

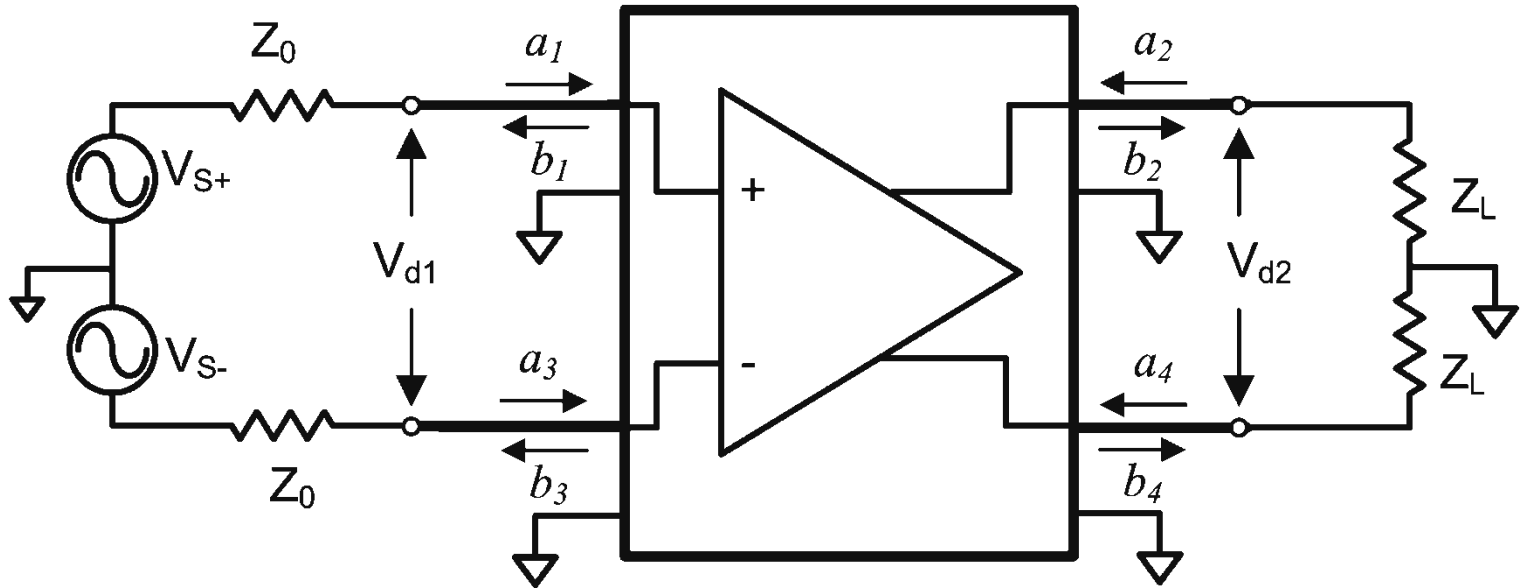
Differential Harmonics, Differential Mixers and IQ Mixer Measurements

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Differential and I/Q Mixer Application

- The “Swiss-Army Knife” of applications
- Set any source to:
 - Any frequency
 - Any power
 - Any phase
- Then measure
 - Any receiver
 - At any of a number of frequencies
- With match corrected power measurements

Consider the fundamentals of differential devices



$$V_d^F = \frac{1}{2}(V_d + I_d Z_d), \quad V_d^R = \frac{1}{2}(V_d - I_d Z_d)$$

$$V_d = V_1 - V_3, \quad I_d = \frac{1}{2}(I_1 - I_3) \quad I_c = I_1 + I_3, \quad V_c = \frac{1}{2}(V_1 + V_3)$$

$$Z_d = 2Z_0, \quad Z_c = \frac{Z_0}{2}$$

Differential S-parameters can be derived for this configuration, for each mode

$$a_d = \frac{V_d^F}{\sqrt{Z_d}}, \quad b_d = \frac{V_d^R}{\sqrt{Z_d}}, \quad a_c = \frac{V_c^F}{\sqrt{Z_c}}, \quad b_c = \frac{V_c^R}{\sqrt{Z_c}}$$

$$\begin{bmatrix} b_{d1} \\ b_{d2} \end{bmatrix} = \begin{bmatrix} S_{dd11} & S_{dd12} \\ S_{dd21} & S_{dd22} \end{bmatrix} \cdot \begin{bmatrix} a_{d1} \\ a_{d2} \end{bmatrix}, \quad \begin{bmatrix} b_{c1} \\ b_{c2} \end{bmatrix} = \begin{bmatrix} S_{cc11} & S_{cc12} \\ S_{cc21} & S_{cc22} \end{bmatrix} \cdot \begin{bmatrix} a_{c1} \\ a_{c2} \end{bmatrix}$$

$$\begin{bmatrix} b_{c1} \\ b_{c2} \end{bmatrix} = \begin{bmatrix} S_{cd11} & S_{cd12} \\ S_{cd21} & S_{cd22} \end{bmatrix} \cdot \begin{bmatrix} a_{d1} \\ a_{d2} \end{bmatrix}, \quad \begin{bmatrix} b_{d1} \\ b_{d2} \end{bmatrix} = \begin{bmatrix} S_{dc11} & S_{dc12} \\ S_{dc21} & S_{dc22} \end{bmatrix} \cdot \begin{bmatrix} a_{c1} \\ a_{c2} \end{bmatrix}$$

This can be configured into a single matrix

$$\begin{bmatrix} b_{d1} \\ b_{d2} \\ b_{c1} \\ b_{c2} \end{bmatrix} = \begin{bmatrix} S_{dd11} & S_{dd12} & S_{dc11} & S_{dc12} \\ S_{dd21} & S_{dd22} & S_{dc21} & S_{dc22} \\ S_{cd11} & S_{cd12} & S_{cc11} & S_{cc12} \\ S_{cd21} & S_{cd422} & S_{cc21} & S_{cc22} \end{bmatrix} \cdot \begin{bmatrix} a_{d1} \\ a_{c2} \\ a_{c1} \\ a_{c2} \end{bmatrix}$$

Thus, 16 differential S-parameters are needed to fully describe a 2-port differential device

The differential parameters can be defined in terms of single-ended measurements from first principals

$$a_{d1} = \frac{(a_1 - a_3)}{\sqrt{2}}, a_{c1} = \frac{(a_1 + a_3)}{\sqrt{2}}, b_{d1} = \frac{(b_1 - b_3)}{\sqrt{2}}, b_{c1} = \frac{(b_1 + b_3)}{\sqrt{2}}$$

$$S_{dd11} = \left. \frac{b_{d1}}{a_{d1}} \right|_{a_{c1}=a_{d2}=a_{c2}=0}$$

recognizing that $a_{c1} = 0$ which implies that $a_3 = -a_1$ so that $a_{d1} = 2a_1$

$$S_{dd11} = \left(\frac{b_1 - b_3}{a_1 - a_3} \right) = \left(\frac{b_1 - b_3}{a_1 - (-a_1)} \right) = \left(\frac{b_1 - b_3}{2a_1} \right)$$

From this beginning, differential S-parameters can be computed from Single-Ended S-parameters

$$S_{dd11} = \left(\frac{b_1 - b_3}{2a_1} \right) = \left(\frac{[S_{11}a_1 + S_{13}a_3] - [S_{31}a_1 + S_{33}a_3]}{2a_1} \right) = \left(\frac{[S_{11}a_1 - S_{13}a_1] - [S_{31}a_1 - S_{33}a_1]}{2a_1} \right)$$

$$S_{dd11} = \frac{1}{2} (S_{11} - S_{13} - S_{31} + S_{33})$$

And similarly for transmission:

$$S_{dd21} = \left(\frac{b_2 - b_4}{a_1 - a_3} \right) = \left(\frac{b_2 - b_4}{a_1 - (-a_1)} \right) = \left(\frac{b_2 - b_4}{2a_1} \right)$$

$$S_{dd21} = \left(\frac{b_2 - b_4}{2a_1} \right) = \left(\frac{[S_{21}a_1 + S_{23}a_3] - [S_{41}a_1 + S_{43}a_3]}{2a_1} \right) = \left(\frac{[S_{21}a_1 - S_{23}a_1] - [S_{41}a_1 - S_{43}a_1]}{2a_1} \right)$$

$$S_{dd21} = \frac{1}{2} (S_{21} - S_{23} - S_{41} + S_{43})$$

We can use these definitions to define Harmonic Power, Mixer Conversion, Image Rejection, LO isolation

Diff. Input Power, Diff. Output Power, Diff. Harmonic Power

$$a_{d1} = \frac{(a_1 - a_3)}{\sqrt{2}}, \quad b_{d2} = \frac{(b_1 - b_3)}{\sqrt{2}}, \quad b_{d2,2} = \frac{(b_{2,2} - b_{4,2})}{\sqrt{2}}$$

Differential Harmonics (in dBc) are defined as:

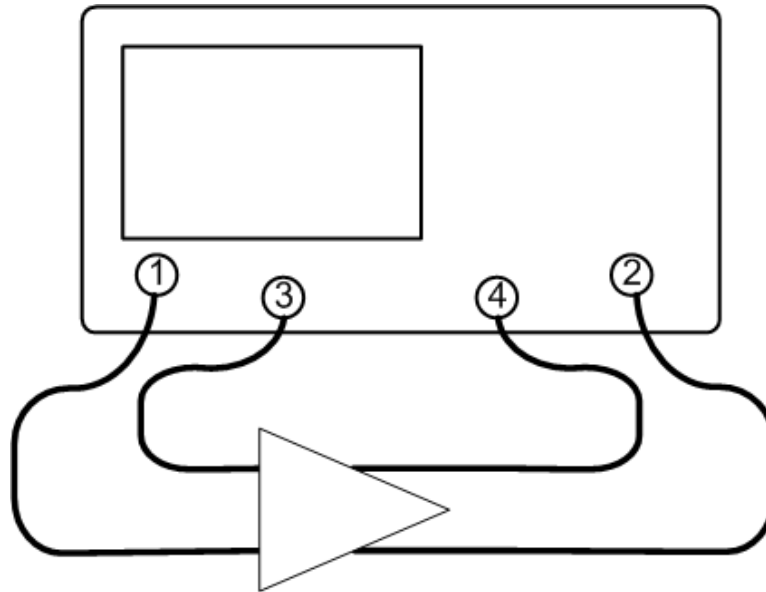
$$H2_d = \frac{(b_{2,2} - b_{4,2})}{(a_1 - a_3)}, \quad H3_d = \frac{(b_{2,3} - b_{4,3})}{(a_1 - a_3)}, \quad \dots \quad Hn_d = \frac{(b_{2,n} - b_{4,n})}{(a_1 - a_3)}$$

Differential Mixers have similarly defined signals

$$b_{d(RF)} = b_{d(LO+IF)} = \frac{(b_{2,(LO+RF)} - b_{4,(LO+RF)})}{\sqrt{2}}, \quad b_{d(Image)} = b_{d(LO+IF)} = \frac{(b_{2,(LO-RF)} - b_{4,(LO-RF)})}{\sqrt{2}}$$

$$b_{d(LO_Isol)} = b_{d(LO)} = \frac{(b_{2,(LO)} - b_{4,(LO)})}{\sqrt{2}}, \quad b_{d(RF_Isol)} = b_{d(LO+IF)} = \frac{(b_{2,(RF)} - b_{4,(LO-RF)})}{\sqrt{2}}$$

Use Case 1 : Measuring Harmonics of Balanced Amplifiers



Test Requirements:

- Stimulate the input with balanced, differential signal
- Measure the input differential power
- Measure the output differential power
- Measure the output differential power at N harmonics, N a small integer (5)
- Provide corrected measurements of power, provide leveled input power
- Measure with swept frequency, swept power or swept phase input
- Function in pulsed mode

Wants:

- Provide leveled output power

First: Define the frequency lists for source and receivers

Each frequency defined will be measured by all the receivers

Editing a line brings up a dialog box

If coupled, some relative offset, and multiplier/divider can be set. If uncoupled, the just set start/stop.

Only linear frequencies are allowed.

The screenshot shows the 'Source Phase Control Converters Setup : Channel 1' dialog box. It has a 'Measurement Set Up' section with a 'Frequency Range' table and a 'Sources' table. The 'Frequency Range' table has four rows (F1-F4) with start and stop frequencies. An 'Edit' button is next to the F2 row. The 'Sources' table lists ports and their associated frequency ranges. Below these are 'New' and 'Remove' buttons. A second dialog box, 'F2 Range Settings', is open, showing detailed settings for the F2 range: Start (10.000000 MHz), Stop (26.500000000 GHz), IFBW (100.000 kHz), and Coupling options (Couple to F1, Offset 0 Hz, Multiplier 1, Divisor 1). The output formula is shown as $Output = Frequency * Multiplier / Divisor + Offset$.

Range Name	Settings
F1	0.0100000000 GHz - 26.5000000000 GHz
F2	0.0100000000 GHz - 26.5000000000 GHz
F3	0.0100000000 GHz - 26.5000000000 GHz
F4	0.0100000000 GHz - 26.5000000000 GHz

Source Name	State	Frequency
Port 1	Active	F1
Port 2	Active	F1
Port 3	Active	F1
Port 4	Active	F1
Port 1 Src2	Active	F1

Parameter	Value
Start	10.000000 MHz
Stop	26.500000000 GHz
IFBW	100.000 kHz

Coupling: Couple to F1

Offset: 0 Hz

Multiplier: 1

Divisor: 1

Output = Frequency * Multiplier / Divisor + Offset

Next Define Source behavior

Source Phase Control Converters Setup : Channel 1

Measurement Set Up

Frequency Range

Range Name	Settings
F1	0.0100000000 GHz - 26.5000000000 GHz
F2	0.0100000000 GHz - 26.5000000000 GHz
F3	0.0100000000 GHz - 26.5000000000 GHz

New Remove

Sources

Source Name	State	Frequency	Power	Phase	
Port 1	Active	F1	-5.00dBm	0.00°	Edit
Port 2	Off	F1	-5.00dBm	N/A	
Port 3	Active	F1	-5.00dBm	180.00°	
Port 4	Off	F1	-5.00dBm	N/A	
Port 1 Src2	Off	F1	-5.00dBm	N/A	

Add Source... Save... Load...

