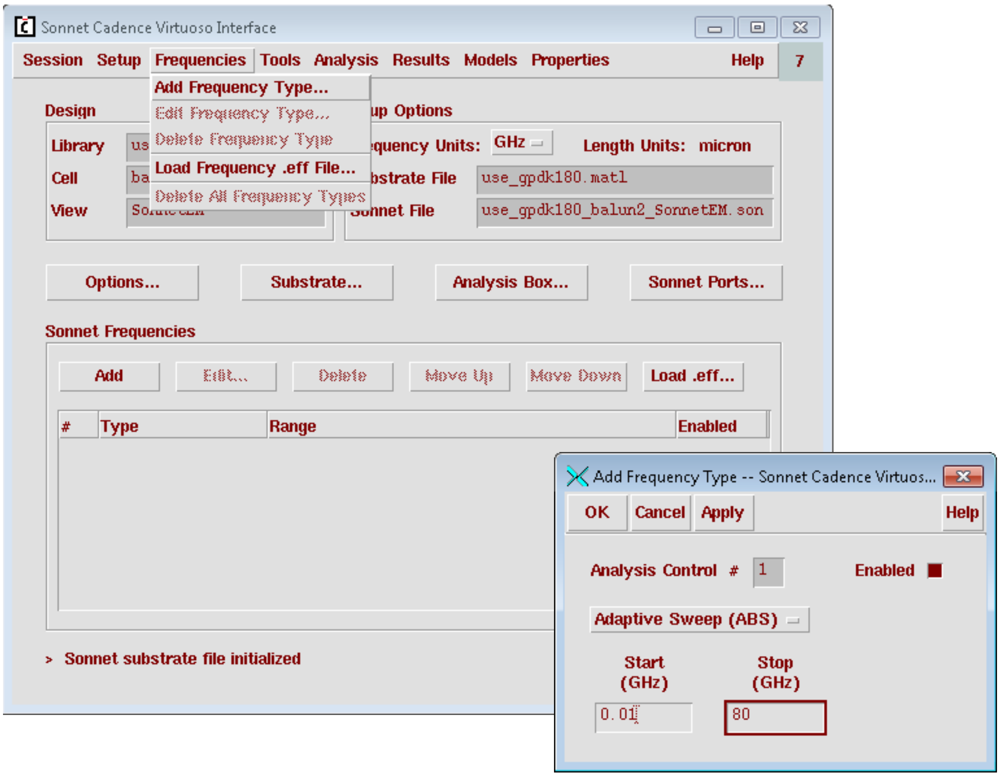


Define the analysis box. With Sonnet's FFT based approach to method of Moments, it is necessary to define a finite analysis area ("box") and a uniform sampling resolution ("cell size"). This defines the granularity for the analysis, and usually requires a trade off between analysis time and accuracy. The user defined cell size is very useful to control the meshing density of very complex shapes, to avoid over-meshing the circuit without any need for manual clean-up.

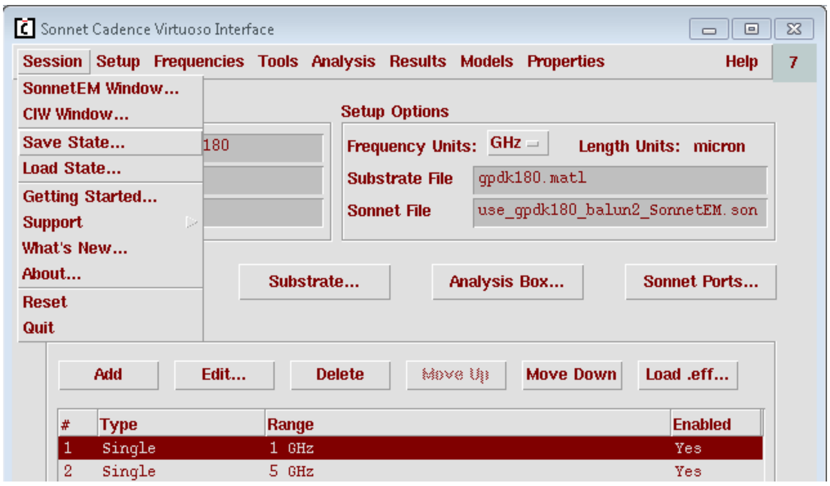
Assign port numbers and properties.
In Sonnet, circuit ports connect the analysed structure with the outer circuit. Different port types are available for different purposes. Cadence pins can be converted to Sonnet ports fully automatically, based on the defined mapping. Where needed, feed lines will be extended to the boundary of the analysis area automatically, and de-embedded from the analysis results.



