Behavioral Modeling

Cardiff Model -
the intuitive advanced behavioral model

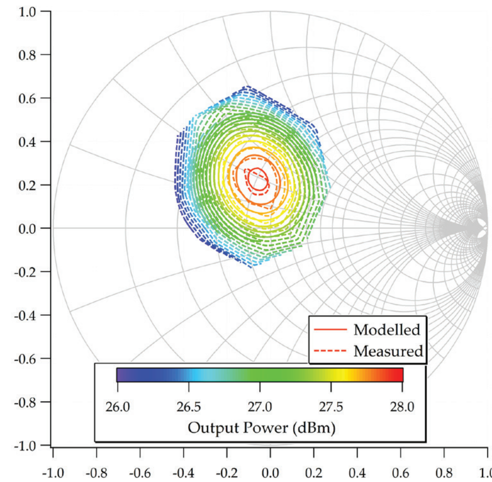
Cardiff Models

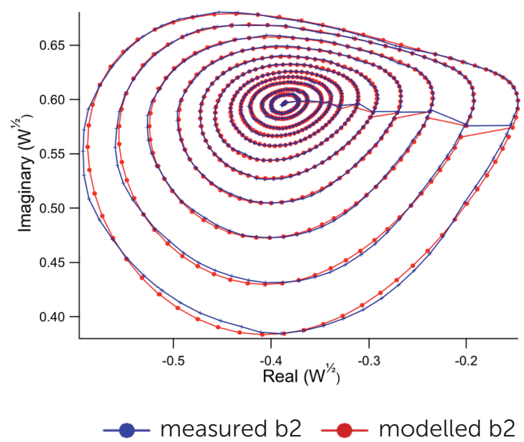
Non-linear measurement data has been exploited in various ways to create behavioral models for high frequency components. Formulations of these models have been defined in terms of traveling waves, with a desire to represent nonlinear behavior of high frequency transistors through a direct extension from linear s-parameters.

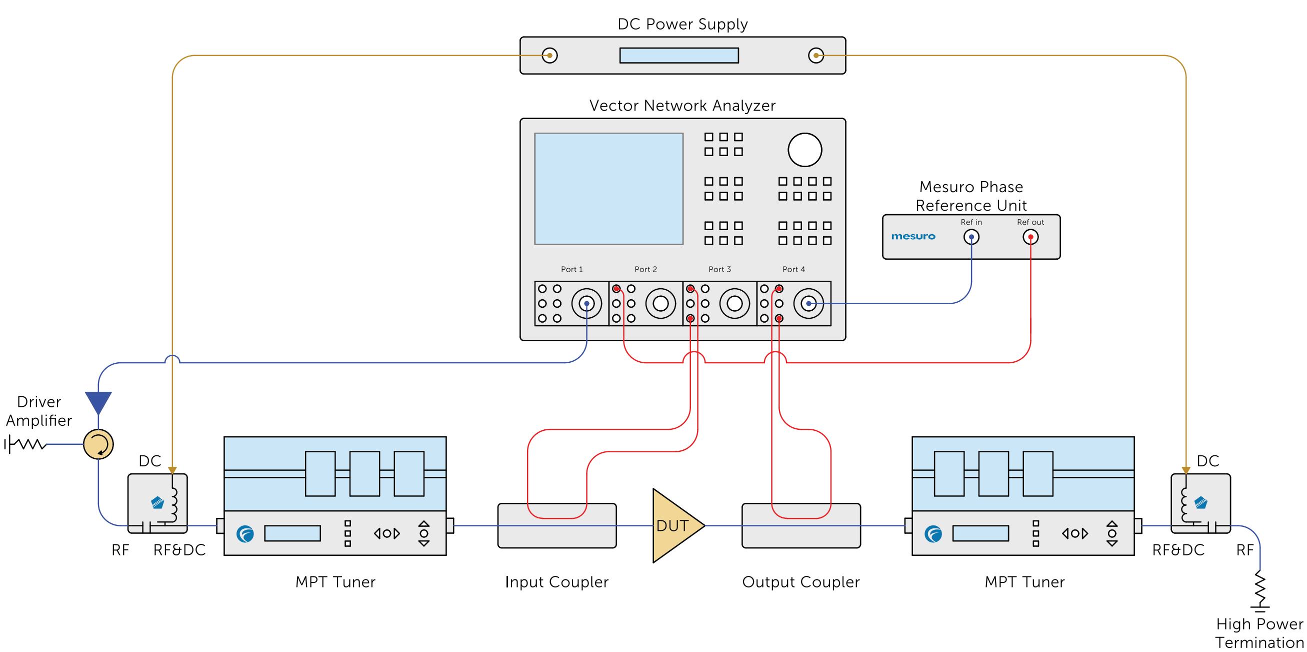
The Mesuro model portfolio is comprised of two models - each targeted at a particular end use - Cardiff Model Lite (CML), where the desired output is a local model, and Cardiff Model+ (CM+), which incorporates higher order mixing terms allowing a single model to fit over a range of impedance space.

The Cardiff Model+ formulation has a number of unique benefits over alternative approaches where formulations are truncated. Once the formulation is extended, the model moves away from a local model, where multiple models are required to define an impedance space (i.e load lookup), to a model that has a set of coefficients that describes the behavior of a device over an entire impedance space. This dramatically reduces file size and also allows any interpolation to be defined by the model itself rather than relying upon the interpolation algorithm in the simulator. Also, as harmonic superposition is not assumed in the CM+ formulation, a full harmonic mixing model is uncovered describing harmonic interactions and improving model accuracy particularly for complex modes of operation.

An example setup is shown below, the Mesuro phase reference and modeling framework is compatible with all major VNA's.