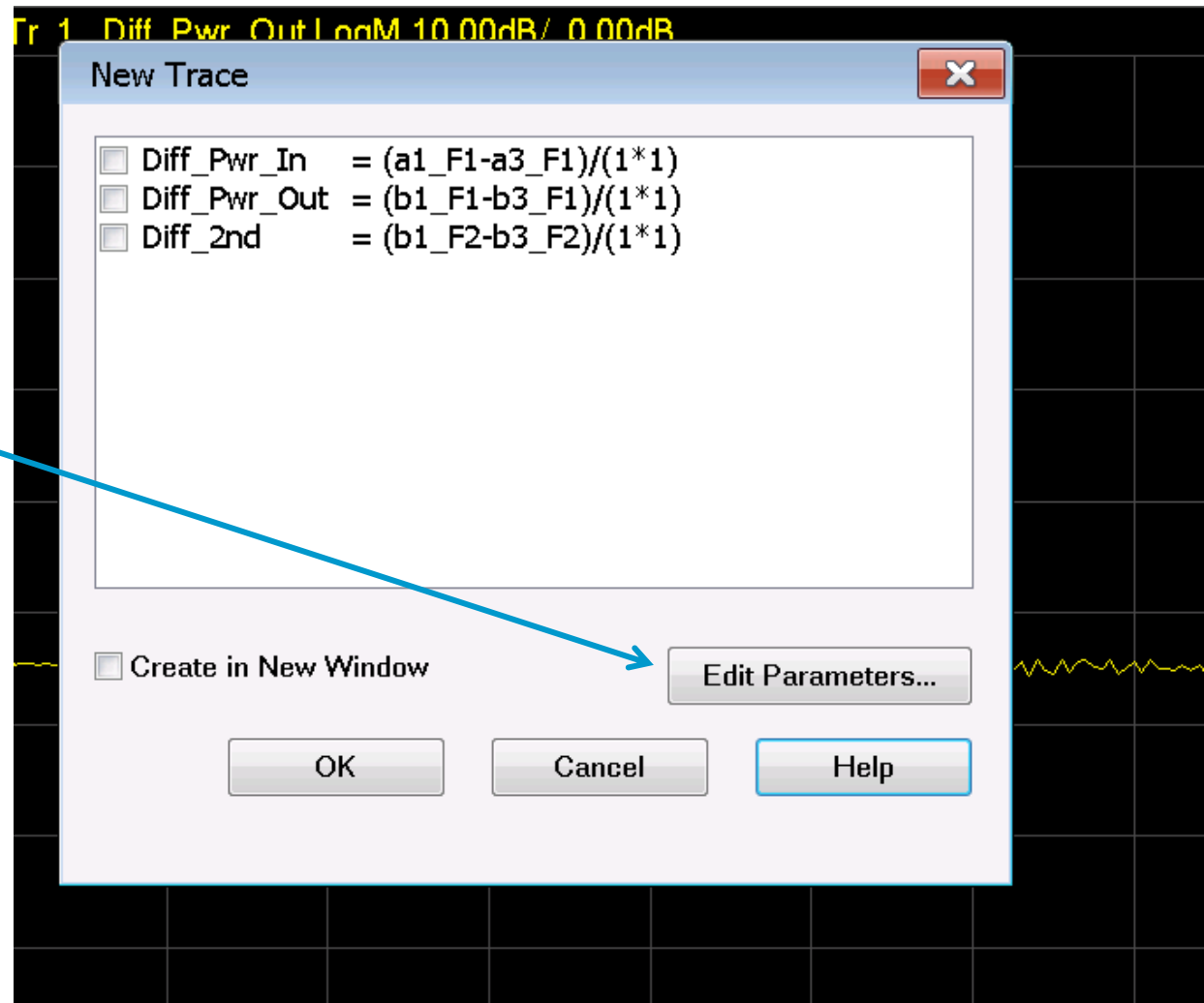
OK Cancel Apply Help

Set which sources are going to be used during the measurement

Set the Power and Phase

Finally, Define the Parameters to Measure based on receivers

Use
“Edit Parameters”
To create new
measurements



Create New Parameters based on measurements of ANY receiver at ANY frequency

Trace/Chan Response Marker/Analysis Stimulus Utility Help

Tr 1 Diff

Edit Parameters

Parameters

- Diff_Pwr_In
- Diff_Pwr_Out
- Diff_2nd
- Diff_3rd_dBc**

Properties

Parameter Name: Diff_3rd_dBc = (b1_F3-b3_F3)/(a1_F1-a3_F1)

Receiver Frequency

[b1 F3 - b3 F3]

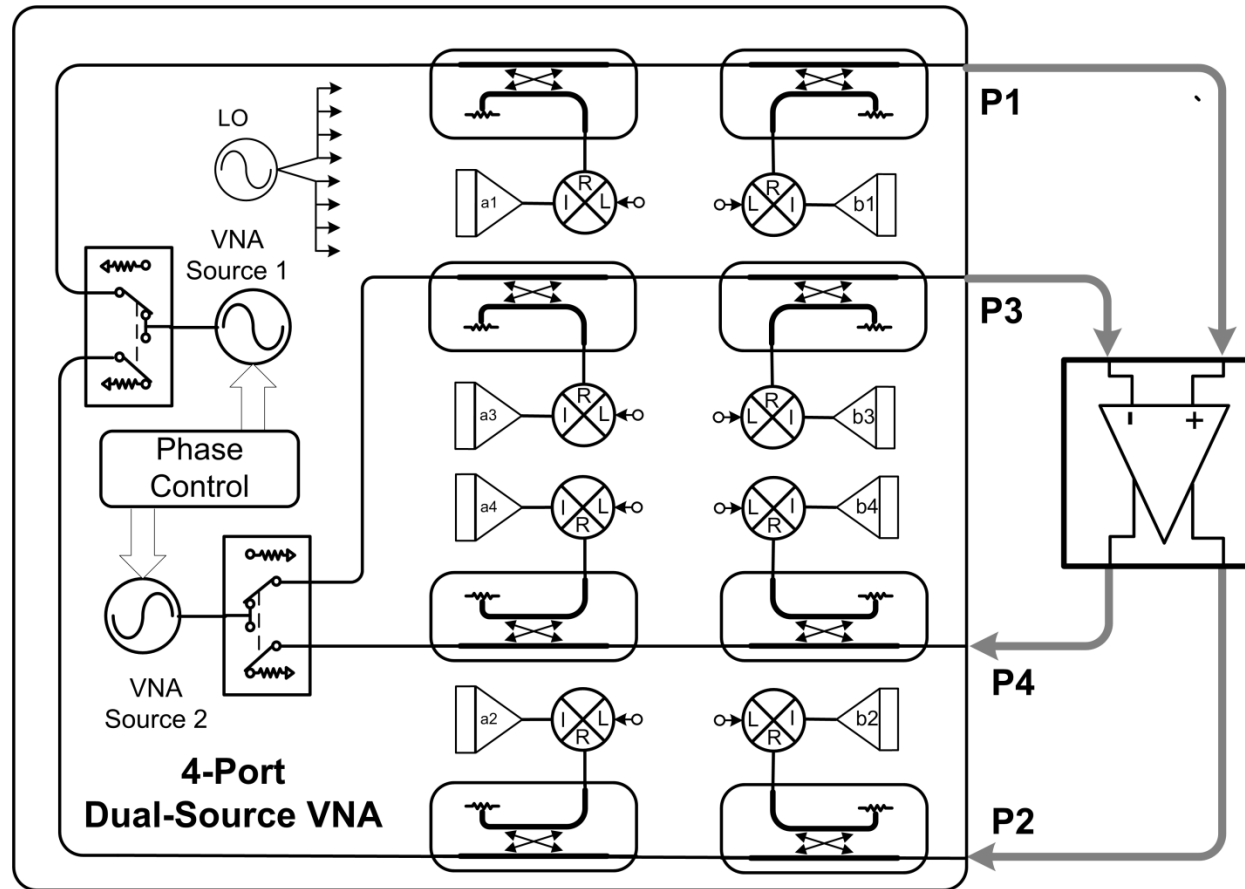
Receiver Frequency

[a1 F1 - a3 F1]

New Remove Save... Load...

OK Cancel Help

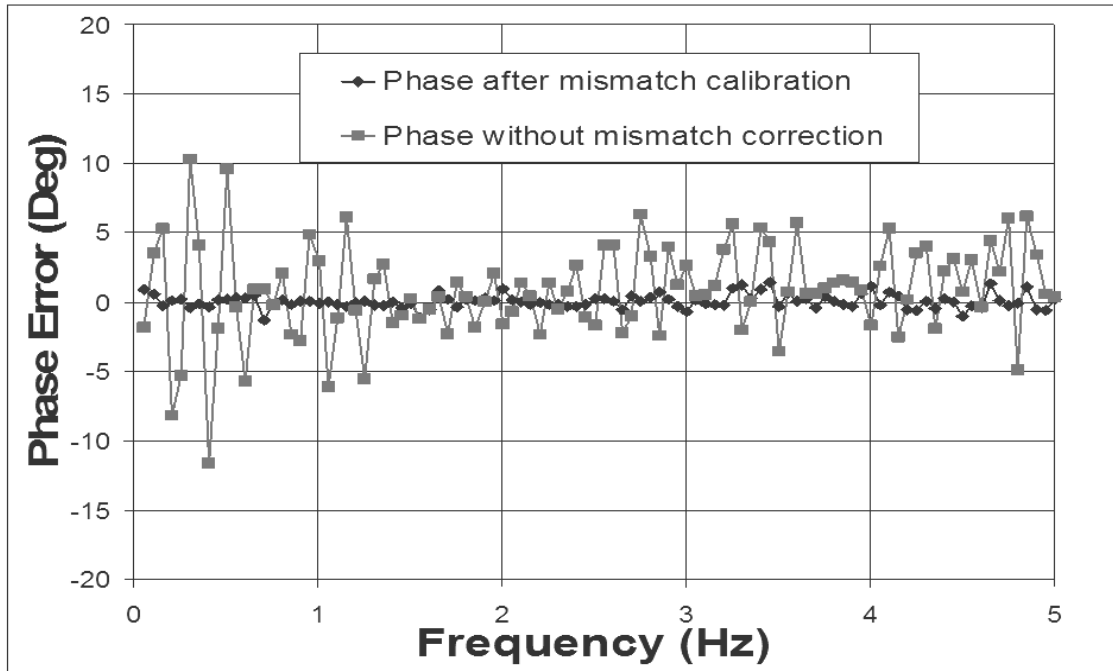
Making True-mode (true differential) measurements



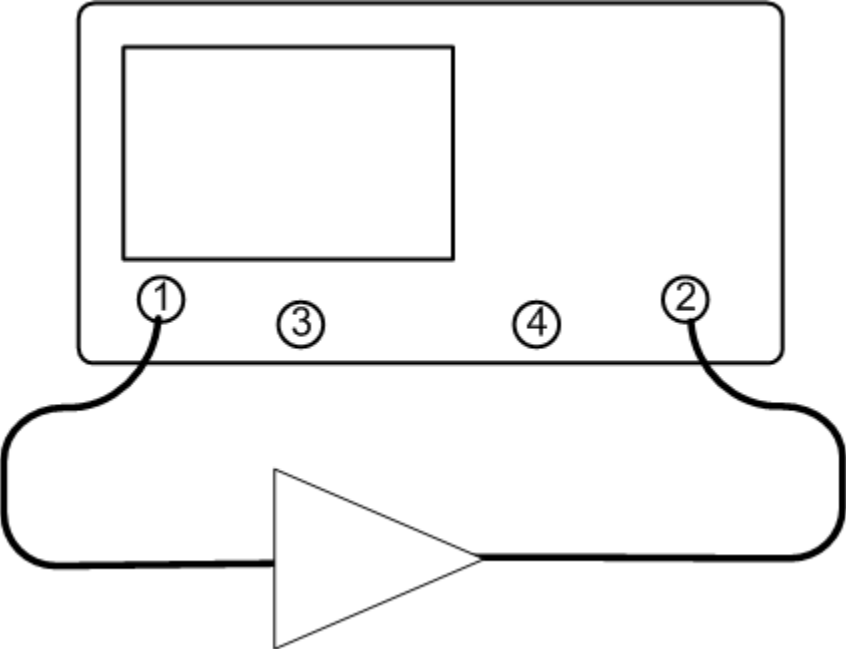
Two sources are controlled to set the differential input, and then the receivers are retuned to measure any other signal, such as output power or harmonics.

Differential signals must be actively adjusted for each new DUT S11 due to mismatch effects and requires special correction

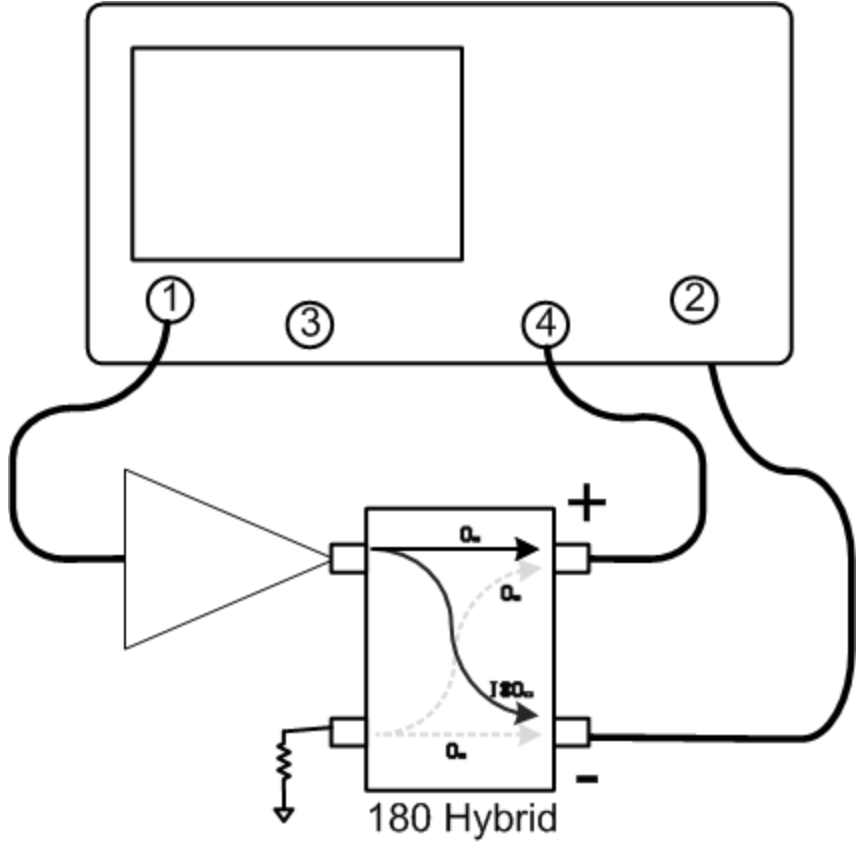
$$\frac{a_1}{a_3} = \frac{(a_{1M}ERF_1 + b_{1M}ESF_1 - a_{1M}ESF_1 \cdot EDF_1)}{(a_{3M}ERF_3 + b_{3M}ESF_3 - a_{3M}ESF_3 \cdot EDF_3)} \frac{ETF_{31}}{ERF_1}$$



To test differential harmonic measurements, measure a single-ended amp then add a balun and test again.



Test1: Harmonics of an SE amp



Test2: Measure Harmonics using Differential Receivers

Example Measurement: Differential Output and Harmonics



Upper Compares 2nd Harmonic Result; Lower Compares 3rd Harmonic Result.
Difference maybe due to hybrid effects (different loss at fundamental and harmonic

Calibration for Differential Output Power:

- Calibration for mismatch and response must use stimulus source for characterizing error terms
- During the measurement, output power mismatch terms (S_{22}) need to be characterized with the input source off
- Match correction can be independently selected for any source, using any receivers, and any frequency range
 - User defined receivers allows match correction on a variety of complex situations such as sources passed through high-power amplifiers and using external couplers; and external sources applied through the test set.

