New Broadband Millimeter Wave Vector network Analyzer

Jan 2018

KEYSIGHT TECHNOLOGIES

TMG 티엠게이트

Module Objectives

- Provide an overview of the new Broadband Millimeter Wave VNA
- Give you background on the key performance criteria
- Provide information to help you configure a solution
- Share additional resources available

Millimeter Wave Application Space

Target Markets and Customers – On wafer Device Characterization

Commercial

Wireless backhaul

802.11 AD
Wireless HDMI

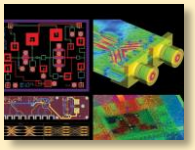
Automotive radar

Radar/EW

Next Gen wireless
communications “5G”

Secure communication system

Courtesy www.NIST.gov



Millimeter Wave imaging

Aerospace Defense

Millimeter Vector Network Analyzer

Agenda

– Product Overview / Key features

– Detailed Component Features

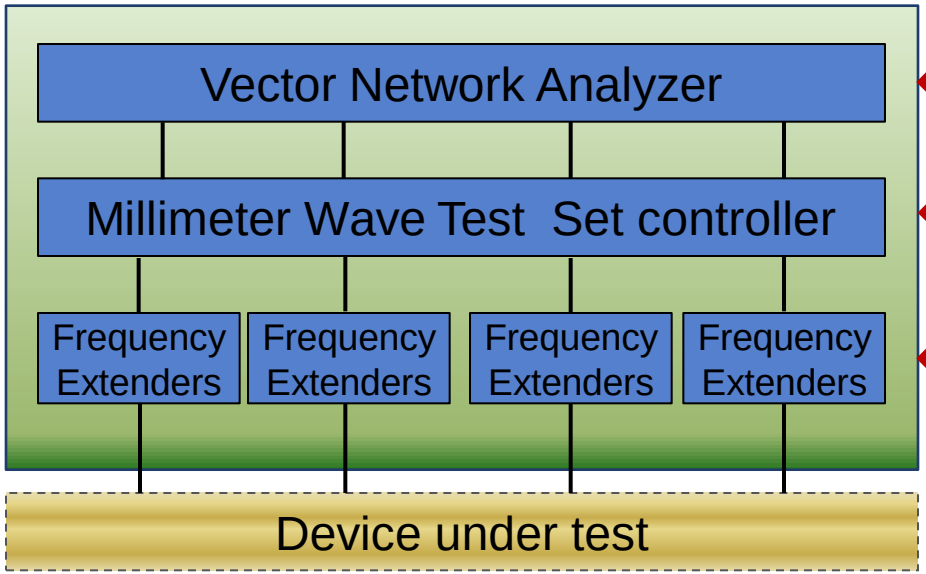
– Key Product Performance Criteria

– Key Software Application

– Summary

N5290/91A Product Overview

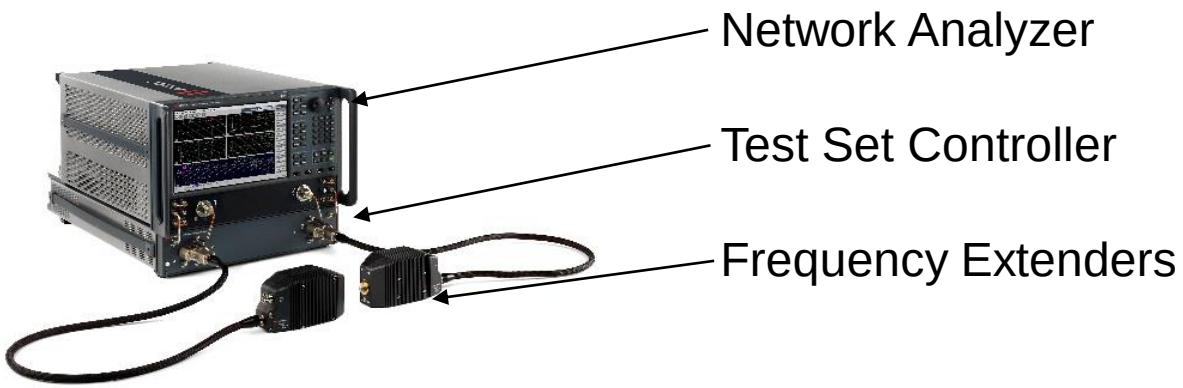
System Architecture



Network Analyzer is the measurement engine

Required ***Test Set Controller*** interfaces to modules

Frequency Extenders provide frequency conversion and signal coupling

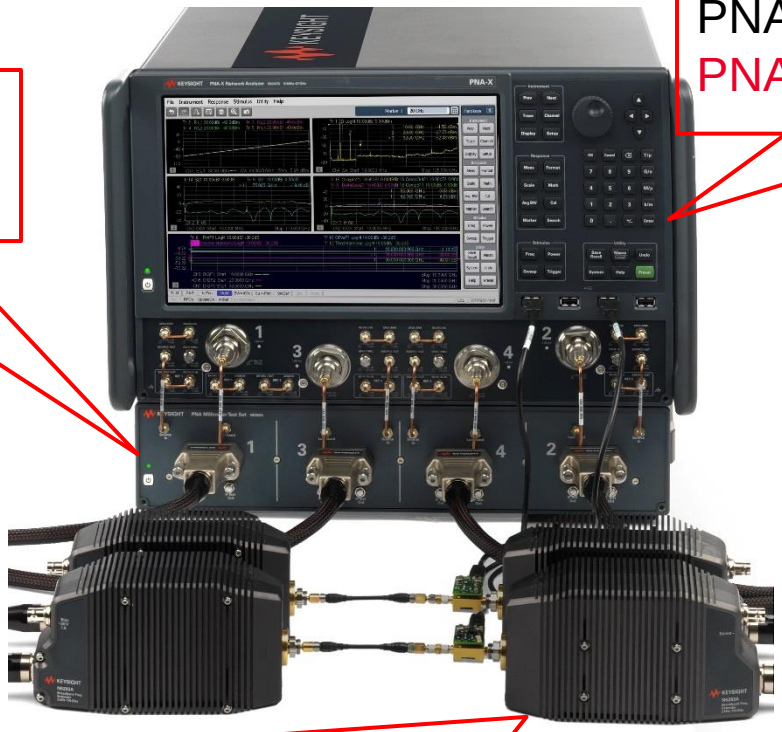


N5290/91A Product Overview

N5291A **900Hz – 120 GHz** mmWave Network Analyzer System
N5290A **900Hz** – 110 GHz mmWave Network Analyzer System (no need of export license)

PNA: 2-port, **26.5**/67 GHz
PNA-X: 4-port, 26.5/67 GHz

New N5292A 2/4 port test set controller



Keysight Design and Compact frequency extender module
N5293AX03 / N5295AX03 (110GHz/120GHz)

N5290/91A Product Overview

N5290/91A Pre-Configured Solutions – What's New

Complete 2/4 port broadband NA system up to 125 GHz with

- *NEW* remote heads and controller
- *NEW* 1.0-mm USB power sensor
- *NEW* 1.0-mm mechanical cal kit

Key Features

- Wide frequency range 900 Hz (500 Hz) to 120 GHz (130GHz)
- Excellent System performance (dynamic range, port power, noise floor, etc.)
- Guaranteed and traceable performances from 900 Hz (500 Hz) to 120GHz (Typical 125 GHz)
- Excellent transmission and reflection stability
- Built-in DC bias tees 1A, 50V
- Simple cabling between compact test heads and instrument
- PNA-X applications available (spectrum analyzer, mixers, differential, etc.)
- New 120 GHz accessories (cal kit, power sensor)
- Complete on-waver solutions with Cascade (WMS Program) – 4 heads easily mounted on Cascade prober

Millimeter Vector Network Analyzer

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Detailed Component Features

PNA / PNA-X B Series

- Widescreen (12.1”) multi-touch display
- New simplified user interface
  - Part of converged VNA software for ENA, PNA, modular
  - Same UI as E5080A ENA
- PNA-X test set configurations now consistent with PNA
- New software-application license structure
  - Former software options now have separate model numbers (e.g. Option 010 → S93010A)
  - Can be ordered with instrument or added later
  - Transportable licenses now available
- Upgrade path available from A to B.
- Dark-gray Keysight color scheme

Detailed Component Features

N5292A Millimeter Wave Test Set Controller

N5292A Option 200

N5292A option 400

- ✓ Dedicated connector interface
- ✓ Support for existing OML/VDI extenders
- ✓ Require external power supplies for VDI / OML Frequency extenders
- ✓ Direct IF access from extenders

Detailed Component Features

N5293/95AX03 Frequency Extenders

Key Features:

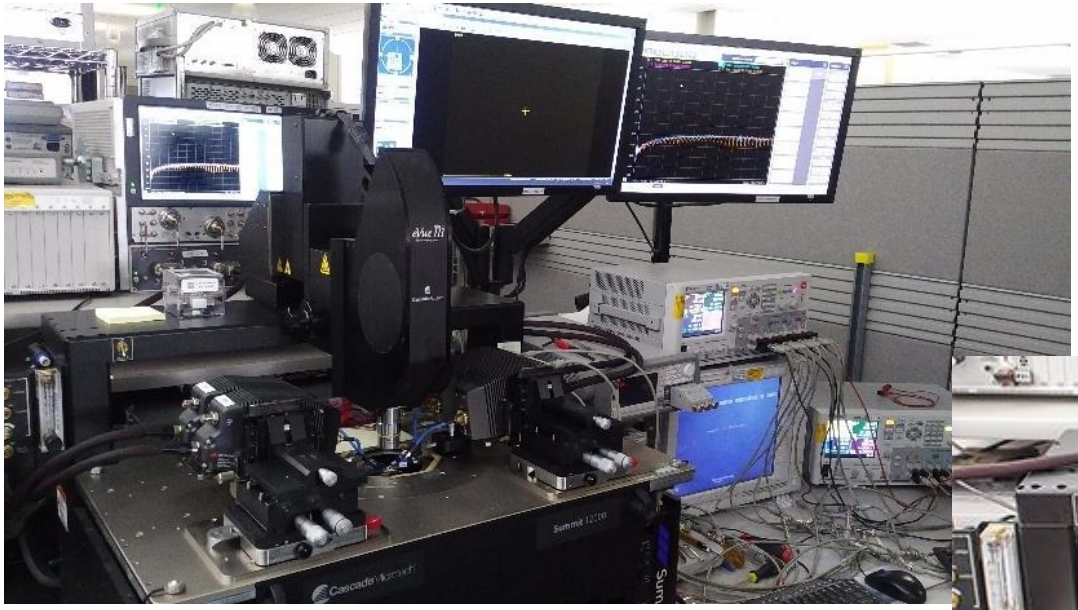
- N5293AX03 (- 110 GHz), N5295AX03 (- 125 GHz)
- **Keysight Design** with compact size and weight
- IEEE 287-2007 compliant 1mm connector with **traceable calibration**
- Ruggedized metal housing and ruggedized 1mm connector
- Attached 48 inch cables to connect to the test set controller, N5292A.

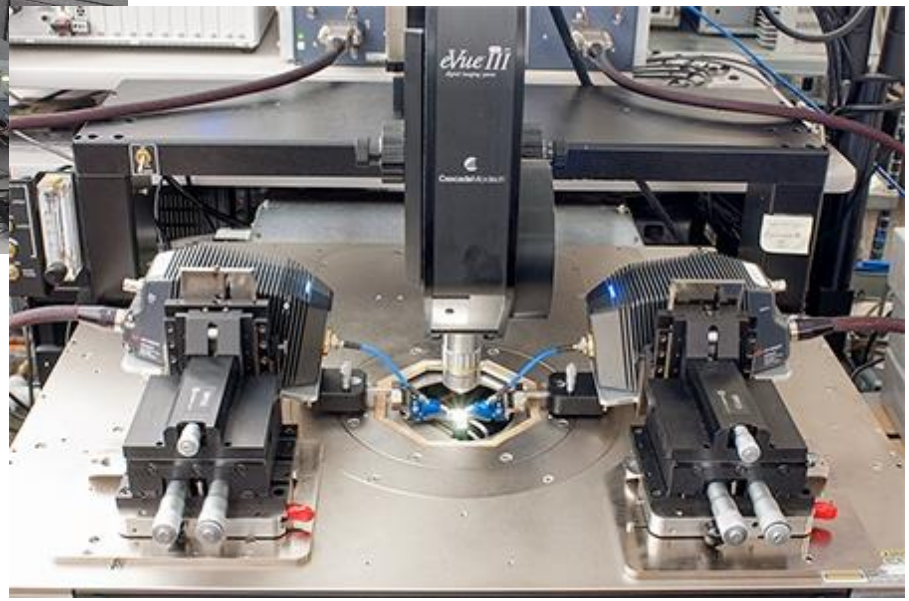
Indicator light when powered on and active

Simplified rear connections easy access to Bias-T

Convection cooled heads. No additional thermal management required.

Wafer-level Measurement Solution (WMS)





N5290A/91A mmWave solution
+Cascade Probe Station
+WaferPro Express SW

- *Guaranteed Configuration*
- *Guaranteed Integration*
- *Guaranteed Support*

Probe Positioner with fully X-Y-Z control

Millimeter Vector Network Analyzer

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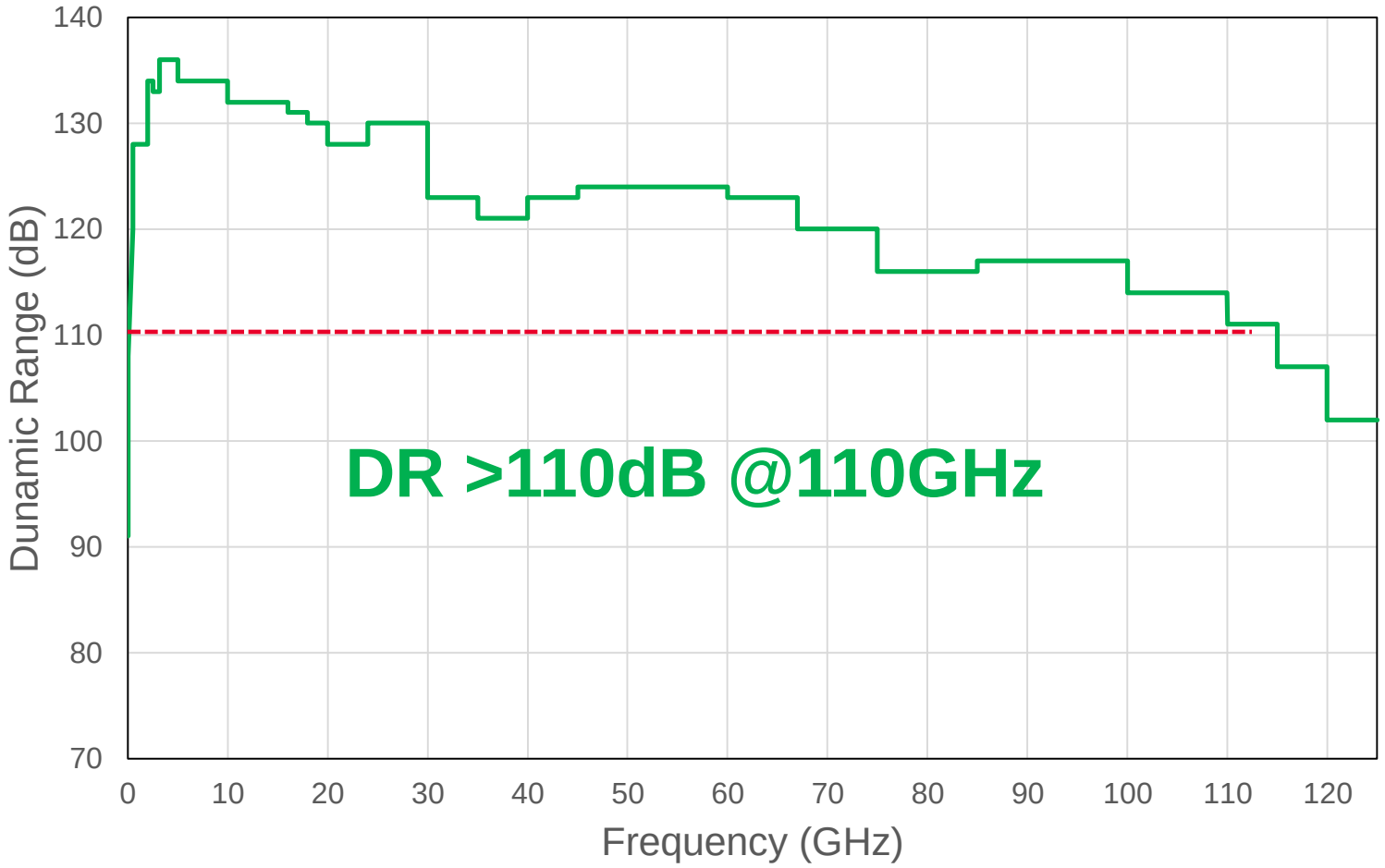
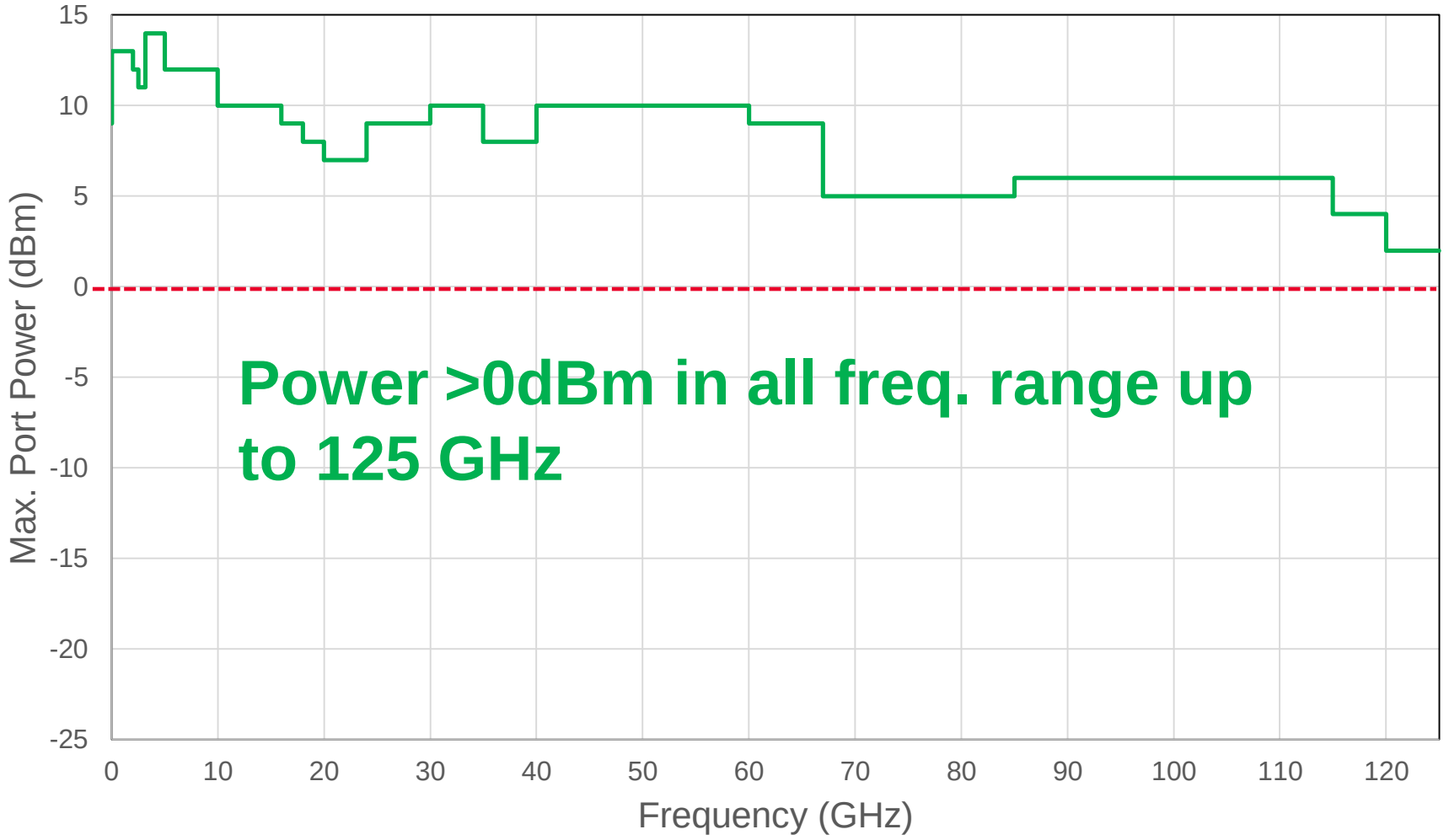
N5290A/91A Key Performance Criteria

