

Swept_Load_Pull_Measurements_Complete

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Design Notes

Swept Load Pull Measurements Complete

Overview

This example is intended to show the functionality of the Load Pull Measurements utilizing the swept load pull file format, otherwise known as Generalized MDIF (GMDIF). This project is setup such that the Circuit Schematics node in the Project Browser has specific data displays, where related graphs and measurements are grouped together. The data displays are numbered 1 through 9 and should be worked through in this same sequence. Each numbered schematic contains notes to guide you through the operation of the marker defined reference.

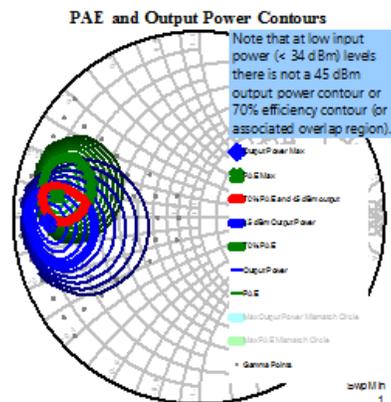
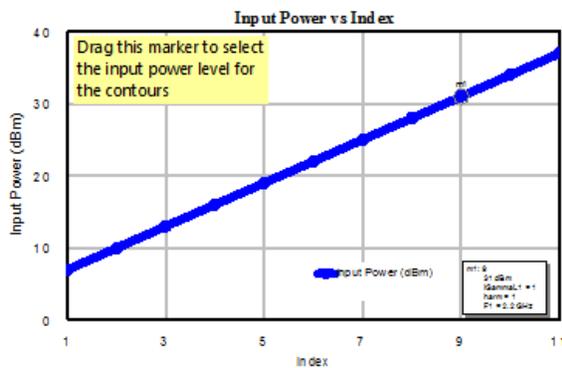
A full listing of measurements' functionality and intended use is listed at the end of the document. A list of measurements used per data display is also provided in the following sections to aid you in future setup of these same coupled measurements.

To properly tile the windows for easy data viewing choose Scripts > Project Scripts > Arrange Windows.

Data Display Schematics

1 Contours

This schematic contains two graphs that are tied together through the use of a defined marker reference.



Input Power vs Index plots the input power in dBm against the input power's sweep index (PlotMD_R). A marker m1 is defined on this graph for use in the **Output Power and Efficiency Contours** graph.

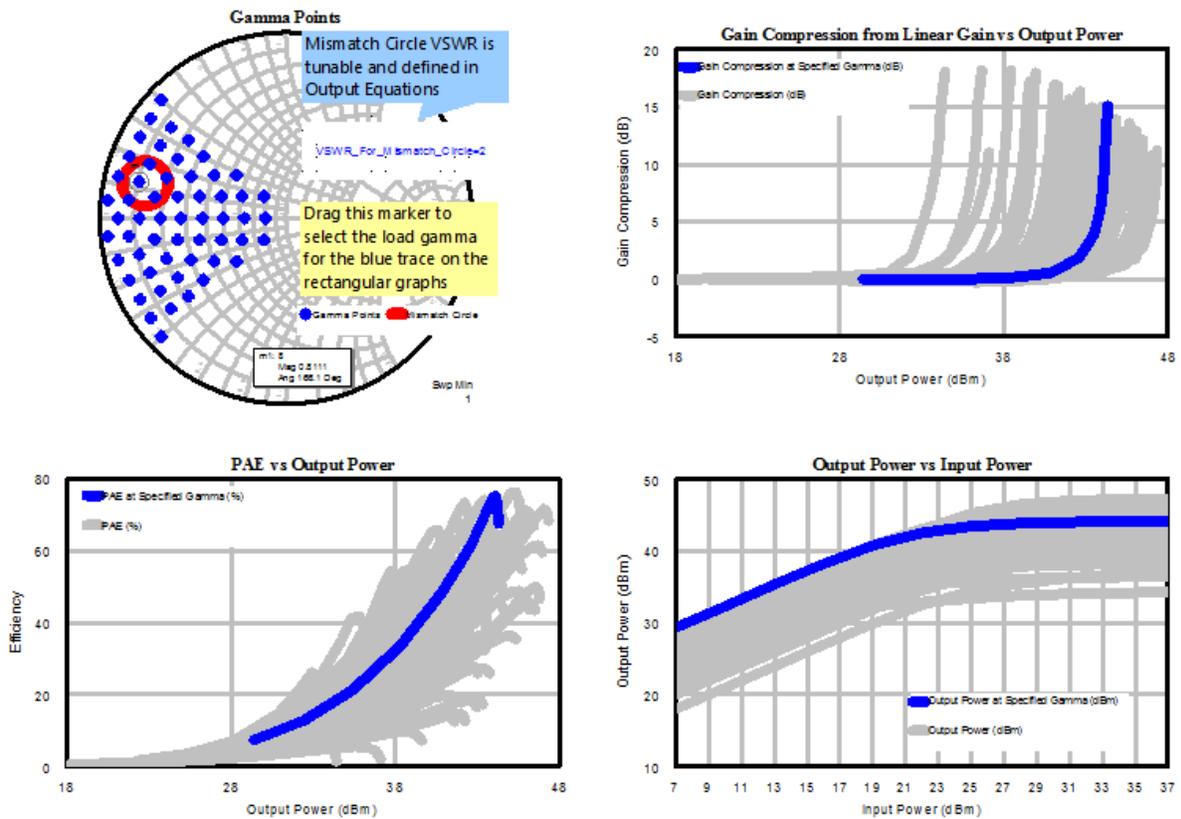
PAE and Output Power Contours uses several different Load Pull measurements, plotting different PAE and Pload data. The maximums of PAE and Pload (G_LPCMMAX), as well as general stepped contours for each measurement (G_LPCM) are also plotted. Displaying contours at specific values (G_LPCM_V) is also shown, as well as the overlapping region between PAE and Pload at specific values (G_LPCM_C2). Lastly, the load pull gamma points are shown (G_LPGPM).