Source definition page includes match correction choices

Source Configuration: Port 1

Source State: Active

Frequency Range: F1

Power

Sweep Power

Start Power: -5 dBm

Stop Power: -5 dBm

Leveling Mode: Internal

Source Attenuator: 0 dB

Auto range source attenuator

Power and Attenuators...

Phase

Phase State: Off

Refer To: Port 3

Sweep Phase

Start Phase: 0.000 °

Stop Phase: 0.000 °

Control Receiver: a1

Phase Control Setup...

Match Correction

Match Correction On

Test Receiver: b1

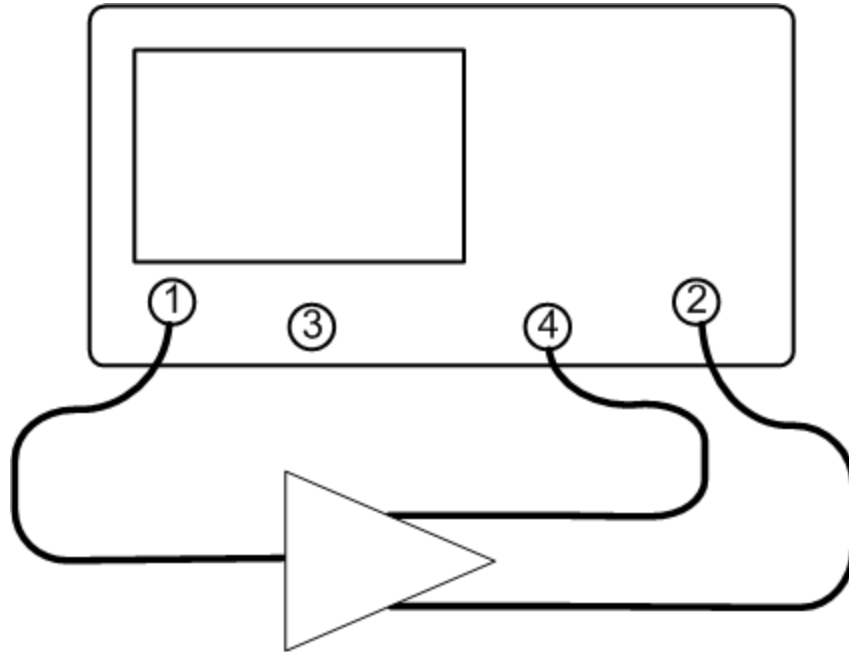
Reference Receiver: a1

Match Frequency Range: F1

Select Freq. Range...

OK Cancel Help

Planned: Use Case 2 : Measuring Harmonics of SE- Balanced Amplifiers



Test Requirements:

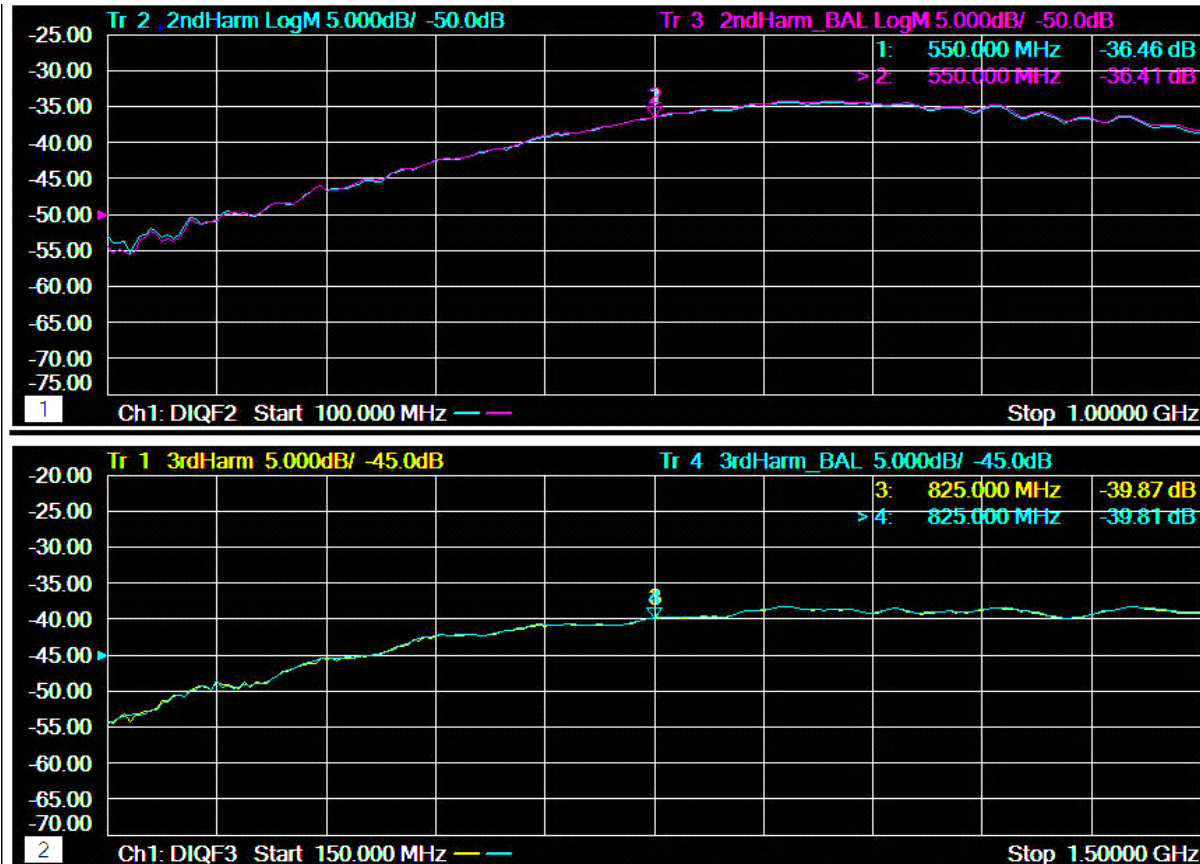
- Stimulate the input with leveled input signal
- Measure the input power
- Measure the output differential power
- Measure the output differential power at N harmonics, N a small integer (5)
- Provide corrected measurements of power, provide leveled input power
- Measure with swept frequency, swept power or swept phase input
- Function in pulsed mode

Wants:

- Provide leveled output power

Notes: In this case there is NO phase controlled source, just offset harmonics and balanced power

Example Measurement: Single-ended and Differential Mixer, with Harmonics

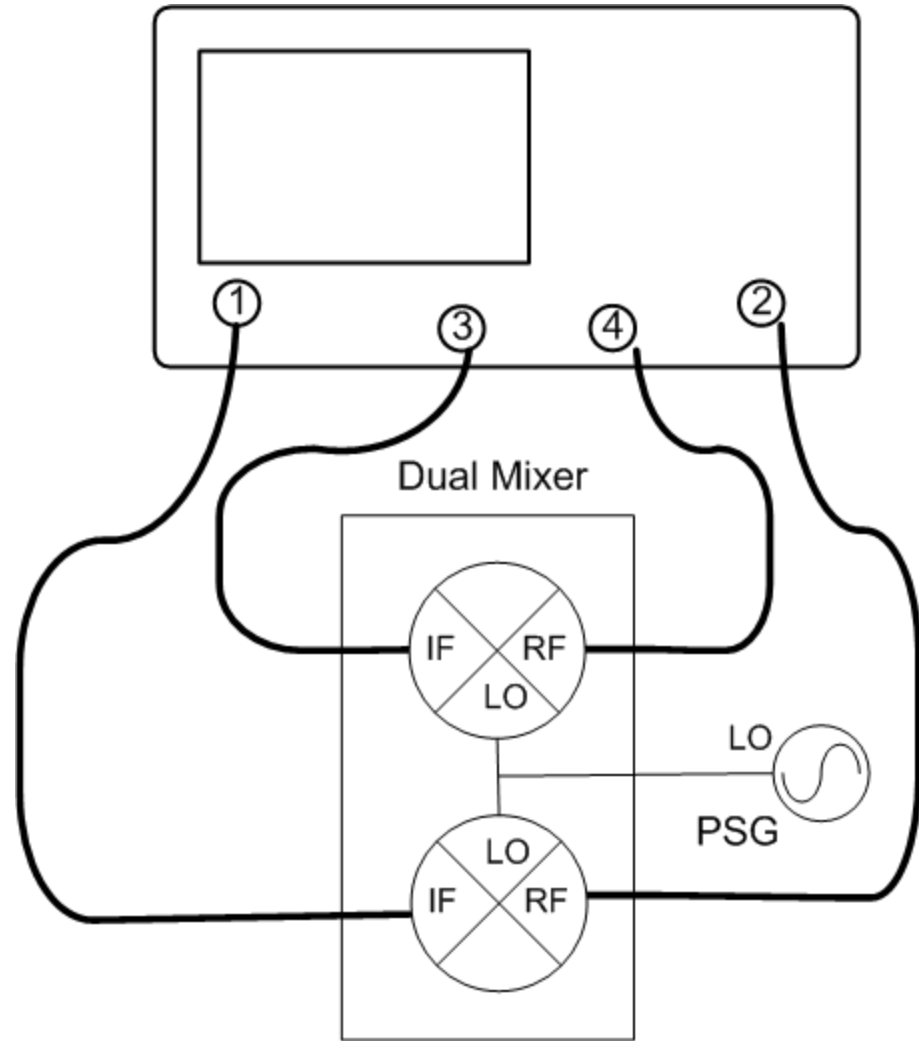


Harmonics are in dBc Values

Use Case: Dual Mixer;

Key measurement difficulty is relative phase response between the two paths of the mixer.

Drive both mixers with identical signals, measure the relative output (magnitude and phase)



Dual Mixer: Creating the Frequency Plan - start

Differential I/Q Setup : Channel 1

Measurement Set Up

Frequency Range

Range Name	Settings
F1	0.5000000000 GHz - 3.0000000000 GHz

New Remove

Sources

Source Name	State	Frequency	Power	Phase
Port 1	Active	F1	-5.00dBm	N/A
Port 2	Off	F1	-5.00dBm	N/A
Port 3	Off	F1	-5.00dBm	N/A
Port 4	Off	F1	-5.00dBm	N/A
Port 1 Src2	Off	F1	-5.00dBm	N/A

Add Source...

OK Cancel Apply Help

Dual Mixer: Creating the Frequency Plan – set the input frequencies

The screenshot displays the 'Differential I/Q Setup : Channel 1' window. On the left, a plot shows a signal trace 'Tr 1' with a vertical axis from -10.00 to 10.00. The main window is divided into 'Measurement Set Up' and 'Sources' sections.

Measurement Set Up

Frequency Range

Range Name	Settings
F1	0.5000000000 GHz - 3.0000000000 GHz

Buttons: New, Remove

Sources

Source Name	State	Frequency
Port 1	Active	F1
Port 2	Off	F1
Port 3	Off	F1
Port 4	Off	F1
Port 1 Src2	Off	F1

Button: Add Source...

F2 Range Settings dialog box:

Frequency

Start/Stop: Start: 500.000000 MHz, Stop: 1.000000000 GHz, IFBW: 1.000 kHz

Coupling

Couple to: F1

Offset: No Offset (checked Up)

Multiplier: 1

Divisor: 1

Output = Frequency * Multiplier / Divisor + Offset

Buttons: OK, Cancel

Dual Mixer: Creating the Frequency Plan – add the LO, fixed 10 GHz

Differential I/Q Setup : Channel 1

Measurement Set Up

Frequency Range

Range Name	Settings
F1	0.5000000000 GHz - 1.0000000000 GHz
F2	0.5000000000 GHz - 1.0000000000 GHz

New Remove Edit

Sources

Source Name	State	Frequ
Port 1	Active	F1
Port 2	Off	F1
Port 3	Off	F1
Port 4	Off	F1
Port 1 Src2	Off	F1

Add Source...

OK

F2 Range Settings

Frequency

Start/Stop

Start: 10.000000000 GHz

Stop: 10.000000000 GHz

IFBW: 1.000 kHz

Coupling

Couple to: F1

Offset: No Offset Up

Multiplier: 1

Divisor: 1

Output = Frequency*Multiplier/Divisor + Offset

OK Cancel

Dual Mixer: Creating the Frequency Plan – Add the output receiver frequencies

The screenshot displays the 'Differential I/Q Setup : Channel 1' dialog box. It is divided into two main sections: 'Frequency Range' and 'Sources'. The 'Frequency Range' section contains a table with three entries: F1, F2, and F3. The 'Sources' section contains a table with five entries: Port 1, Port 2, Port 3, Port 4, and Port 1 Src2. A sub-dialog box titled 'F2 Range Settings' is open, showing configuration options for the F2 range, including Start, Stop, IFBW, Coupling, Offset, Multiplier, and Divisor. The background shows a plot of Tr 1 and Ch1.

Frequency Range Table:

Range Name	Settings
F1	0.5000000000 GHz
F2	CW Freq 10.0000 GHz
F3	0.5000000000 GHz

Sources Table:

Source Name	State	Freq
Port 1	Active	
Port 2	Off	
Port 3	Off	
Port 4	Off	
Port 1 Src2	Off	

F2 Range Settings:

Frequency: Start/Stop

Start: 500.000000 MHz

Stop: 1.00000000 GHz

IFBW: 1.000 kHz

Coupling: Couple to F1

Offset: F2 Up

Multiplier: 1

Divisor: 1

Output = Frequency * Multiplier / Divisor + Offset

Dual Mixer: Creating the Frequency Plan – Final frequency Plan

Differential I/Q Setup : Channel 1

Measurement Set Up

Frequency Range

Range Name	Settings
F1	0.5000000000 GHz - 1.0000000000 GHz
F2	CW Freq 10.0000000000 GHz
F3	10.5000000000 GHz - 11.0000000000 GHz

New Remove Edit

Sources

Source Name	State	Frequency	Power	Phase
Port 1	Active	F1	-5.00dBm	N/A
Port 2	Off	F1	-5.00dBm	N/A
Port 3	Off	F1	-5.00dBm	N/A
Port 4	Off	F1	-5.00dBm	N/A
Port 1 Src2	Off	F1	-5.00dBm	N/A

Add Source...

OK Cancel Apply Help

Dual Mixer: Setup the sources, start with port 1

Differential I/Q Setup : Channel 1

Measurement Set Up

Frequency Range

Range Name	Settings
F1	0.5000000000
F2	CW Freq 10.00
F3	10.5000000000

New Remove

Sources

Source Name	State	Freq
Port 1	Active	
Port 2	Off	
Port 3	Off	
Port 4	Off	
Port 1 Src2	Off	

Add Source...

Source Configuration: Port 1

Source State: Active

Frequency Range: F1

Power

Sweep Power

Start Power: -20 dBm

Stop Power: -20 dBm

Leveling Mode: Internal

Source Attenuator: 0 dB

Auto range source attenuator

Power and Attenuators...