Average Dynamic Range Across all Ports



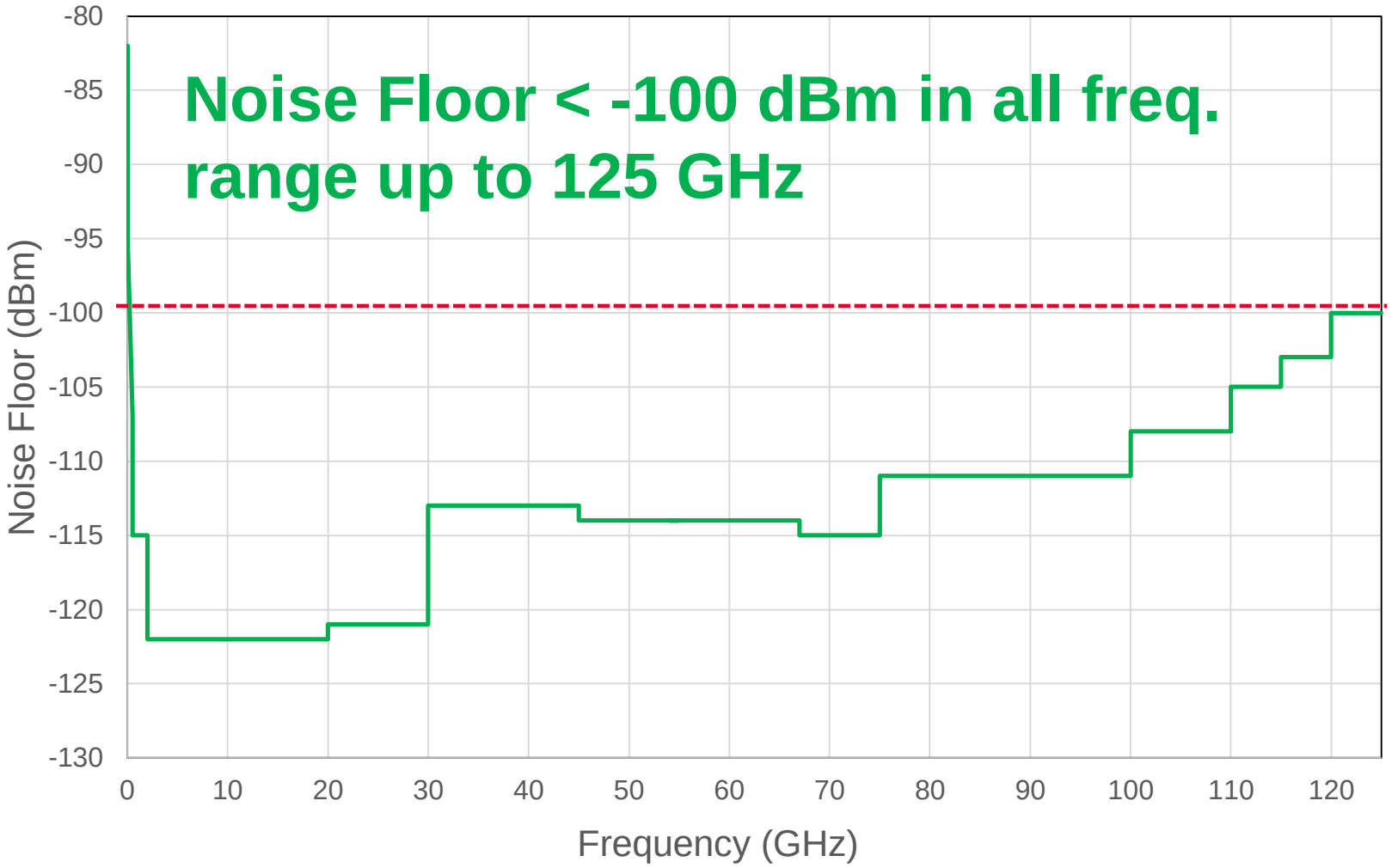
N5290A/91A Key Performance Criteria

Typical Max power at Test Port



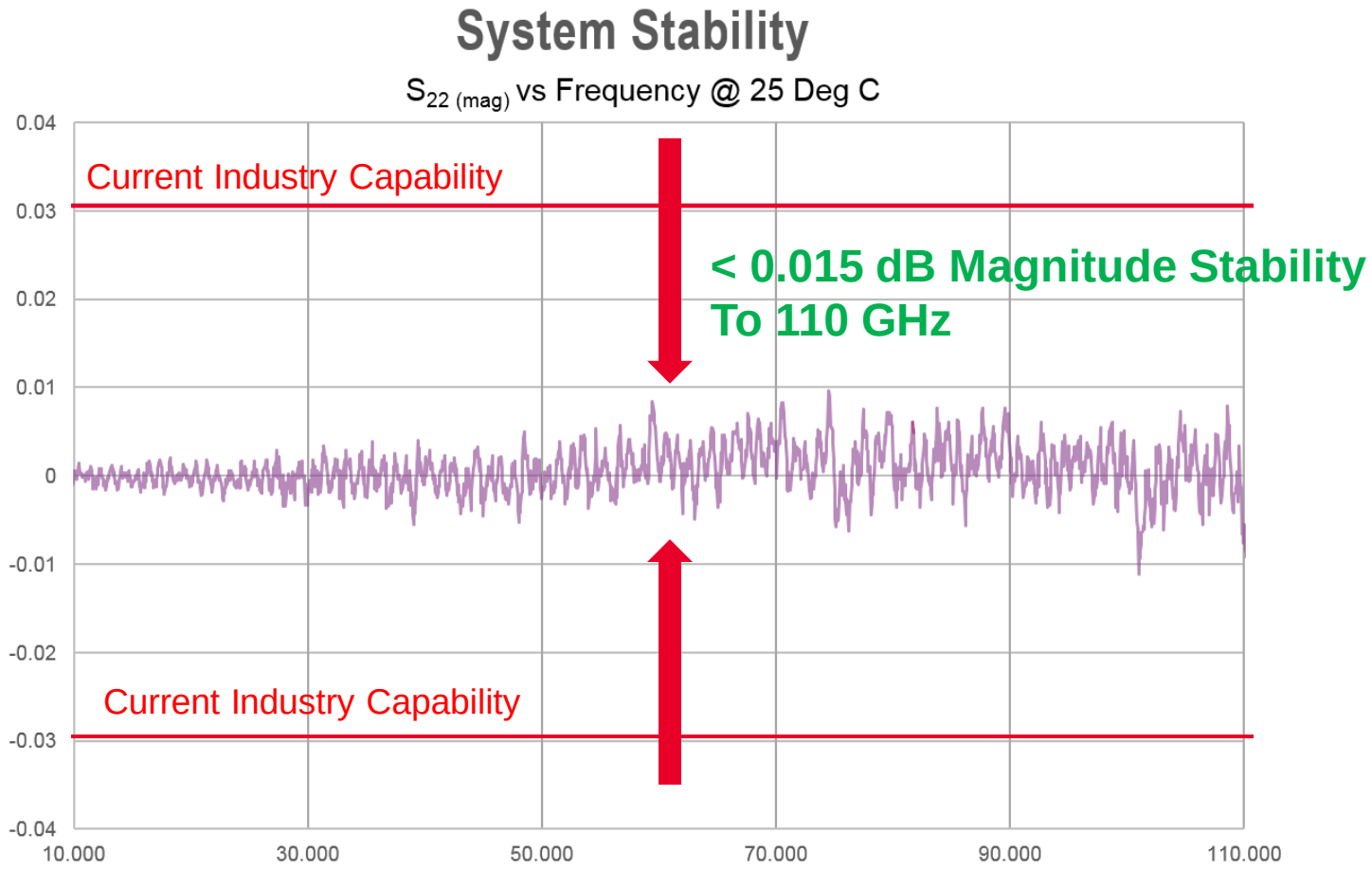
N5290A/91A Key Performance Criteria

Typical Noise Floor Across All Ports



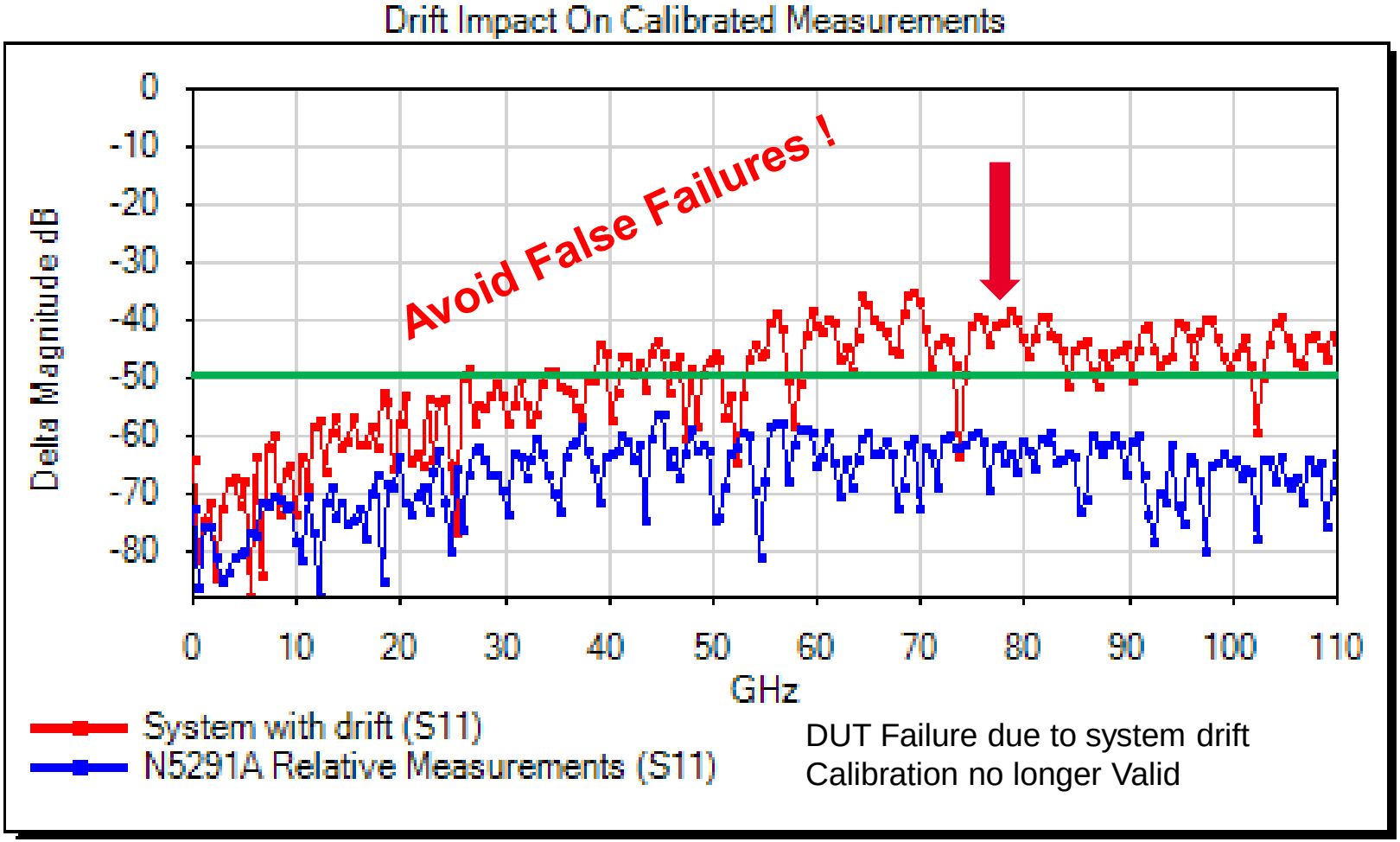
N5290A/91A Key Performance Criteria

24 Hr 1-Port Magnitude stability 110 GHz



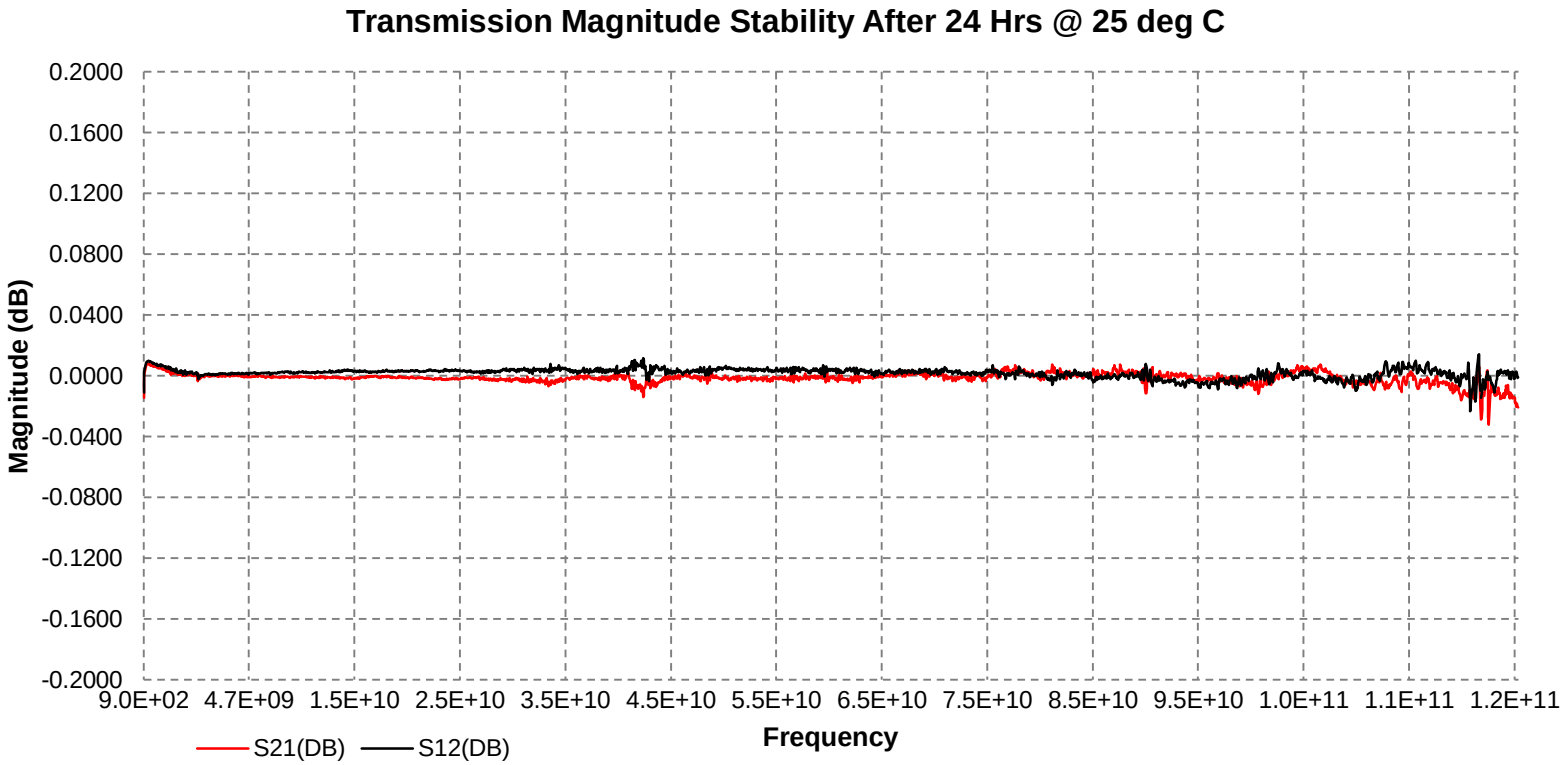
Key Product Performance Criteria

Why is stability Important?