List of Load Pull Measurements Used

G_LPGPM
 G_LPCM
 G_LPCM_C2
 G_LPCM_V
 PlotMD_R

2 Rectangular Plots

This data display schematic begins with a Smith Chart titled **Gamma Points**, which displays all of the gamma points present in the swept load pull data file (G_LPGPM).



A marker reference is also defined on this graph which is tied to every other plot present in this display. Moving the marker will change the impedance point, which will update the mismatch circle on **Gamma Points** while also updating the active (blue) trace accordingly in each of the other graphs.

Gain Compression from Linear Gain vs Output Power shows the compression from linear gain in dB plotted vs output power (PlotMD_R), where the active (blue) trace is defined by the marker position in **Gamma Points**.

PAE vs Output Power shows the power added efficiency on percent vs output power (PlotMD_R), where the active (blue) trace is defined by the marker position in **Gamma Points**.

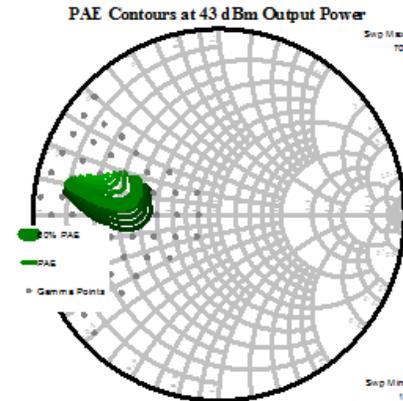
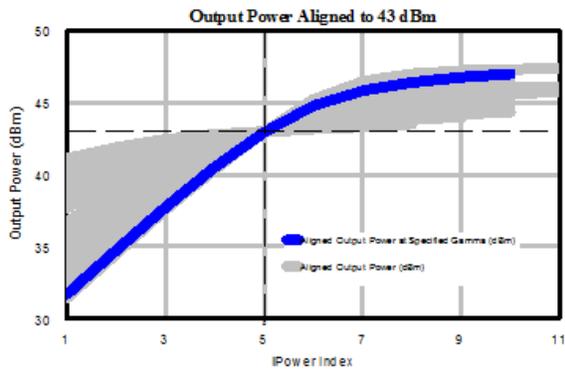
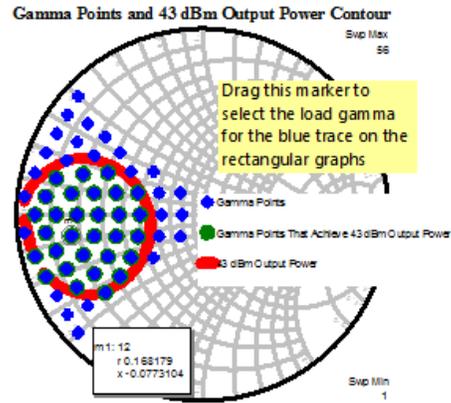
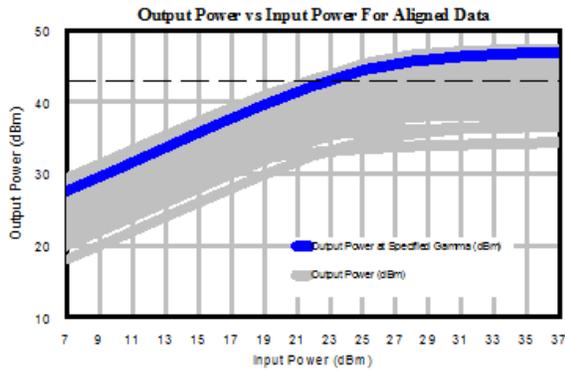
Output Power vs Input Power shows the device output power vs its input power (PlotMD_R), where the active (blue) trace is defined by the marker position in **Gamma Points**.

List of Load Pull Measurements Used

G_LPGPM

3 Aligned Rectangular Plots

This data display is meant to show the functionality of the alignment based load pull measurements. Aligning is the process of adjusting the load pull data such that all the values that achieve a given metric are aligned at the same x-axis index. In other words, data aligning allows the user to plot contours at a fixed output power level, PAE, compression, drain current, etc. On this particular data display the data is aligned to a fixed output power (43 dBm).



Gamma Points and 43 dBm Output Power Contour displays all of the impedance points swept for the load pull (G_LPGPM), the impedance points where the specified output power was achieved (G_LPGPM_A), and the output power contour at 43 dBm overlaid (G_LPCM_V). The m1 marker is used to select the load impedance for the active (blue) trace on the **Output Power vs Input Power for Aligned Data** graph and the **Output Power Aligned to 43 dBm** graph.