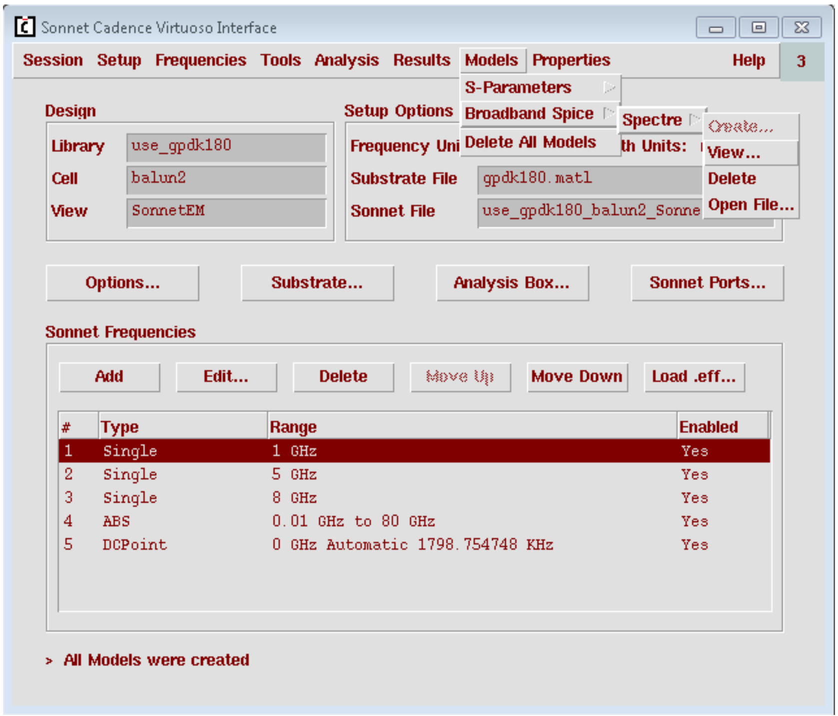
Define analysis frequencies. Sonnet uses the Method of Moments where the circuit is analysed at different frequencies of interest. With the unique Adaptive Band Synthesis (ABS) in Sonnet, an accurate wide band response can be obtained from a minimum number of EM simulated data points within a given frequency range.
Using ABS, the designer only needs to enter the start and stop frequency. Of course, composite frequency sweeps are also possible, as well as a "DC" point.



Save state (optional). An optional step after setting up all these parameters is to store the current "state" of the analysis settings for later re-use. This way, all settings can be loaded into a similar project easily.