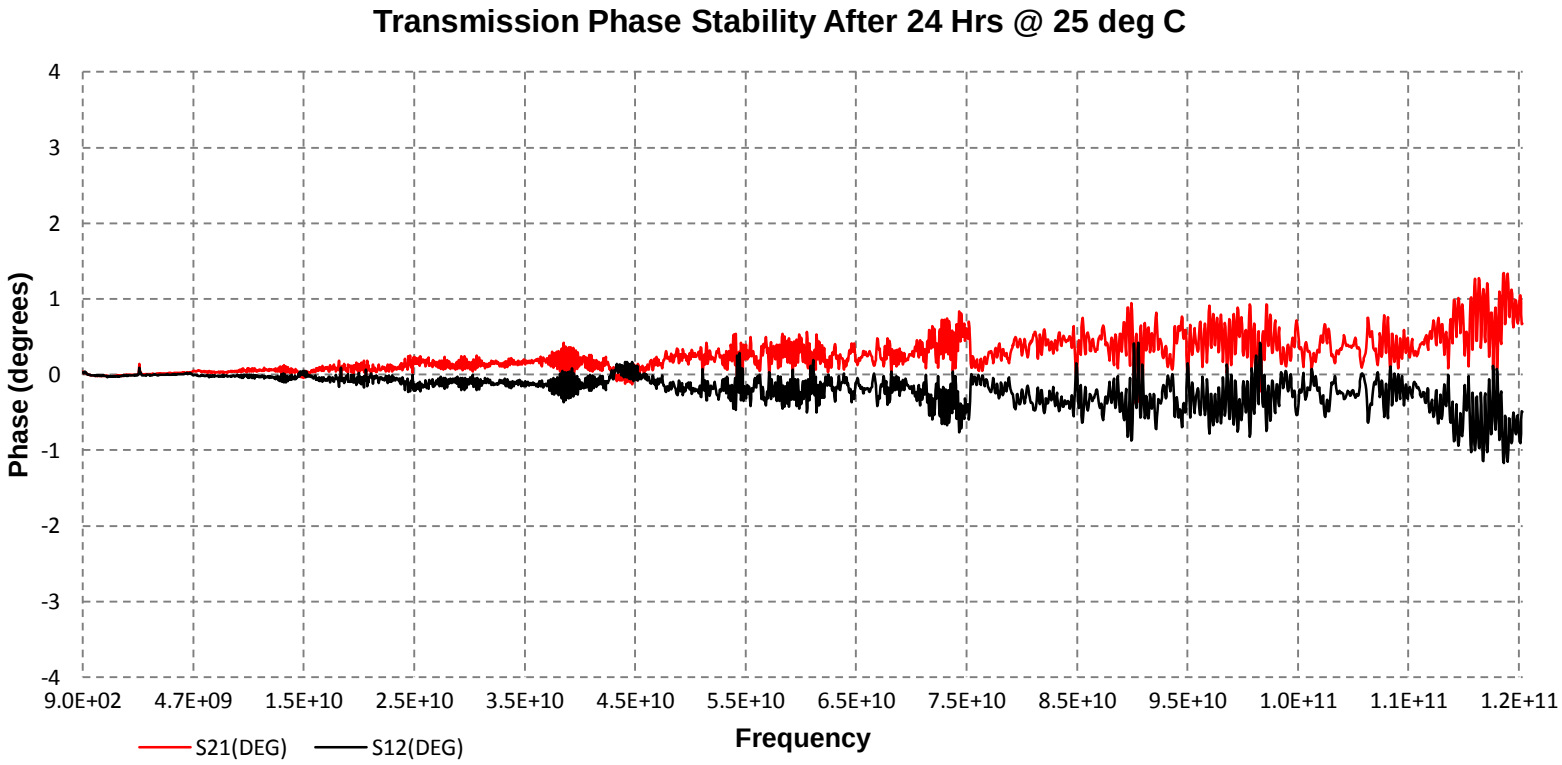
Key Product Performance Criteria

Transmission Magnitude Stability



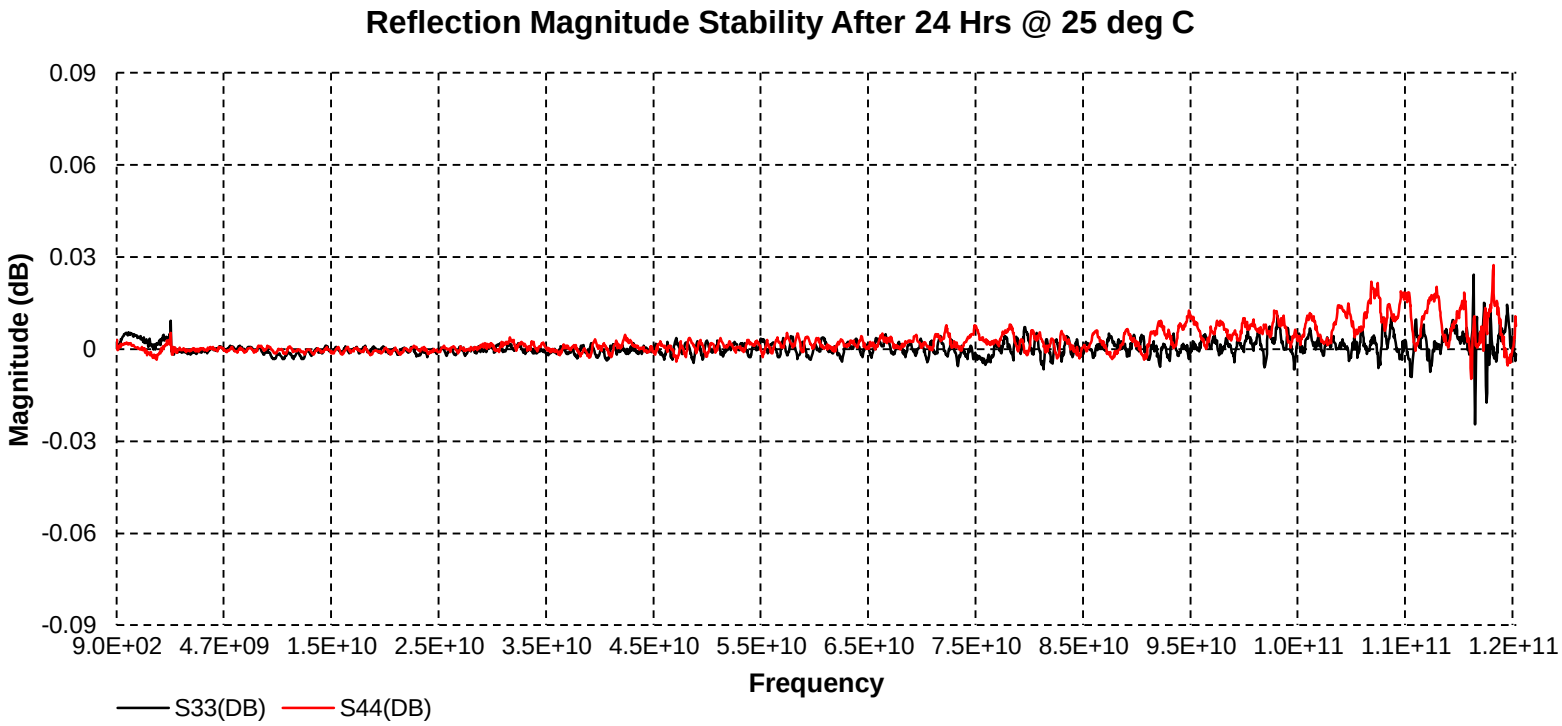
Key Product Performance Criteria

Transmission Phase Stability



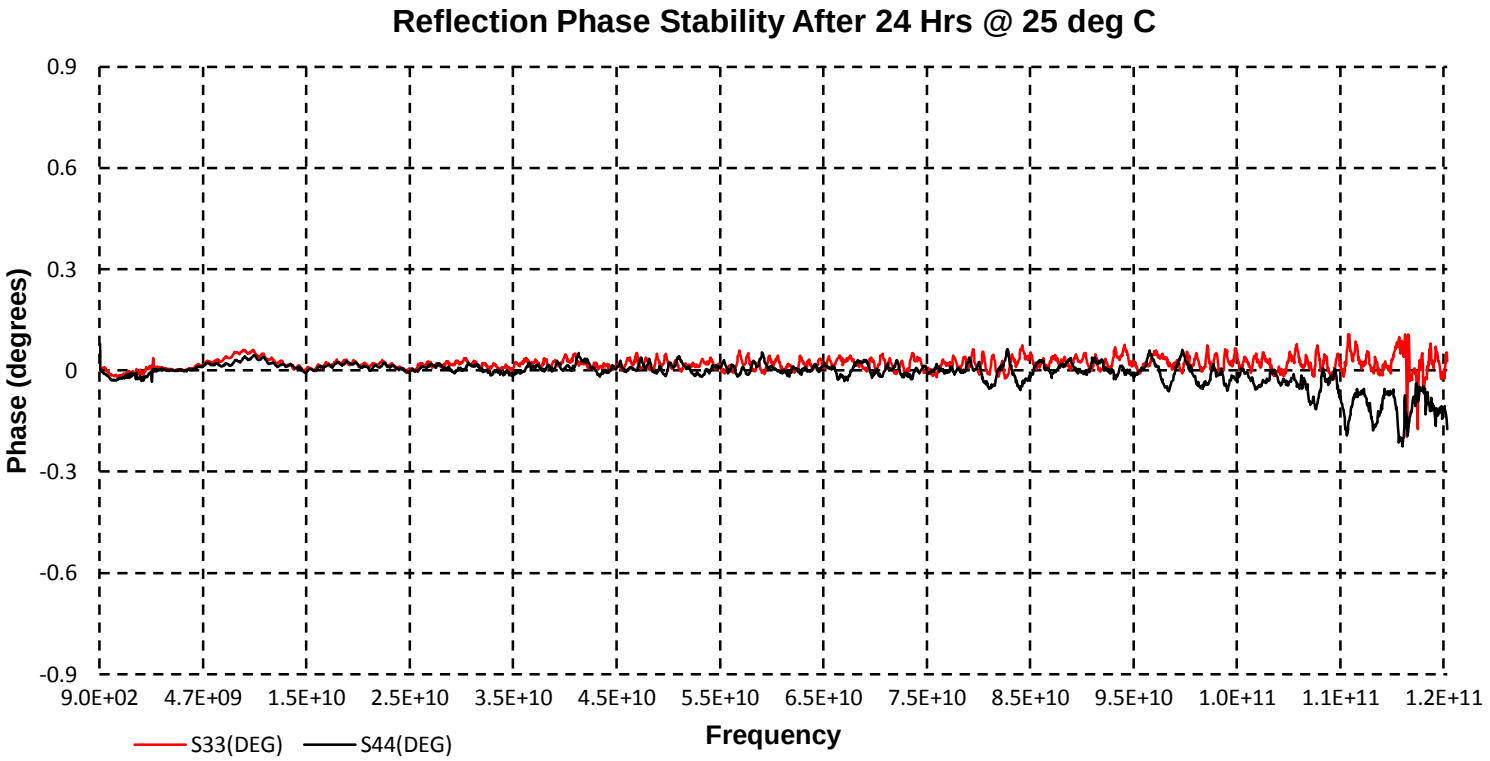
Key Product Performance Criteria

Reflection Magnitude Stability



Key Product Performance Criteria

Reflection Phase stability



Millimeter Vector Network Analyzer

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Key Software Application

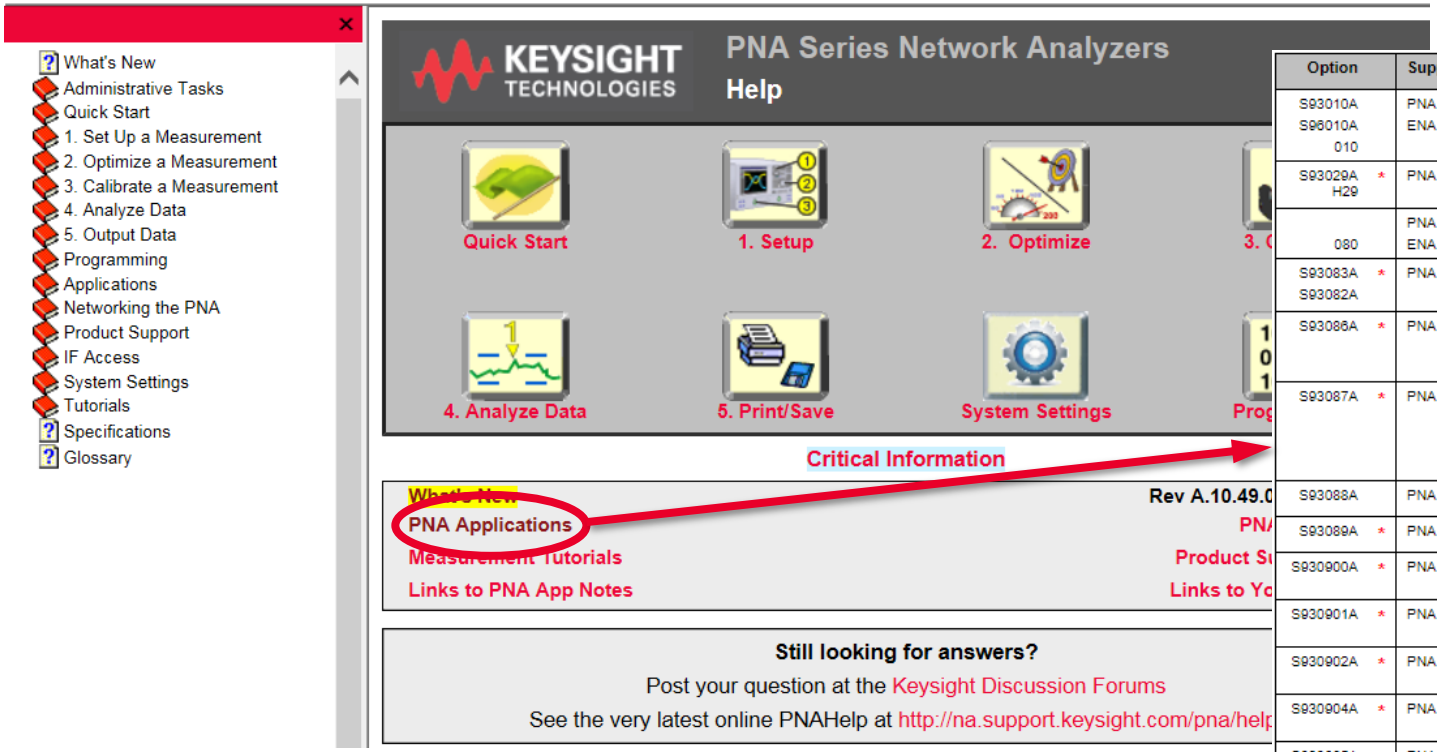
Supported Measurement Applications

SW Appl.	Description
S93007A	Automatic Fixture Removal[1]
S9309xxA	Spectrum analysis (up to 90 GHz)
S93093A	Spectrum analysis up to 120 GHz
S93094A	Spectrum analysis beyond 120 GHz
S93029A	Noise figure measurements[1,2]
S93086A	Gain-compression measurements [1]
S93080A	Frequency-offset measurements[1]
S93087A	Intermodulation Distortion Measurements
S93082A	Scalar mixer/converter measurements[1]
S93089A	Differential I/Q device measurements

Notes:
1. Start Frequency is from 900Hz, others are from 10MHz.
2. NFX for converters

Learn More About Applications from Help

http://na.support.keysight.com/pna/help/latest/help.htm



Option	Supported Model	Application
S93010A S96010A 010	PNA ENA	Time Domain
S93029A * H29	PNA	Noise Figure and Noise Figure on Converters
080	PNA ENA	Frequency Offset
S93083A * S93082A	PNA	Frequency Converter (FCA) SMC Only
S93086A *	PNA	Gain Compression Gain Compression on Converters
S93087A *	PNA	Swept IMD Swept IMD on Converters IM Spectrum IM Spectrum on Converters
S93088A	PNA	Source Phase Control
S93089A *	PNA	Differential IQ
S930900A *	PNA	Spectrum Analysis, up to 8.5 GHz
S930901A *	PNA	Spectrum Analysis, up to 13.5 GHz
S930902A *	PNA	Spectrum Analysis, up to 26.5 GHz
S930904A *	PNA	Spectrum Analysis, up to 43.5 GHz
S930905A *	PNA	Spectrum Analysis, up to 50 GHz
S930907A *	PNA	Spectrum Analysis, up to 67 GHz
S93093A *	PNA	Extend spectrum analysis to 110 GHz
S93094A *	PNA	Extend spectrum analysis beyond 110 GHz
S93460A	PNA	iTMSA
S93026A H08	PNA	Integrated Pulse
S96790A 790	ENA	Measurement Wizard Assistant

Key Software Application

AFR Enhancements

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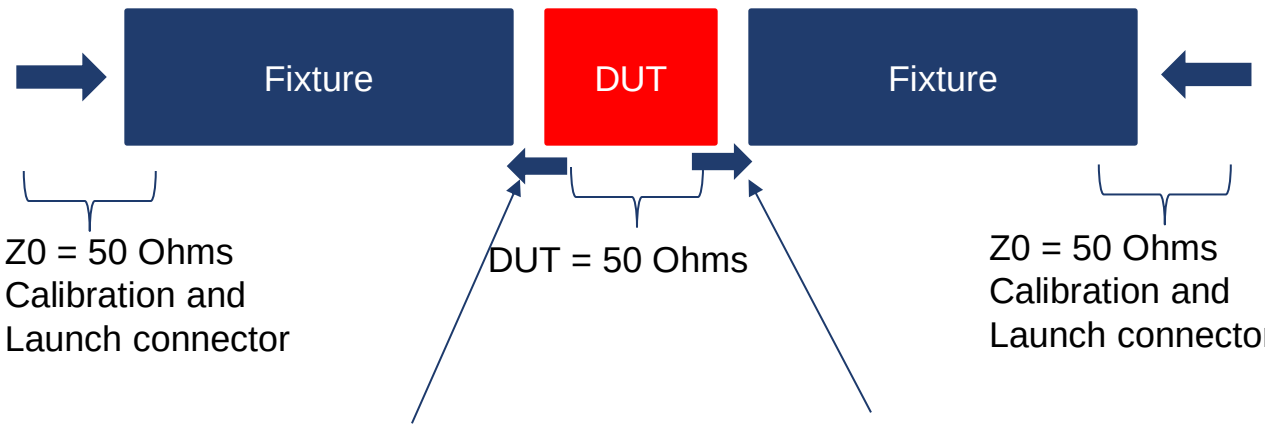
S93083A	Vector mixer/converter measurements[1]
S93089A	Differential I/Q device measurements

AFR Fixture Impedance Refresher

Fixtures that are 50 Ohms (system Z0) keep measurements simple

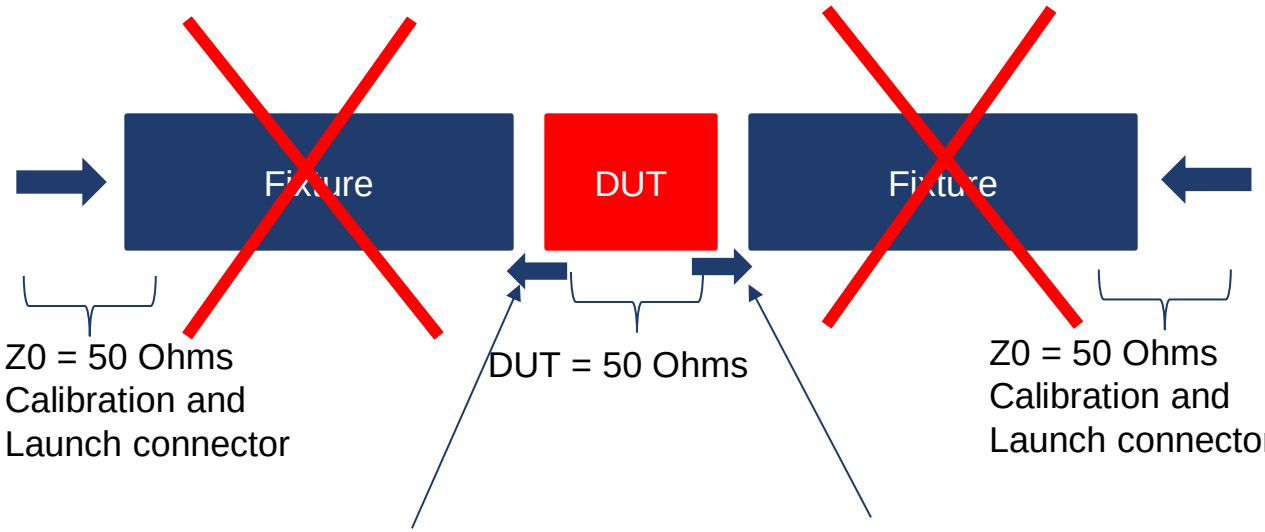


Fixture Impedance at cut plane (2X thru) = 50 Ohms

Remove the fixture effects and Z0 still = 50 Ohms – life is good

AFR Fixture Impedance Refresher

Fixtures that are NOT 50 Ohms (system Z0) act like impedance transformers

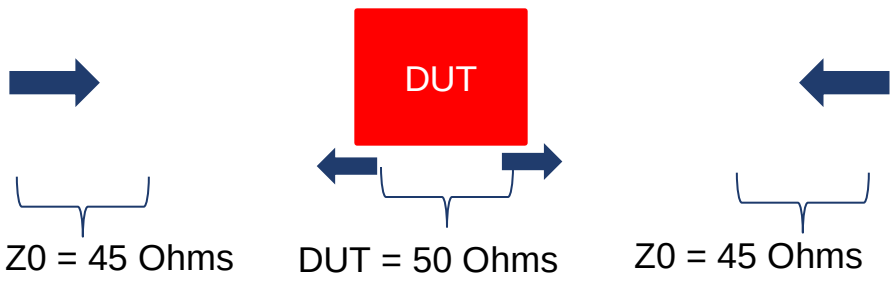


Fixture Impedance at cut plane (2X thru) = 45 Ohms

Remove the fixture effects and Z0 changes

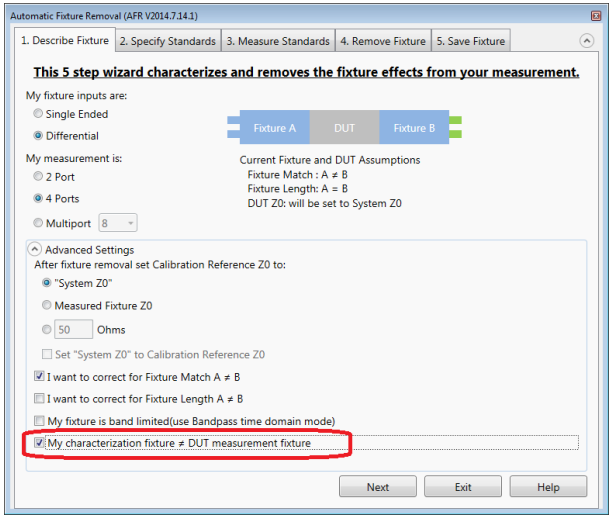
AFR Fixture Impedance Refresher

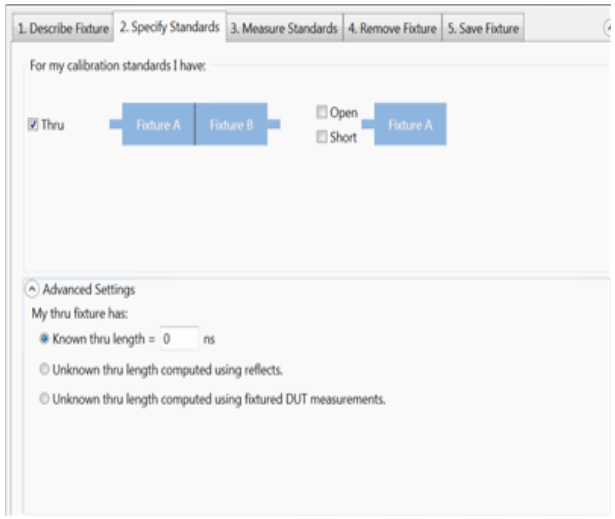
Fixtures that are NOT 50 Ohms (system Z0) act like impedance transformers.