Output Power vs Input Power for Aligned Data displays the output power vs. input power for every load impedance (PlotMD_R). The active (blue) trace is defined by the marker position in the **Gamma Points and 43 dBm Output Power Contour** graph (PlotMD_R). The horizontal line marks 43 dBm output power and shows that 43 dBm was not achieved with all swept load values.

Output Power Aligned to 43 dBm displays output power aligned to 43 dBm vs sweep index, for every sweep that passes through the 43 dBm power level (PlotMD_R_A). Any traces that do not pass through the specified alignment value, in this case 43 dBm output power, will be excluded from the plotted traces automatically. The active (blue) trace is defined by the marker position in the **Gamma Points and 43 dBm Output Power Contour** graph. Note that as expected gamma points inside the 43 dBm output power contour have a corresponding trace on this graph while gamma points outside the 43 dBm output power contour do not. This graph shows that the data is nicely aligned at iPower = 5 and that contours (or any other plots) made at that iPower point will be the equivalent of load pull done at a fixed 43 dBm output power.

PAE Contours at 43 dBm Output Power displays the PAE contours at an output power of 43 dBm (G_LPCM_A). The bold contour corresponds to a PAE of 60% (G_LPCM_VA). The grey dots are the load pull gamma points (G_LPGPM). Also note that the G_LPCM_A and G_LPCM_VA measurements use "Auto Align" for the iPower index so that they automatically plot at the iPower index at which the data is aligned (iPower = 5 in this case)

List of Load Pull Measurements Used

- G_LPGPM
- G_LPGPM_A
- G_LPCM_V

G_LPCM_VA

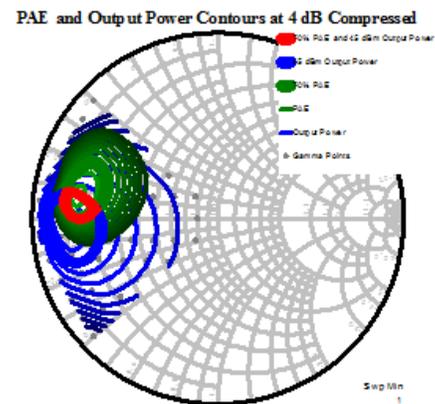
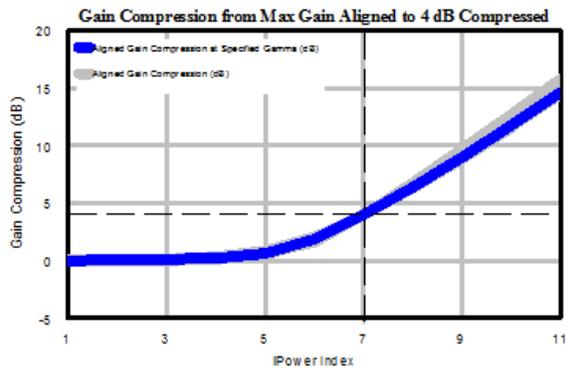
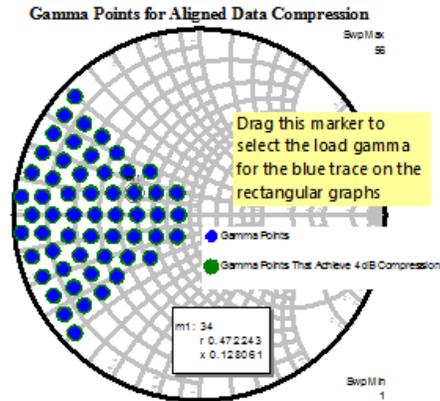
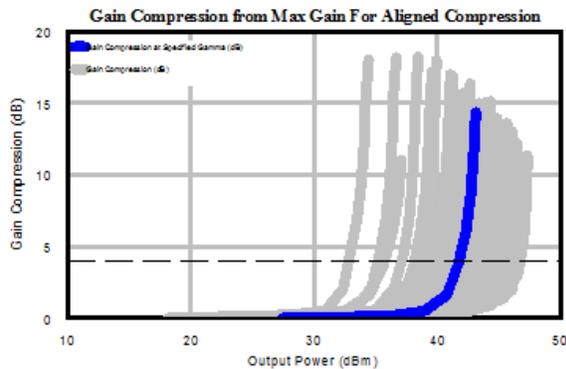
G_LPCM_A

PlotMD_R

PlotMD_R_A

3b Aligned Data Compression

This data display is similar to the 3 Aligned Rectangular Plots data display but the data is aligned to a fixed compression point (4 dB) rather than a fixed output power.



Gamma Points for Aligned Data Compression displays all of the impedance points swept for the load pull (G_LPGPM) and the impedance points where the specified gain compression (defined from max gain) was achieved (G_LPGM_A). The m1 marker is used to select the load impedance for the active (blue) trace on the **Gain Compression from Max Gain for Aligned Compression** graph and the **Gain Compression from Max Gain Aligned to 4 dB Compressed** graph.

Gain Compression from Max Gain For Aligned Compression displays gain compression (defined from max gain) vs. output power for every load impedance (PlotMD_R). The active (blue) trace is defined by the marker position in the **Gamma Points for Aligned Data Compression** graph. The horizontal line marks 4 dB compression and shows that 3 dB compression is achieved with all swept load values.