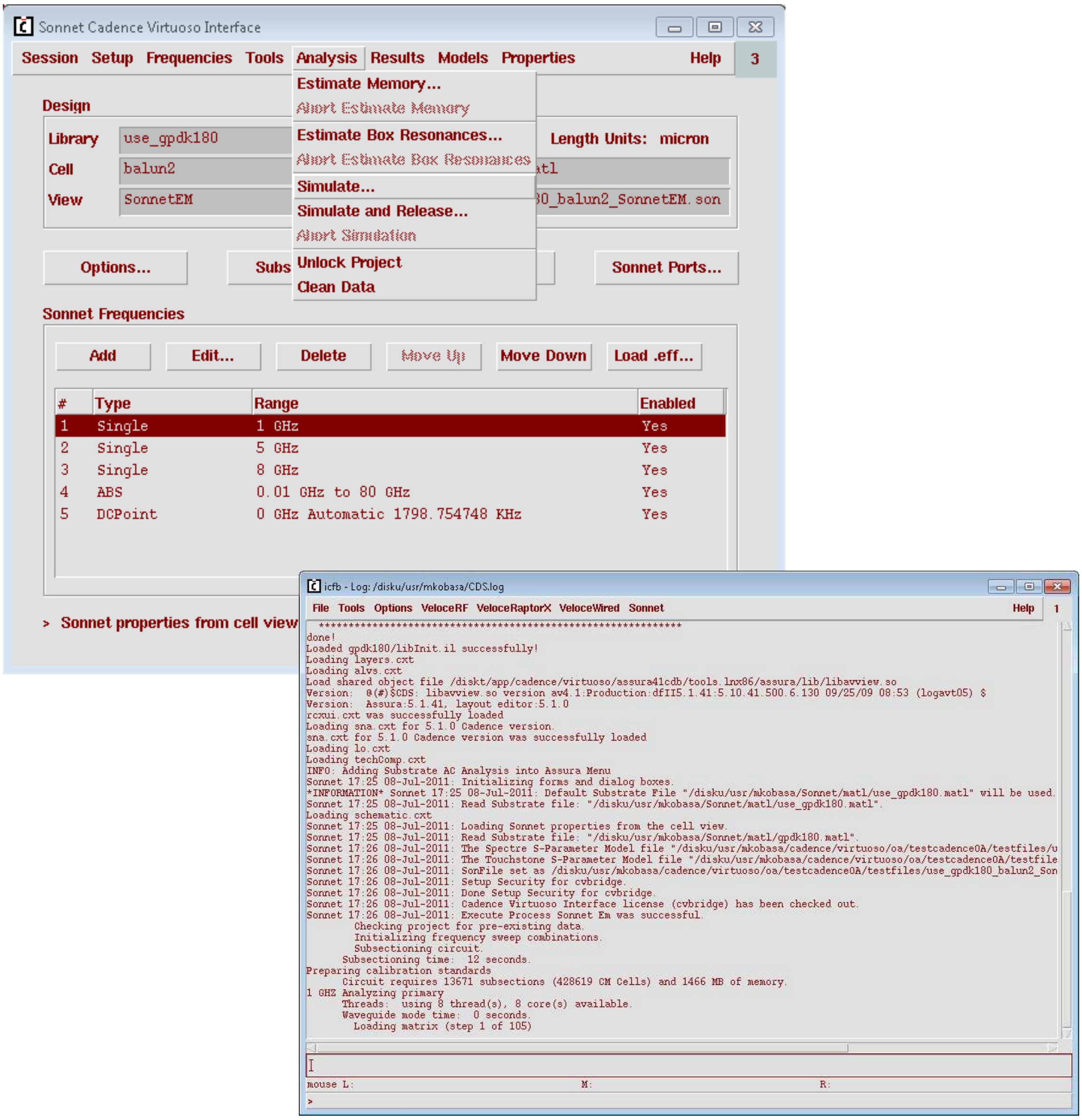


Define desired output format (optional). The desired analysis results can be for example S/Y/Z parameters, a schematic symbol with ADS or Spectre frequency domain data or a schematic symbol for broad band SPICE extracted data. The designer can define the desired output data before starting the Sonnet EM simulation, or generate the data later as a post processing task after EM analysis has finished.