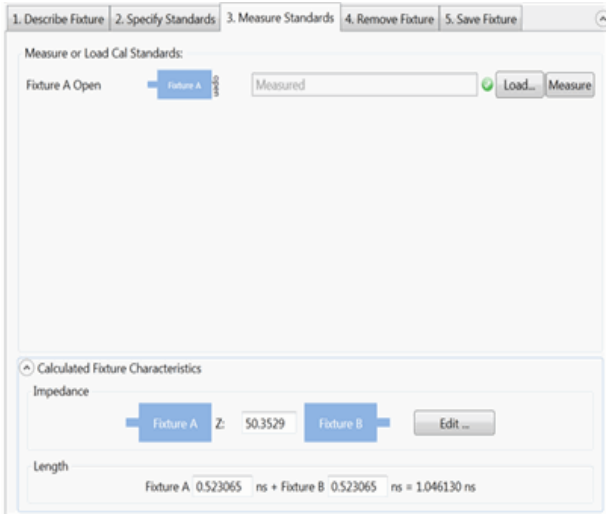


We should really change Z0 = 45 Ohms
it is NOT 50 Ohms anymore

Accuracy Enhancement for AFR







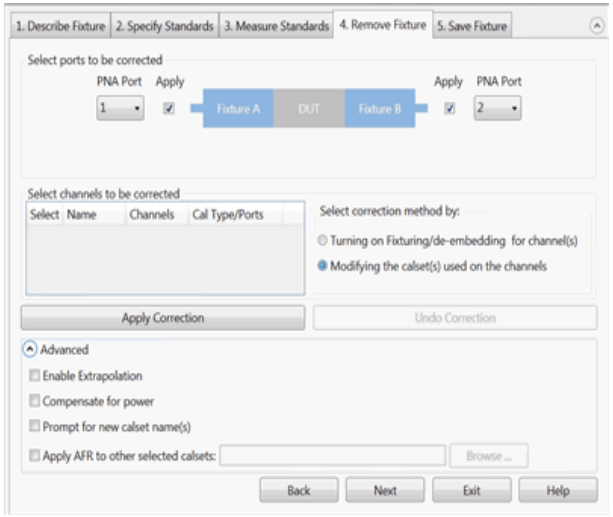
Changes

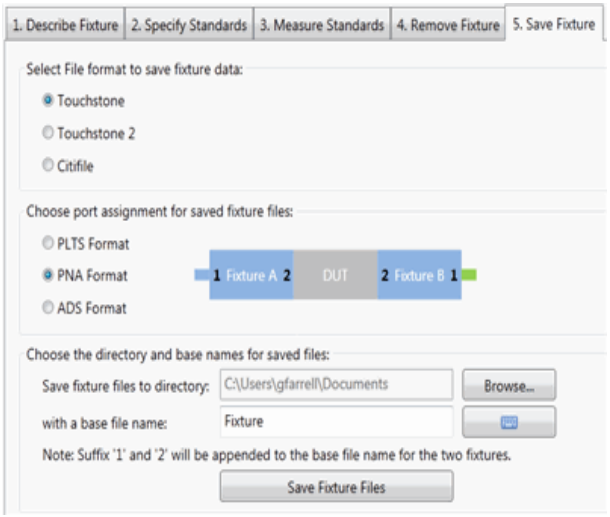
Tab 1: add another checkbox "*My Characterization fixture ≠ DUT measurement fixture*" under advanced settings.

Tab 2: (if checked in tab 1) show another standard, and it must be checked.

Tab 3: need measure the additional standard.

Accuracy Enhancement for AFR





Key Software Application

Spectrum analysis

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S93086A	Gain-compression measurements [1]
S93087A	Intermodulation Distortion Measurements
S93082A	Scalar mixer/converter measurements[1]
S93083A	Vector mixer/converter measurements[1]
S93089A	Differential I/Q device measurements

Millimeter Wave Spectrum Analysis

Option Overview

- There are two options and are currently available. These are options S93093A and S93094A for the PNA / PNA-X used in a millimeter wave solution.
  - Option S93093A allows customer to make SA measurements from 10 MHz to 110 GHz using our single sweep and banded extenders to 110 GHz.
  - Option S93094A allows user to make SA measurements in THz banded frequencies above 110 GHz.
- Option S93094A
  - Highest frequency band evaluated is to 750GHz- 1.1 THz
  - Support on broadband solution is limited to configurations in which both the PNA/PNA-X and the test set controller both have either have 2 or 4 ports.
- Also requires a source power calibration.
- Each configuration requires a IF receiver calibration.

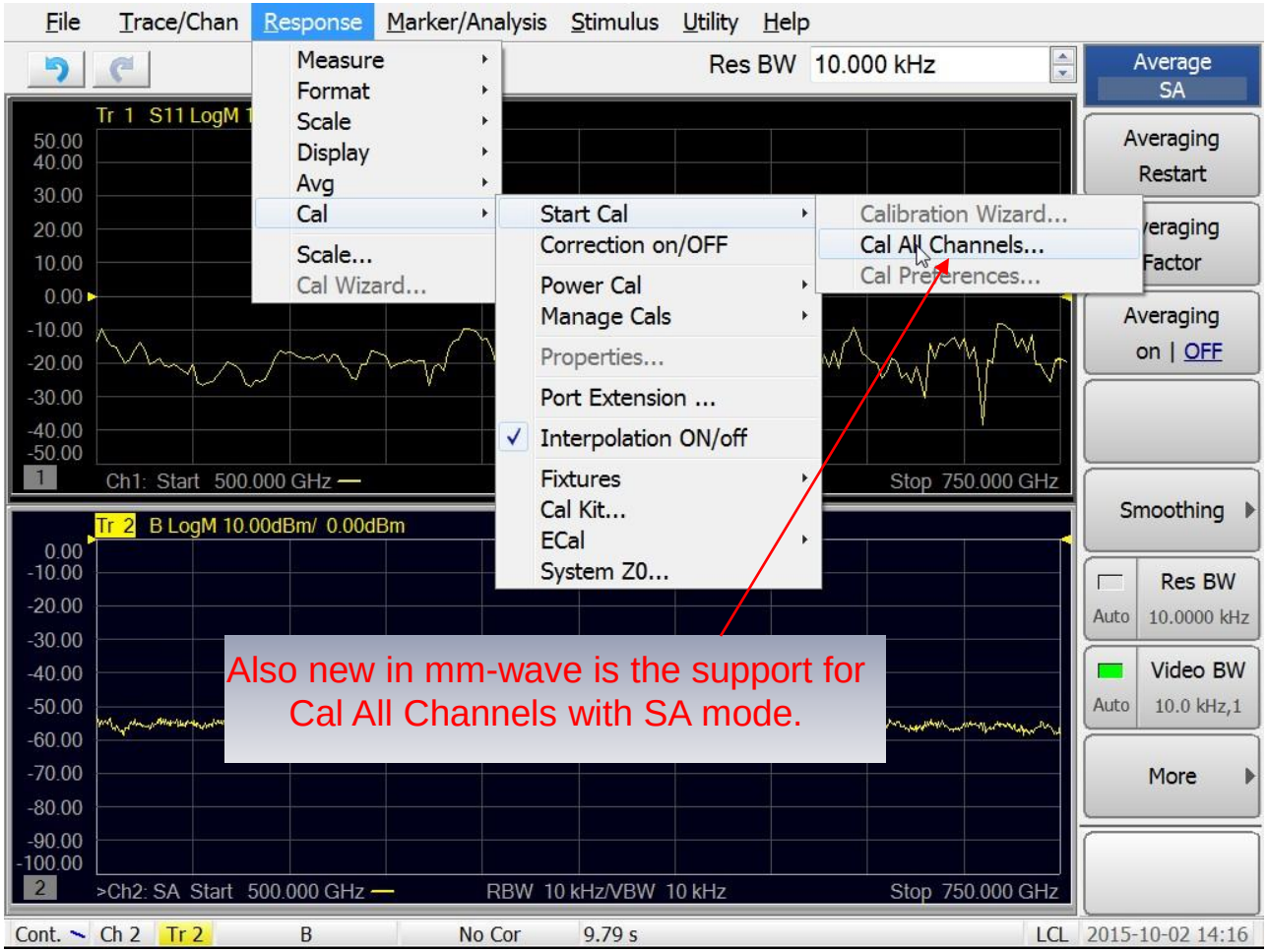
Fully Calibrated Millimeter Wave Spectrum Analysis

Key Features _ Match Corrected Source Power Calibration

- Provides fast, broadband spurious searches
- Works on standalone instruments and with millimeter extenders
- Adds multi-channel spectrum analysis (multiple receivers/frequencies)
- Provides calibrated spectrum analysis
  - Takes advantage of PNA calibration and fixturing features
  - Works for on-wafer or in-fixture situations
- Guided power Cal with integrated power table
- Power table stored in same directory as IF Cal
- Source power cal is accessible through Cal All function
- The guided power cal uses the power table to calibrate the Reference and Test receivers of the mm-head.
- Test receiver cal is used in SA mode.
- The power corrections are “match-corrected” during the guided-power-cal, to get precise readings.16

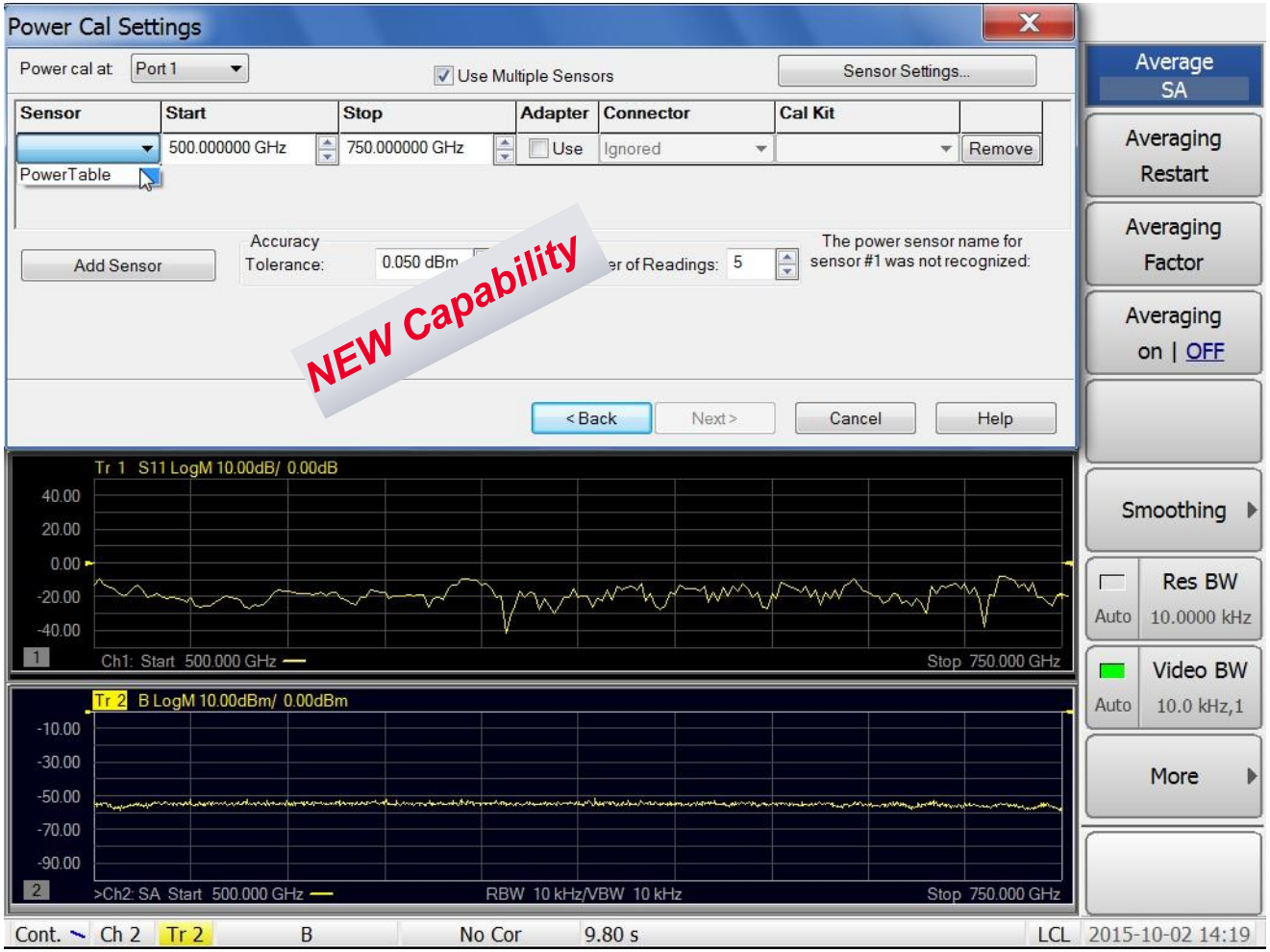
Fully Calibrated Millimeter Wave Spectrum Analysis

Key Features _ Match Corrected Source Power Calibration



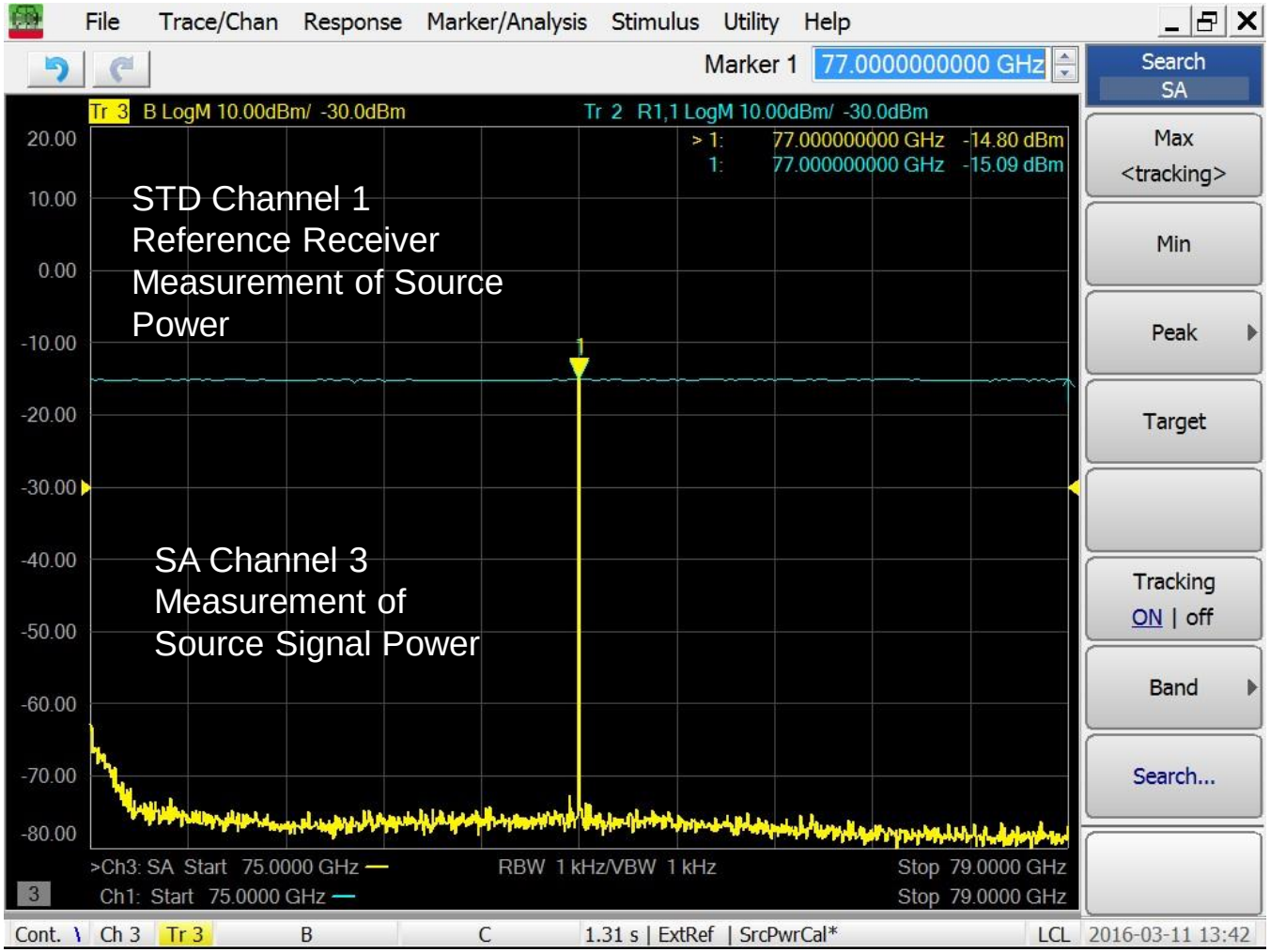
Fully Calibrated Millimeter Wave Spectrum Analysis

Key Features _ Match Corrected Source Power Calibration



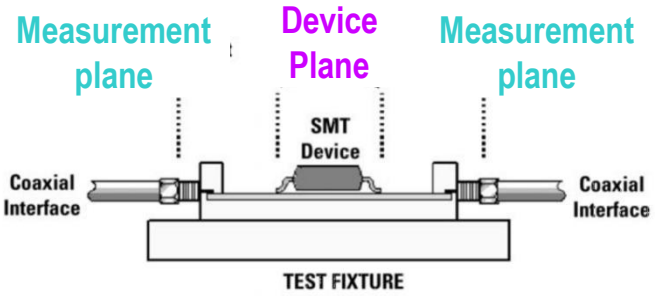
Fully Calibrated Millimeter Wave Spectrum Analysis

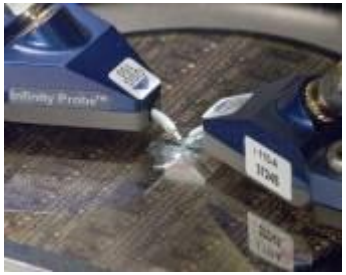
Accurate Amplitude Measurements of Spectral components

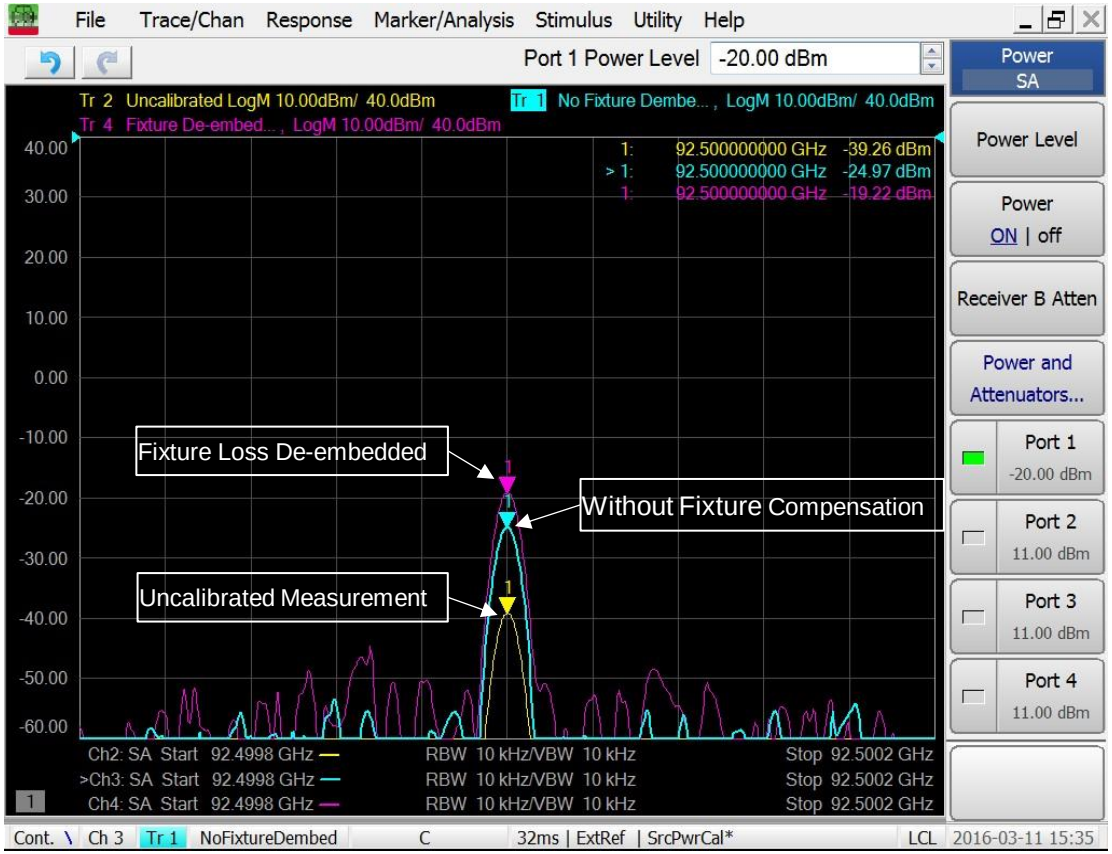


Measure Spectrum a DUT Port

Full De-embed of fixture loss







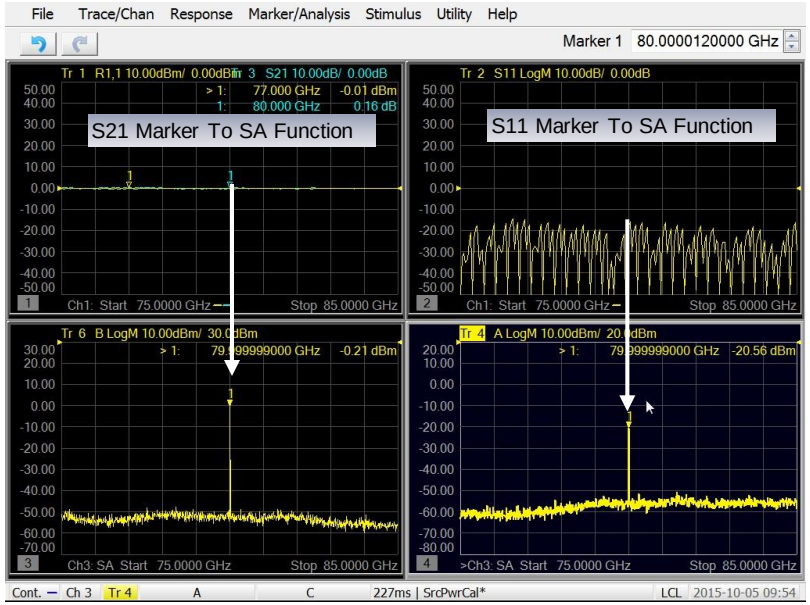
Enabling Spectrum Analysis with Standard channel