Gain Compression from Max Gain Aligned to 4 dB Compressed displays gain compression (defined from max gain) aligned to 4 dB versus sweep index (PlotMD_R_A). The active (blue) trace is defined by the marker position in the **Gamma Points for Aligned Data Compression** graph. This graph shows that the data is nicely aligned at index = 9 and that contours (or any other plots) made at that iPower point will be the equivalent of a load pull done at a fixed 4 dB compression.

PAE and Output Power Contours at 4 dB Compressed displays PAE and output power contours at 4 dB compressed (G_LPCM_A). The bold contours represent a PAE of 70% and an output power of 45 dBm (G_LPCM_VA). The red contour shows the overlap of the 70% PAE and 45 dBm output power contours (G_LPCM_C2A). The grey dots are the load pull gamma points (G_LPGM). Also note that the G_LPCM_A, G_LPCM_VA, and G_LPCM_C2A measurements use "Auto Align" for the iPower index so that they automatically plot at the iPower index at which the data is aligned (iPower = 9 in this case)

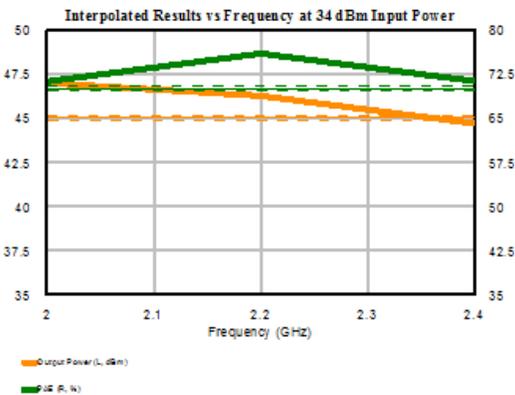
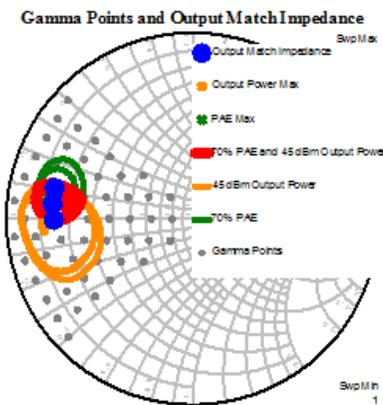
List of Load Pull Measurements Used

G_LPGPM

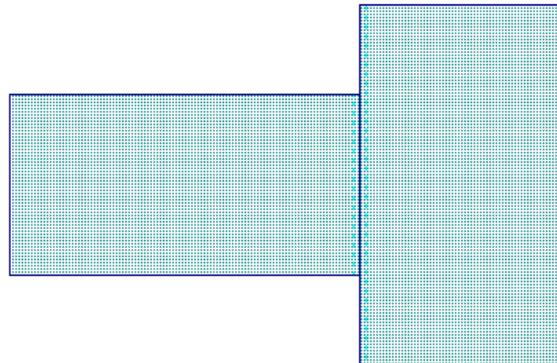
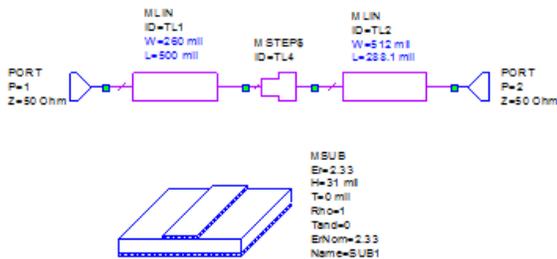
G_LPGPM_A
 G_LPCM_V
 G_LPCM_VA
 G_LPCM_A
 G_LPCM_C2A
 PlotMD_R
 PlotMD_R_A

4 Interpolated Results

This data display is intended to be used with the Tuner, allowing direct access to interpolated load pull results based on loading with a user specified output matching network. Opening the tuner provides the ability to manually adjust the width and length of the two MLINs present in the data display. The adjustment of these MLIN parameters will update not only the layout view, but also the output match impedance on **Gamma Points and Output Match Impedance** as well as the results displayed in Interpolated Results vs Frequency at 34 dBm Input Power.



Simple Matching Network



Gamma Points and Output Match Impedance displays all gamma points present in the swept load pull simulation data as grey dots (G_LPGPM) and the frequency dependent impedance of the Output Match schematic that is presented to the load pull data file as a blue circle (conj(S(1,1))). It also shows the orange 70% PAE contours vs. frequency (G_LPCM_V), the orange 45 dBm Output Power contours vs. frequency (G_LPCM_V), and the red overlap between 70% PAE and 45 dBm output power contours vs. frequency (G_LPCM_C2). Thus, to achieve the goal of having 70% PAE and 45 dBm output power across the frequency band the circuit should be tuned such that the blue dots are inside the red contours.

Interpolated Results vs Frequency at 34 dBm Input Power displays the interpolated Output Power, PAE, Gain, and Gain Compression (G_LPINT) vs frequency based on loading the load pull data file with the matching network design. Note that the output power, gain, and PAE interpolated values also account for the frequency dependent loss of the matching circuit and, thus, the results are effectively plotted at the output pin of the matching circuit rather than the output pin of the device.