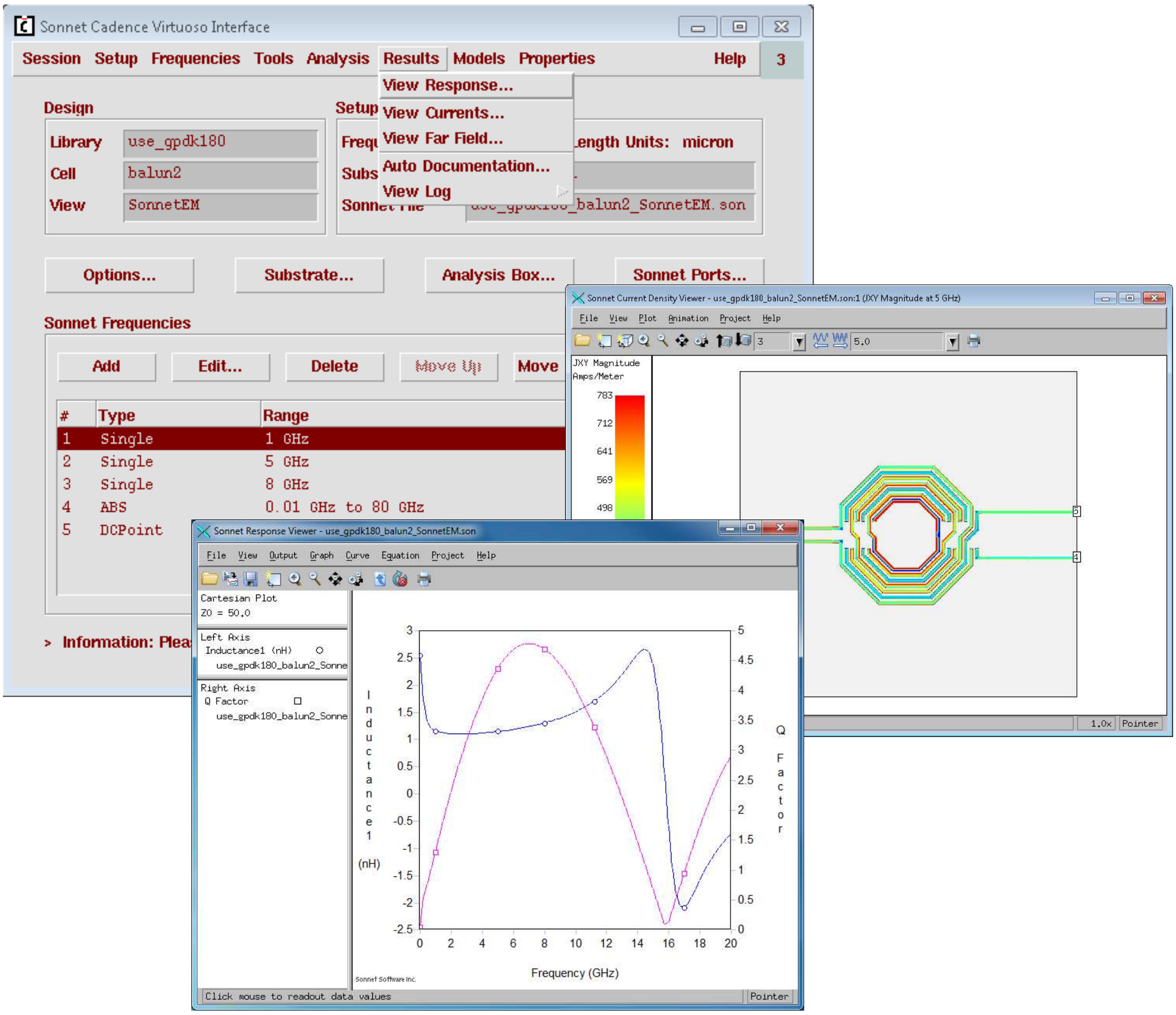


View simulation model in Sonnet (optional). If desired, the designer can take the simulation model as a 2D or 3D view to Sonnet, and review it in the Sonnet model editor. This is especially useful for complex multi layer circuits. The Sonnet interface will keep track of any manual changes, to makes sure that the Virtuoso view and the Sonnet view stay in sync.

Simulate the circuit. The simulation can be started from within Cadence Virtuoso. The Sonnet analysis monitor will show analysis progress and an estimate of the memory requirement and total simulation time.