Key Features _ Gain Deeper Insights to S-Parameter Behavior

– Quickly & easily add SA channel with DUT in the same test condition

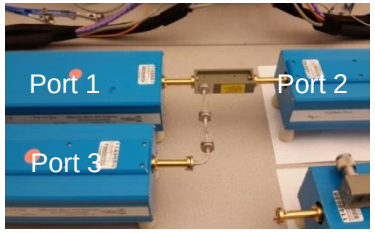
- Preserve frequency range and stimulus settings at the marker
- Refer to active trace with the marker to choose the sources and receiver
  - Example1: Marker on S11 adds Port1 (A) with stimulus on port 1
  - Example2: Marker on S21 adds Port2 (B) with stimulus on port 1

– Enables users to deeper insights to standard S Parameter behavior



Multi-channel Spectrum Analysis

Fully Characterize the DUT with a single connection

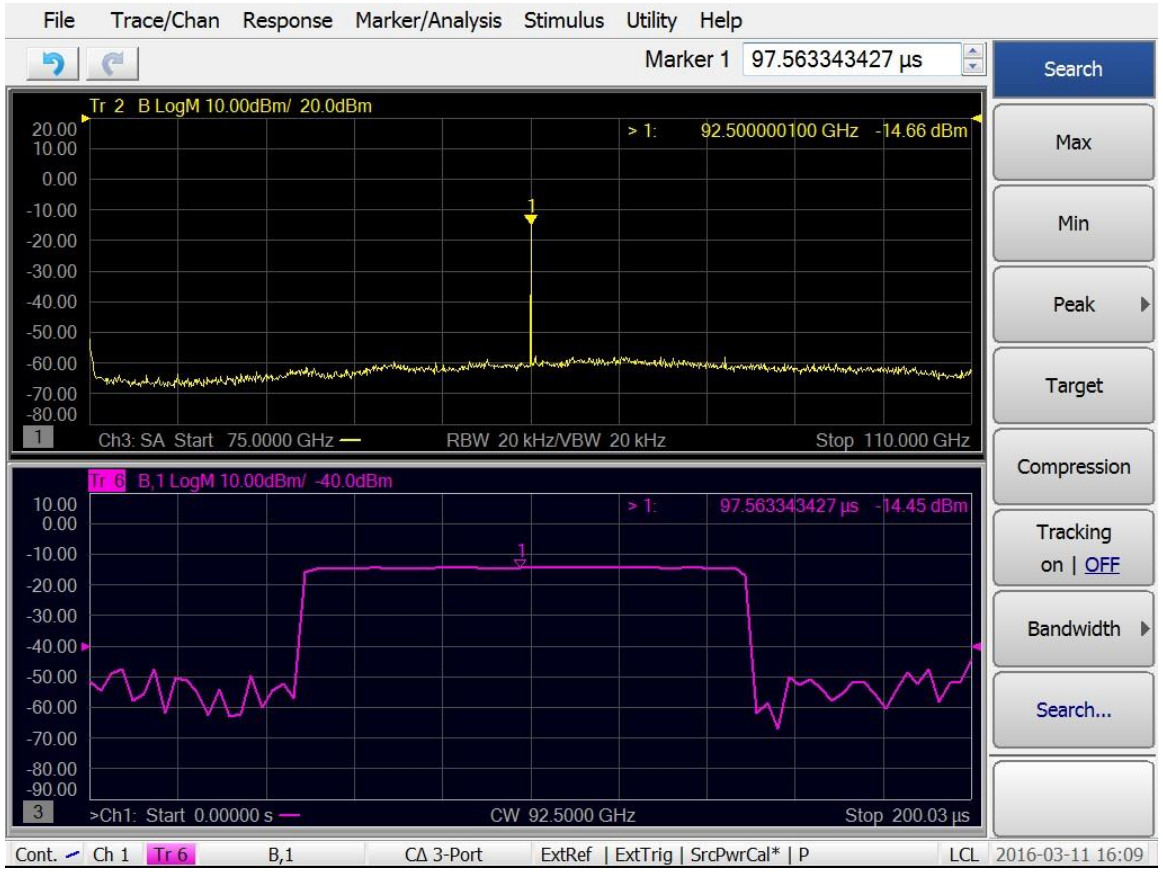


Port 1 : 91.5 to 92.5 GHz , -15 dBm
Port 3 : 92.5 to 93.5 GHz, -15 dBm

Integrated Stimulus Response Spectrum Analysis

Understanding Pulse Spectral Behavior

Utilize the pulse gated spectrum analysis to understand low power DUT behavior



Pulsed Modulated 92.5 GHz Spectrum

Key Software Application

Noise figure measurements

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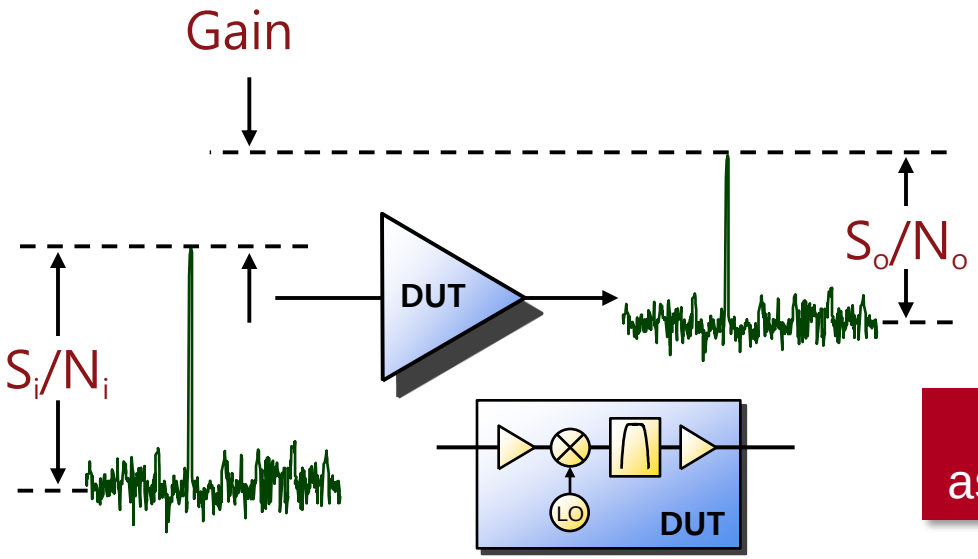
Noise Figure Definition

Noise figure is defined in terms of SNR degradation:

$$F = \frac{(S_i/N_i)}{(S_o/N_o)} = \frac{(N_o)}{(G \times N_i)} = \frac{N_a + kT_oBG}{kT_oBG} \quad \text{(noise factor)}$$

$$NF = 10 \times \log (F) \quad \text{(noise figure)}$$

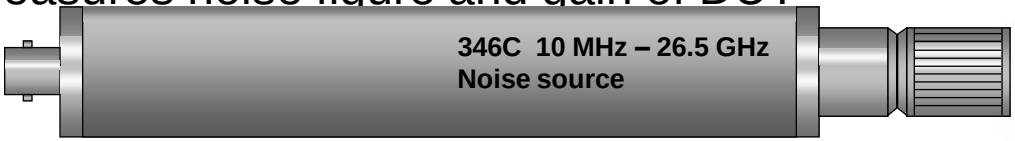


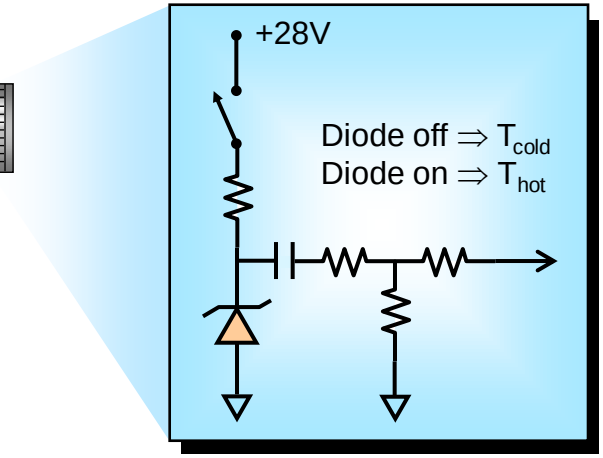
Test system is assumed to be 50 Ω

Noise Figure Measurement Techniques

– Y-factor (hot/cold source)

- Used by NFA and spectrum-analyzer-based solutions
- Uses noise source with specified “excess noise ratio” (ENR)
- Measures noise figure and gain of DUT





Excess noise ratio (ENR) = $\frac{T_{hot} - T_{cold}}{290K}$

– Cold source (direct noise)

- Used by vector network analyzers (e.g. PNA-X)
- Uses cold (room temperature) termination plus separate gain measurement
- Allows single-connection S-parameters and noise figure (and more)
- More advanced error correction yields higher measurement accuracy

Y-factor and cold source positioning

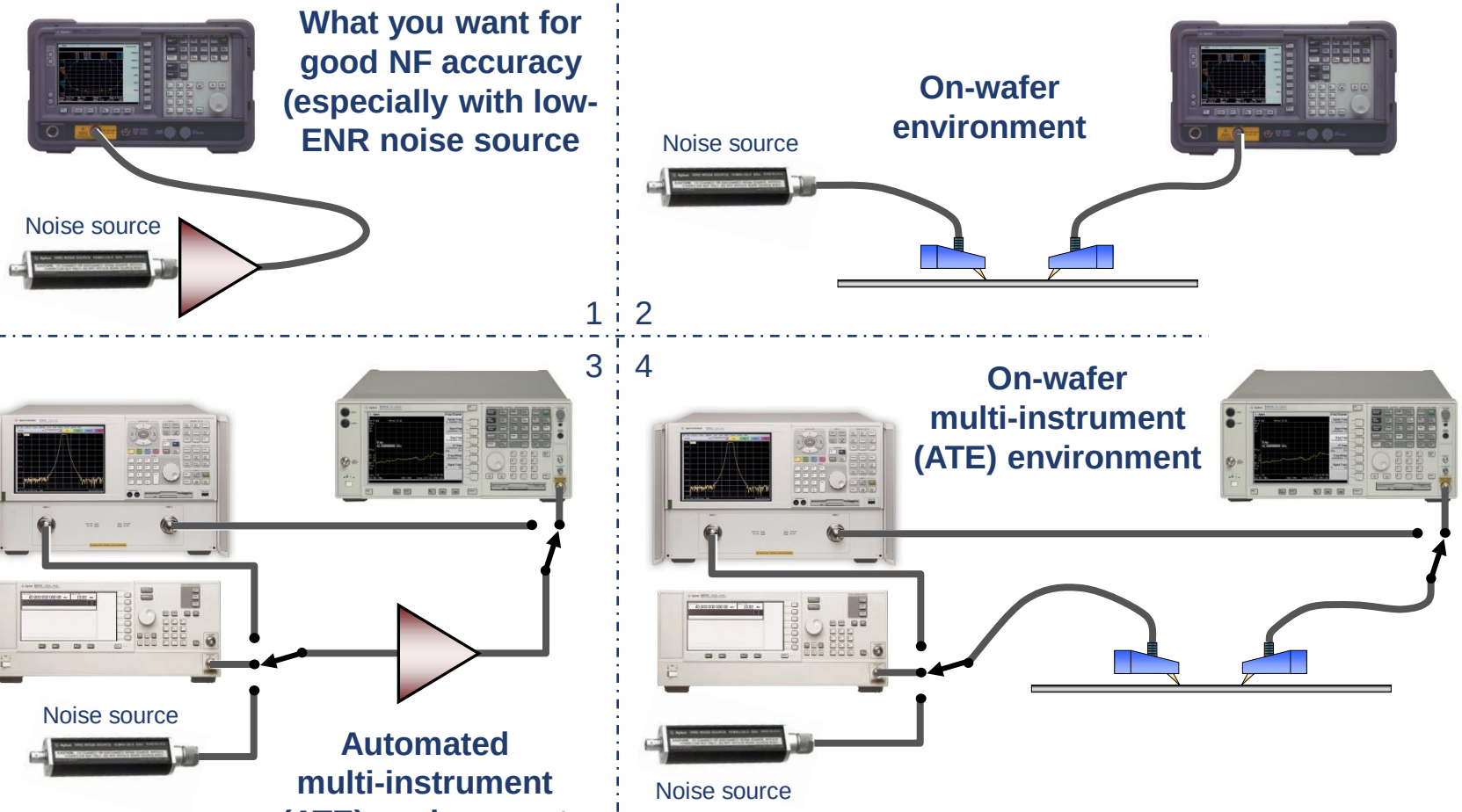
Y-factor method provides cost-effective and accurate noise figure measurements for many devices

- Excellent measurement accuracy when using low-ENR noise sources connected directly to DUT
- Measurement uncertainty usually increases if these conditions cannot be met
- Has been considered as industry standard for the NF measurement

Keysight cold source uses more advanced error-correction methods

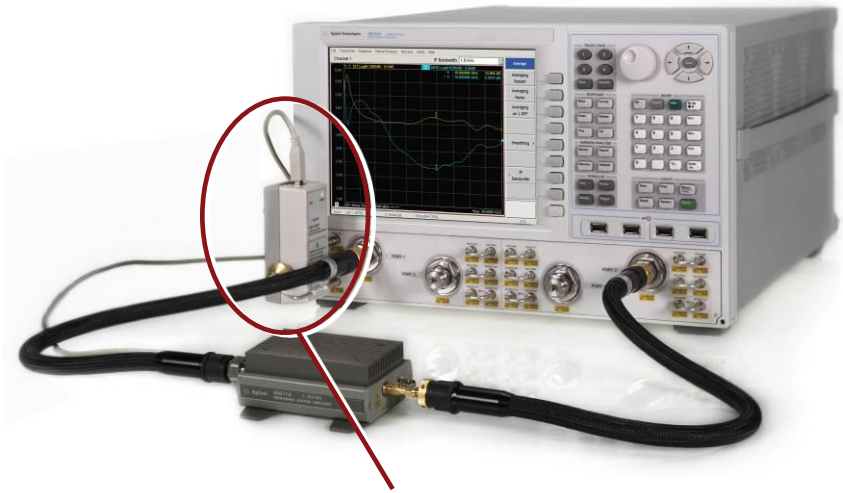
- Provides excellent accuracy in all cases, and for the widest variety of devices
- Especially useful for in-fixture, on-wafer, or automated-test environments, where Y-factor measurement uncertainty is often significantly higher
- Also has measurement speed advantage

Noise Figure Measurements with Y-Factor Method

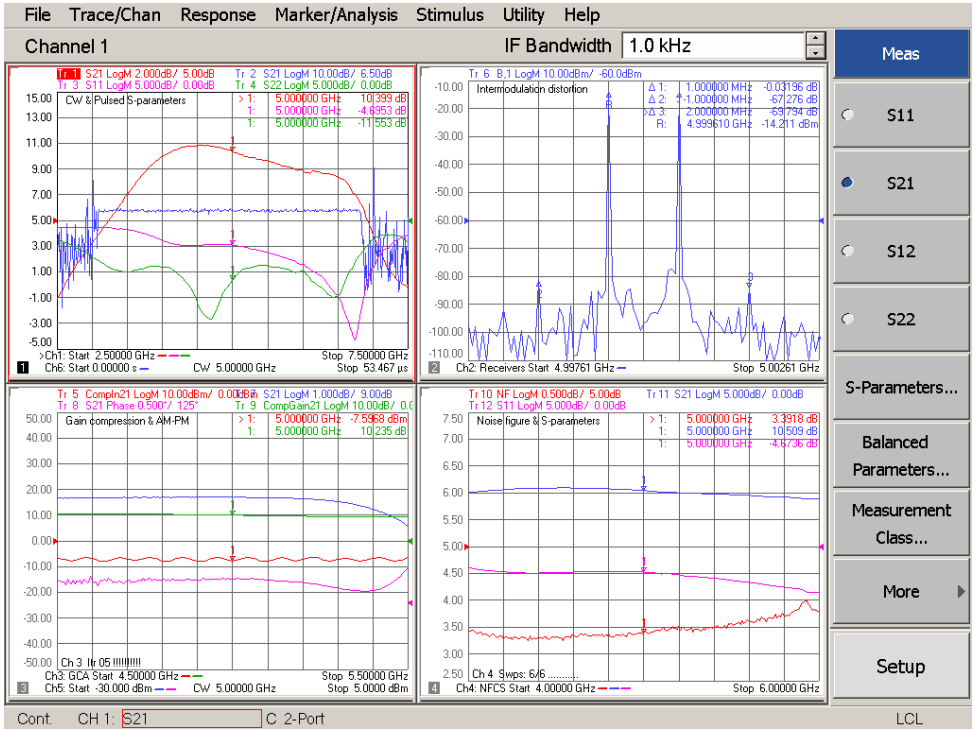


Any electrical network between noise source and DUT degrades accuracy

Noise Figure Measurement Options 028, 029 / S93029A



ECal module used as an impedance tuner removes the effects of imperfect system source match*



– Measure key amplifier parameters up to 50 GHz with a **single connection**

– Achieve the **highest measurement accuracy** of any solution on the market

– Typically 4 to 10 times **faster** than the NFA

– Works on amplifiers, and frequency converters with external or embedded LOs

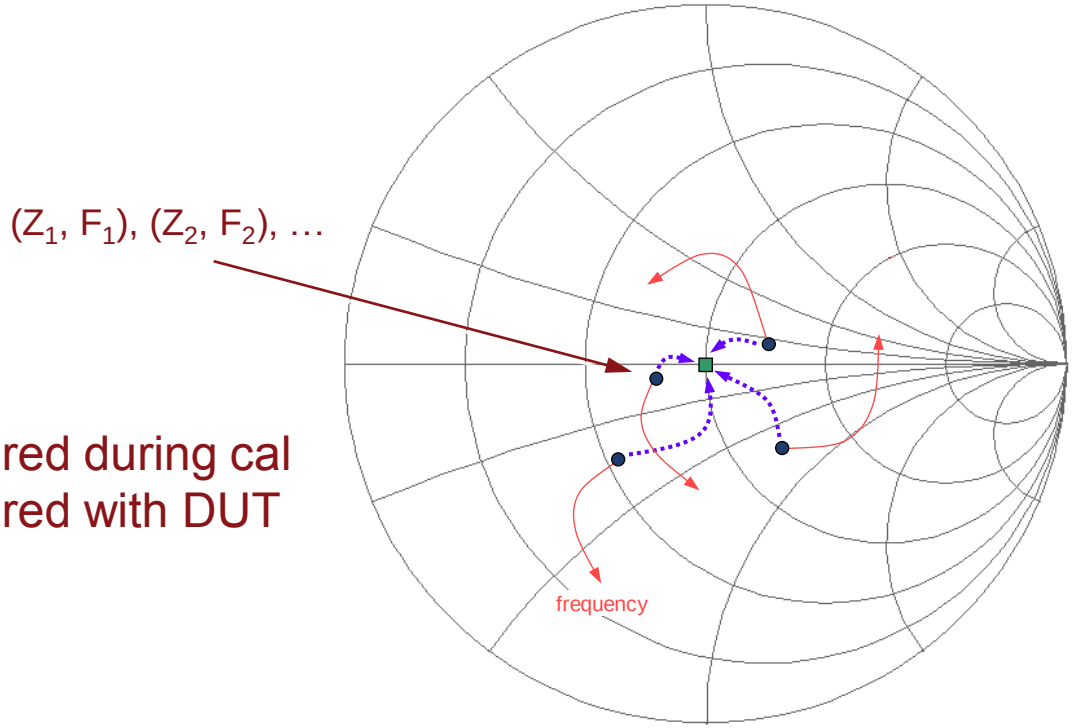
* External ECal required for 8.5/13.5/26.5 GHz units with Option 029, or any unit with Option 028. Internal tuner is standard for 43.5/50/67 GHz units with Option 029.