List of Load Pull Measurements Used

G_LPGPM

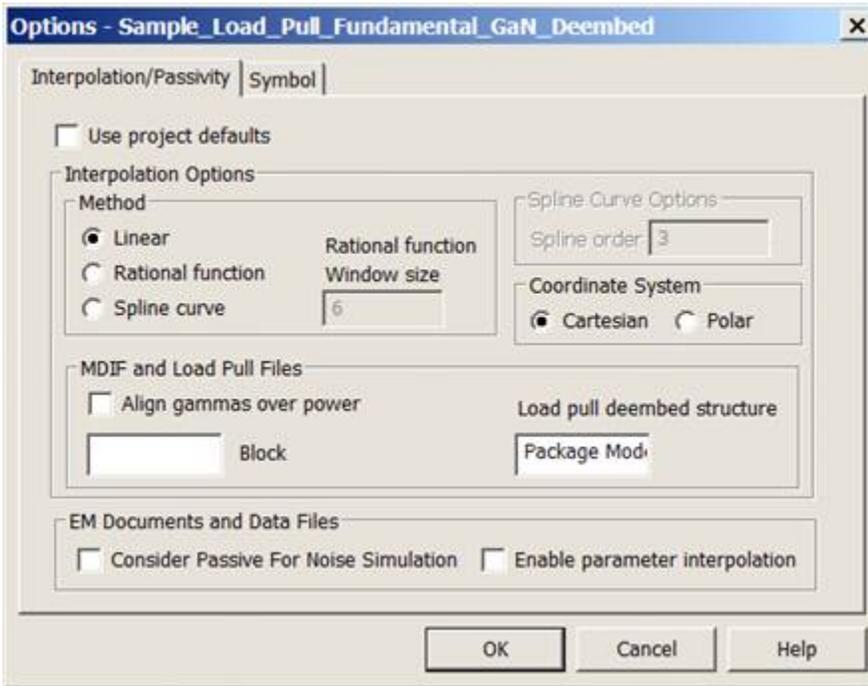
G_LPCM_V

G_LPCM_C2

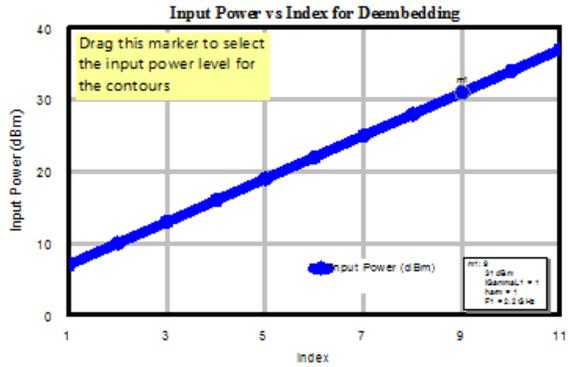
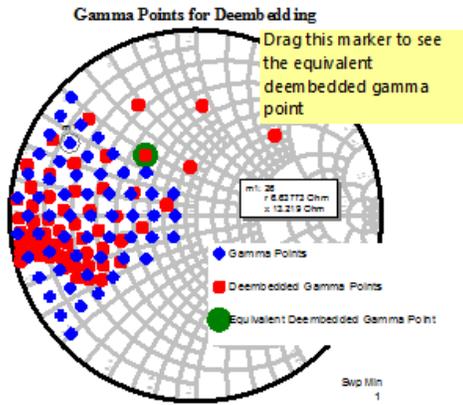
G_LPINT

5 Deembedding

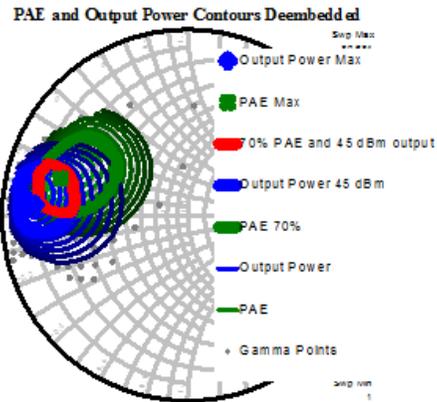
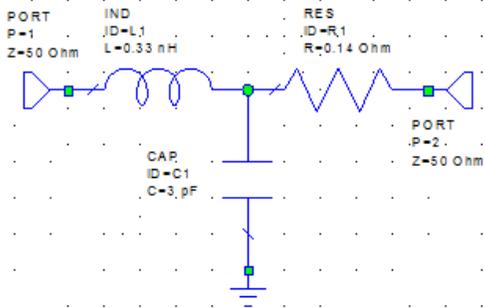
This data display shows how to deembed a package model from load pull data to move the reference plane from the external pin of the device to the internal pin of the device. The deembedding is applied to the load pull file by specifying a "Load pull deembed structure" in the load pull data file options. The deembedding structure can be any simulation document in the project (i.e. Circuit Schematic, Data File, EM Structure, etc.).



Gamma Points for Deembedding displays the gamma points at the external pin of the device in blue and the equivalent gamma points after deembedding the Simple Package Model (i.e. the gamma points at the internal pin of the device) in red (G_LPGPM). The m1 marker is on the original load pull gamma points and the green trace shows the equivalent to the m1 impedance after the deembedding network is applied.



Simple Package Model



Input Power vs Index for Deembedding plots the input power in dBm against the input power's sweep index (PlotMD_R). The m1 marker is defined on this graph for selecting a specific input power level on the **PAE and Output Power Contours Deembedded** graph.