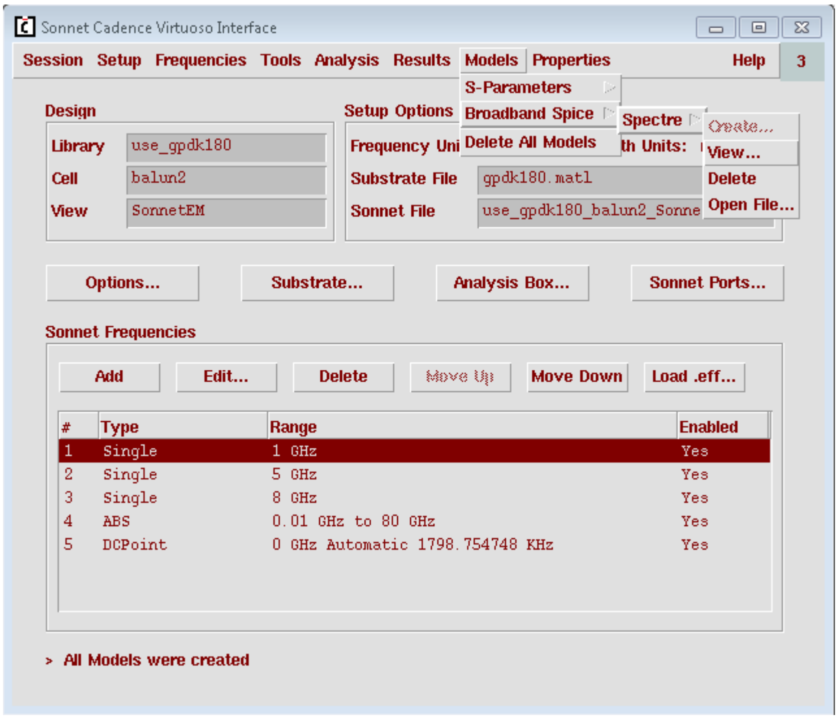
View simulation results. When the simulation is done, simulation results can be viewed with the Sonnet plotting tool. It is possible to plot already available results while the analysis engine is still analysing more frequencies. Parameters like inductor L and Q or capacitor C and Q can be plotted immediately by using pre-defined equations.



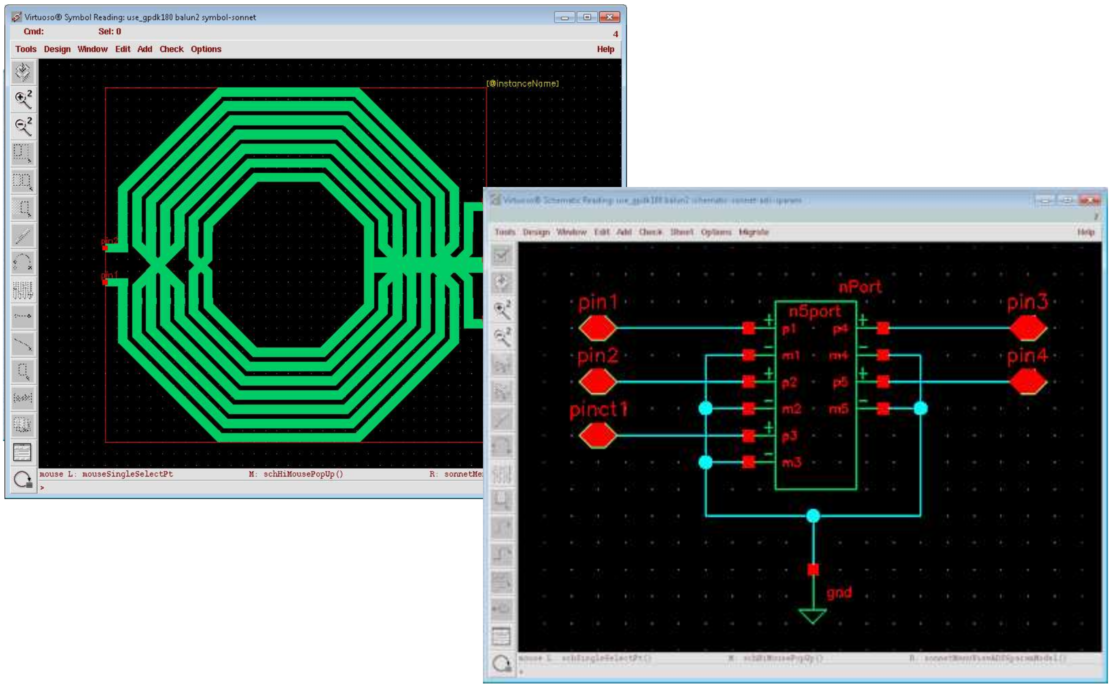
When the current distribution is of interest, the simulation can be configured to store current density data. That data can be visualized in various ways as 2D or 3D graphs. For a better understanding of the circuit, the current density or charge visualization can also be animated over time or frequency. Current density results can be exported to a spread sheet for post processing.