Phase

Phase State: Off

Start Phase: Open Loop - I

Stop Phase: 0.000 °

Control Receiver: a1

Refer To: Port 3

Phase Control Setup...

Match Correction

Match Correction On

Test Receiver: b1

Reference Receiver: a1

Match Frequency Range: F1

Select Freq. Range...

OK Cancel Help

OK Cancel Apply Help

3.00000 GHz

Differential IQ Setup...

Dual Mixer: Setup the sources, add port 3, and make it match P1 phase.

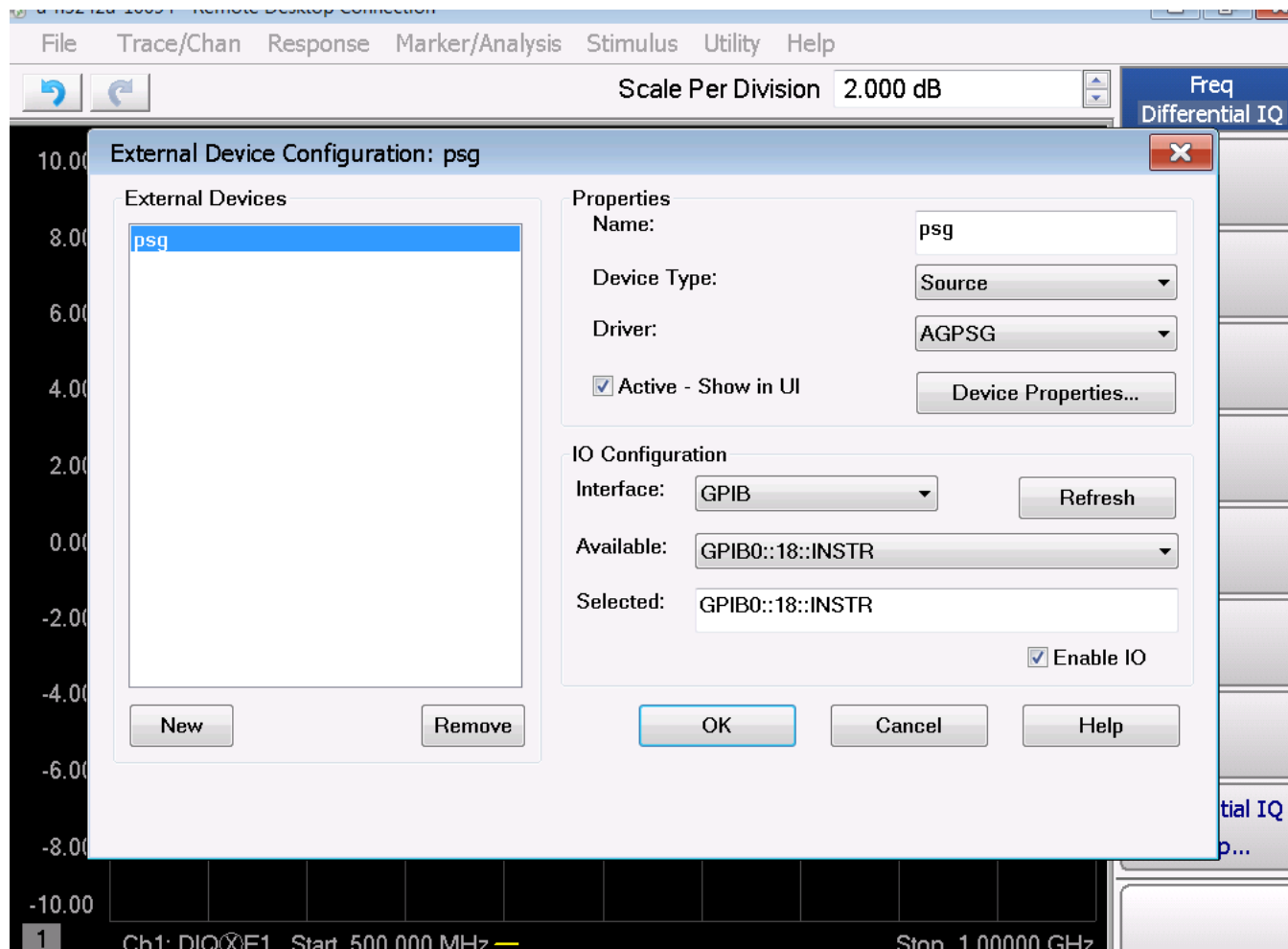
The screenshot displays two overlapping dialog boxes in a software interface. The background window is titled "Differential I/Q Setup : Channel 1" and shows a "Measurement Set Up" section with a "Frequency" table containing "Range", "F1", "F2", and "F3". A "Sources" section on the left lists "Port 1". A plot on the right shows a value of "-5.0834 dB".

The foreground dialog box is titled "Source Configuration: Port 3". It contains the following settings:

- Source State: Active
- Frequency Range: F1
- Power: Sweep Power (unchecked), Start Power: -5 dBm, Stop Power: -5 dBm, Leveling Mode: Internal, Source Attenuator: 0 dB, Auto range source attenuator (checked).
- Phase: Phase State: Off, Refer To: Port 1, Start Phase: 0.000°, Stop Phase: 0.000°.

A second dialog box, "Phase Control Setup: Channel 1", is open in front of the first. It has a list of ports on the left with "Port 1" selected. The "Referenced to" dropdown is set to "Port 3", and the "Control Parameter" is set to "a3 / a1". Under "Background Sweep Properties", "Apply Settings to All Ports" is checked, "Use Leveling IFBW" is unchecked, "Tolerance" is 1.000°, and "Max Iterations" is 5. Buttons for "OK", "Cancel", and "Help" are at the bottom.

Dual Mixer: Setup the sources, add the PSG



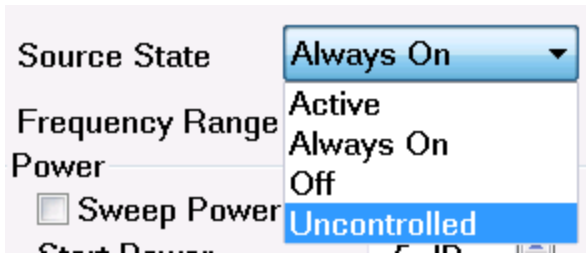
Dual Mixer: Setup the sources, add the PSG

The screenshot displays the 'Source Configuration: psg' dialog box within a software interface. The dialog is titled 'Source Configuration: psg' and contains the following settings:

- Source State:** Always On
- Frequency Range:** F2
- Power:**
 - Sweep Power
 - Start Power: -5 dBm
 - Stop Power: -5 dBm
 - Leveling Mode: Internal
 - Source Attenuator: 0 dB
 - Auto range source attenuator
- Phase:**
 - Phase State: Off
 - Start Phase: 0.000 °
 - Stop Phase: 0.000 °
 - Control Receiver: a2
 - Refer To: Port 1
- Match Correction:**
 - Match Correction On
 - Test Receiver: b1
 - Reference Receiver: a1
 - Match Frequency Range: F1

Buttons for 'Power and Attenuators...', 'Phase Control Setup...', and 'Select Freq. Range...' are visible. The background shows a 'Differential I/Q Setup : Channel 1' window with a 'Sources' list containing 'Port 1', 'Port 2', 'Port 3', 'Port 4', 'Port 1 Src', and 'psg'. A graph on the left shows a trace labeled 'Tr 1' with a peak at 0.00 and a trough at -6.00.

Let's try to understand Source State: It's flexible but maybe a little confusing



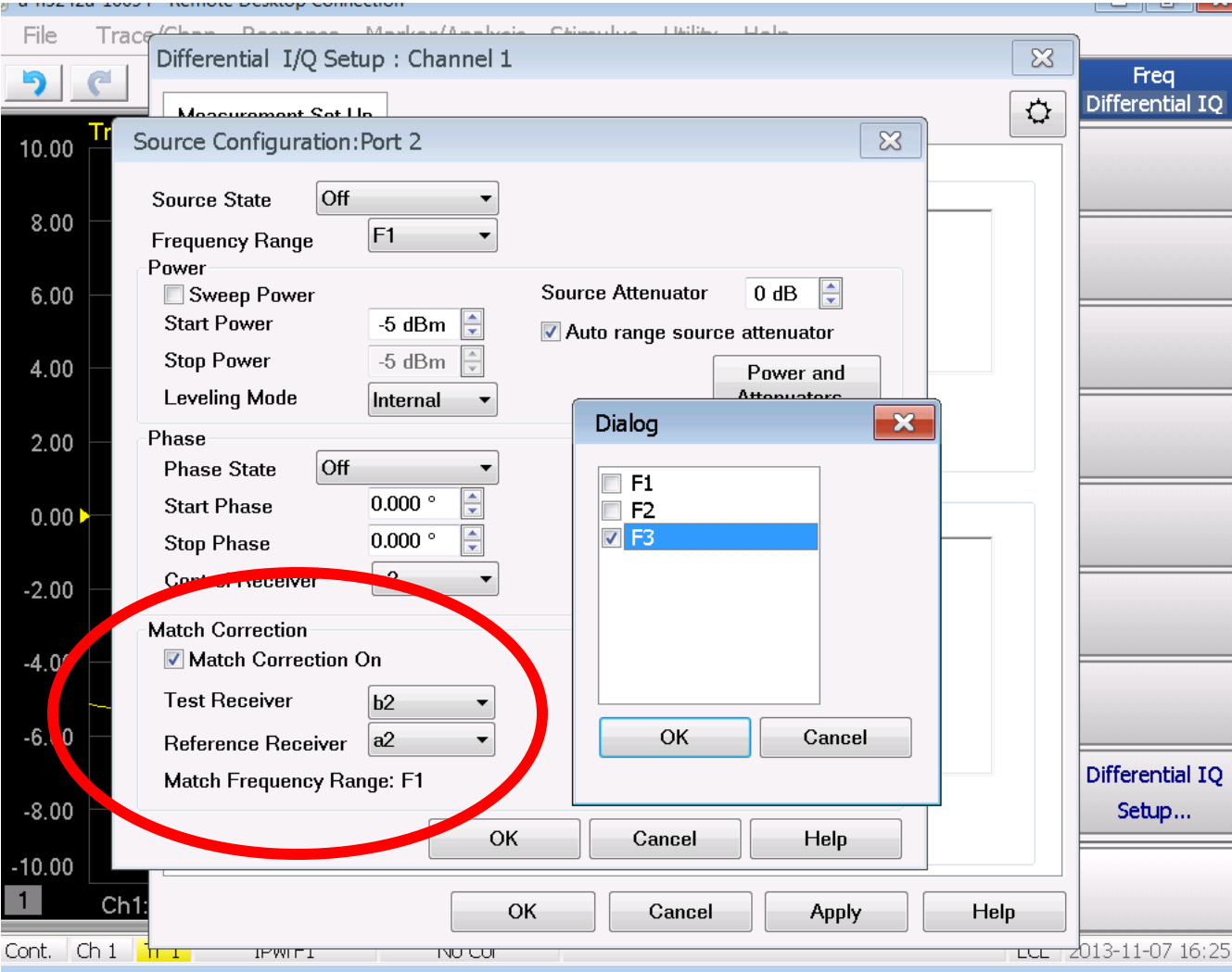
Always On: Always On

Active: turn on during measurement sweep

Uncontrolled: don't write to the source at all.

Off: Sometimes OFF unless the source is needed for match correction on that port.

We need match correction for the RF output of the dual mixer



Dual Mixer: setup the mixer Parameters (relative phase input and output, overall relative phase)

The screenshot displays the 'Edit Parameters' dialog box for a Dual Mixer in a software application. The dialog is titled 'Edit Parameters' and has a close button (X) in the top right corner. It is divided into two main sections: 'Parameters' and 'Properties'.

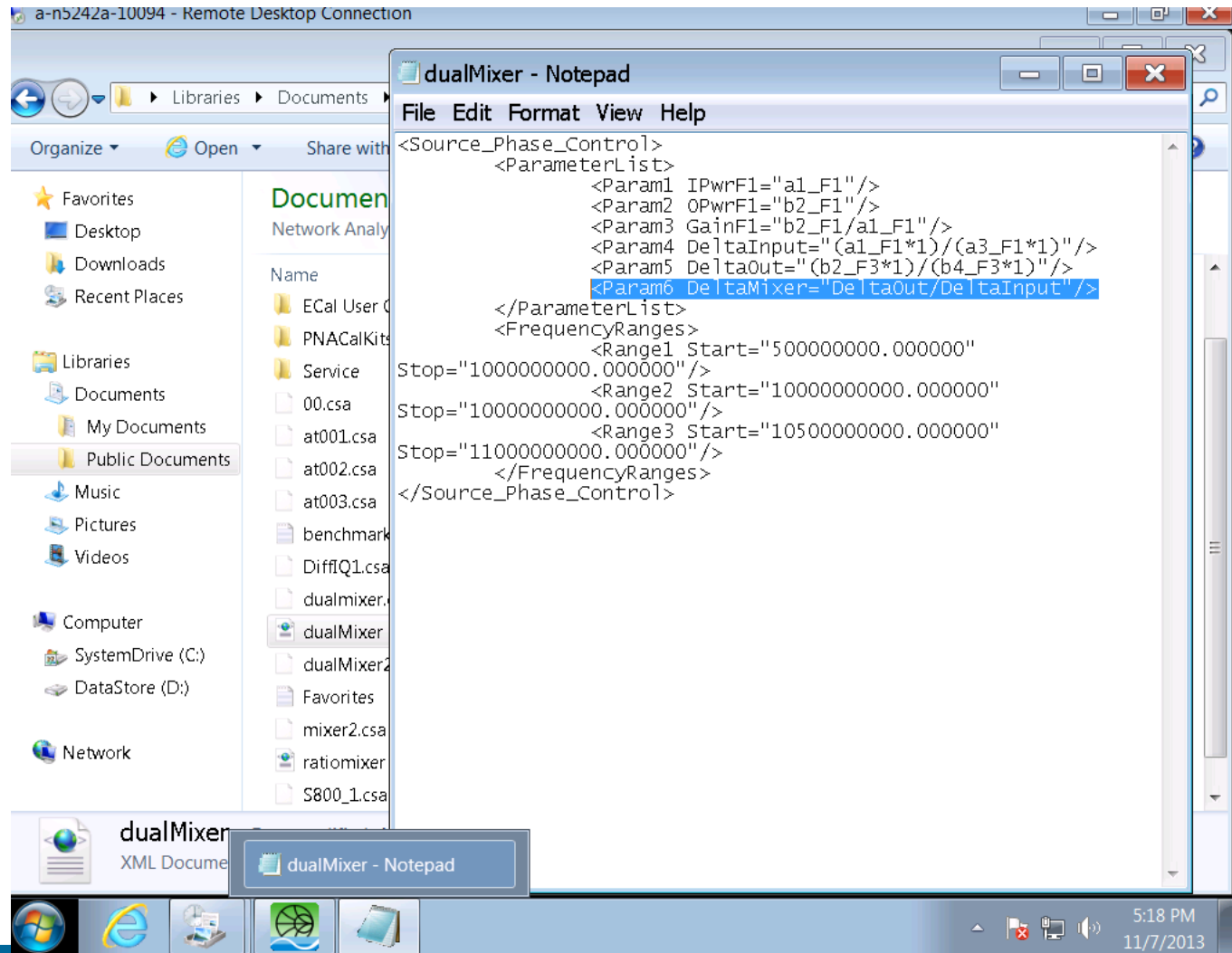
Parameters Section: A list of parameters is shown on the left, including IPwrF1, OPwrF1, GainF1, DeltaInput, DeltaOut, and Param1. 'Param1' is currently selected and highlighted in blue.