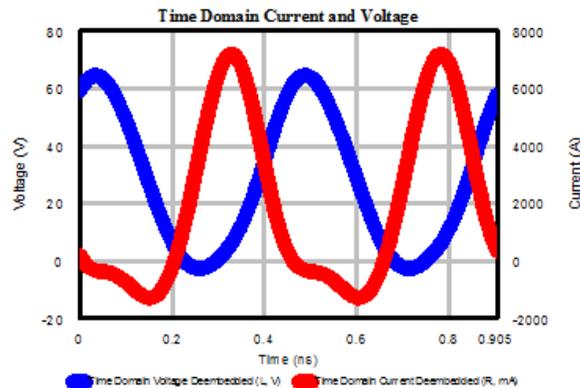
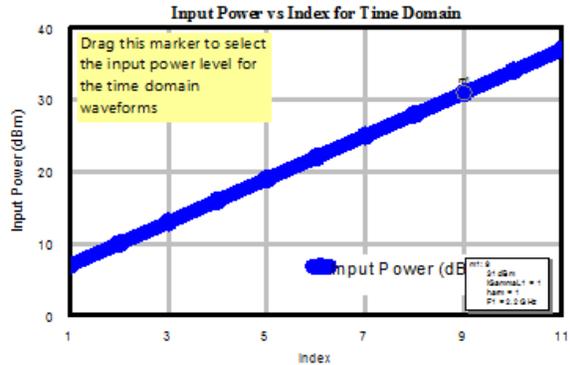
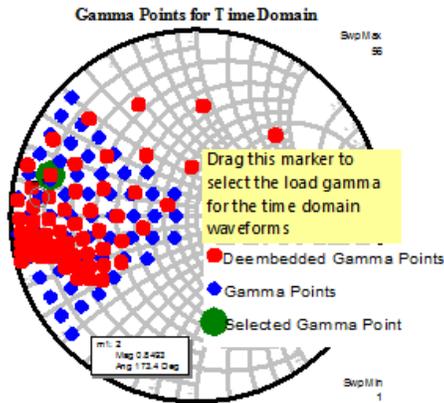
PAE and Output Power Contours Deembedded uses several different Load Pull measurements, plotting different deembedded PAE and Pload data. The maximums of PAE and Pload (G_LPCM_MAX), as well as general stepped contours for each measurement (G_LPCM) are also plotted. Displaying contours at specific values (G_LPCM_V) is also shown, as well as the overlapping region between PAE and Pload at specific values (G_LPCM_C2). Lastly, the load pull gamma points are shown (G_LPGPM).

List of Load Pull Measurements Used

- G_LPGPM
- G_LPCM_MAX
- G_LPCM
- G_LPCM_C2
- G_LPCM_V
- PlotMD_R

6 Time Domain

This data display shows plotting time domain waveforms from load pull data files. This technique is often used in combination with the deembedding shown in the **5 Deembedding** data display to allow for inspection of amplifier operational modes at the internal device pins.



Gamma Points for Time Domain displays the gamma points at the external pin of the device in blue and the equivalent gamma points after deembedding (i.e. the gamma points at the internal pin of the device) in red (G_LPGPM). The m1 marker is on the original load pull gamma points and the green trace shows the equivalent to the m1 impedance after the deembedding network is applied. In addition, the m1 marker is used to select a specific load gamma for the **Time Domain Current and Voltage Graph**.

Input Power vs Index for Time Domain plots the input power in dBm against the input power's sweep index (PlotMD_R). The m1 marker is defined on this graph for selecting a specific input power level on the **Time Domain Current and Voltage** graph.

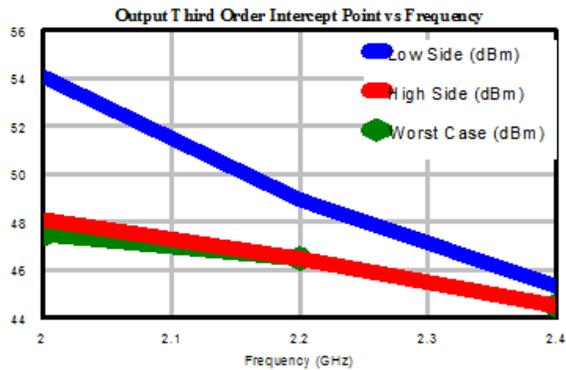
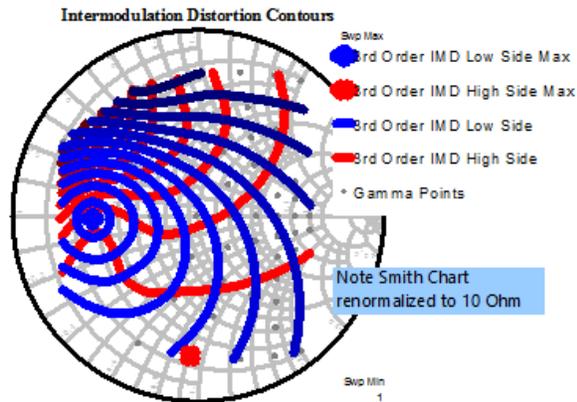
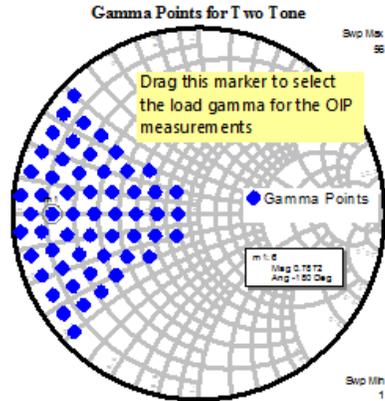
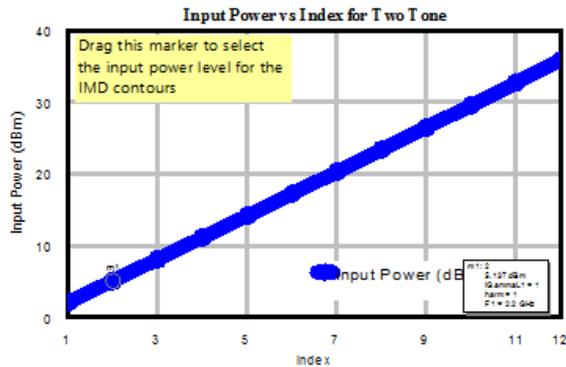
Time Domain Current and Voltage displays the deembedded time domain voltage in blue (G_LP_VTIME) and the deembedded time domain current in red (G_LP_ETIME). The load impedance point and input power level used for these waveforms are chosen with the m1 markers in the **Gamma Points for Time Domain** and **Input Power vs Index for Time Domain** graphs.