In the current density image shown here, note the smooth display of the current distribution, which shows high edge current (required to calculate the conductor losses properly) and current crowding. This is one indication of the high resolution and high precision of the Sonnet analysis result.

Back annotate results to the Cadence schematic. When the Sonnet analysis is finished, results are available in different formats. This includes both S/Y/Z-parameters for frequency domain simulation, as well as a broad band SPICE extraction for time domain (SPICE) simulation.



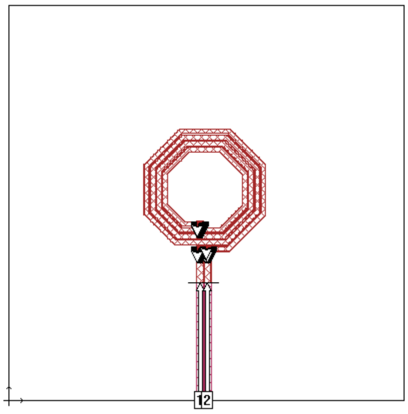
Cadence schematic symbols to hold those Sonnet results are created fully automatically, with all the required mapping files. A sub-circuit schematic for the analysed cell is also created fully automatically.

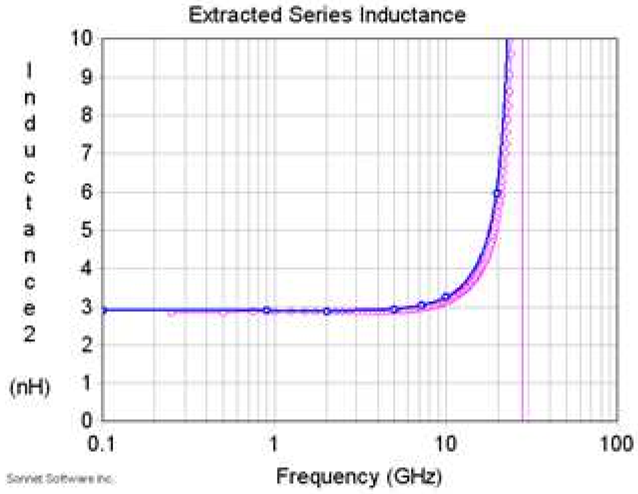


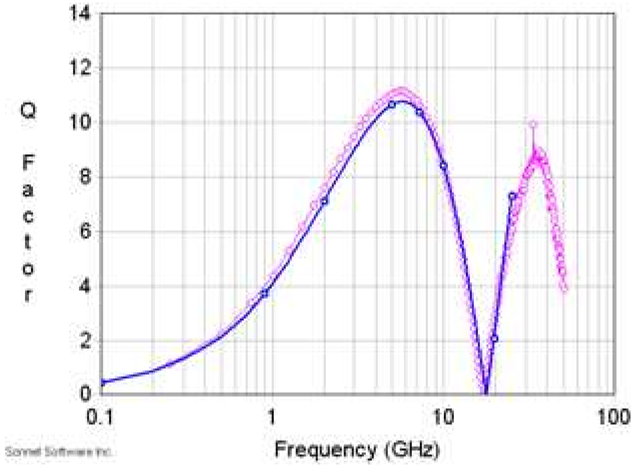
Example 1

Octagon inductor in the IHP 250nm technology (SGB25V) with thick metal effects modeled. The technology files for Sonnet EM analysis have been developed by Dr. Mühlhaus Consulting & Software GmbH and are available to IHP customers with the design kit.