PNA-X's Unique Source-Corrected Technique

Vector Noise Calibration (VNC)

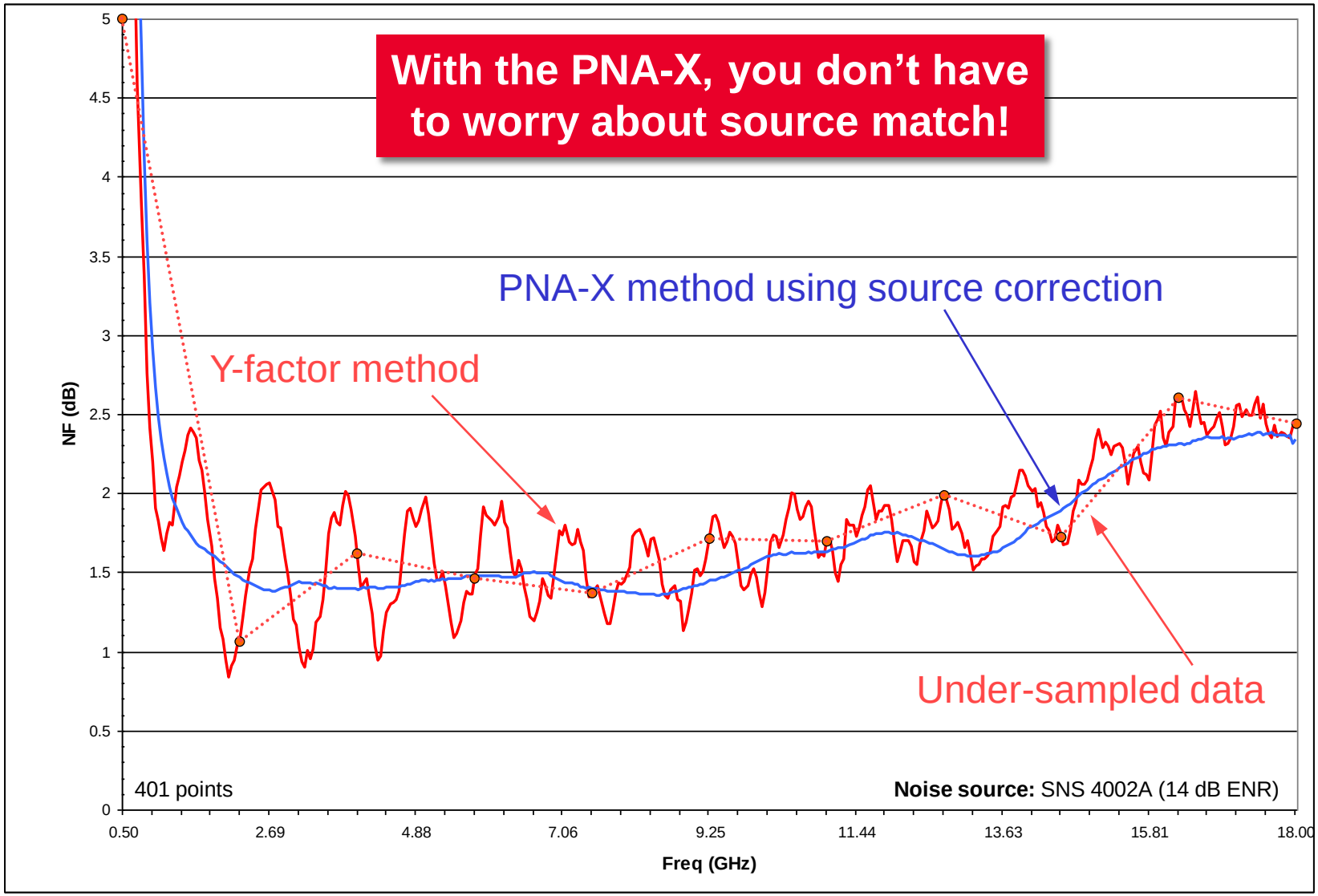
– PNA-X varies source match around 50 ohms using an internal or external ECal module (source-pull technique)

– With resulting impedance/noise-figure pairs and vector-error terms, very accurate 50-ohm noise figure can be calculated versus frequency



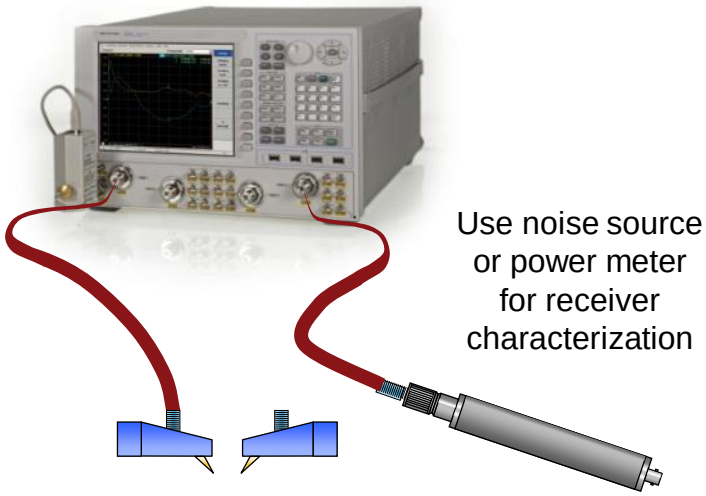
Z's measured during cal
F's measured with DUT

Example NF Measurements of Unmatched Device

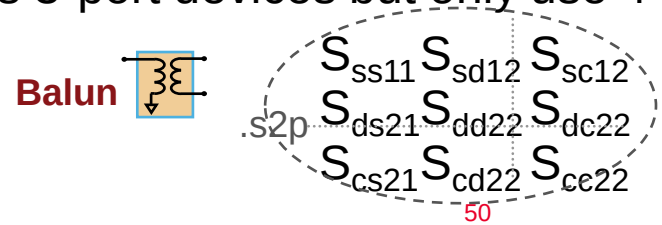


Cold Source Measurement Science

Calibration



- Calibration requires standard S-parameter error coefficients plus noise-receiver characterization
- Noise receiver can be characterized using a noise source or power meter
- On-wafer calibration
  - Choice 1: Use Calibration Wizard (or Cal All Channels) to combine coaxial and on-wafer calibration (noise receiver characterization requires coaxial standard)
  - Choice 2: Calibrate completely with coaxial standards and de-embed wafer probes (s2p files for probes can be obtained from Cal Plane Manager feature)
  - Choice 3: Merge WinCal and PNA-X coaxial noise calibration for higher accuracy
- Differential devices require de-embedding of baluns or hybrid couplers with s2p files (measure baluns as 3-port devices but only use 4 single-ended, differential terms)



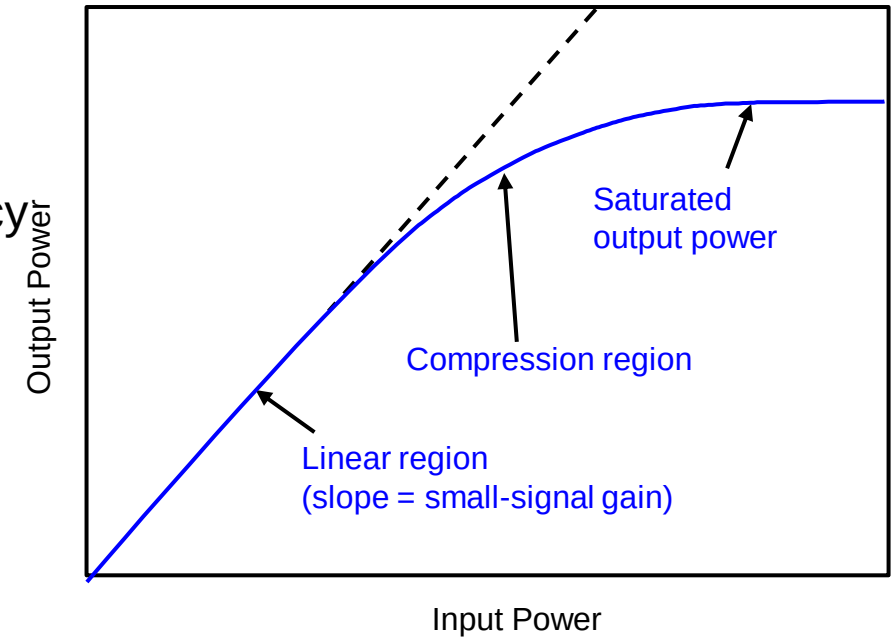
Key Software Application

Gain-compression measurements

SW Appl.	Description
S93007A	Automatic Fixture Removal[1]
S9309xxA	Spectrum analysis (up to 90 GHz)
S93093A	Spectrum analysis up to 120 GHz
S93094A	Spectrum analysis beyond 120 GHz
S93029A	Noise figure measurements[1,2]
S93086A	Gain-compression measurements [1]
S93087A	Intermodulation Distortion Measurements
S93082A	Scalar mixer/converter measurements[1]
S93083A	Vector mixer/converter measurements[1]
S93089A	Differential I/Q device measurements

What is Gain Compression?

- An industry-wide figure-of-merit that indicates the crossover point between linear and nonlinear operation
- Defined as the input or output power that causes DUT gain to drop by specified amount (usually 1 dB)
- Simplest measure of nonlinearity
  - Uses one signal at input
  - Only measures fundamental frequency at output (harmonics are ignored)
  - Easily measured with a VNA using a power sweep

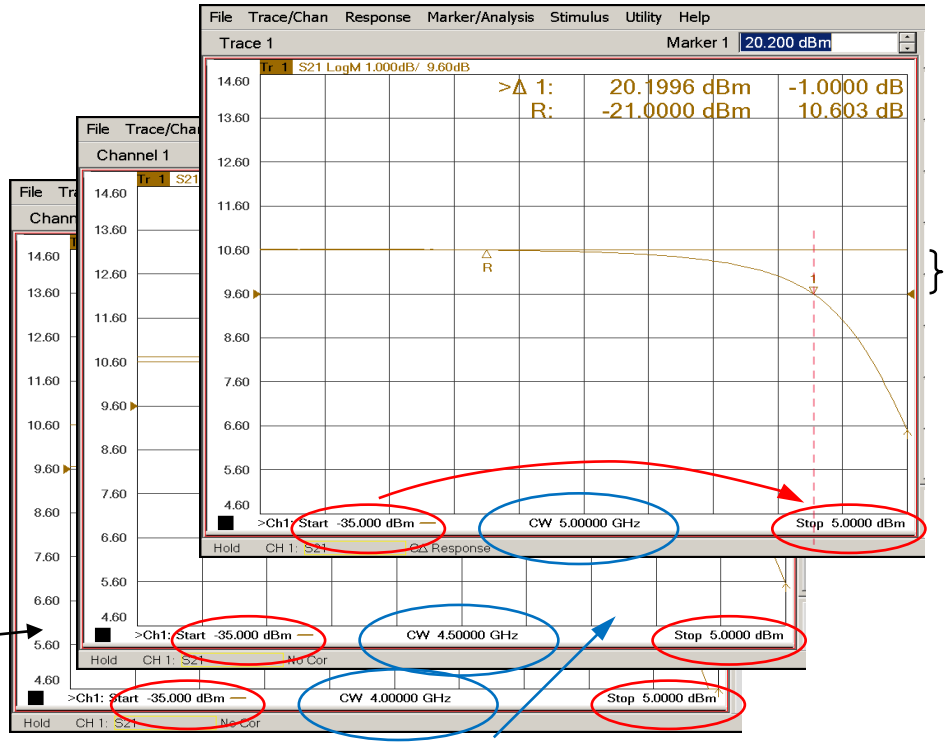


Gain Compression Application (GCA)

Option 086 / S93086A

GCA provides **fast** and **accurate** amplifier and converter gain-compression data, at **multiple frequencies**, with a **simple setup**

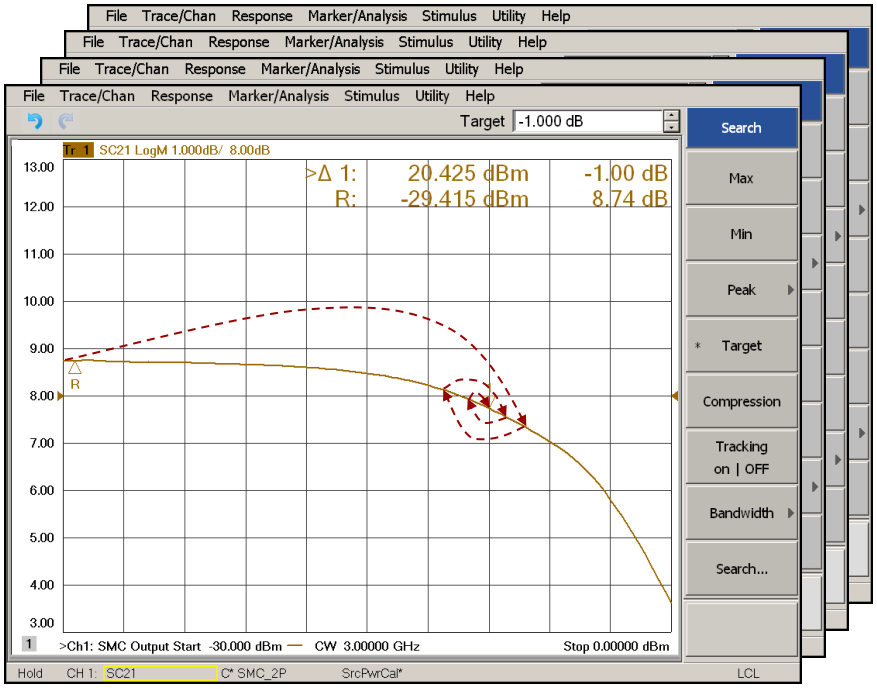
- Measure many times faster than current methods with GCA's **SMART Sweep**
- Achieve the highest measurement accuracy of any solution in the market by using **match-corrected** power measurements with specified tolerance
- Works on amplifiers, and frequency converters with external or embedded LOs



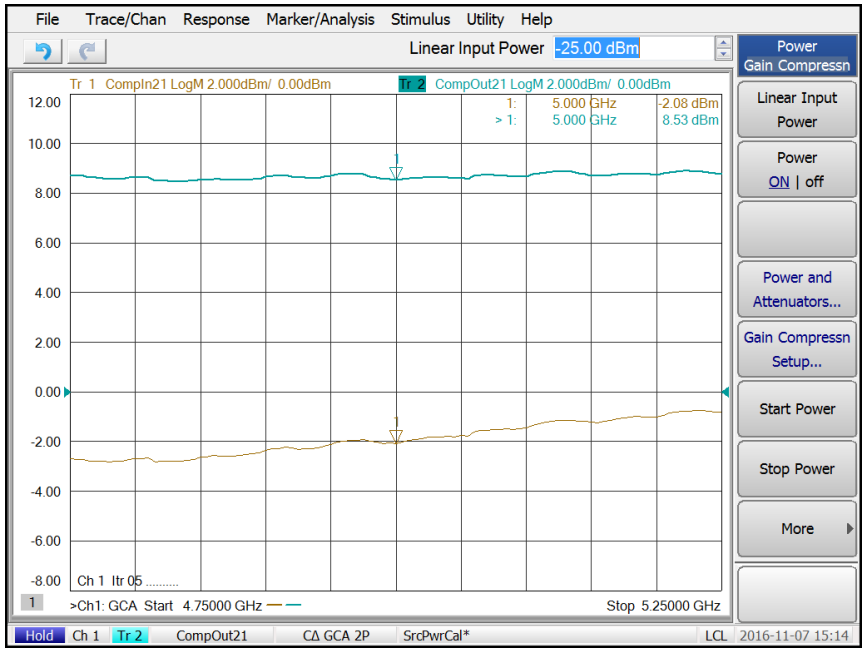
Gain compression is typically a 2-D measurement: swept power + swept frequency

GCA's SMART Sweep: A Better Way!

- Iterates input power in a smart way to find compression point faster than a linear power sweep
- Takes fewer (but smarter) data points
- Utilizes a curve-fitting algorithm to estimate compression point to decrease number of iterations

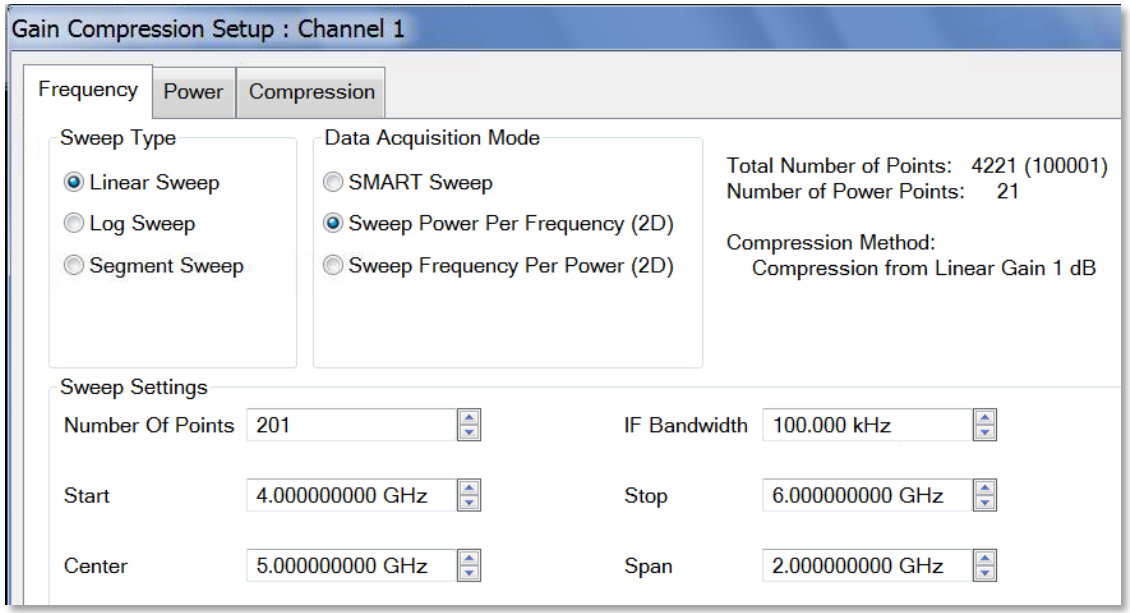


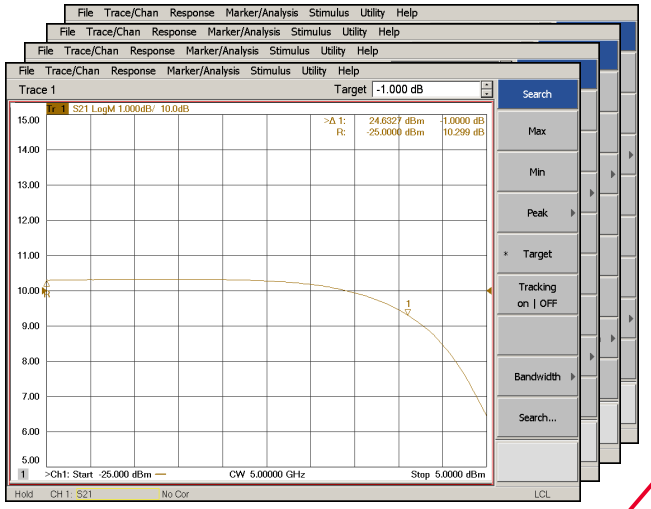
GCA SMART Sweep concept



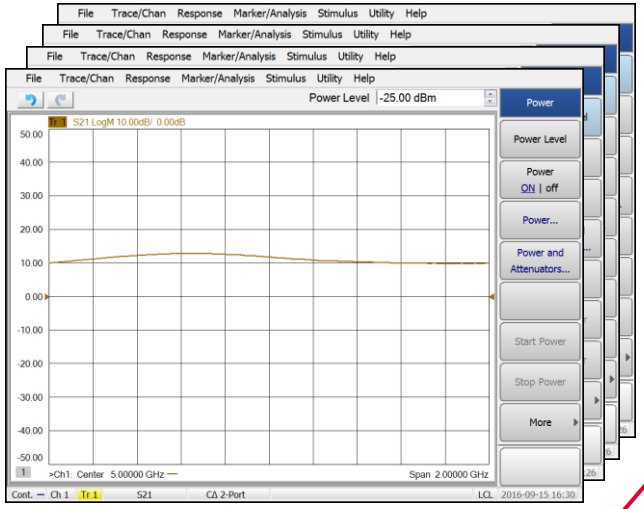
GCA results: compression versus frequency