List of Load Pull Measurements Used

G_LPGPM
G_LP_ETIME
G_LP_VTIME
PlotMD_R

7 Two Tone

This data displays how to setup and use the two tone calculated values from two tone load pull files. Both output intercept point (IPN) and intermodulation distortion product power deltas (IMD) are available. In addition, the best case or worst case IPN or IMD is supported for 3rd order intermodulation products.



Input Power vs Index for Two Tone plots the input power in dBm against the input power's sweep index (PlotMD_R). The m1 marker is defined on this graph for selecting a specific input power level on the **Intermodulation Distortion Contours** graph.

Intermodulation Distortion Contours displays the low side and high side IMD contours (G_LPCM) and the interpolated maximum value and impedance of the low side and high side IMD (G_LPCM_MAX) at the input power level defined by m1 on the **Input Power vs Index for Two Tone** graph. The grey dots are the load gamma points (G_LPGPM). Note that these measurements were renormalized to 10 ohms to make it easier to see the contour details.

Gamma Points for Two Tone displays all of the impedance points swept for the load pull (G_LPGPM). The m1 marker is defined on this graph for selecting a specific load gamma point on the **Output Third Order Intercept Point vs Frequency** graph.

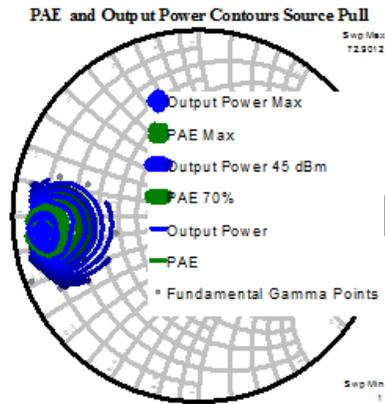
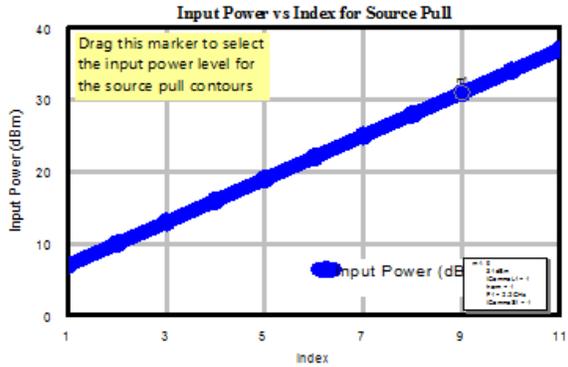
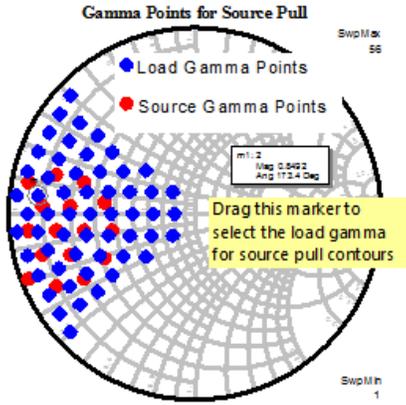
Output Third Order Intercept Point vs Frequency displays the low side, high side, and worst case output intercept point vs. frequency (PlotMD_R) at the load impedance defined by m1 on the **Gamma Points for Two Tone** graph.

List of Load Pull Measurements Used

- G_LPGPM
- G_LPCM_MAX
- G_LPCM
- PlotMD_R

8 Source Pull

This data displays how to use source pull (or nested source and load pull) data. The example file in the project is a nested source and load pull file which means that at each load gamma point a full source pull was done.