Design and Measurement courtesy of IHP Microelectronics





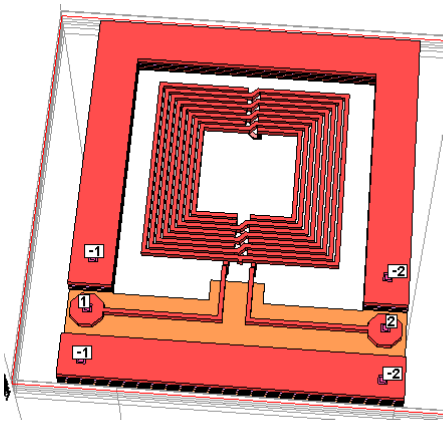


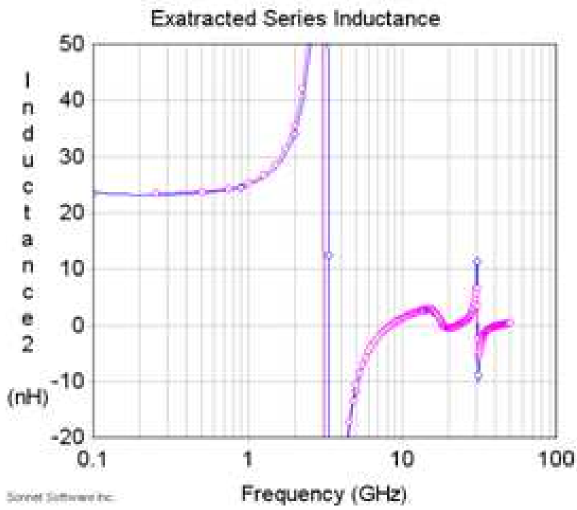
Measured vs. Calculated
pink = measured
blue = Sonnet result

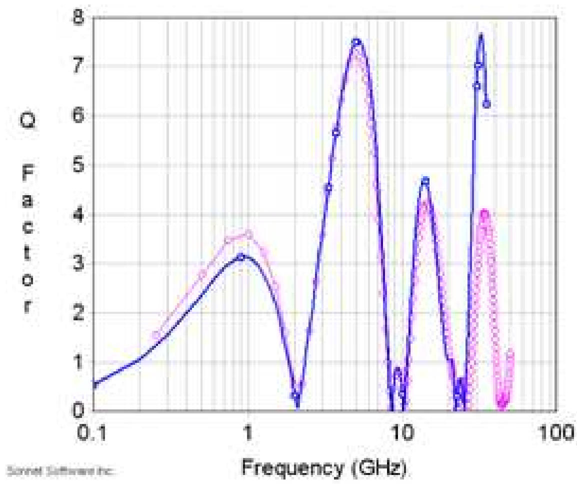
Example 2

Octagon inductor in the IHP 250nm technology (SGB25V) with thick metal effects modeled. The technology files for Sonnet EM analysis have been developed by Dr. Mühlhaus Consulting & Software GmbH and are available to IHP customers with the design kit.