Properties Section: The 'Parameter Name' is set to 'Param1' with a value of '= a1_F1'. Below this, there are two rows of configuration options, each enclosed in square brackets. Each row contains a 'Receiver' dropdown (set to 'b2' and 'b4' respectively), a 'Frequency' dropdown (set to 'F3' for both), a multiplier dropdown (set to '*'), and another 'Receiver' dropdown (set to '1' for both). The first row also includes a 'Frequency' dropdown (set to 'F1').

Buttons: At the bottom of the dialog are buttons for 'New', 'Remove', 'Save...', 'Load...', 'OK', 'Cancel', and 'Help'.

Background Interface: The background shows a plot with a vertical axis ranging from -10.00 to 10.00 and a horizontal axis from 500.000 MHz to 1.00000 GHz. A yellow trace is visible. A 'Scale Per Division' of 2.000 dB is indicated. A 'Freq Differential IQ' panel is visible on the right side of the interface.

Dual Mixer: Parameter List uses equation editor, so you can 'hack' the xml file to create any parameter



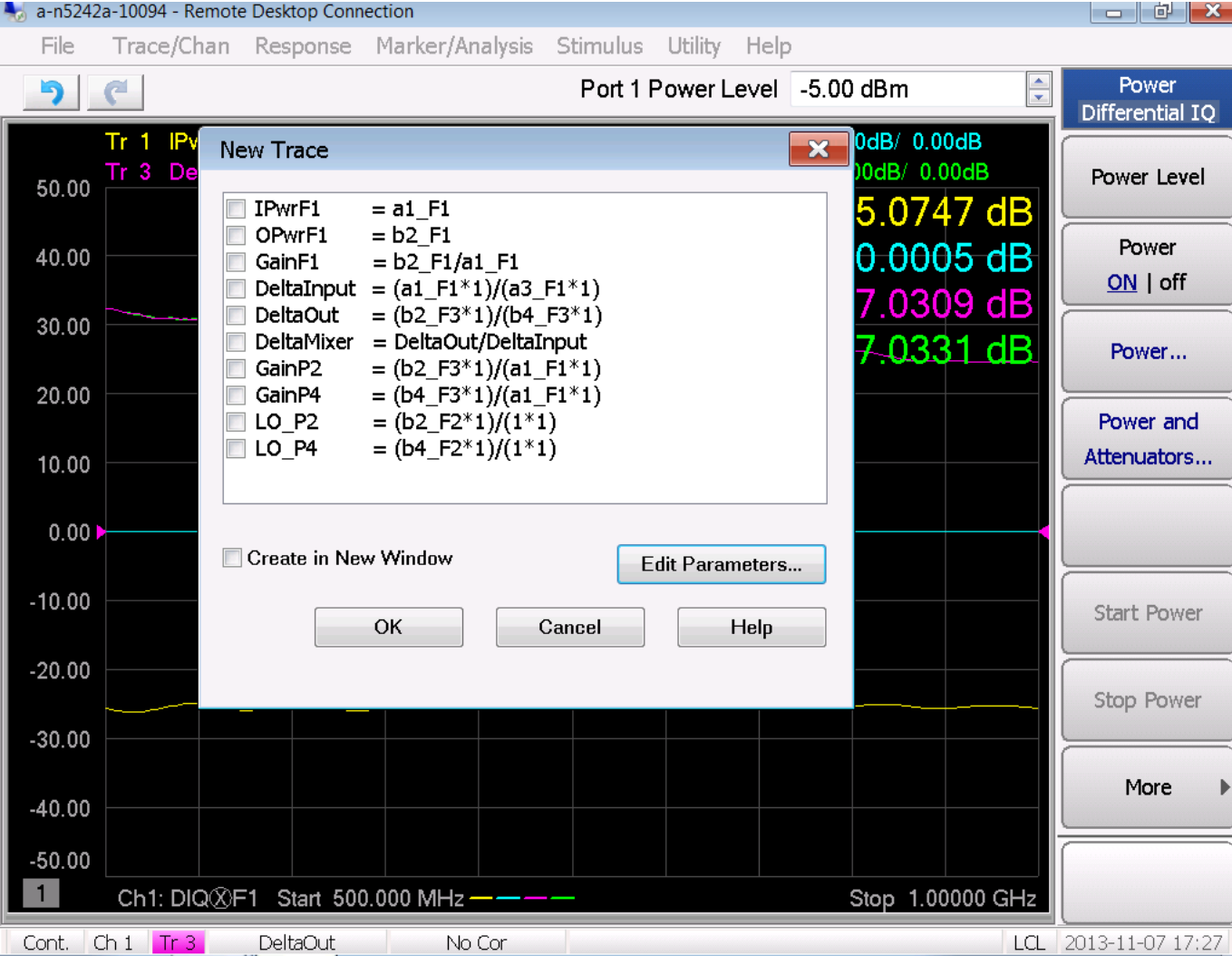
Dual Mixer: Now the new parameter shows up.

The screenshot displays a software interface for a Dual Mixer. The main window shows a plot with a vertical axis ranging from -10.00 to 10.00 and a horizontal axis from 500.000 MHz to 1.00000 GHz. A data point is highlighted at 5.1286 dB. The 'Edit Parameters' dialog box is open, showing the following details:

- Parameters List:** IPwrF1, OPwrF1, GainF1, DeltaInput, DeltaOut, DeltaMixer (selected).
- Properties:** Parameter Name: DeltaMixer = DeltaOut/DeltaInput
- Receiver Frequency:** Two rows of settings, each with a Receiver dropdown (set to 1) and a Frequency dropdown (set to F1), separated by a multiplication sign (*).
- Buttons:** New, Remove, Save..., Load..., OK, Cancel, Help.

The background plot shows a grid with a blue arrow pointing to the 5.1286 dB value on the right side. The status bar at the bottom indicates 'Ch1: DIQ⊗F1 Start 500.000 MHz Stop 1.00000 GHz'.

Dual Mixer: Let's also add gain P2 and gain Port 4, and while were at it, LO leakage to each port.



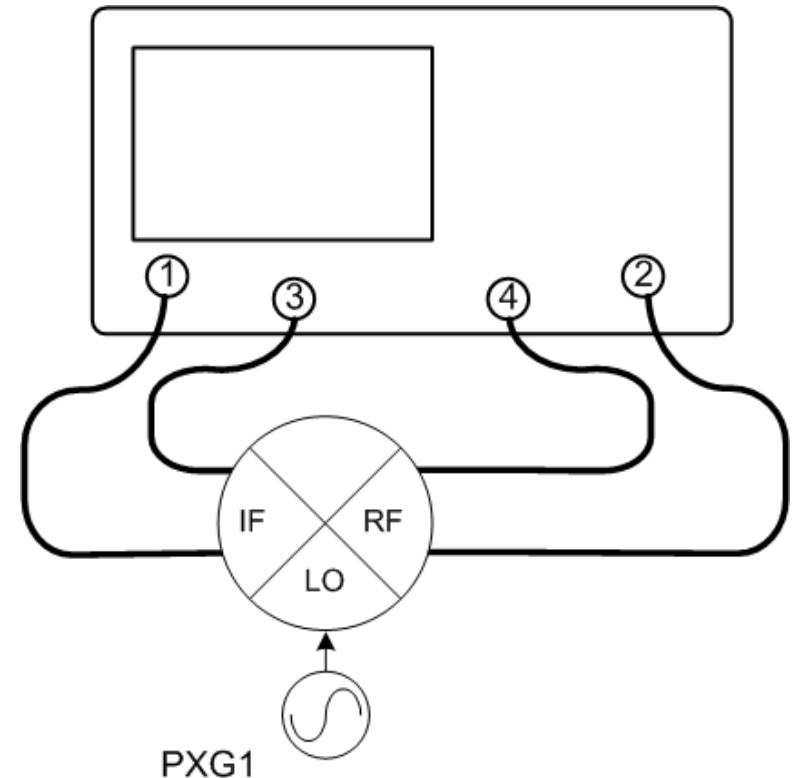
Use Case 4 – Balanced Mixer

Test Requirements:

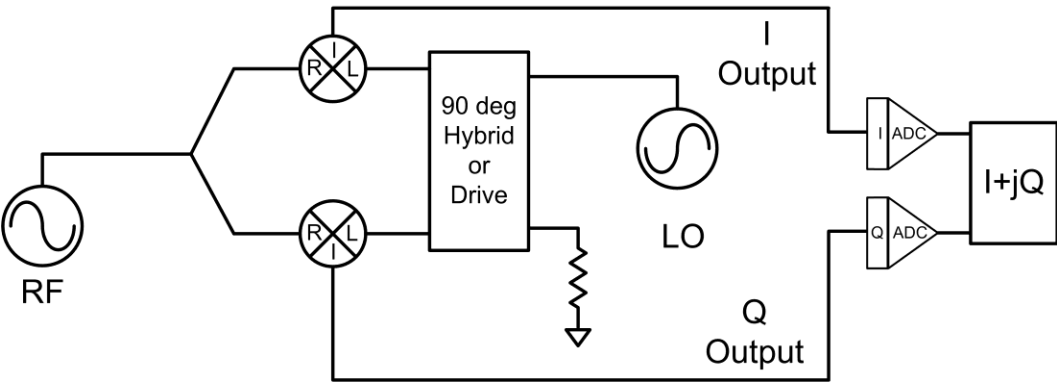
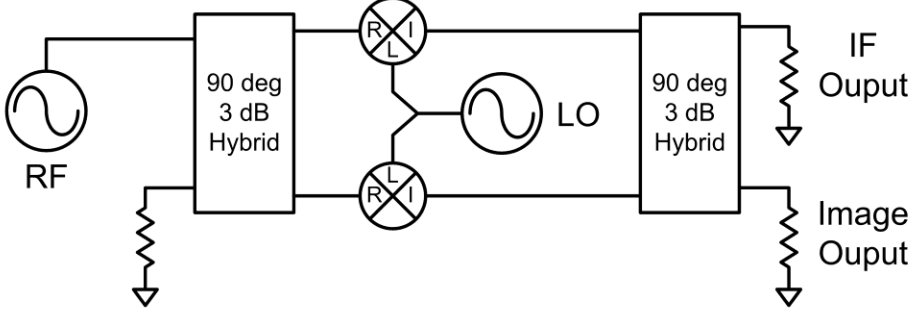
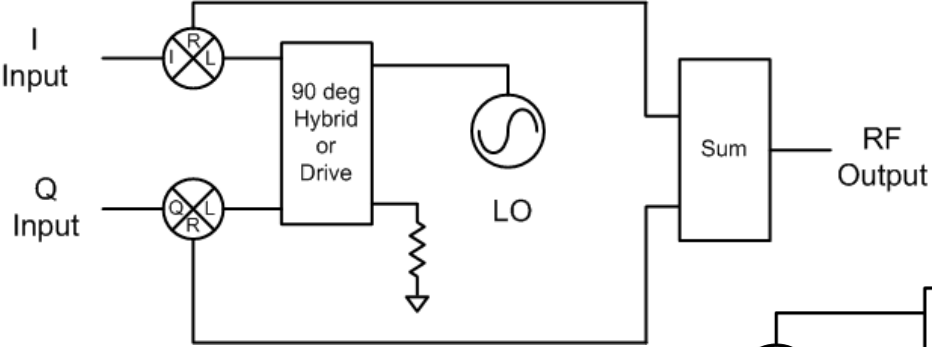
- Stimulate the input with balanced signal
- Measure the input differential power
- Measure the output differential power
- Measure output at both LO+Input (main signal) and LO-Input (Image signal)
 - As a function of frequency
 - As a function of input phase
- LO may be embedded.
- Provide match corrected measurements of power, provide leveled input power.

Wants

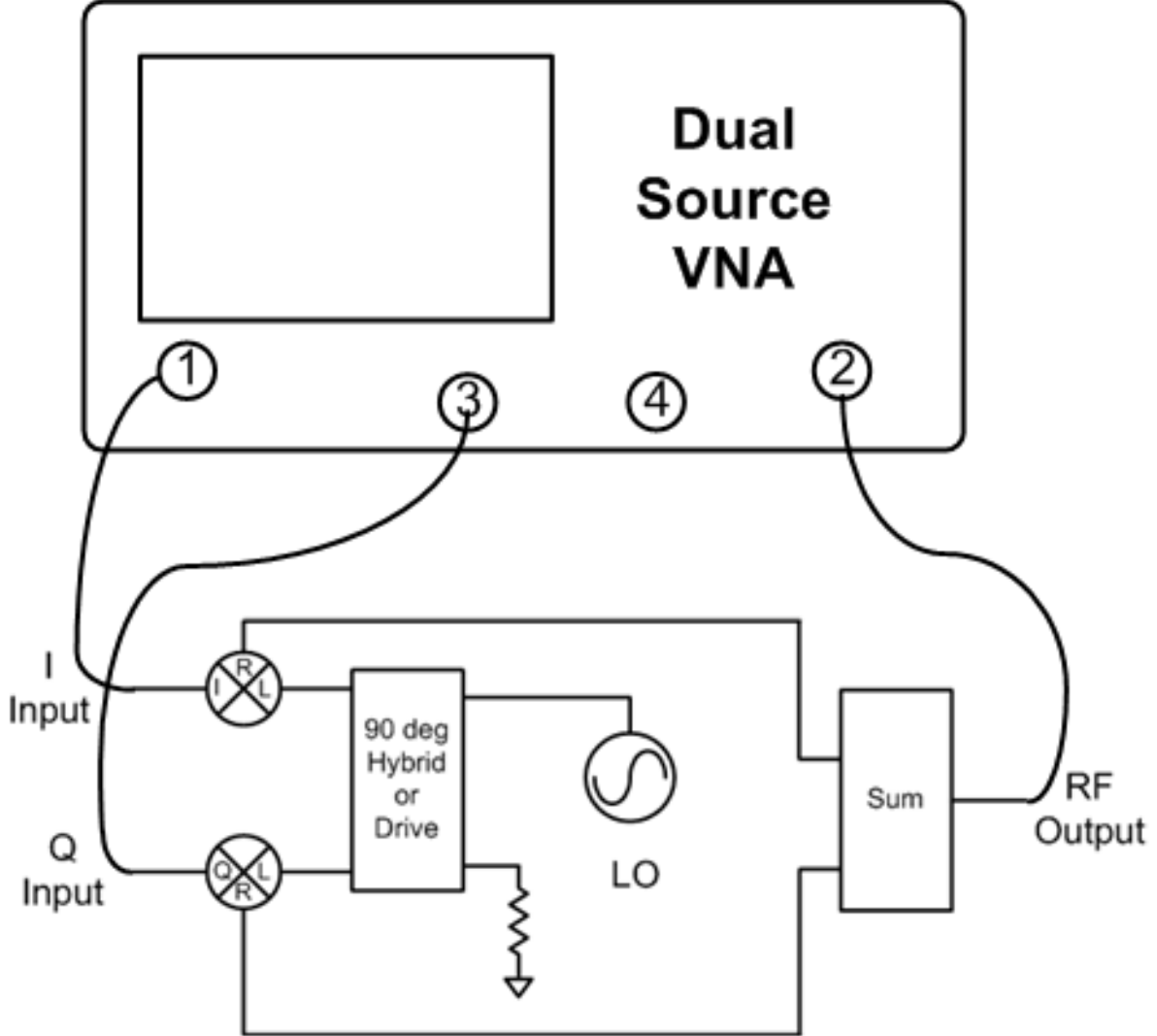
- Measure higher order products of $m \cdot \text{LO} + n \cdot \text{Input}$



IQ Mixers and Modulators and Down Converters



IQ Mixers and Modulators and Down Converters



Making IQ Mixer Measurements

- Special Characteristics of IQ mixer and modulators
 - Image Signal is suppressed
 - Output signal can be on either side of the LO, depending upon the phase of the Q signal
 - Provides direct modulation without the need for image filters
 - Key performance criteria:
 - LO Suppression
 - Image Suppression
 - Often requires determining LO, I and Q offsets for optimum performance
 - Very slow and difficult to determine over a wide frequency range.