Behavioral Models

Cardiff Model+ is a behavioral modeling strategy, based on a polynomial fit of the measurement data.

• Generalized to an n^{th} odd order in terms of the relative phase component of the incident wave a (p,h) at harmonic h and port p.

• The formulation is flexible in the number of coefficients and mixing terms allowing the best possible model fit for different devices.

• The formulation is scalable to include input and output harmonics and does not assume superposition ensuring model accuracy.

$$b_{2,1} = P_1 \cdot g\left(v_{1,0}, |a_{1,1}|, v_{2,0}, |a_{2,1}|, {Q_1}/{P_1} \right)$$

$$P_1 = \angle a_{1,1} = \frac{a_{1,1}}{|a_{1,1}|} \qquad Q_1 = \angle a_{2,1} = \frac{a_{2,1}}{|a_{2,1}|}$$

$$K_{p,h,m} = g\left(v_{1,0}, |a_{1,1}|, v_{2,0}, |a_{2,1}|\right)$$

$$b_{p,h} = P_1^h \cdot \left(\sum_{m=-(w-1)/2}^{m=+(w+1)/2} K_{p,h,m} \left({Q_1}/{P_1} \right)^m \right)$$

Measurement strategy

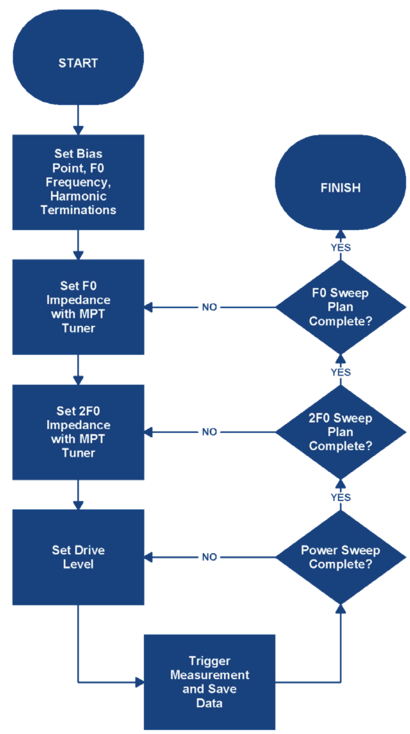
For fundamental (F0) and harmonic (2F0 and 3F0) model generation, the load-F0 impedance is swept through a pre-defined sweep plan; centred around the optimum for power and efficiency performance.

• The model is generated directly from Load Pull data and no special configuration is required.

• The model can capture fundamental and harmonic behavior at the source and/or load of the DUT. For an F0 model generation the harmonic frequencies remain static, and need to be swept in a nested fashion for harmonic model generation.

• Measurements of calibrated a and b waves and dc values v1dc, v2dc, i1dc, i2dc are captured and stored in a file indexed by fundamental load impedance and input drive.

• Fundamental source-pull is not necessary, as the effect of source pull is captured by the model (in FDCS), however it can aid in minimising the input return loss and thus provide a facility for driving the DUT into compression.

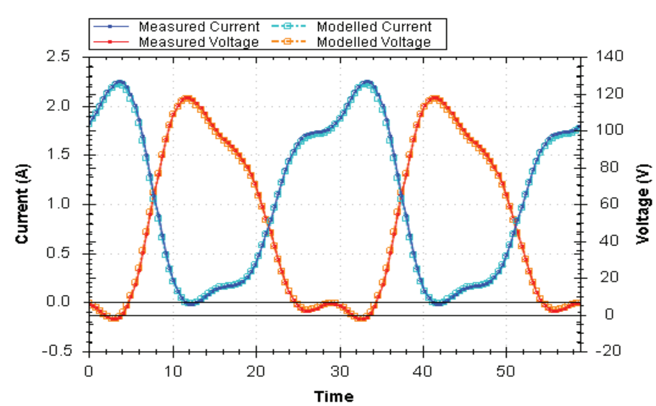


Verification

• Once the model is generated, the model coefficients can be used to model the data that filled the model.

• Error bars, time-domain waveforms and other plots are displayed to check the accuracy of the model.

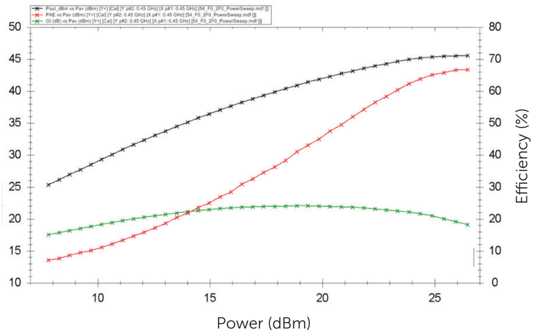
• This allows the user to save time by verifying the modeled data before importing it into the CAD environment.



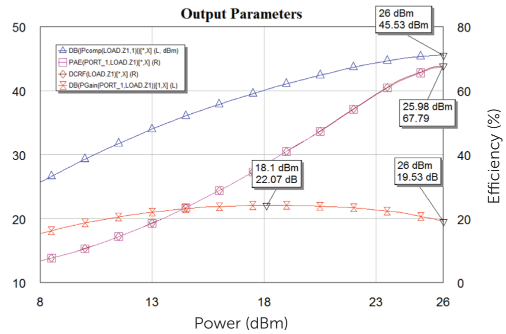
Result Comparison

As the aim of a behavioral model is to predict performance over a defined set of operating conditions, the model fits to measured data and the prediction of circuit is excellent.

Measured



Simulated



EDA example using CM+

The Cardiff Model portfolio is fully supported in all major EDS tools including AWR Microwave office and Keysight Advanced Design System.

These models are ideal for release to customers. They are accurate and as they are black box no reverse engineering of the underlying technology is possible.