Traditional Two-Dimensional (2D) Sweeps Also Available



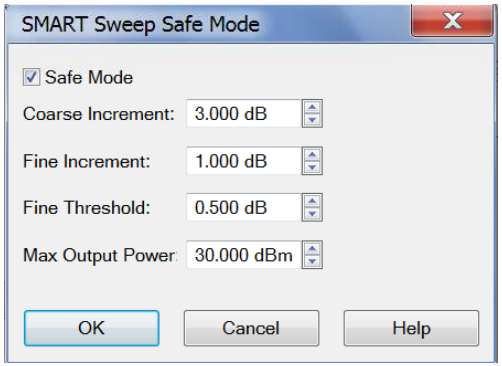


Power → Frequency

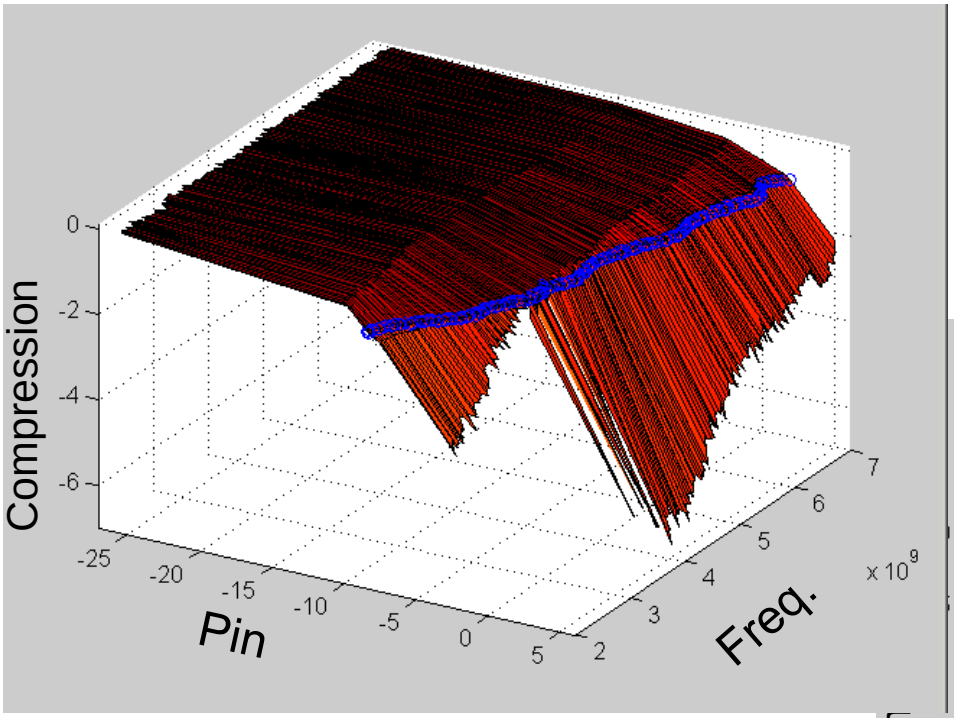


Frequency → Power

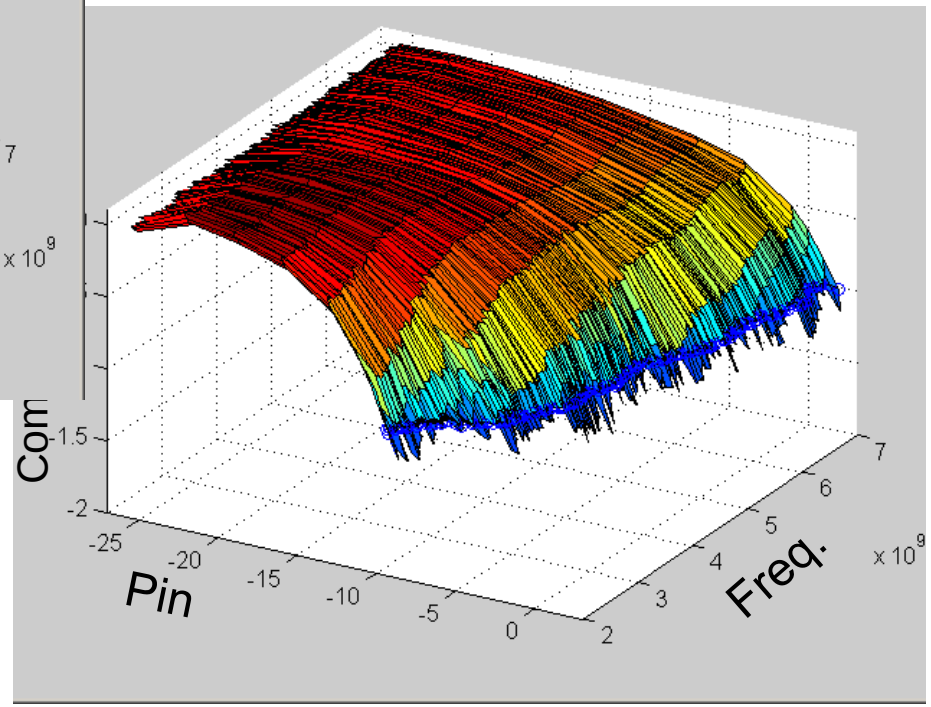
Safe-Mode Algorithm Prevents Overdriving DUT



Safe Mode Off

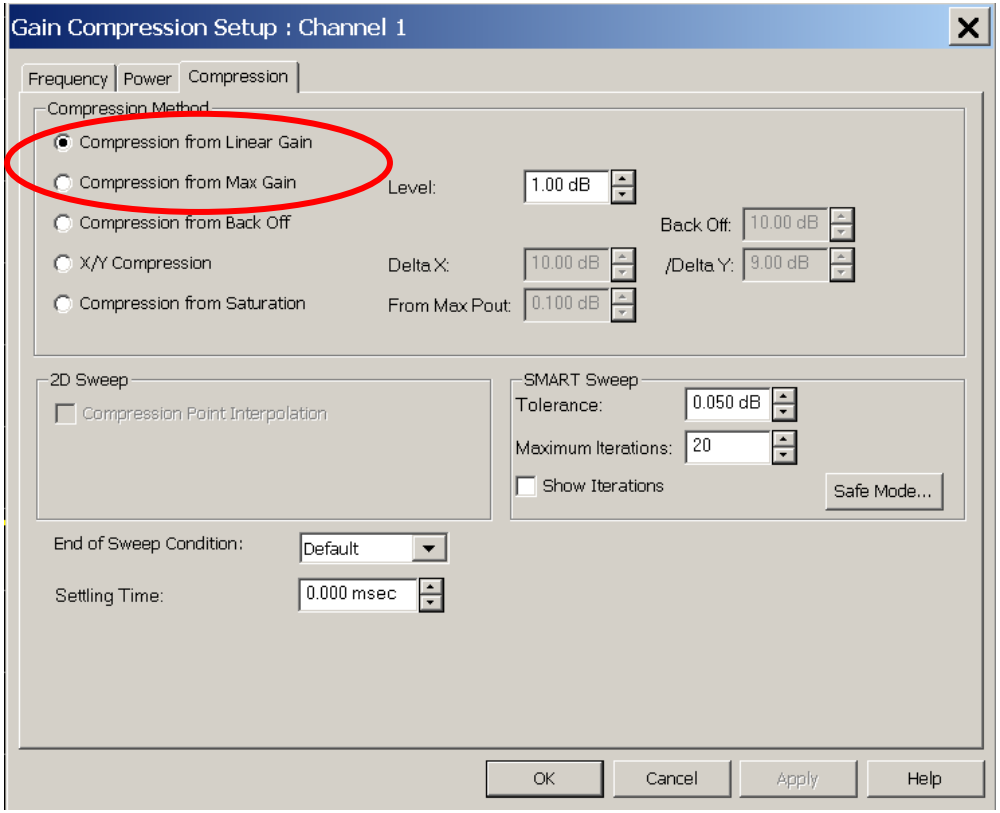


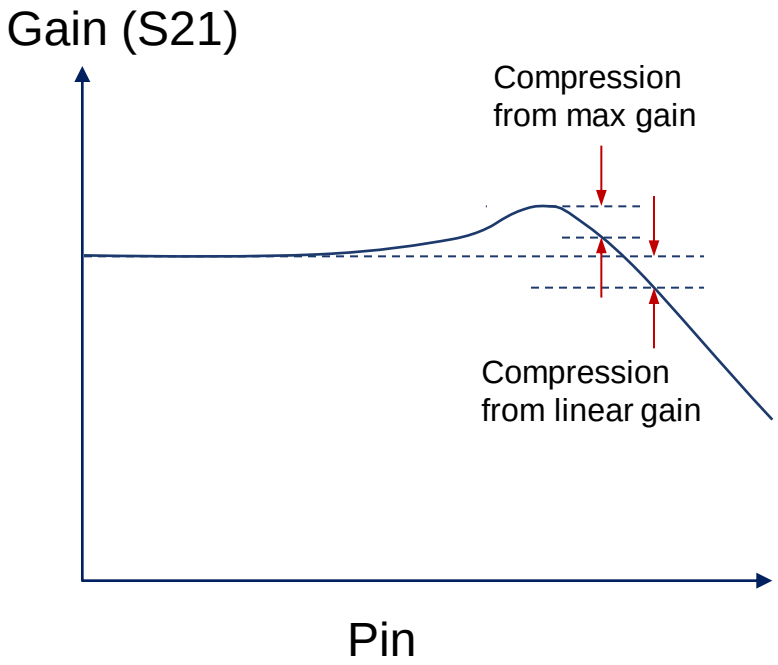
Safe Mode On



Safe Mode prevents overdriving the DUT, but is slower than normal mode (more data points are needed)

Gain Compression Methods

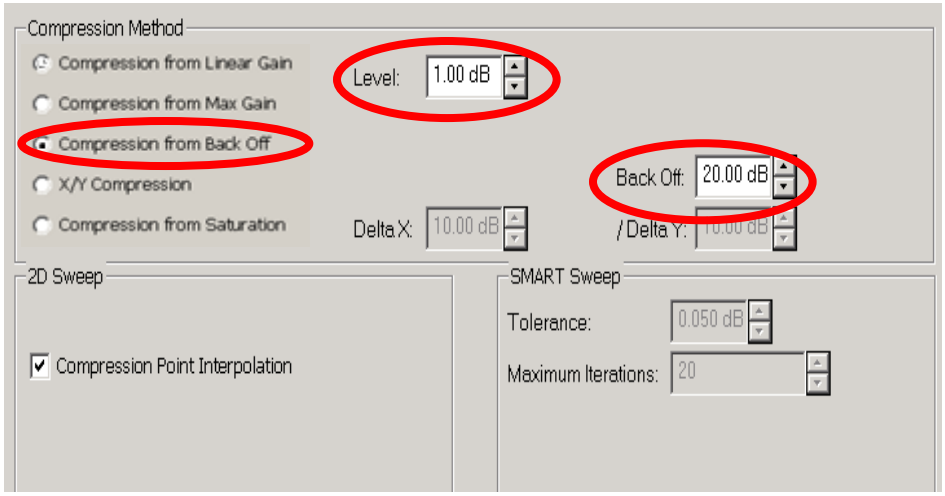




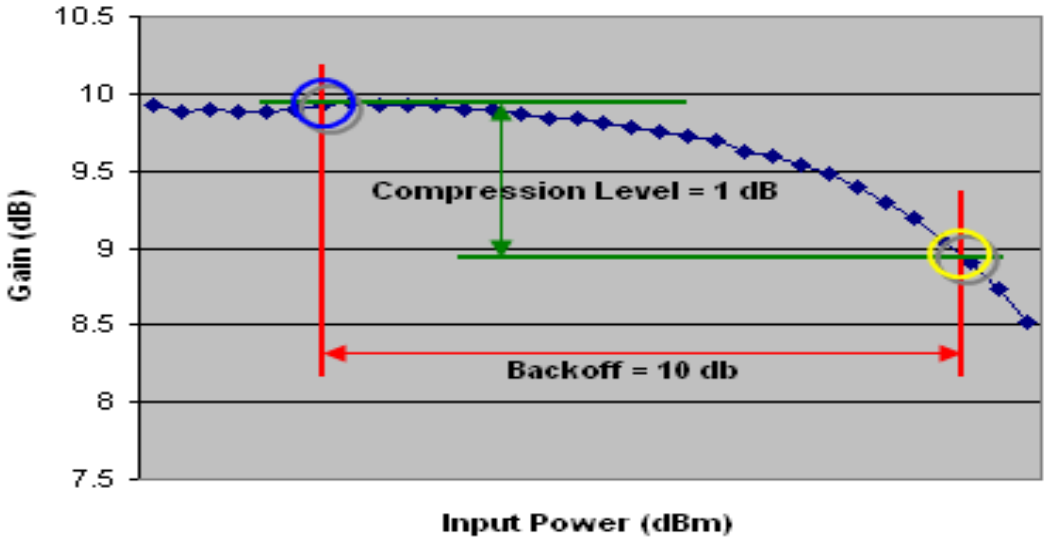
Compression From Back-off

Uses gain versus input power data array

- Starting from max input power, looks for pair of data points where the delta input power (back-off level) gives the desired compression
- If multiple pairs fit this criteria, pair with highest input power is used
- Works for 2D and SMART sweep



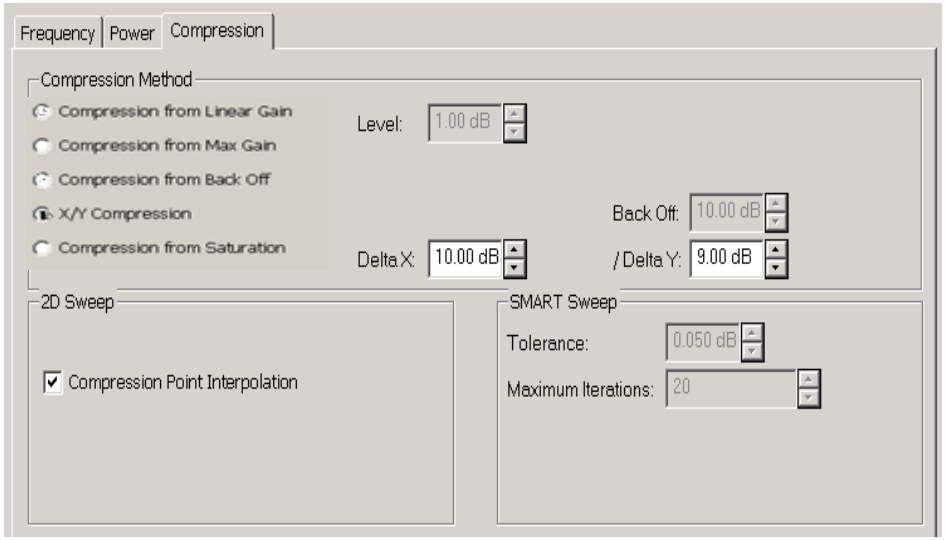
Backoff Method

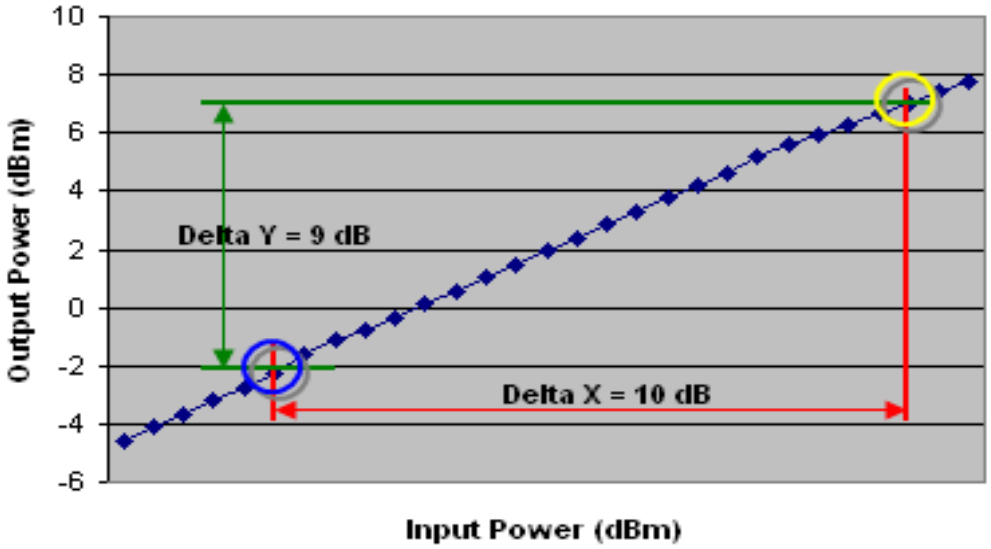


X-Y Compression

Uses output power versus input power data array

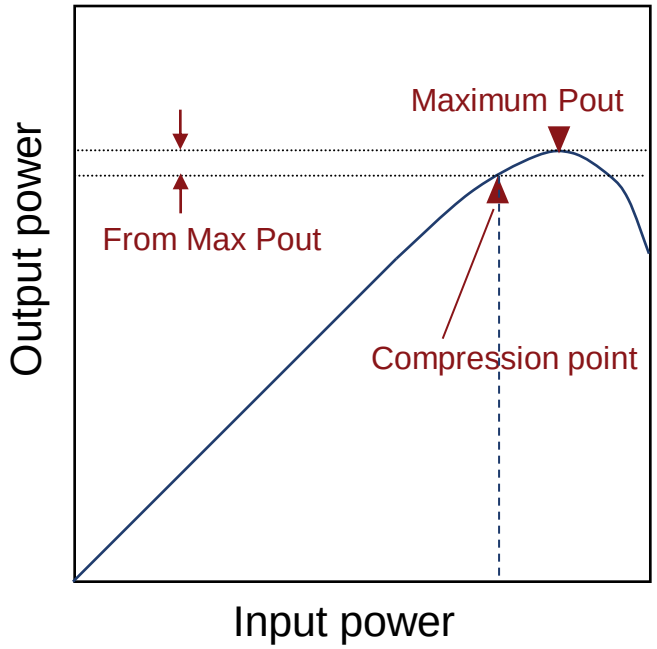
- Starting from max input power, looks for pair of data points where the delta X and delta Y match the specified values
- If multiple pairs fit this criteria, pair with highest input power is used
- Works for 2D and SMART sweeps