IQ Mixer Mixer: Setup the sources, make the phase 90 degrees

The screenshot displays the 'Source Configuration: psg' dialog box within a software interface. The dialog is titled 'Source Configuration: psg' and contains the following settings:

- Source State:** Always On
- Frequency Range:** F2
- Power:**
 - Sweep Power
 - Start Power: -5 dBm
 - Stop Power: -5 dBm
 - Leveling Mode: Internal
 - Source Attenuator: 0 dB
 - Auto range source attenuator
- Phase:**
 - Phase State: Off
 - Start Phase: 0.000 °
 - Stop Phase: 0.000 °
 - Control Receiver: a2
 - Refer To: Port 1
- Match Correction:**
 - Match Correction On
 - Test Receiver: b1
 - Reference Receiver: a1
 - Match Frequency Range: F1

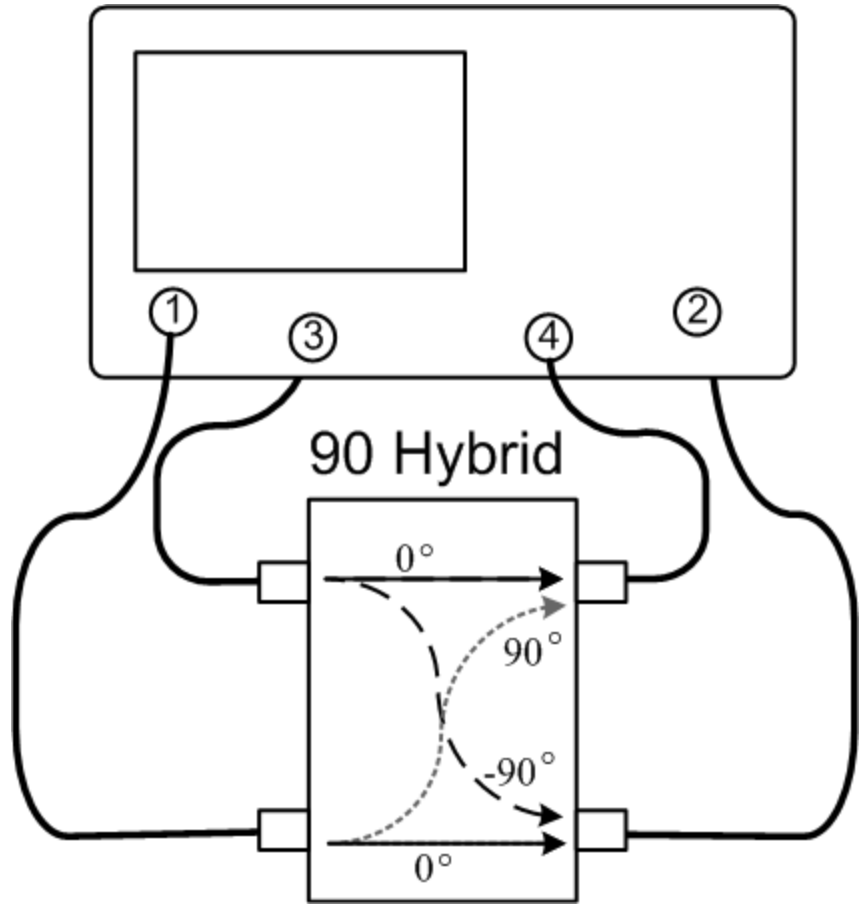
Buttons for 'Power and Attenuators...', 'Phase Control Setup...', 'Select Freq. Range...', 'OK', 'Cancel', and 'Help' are visible at the bottom of the dialog.

IQ mixer theory

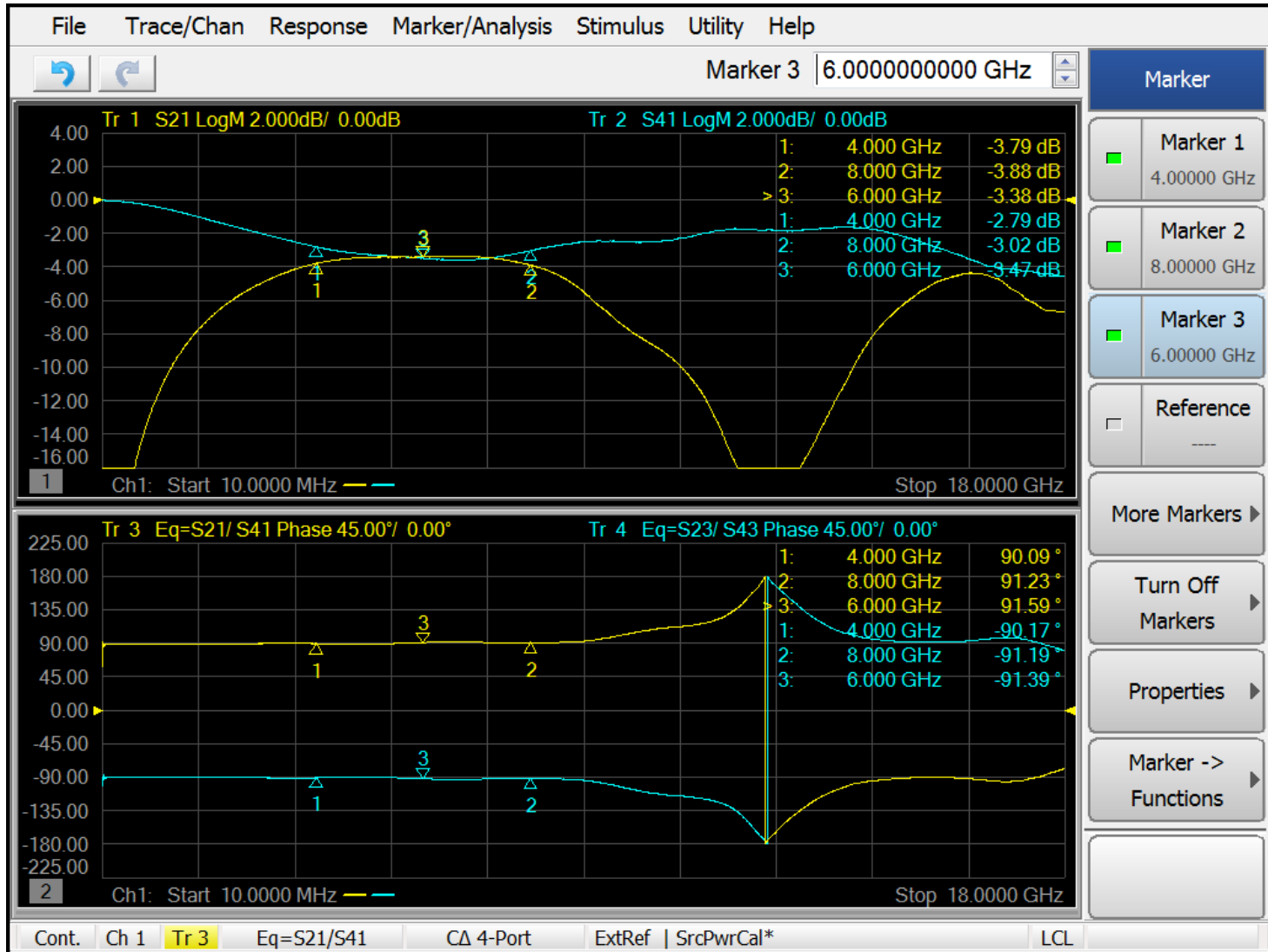
$$a_I = \frac{V_I^F}{\sqrt{Z_0}}, \quad a_Q = \frac{V_Q^F}{\sqrt{Z_0}}, \quad IQ_power = a_I + j \cdot a_Q$$

User defined parameters can make use of the equation editor to determine the overall input power