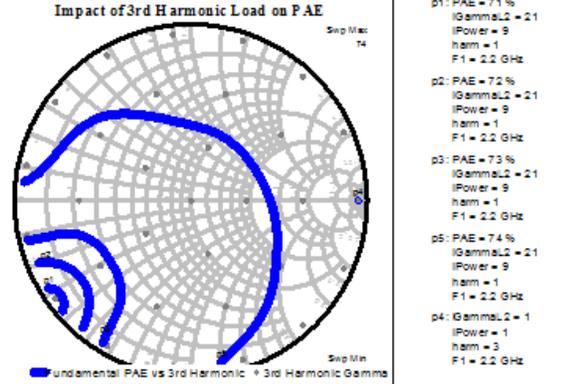
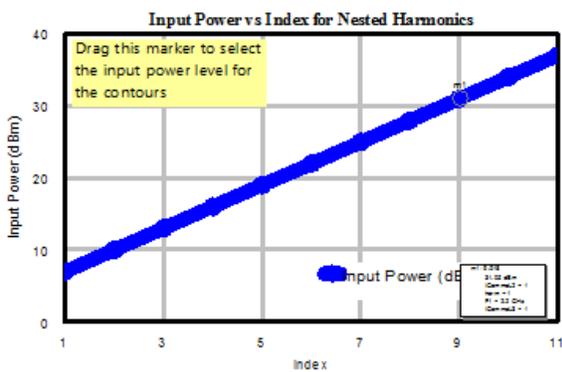
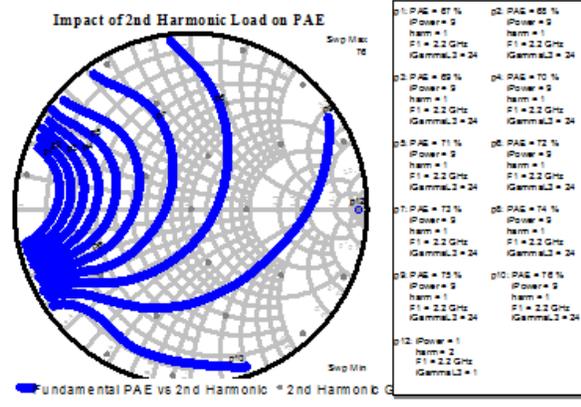
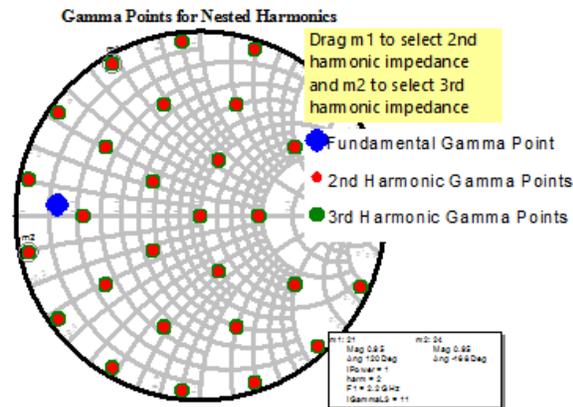
Gamma Points for Source Pull displays the load pull displays the load gamma points and the source gamma points (G_LPGPM).

List of Load Pull Measurements Used

G_LPGPM

9 Advanced Contours

This data display is designed to begin showing the power of nested harmonic load pull. The example load pull file has a fixed fundamental load value with nested 2nd harmonic and 3rd harmonic load pull sweeps (i.e. at each 2nd harmonic load a full 3rd harmonic load sweep was done).



Gamma Points for Nested Harmonics displays the impedance points of the fundamental load in blue, the swept 2nd harmonic load in red, and the swept 3rd harmonic load in green (G_LPGPM). The m1 marker is attached to the 2nd harmonic impedance points and is defined on this graph for selecting a specific 2nd harmonic load value on the **Impact of 3rd Harmonic Load on PAE** graph. Additionally, the m2 marker is attached to the 3rd harmonic impedance points and is defined on this graph for selecting a specific 3rd harmonic load value on the **Impact of 2nd Harmonic Load on PAE** graph.

Input Power vs Index for Nested Harmonics plots the input power in dBm against the input power's sweep index (PlotMD_R). The m1 marker is defined on this graph for selecting a specific input power level on the **Impact of 2nd Harmonic Load on PAE** and **Impact of 3rd Harmonic Load on PAE** graphs.

Impact of 2nd Harmonic Load on PAE is a really cool graph that shows PAE contours vs. 2nd harmonic load (G_LPCM_EX). On this graph the 3rd harmonic load is set by m2 on the **Gamma Points for Nested Harmonics** graph and the input power is set by m1 on the **Input Power vs Index for Nested Harmonics** graph. From reading the data marker legend it can be seen that for the default input power and 3rd harmonic load the 2nd harmonic load impedance impacts the PAE by up to 9% (67% to 76%).

Impact of 3rd Harmonic Load on PAE is a really cool graph that shows PAE contours vs. 3rd harmonic load (G_LPCM_EX). On this graph the 2nd harmonic load is set by m1 on the **Gamma Points for Nested Harmonics** graph and the input power is set by m1 on the **Input Power vs Index for Nested Harmonics** graph. From reading the data marker legend it can be seen that for the default input power and 2nd harmonic load the 3rd harmonic load impedance impacts the PAE by up to 3% (71% to 74%).

List of Load Pull Measurements Used

- G_LPGPM
- G_LPCM_EX
- PlotMD_R