Design and Measurement courtesy of IHP Microelectronics





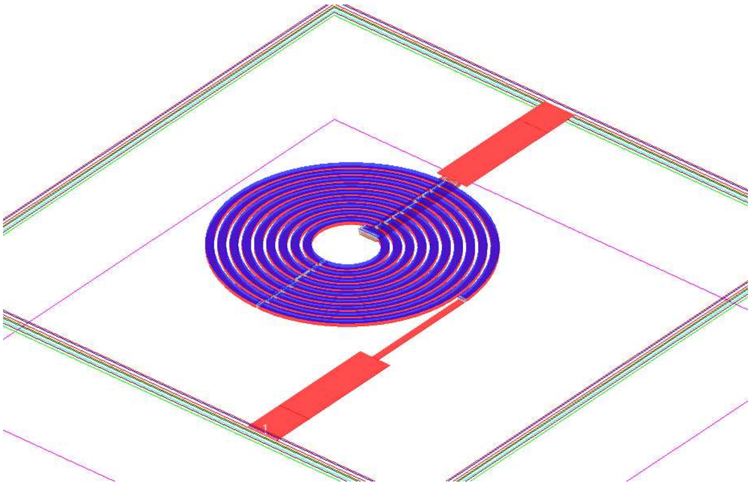


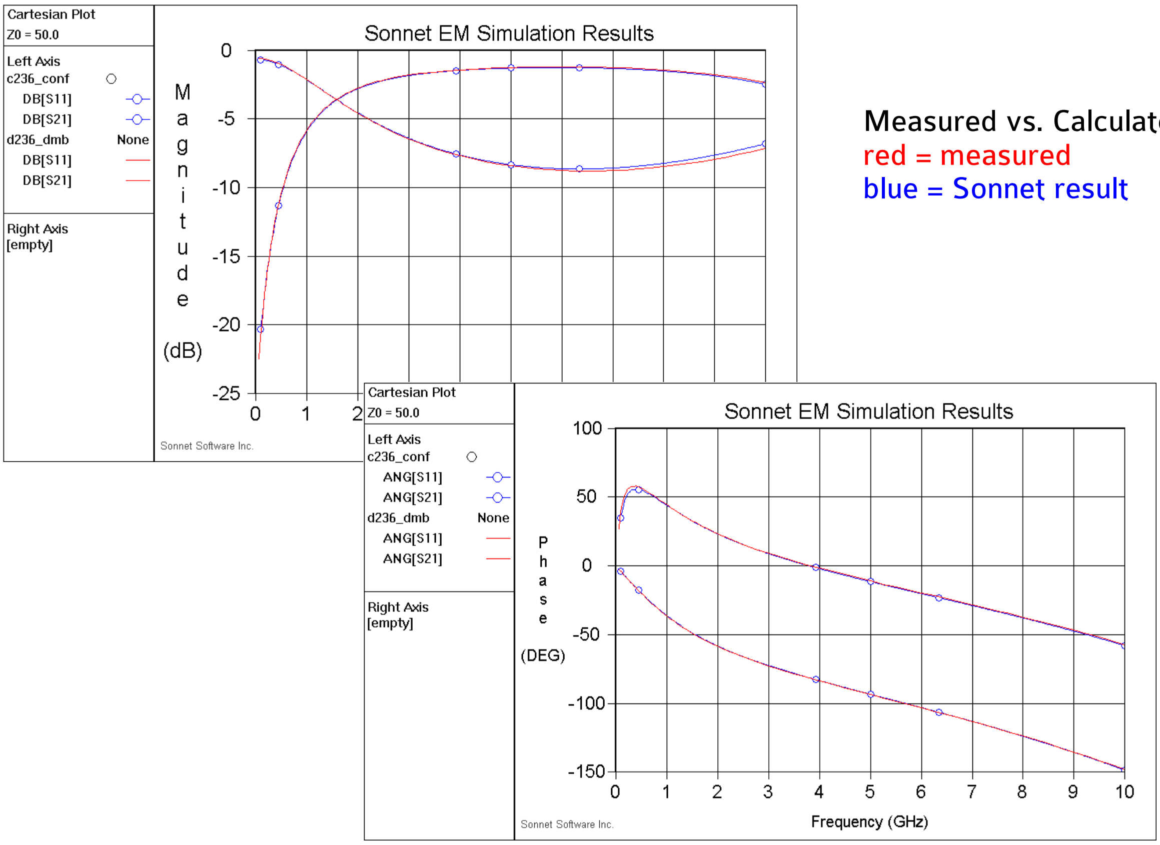
Measured vs. Calculated
pink = measured
blue = Sonnet result

Example 3

9.25-turn Circular Spiral Inductor on 100 um Silicon (step-graded conductivity in substrate).
5 insulating layers between 1 um and 3 um, thick metal effects modeled

Data and design courtesy of Motorola SPS/WISD





Measured vs. Calculated
red = measured
blue = Sonnet result