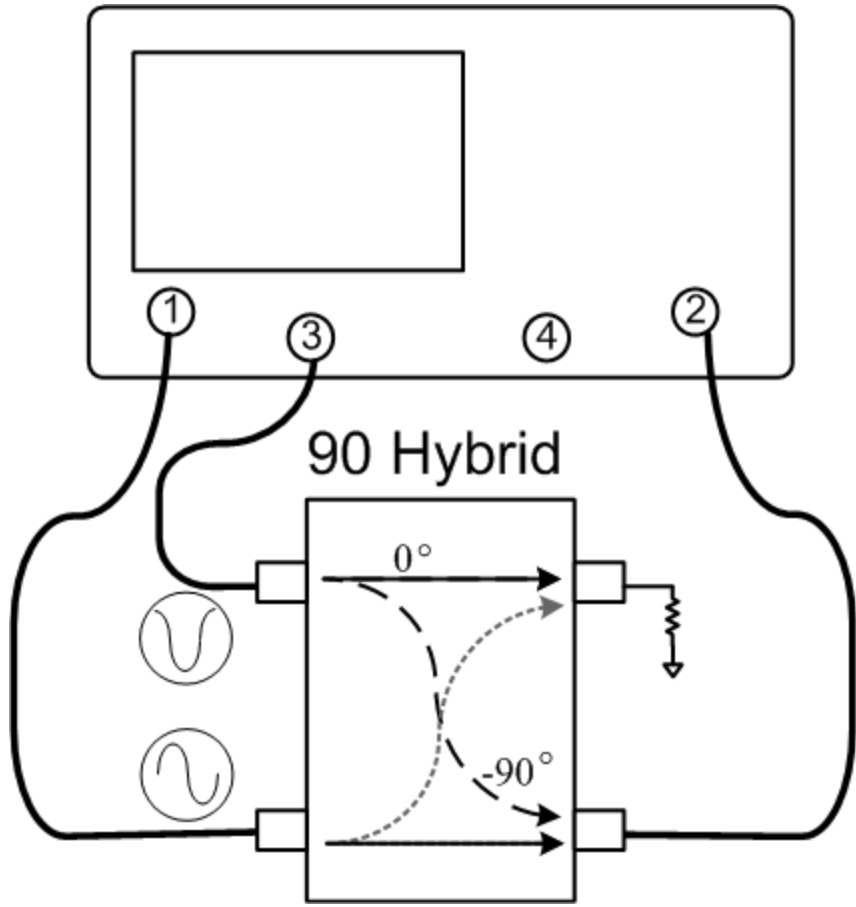
Lets look at a 90 degree Hybrid



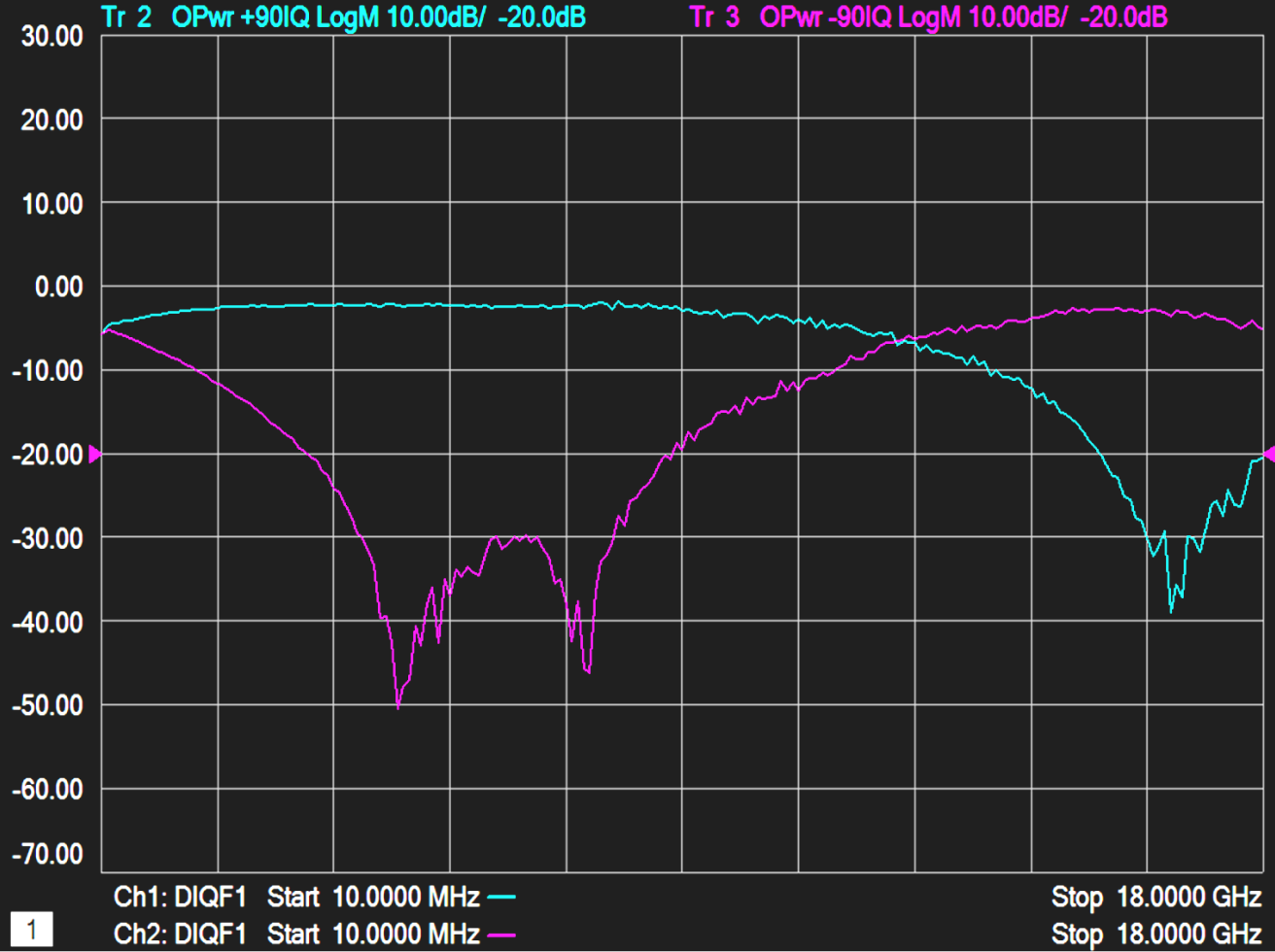
Lets look at a 90 degree Hybrid



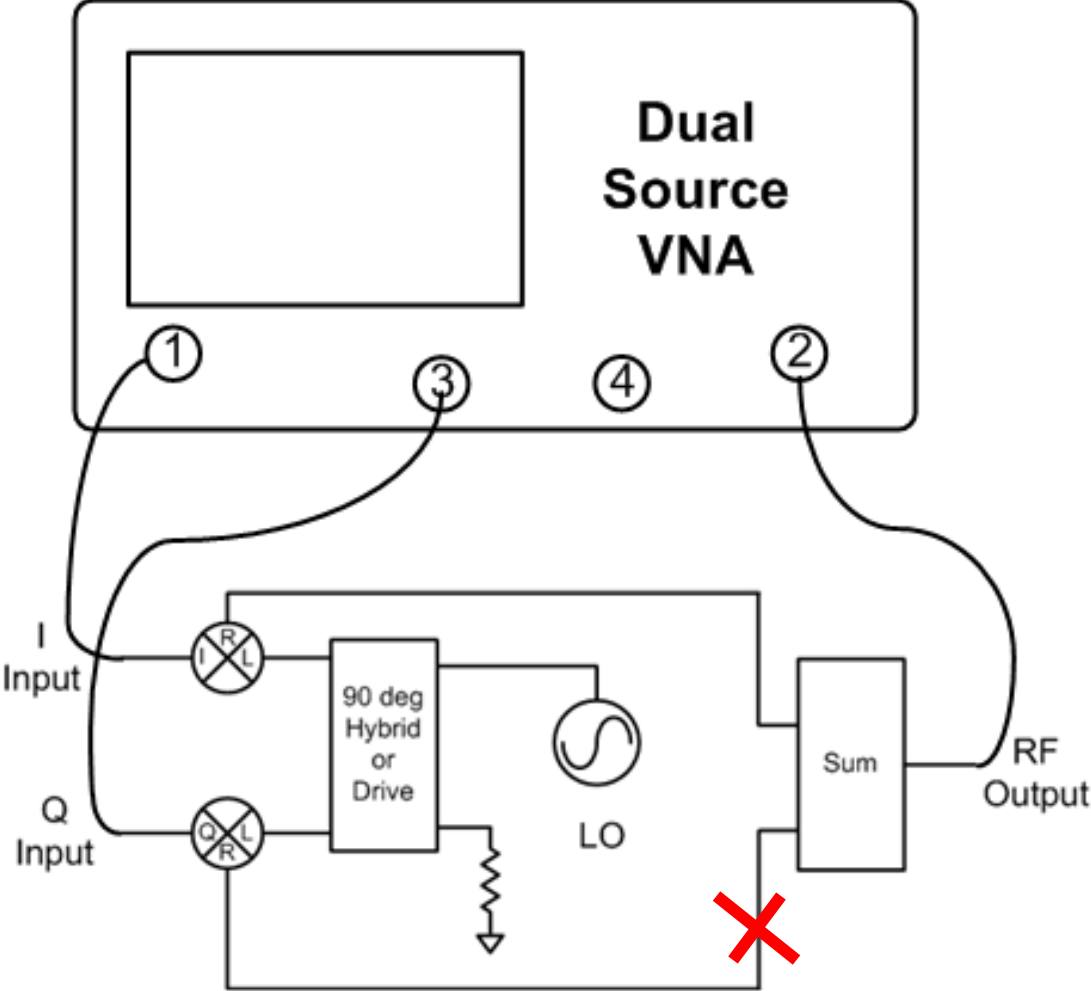
Now Measure it with 0 and 90 degree true-mode drive on the input ports, and sweep frequency



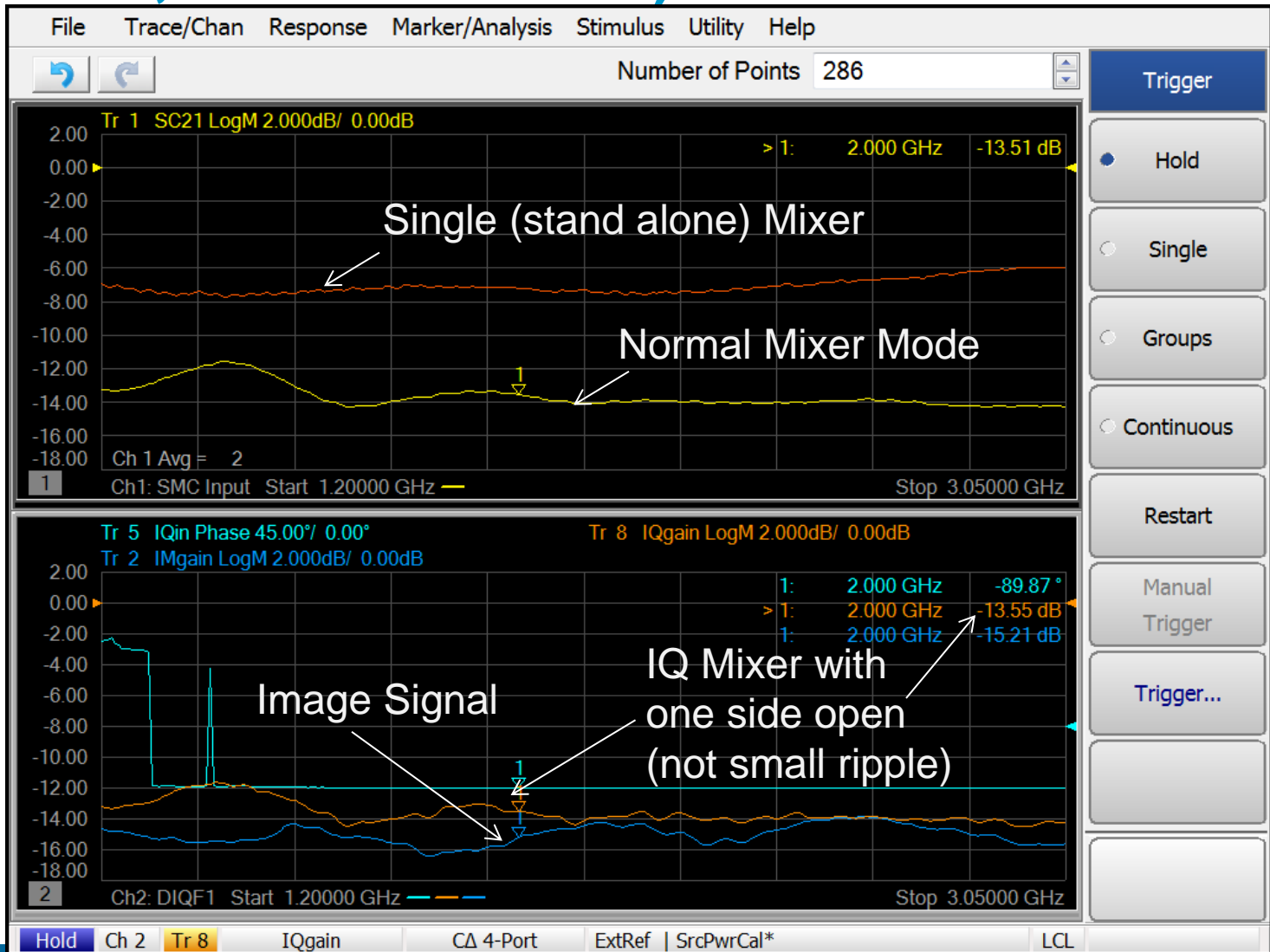
IQ Measurements: Output of Hybrid, across frequency. Phase of IQ set to + or - 90 deg.



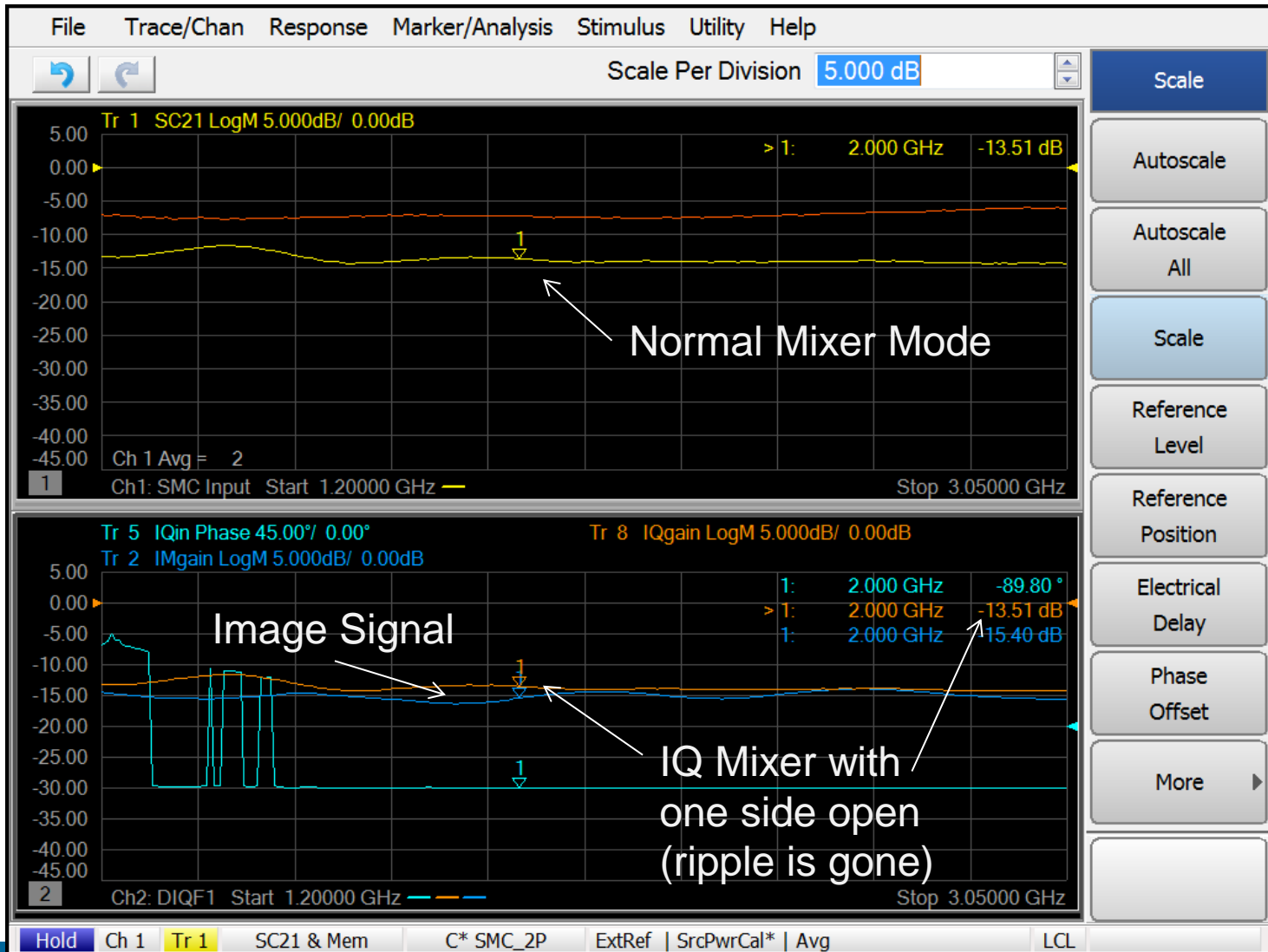
IQ Mixers: Measure just one side (in normal Scalar Mixer Mode, and in IQ Mode)



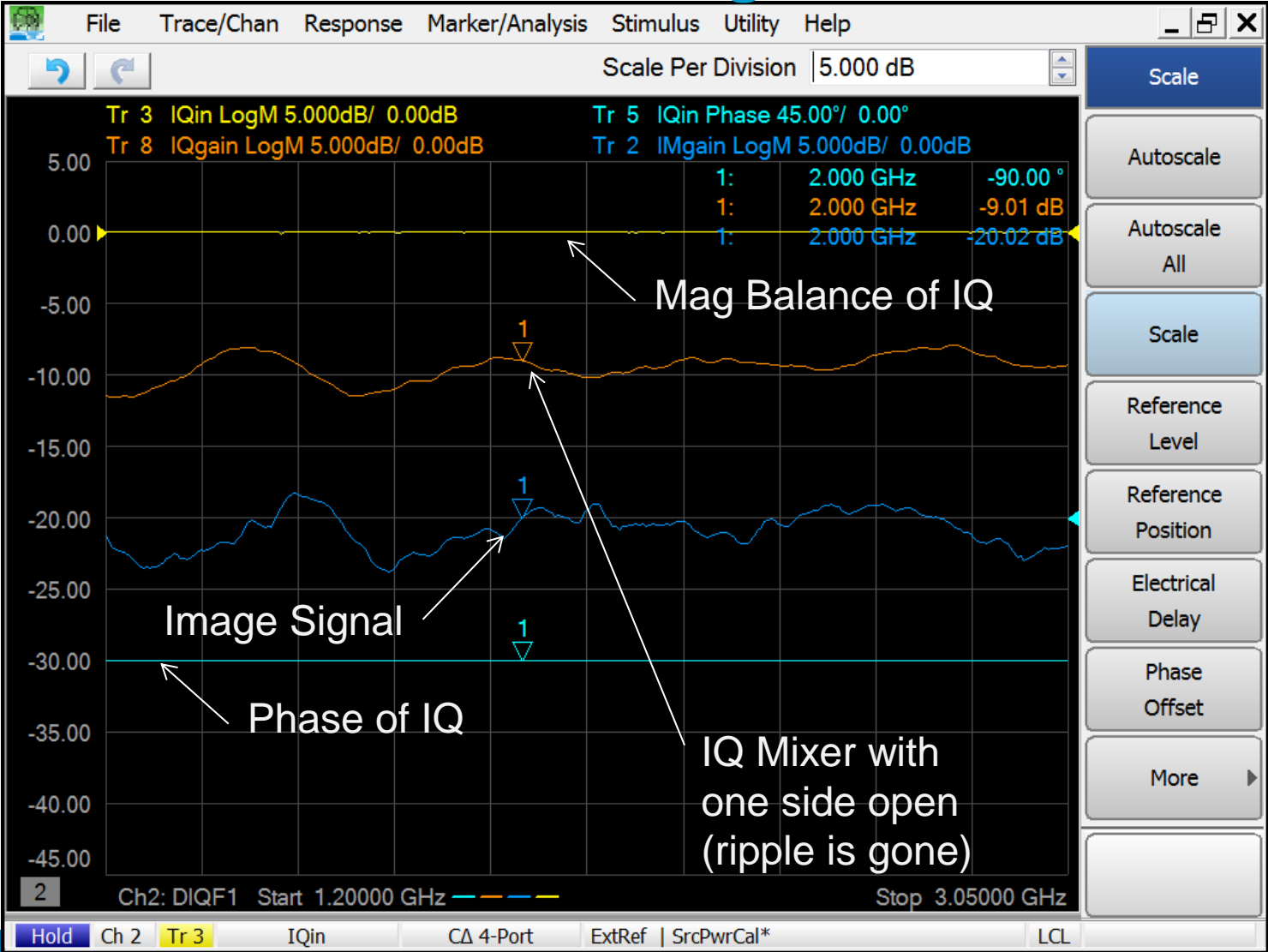
IQ Mixers: Measure just one side (in normal Scalar Mixer Mode, and in IQ Mode)



IQ Mixers: Measure just one side: Add Match Correction

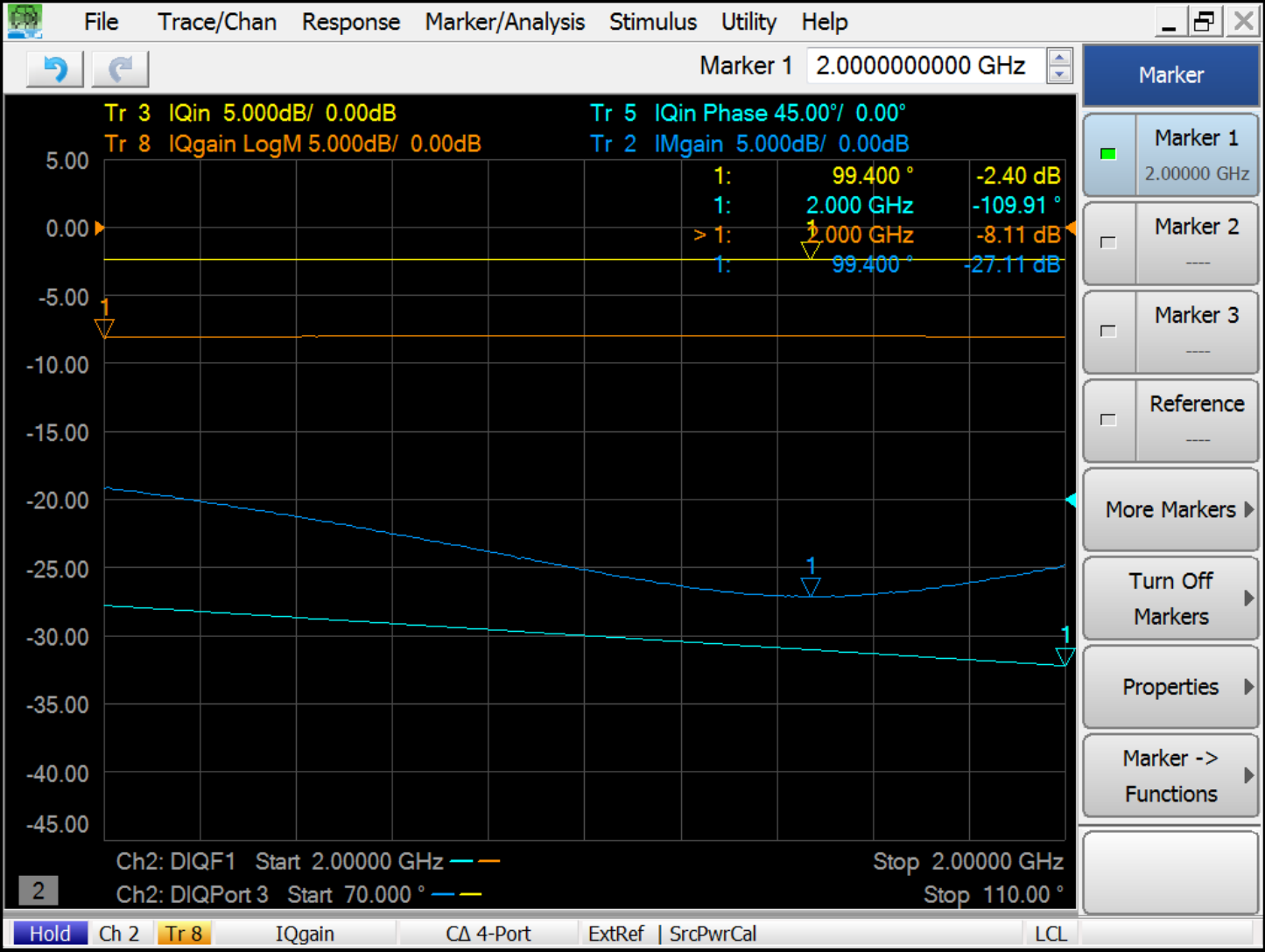


IQ Mixers: Both sides connected now shows image rejection! And increased IQ gain.



IQ Measurements: IQ input power, output power, image power, LO power vs frequency

IQ Measurements: Output Gain, Image Gain, vs IQ Phase Skew: Fix CW and Sweep Phase



IQ Measurements: Output gain, Image Gain vs IQ Amplitude Skew



Other Measurement Configurations can make use of External Sources

- Use an arb (currently supported for 81150A and 81160A arbs) to generate IF signal input up to 500 MHz
- Use external PSG or MXG to generate I/Q Balanced signal or Balanced LO (utilizing an external test set for switching).
- Use external PSGs and MXG on all 8 receivers (no match correction)

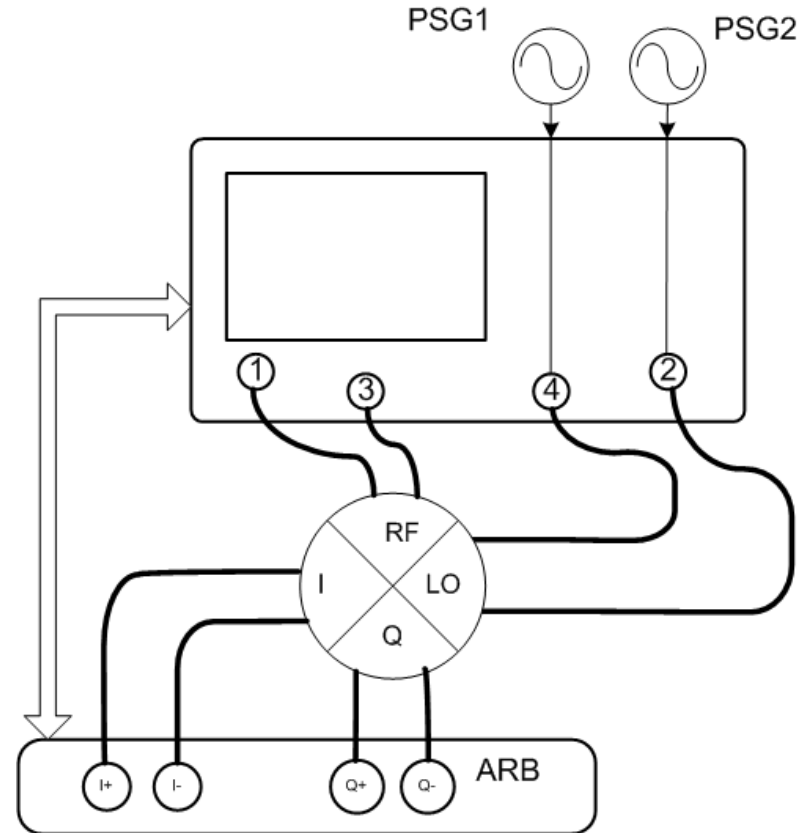
Wideband I/Q Mxr. using ARB Match RF, LO; Balanced Everything, with phase controlled LO, I/Q

Test Requirements:

- Stimulate the input with balanced, I Signal
- Stimulate the input with balanced, Q Signal
- Stimulate the LO with a Balanced Signal
- Set phase of I vs. Q
- Measure the input differential power
- Measure the output differential power
- Measure output at both LO+Input (main signal) and LO-Input (Image signal)
 - As of function of frequency
 - As a function of I/Q phase
- Provide corrected measurements of power, provide leveled input power
 - Open: How to calibrate mag and phase I and Q outputs from the ARB
- Issue: Controlling ARB (generic exe?)
- Cover SE cases for RF, LO (subset of balanced)

Wants

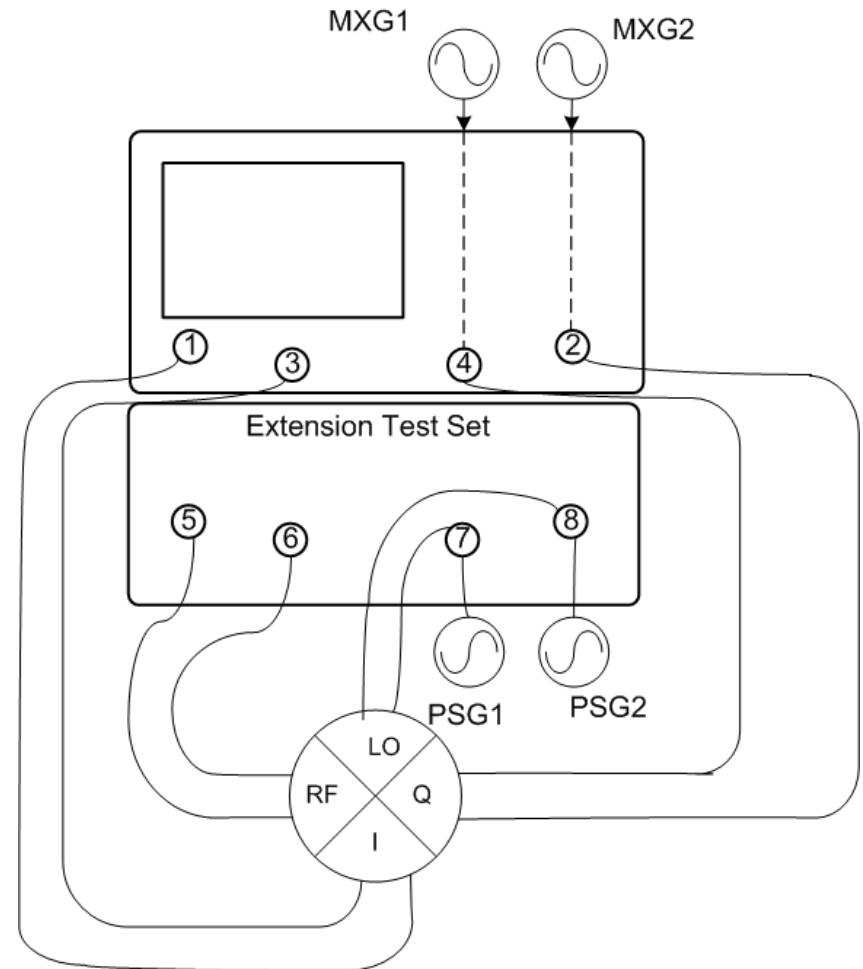
- Measure higher order products of $m \cdot LO + -n \cdot \text{Input}$



- Wideband I/Q mixer measurement w/extension testset
 Match corrected I/Q, RF; Balanced Everything, with phase controlled LO

Test Requirements:

- Stimulate the input with balanced, I Signal
 - Stimulate the input with balanced, Q Signal
 - Stimulate the LO with a Balanced Signal
 - Set phase of I vs. Q
 - Measure the input differential power
 - Measure the output differential power
 - Measure output at both LO+Input (main signal) and LO-Input (Image signal)
 - As of function of frequency
 - As a function of I/Q phase
 - Provide corrected measurements of power, provide leveled input power
 - Open: How to calibrate mag and phase of PSG1 and PSG2 paths.
 - How to control 6 or 8 port paths (test set control?)
- Wants
- Measure higher order products of $m \cdot LO + n \cdot \text{Input}$



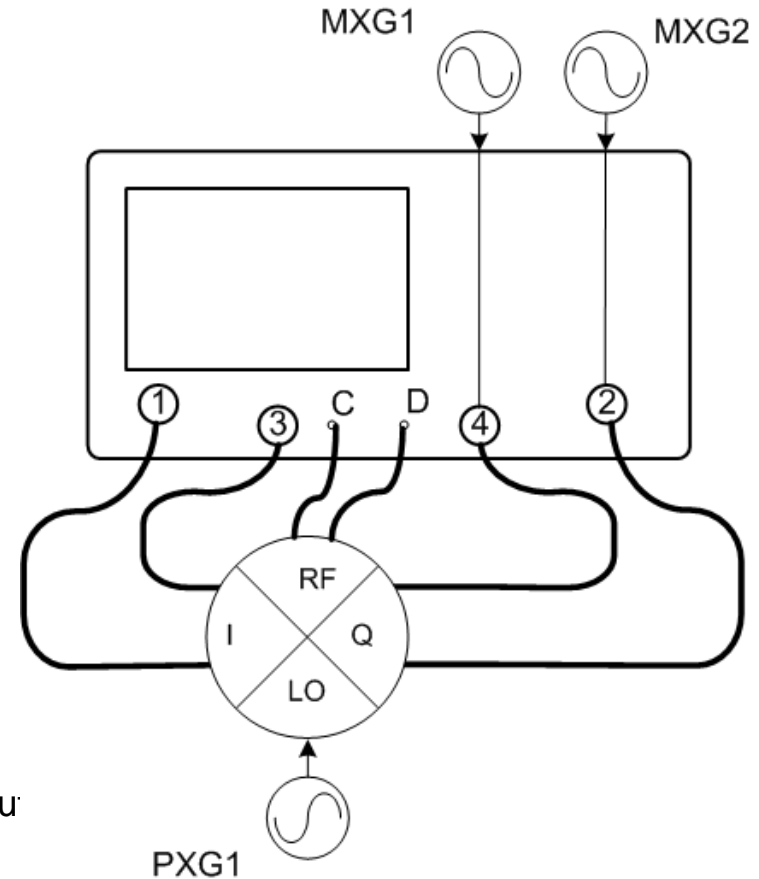
- Wideband I/Q mixer measurement, No match correction on port 3 or 4 (I-, Q-) or on C or D receiver (output),

Test Requirements:

- Stimulate the input with balanced, I Signal
- Stimulate the input with balanced, Q Signal
- Set phase of I vs. Q
- Measure the input differential power
- Measure the output differential power
- Measure output at both LO+Input (main signal) and LO-Input (Image signal)
 - As a function of frequency
 - As a function of I/Q phase
- Provide corrected measurements of power, provide leveled input power
 - Open: How to calibrate C & D receivers.
- Support SE case for RF out (subset)

Wants

- Measure higher order products of $m \cdot \text{LO} + n \cdot \text{Input}$



Summary:

- New software control methods allow users to create very sophisticated stimulus conditions at microwave frequencies.
- Match corrected calibration implies that de-embedding is possible, meaning on-wafer and in-fixture applications are now possible
- Flexible receiver control allows a single channel to make multiple phase-related measurements in a single acquisition.
- Full match correction on all receivers improves accuracy.
- Really hard to do all the control...don't look under the covers. 😊

These capabilities were only dreamed of... Dreams Made Real!