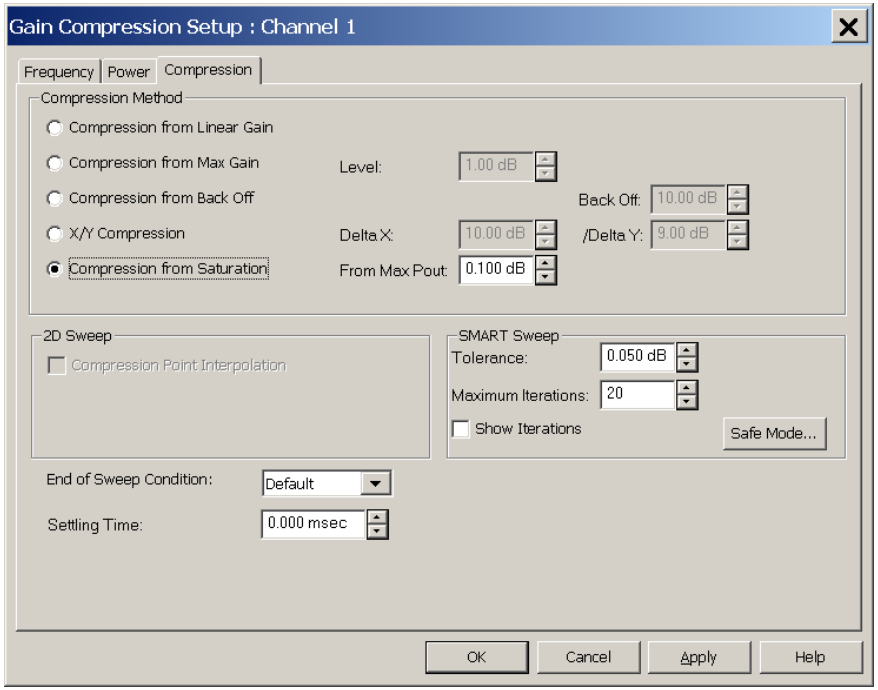




Compression from Saturation

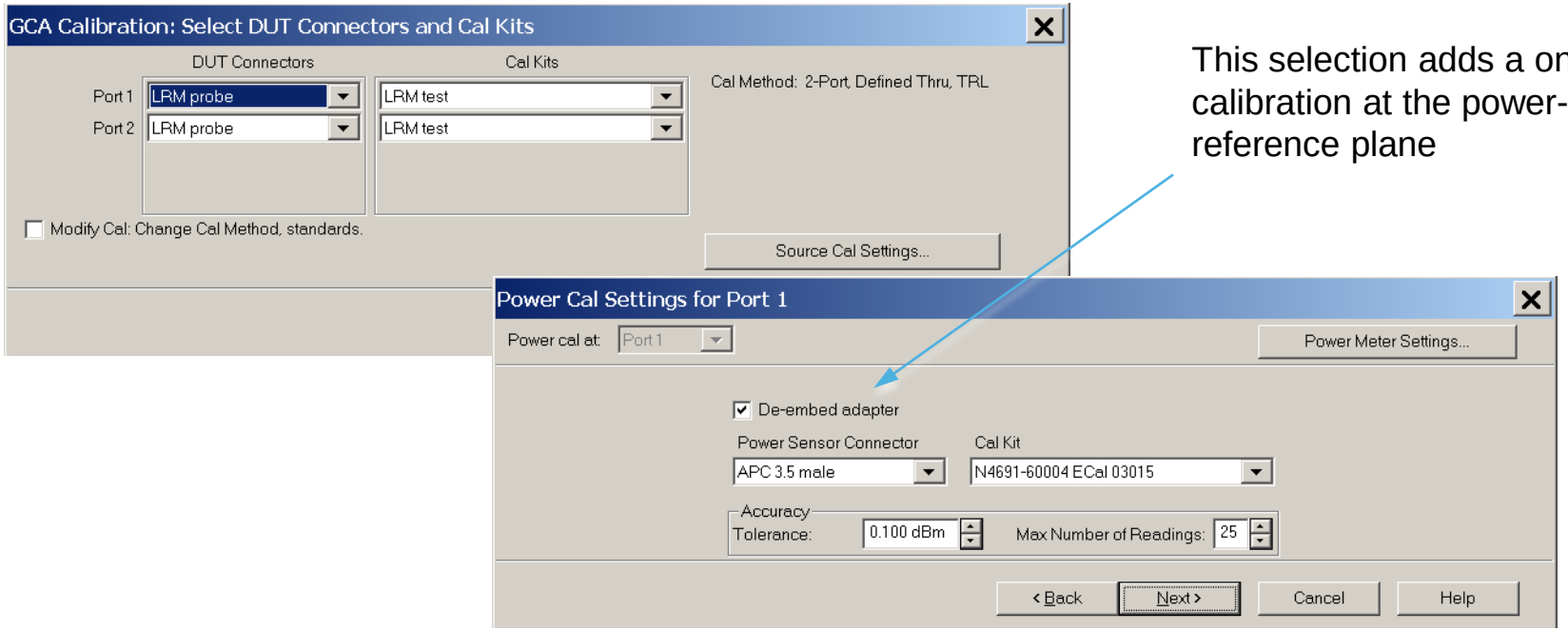
- Defined by the point that is lower from the max output power by a specified value
- Works for 2D and SMART sweeps





GCA Calibration

- Combines source power calibration (using a power meter) with S-parameter calibration, using a guided Calibration Wizard
- All receivers are calibrated for absolute power measurements
- On-wafer calibration: alignment of power sensor and wafer probe calibration planes is automatic (no need for s2p files)



This selection adds a one-port calibration at the power-sensor reference plane

Key Software Application

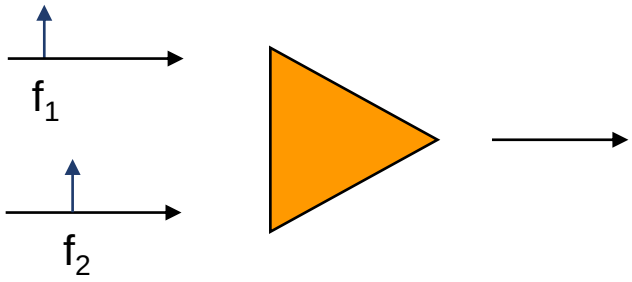
Intermodulation Distortion Measurements

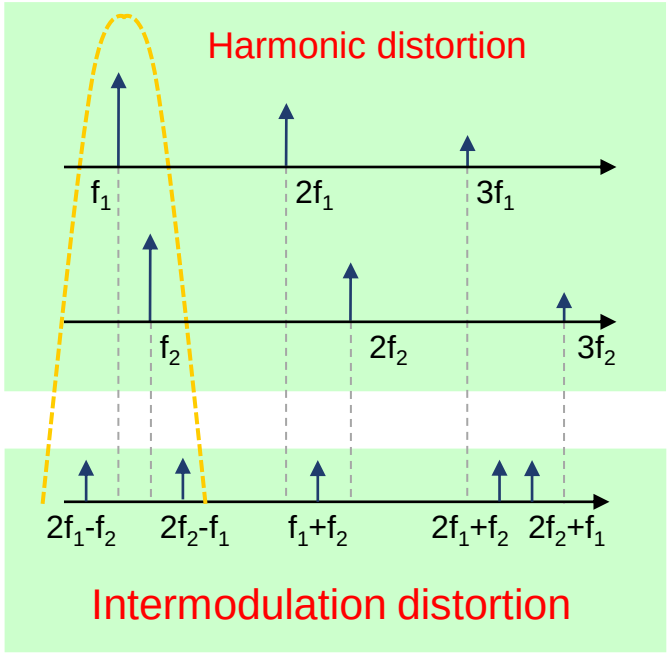
SW Appl.	Description
S93007A	Automatic Fixture Removal[1]
S9309xxA	Spectrum analysis (up to 90 GHz)
S93093A	Spectrum analysis up to 120 GHz
S93094A	Spectrum analysis beyond 120 GHz
S93029A	Noise figure measurements[1,2]
S93086A	Gain-compression measurements[1]
S93087A	Intermodulation Distortion Measurements
S93082A	Scalar mixer/converter measurements[1]
S93083A	Vector mixer/converter measurements[1]
S93089A	Differential I/Q device measurements

What is IMD?

– Provides a more-sophisticated look at device nonlinearity than gain compression or harmonics
  - Uses two signals at input
  - Measures multiple signals at output (usually odd order)

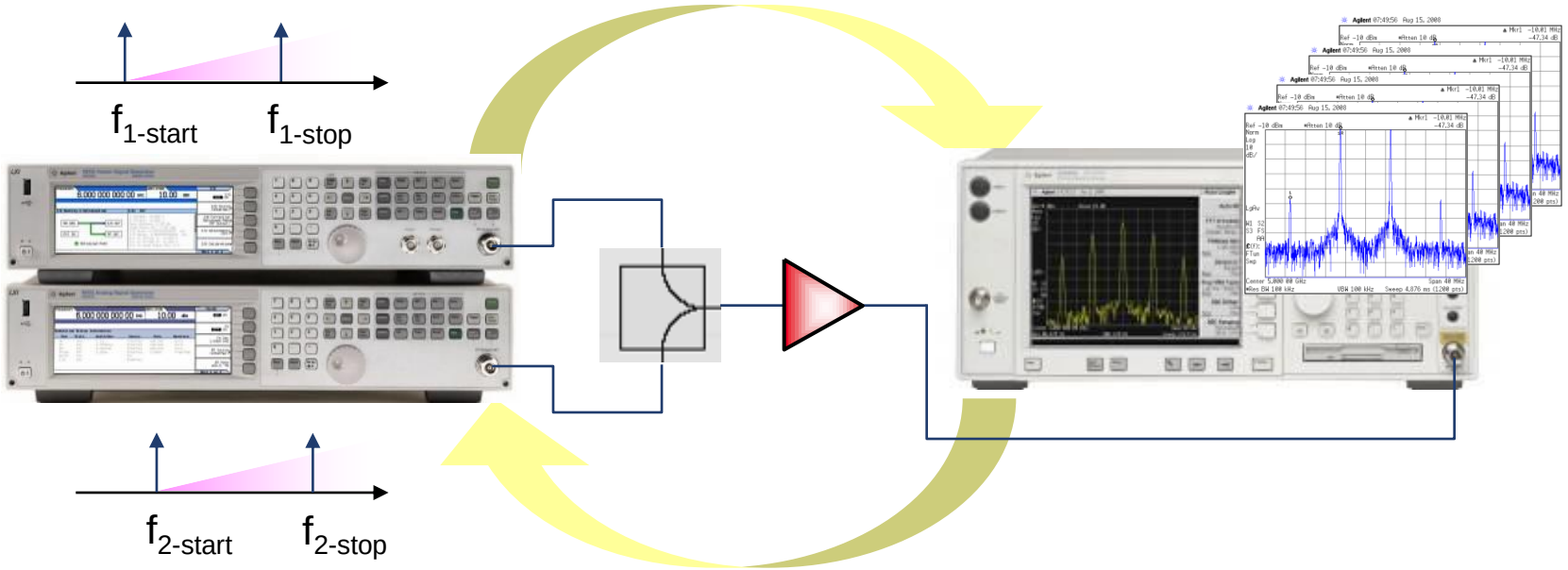
– Shows in-band distortion performance than cannot be fixed by adding harmonic filters





Traditional Approach For CW and Stepped IMD

Use separate signal sources, combiner, and spectrum analyzer



- Takes a long time to measure many frequency or power points
- Inefficient: data between desired spectral products is discarded
- Requires a program to synchronize instruments
- Separate network analyzer is required for S-parameter measurements

Swept IMD Application

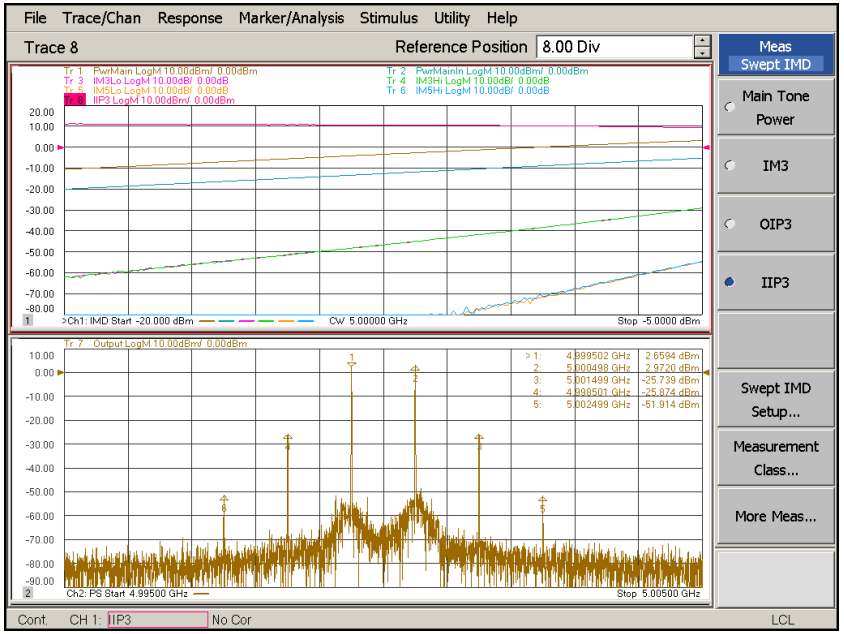
Option 087 / S93087A

– Provides **fast** and **accurate** IMD measurements by taking advantage of PNA-X's internal combiner, and two internal sources with high power and low harmonics

– Easy to set up and calibrate with **simple, flexible user interface**

- Measures tone powers, IMD products (dBm or dBc), and intercept points of order 2, 3, 5, 7, or 9
- Sweep center frequency, tone spacing, tone power, or LO power
- Includes simple SA mode for setting up and trouble-shooting measurements (not as fast as SA measurement class)

– Works on amplifiers, and frequency converters with external or embedded LOs



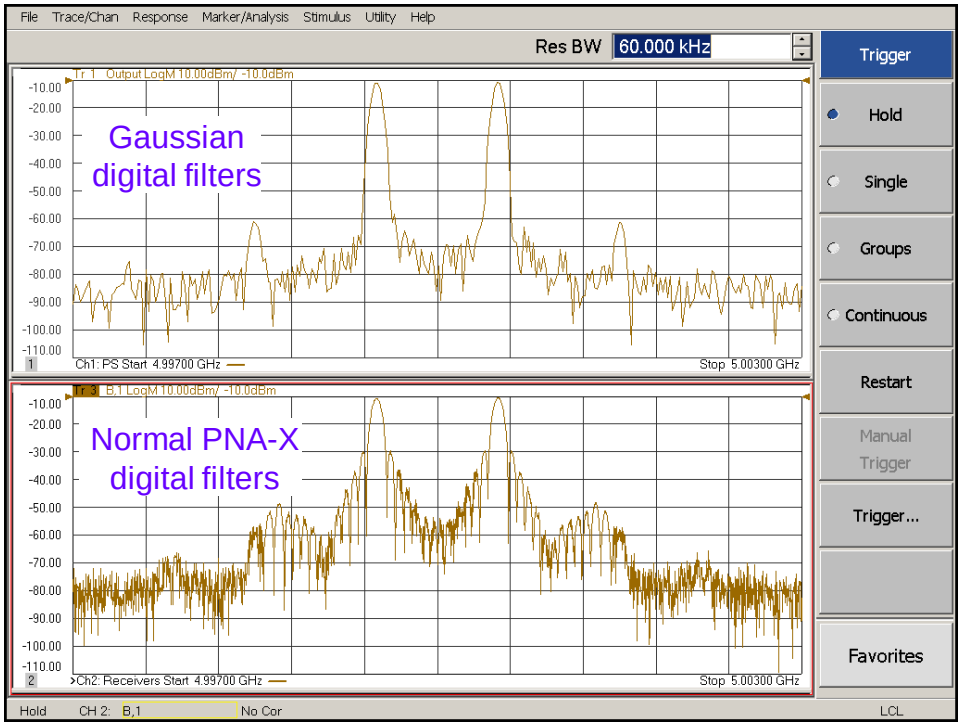
IM Spectrum Measurement Class

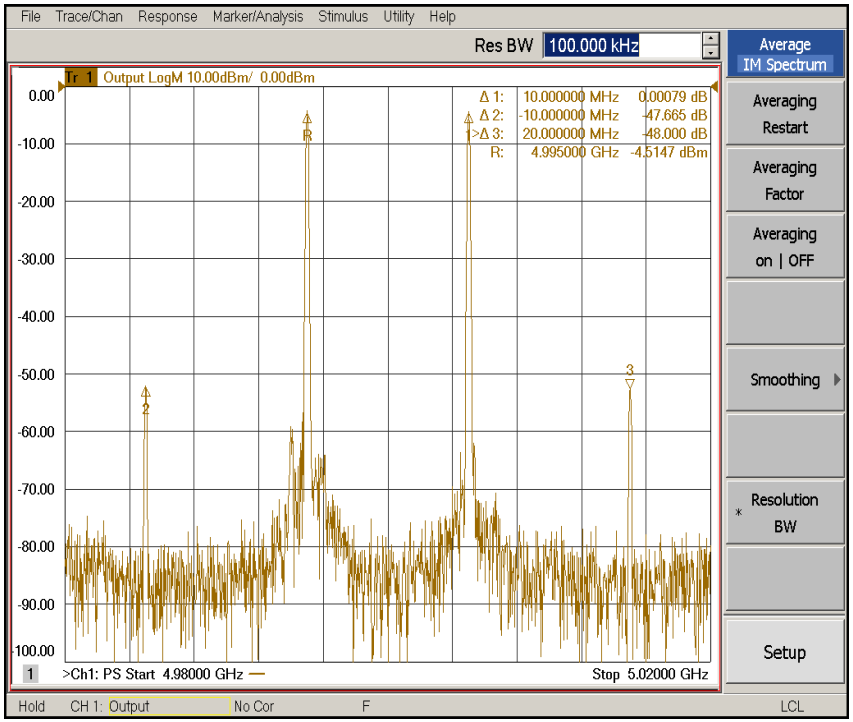
Original spectrum analyzer application

– Spectrum analyzer mode helpful to look at IM products or spurious signals

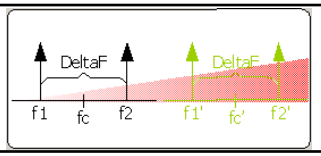
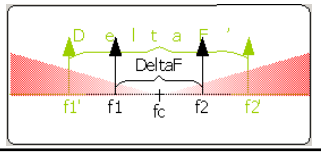
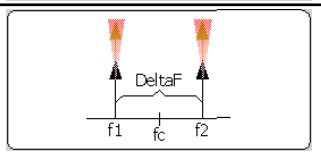
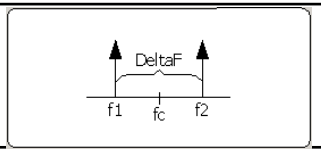
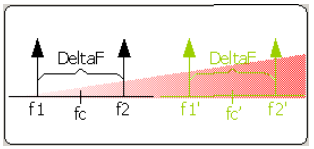
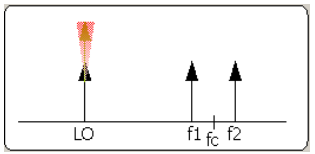
– Includes software preselection algorithm to eliminate image signals

– Gaussian filters provide good selectivity

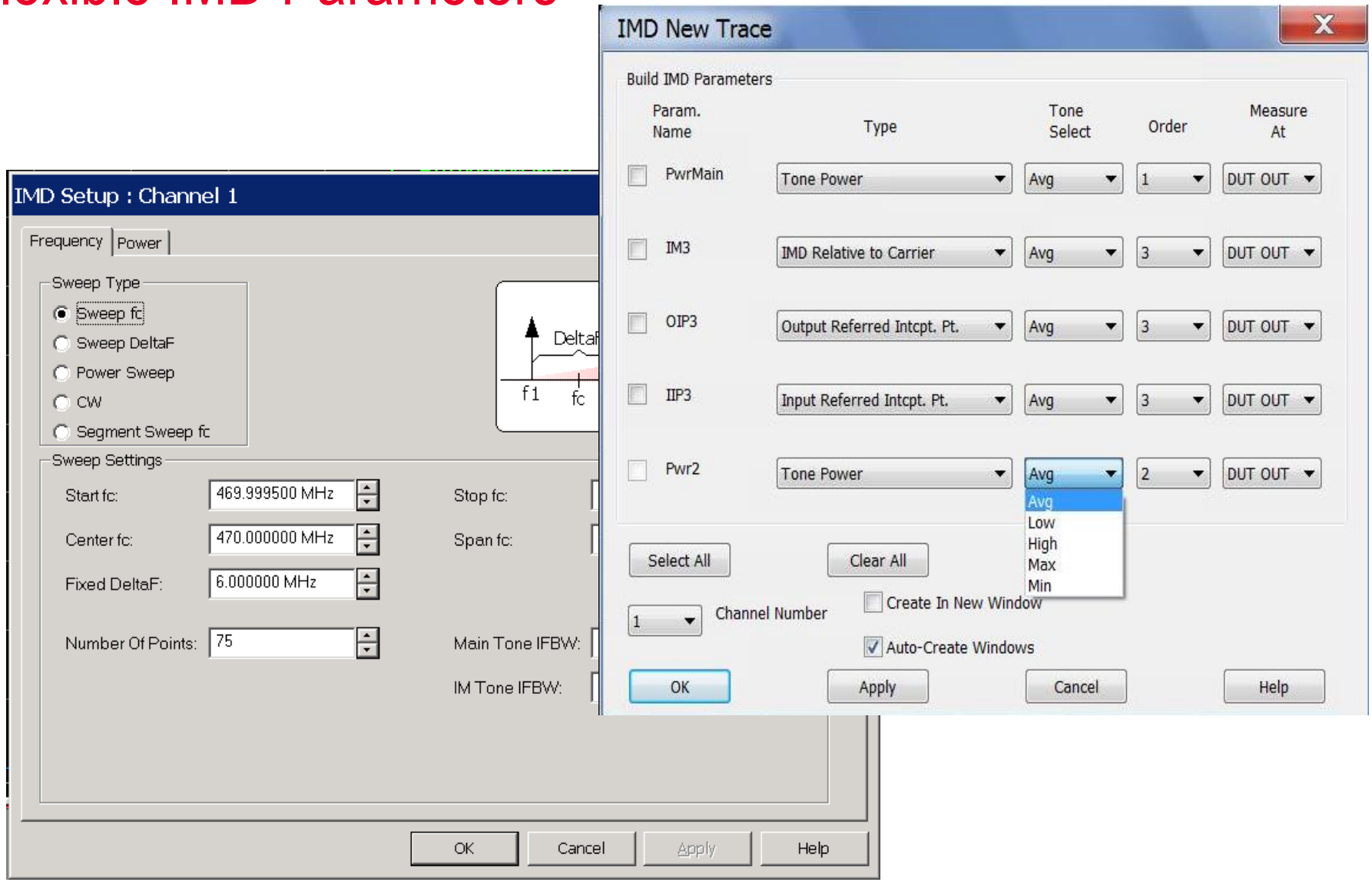




IMD Sweep Types

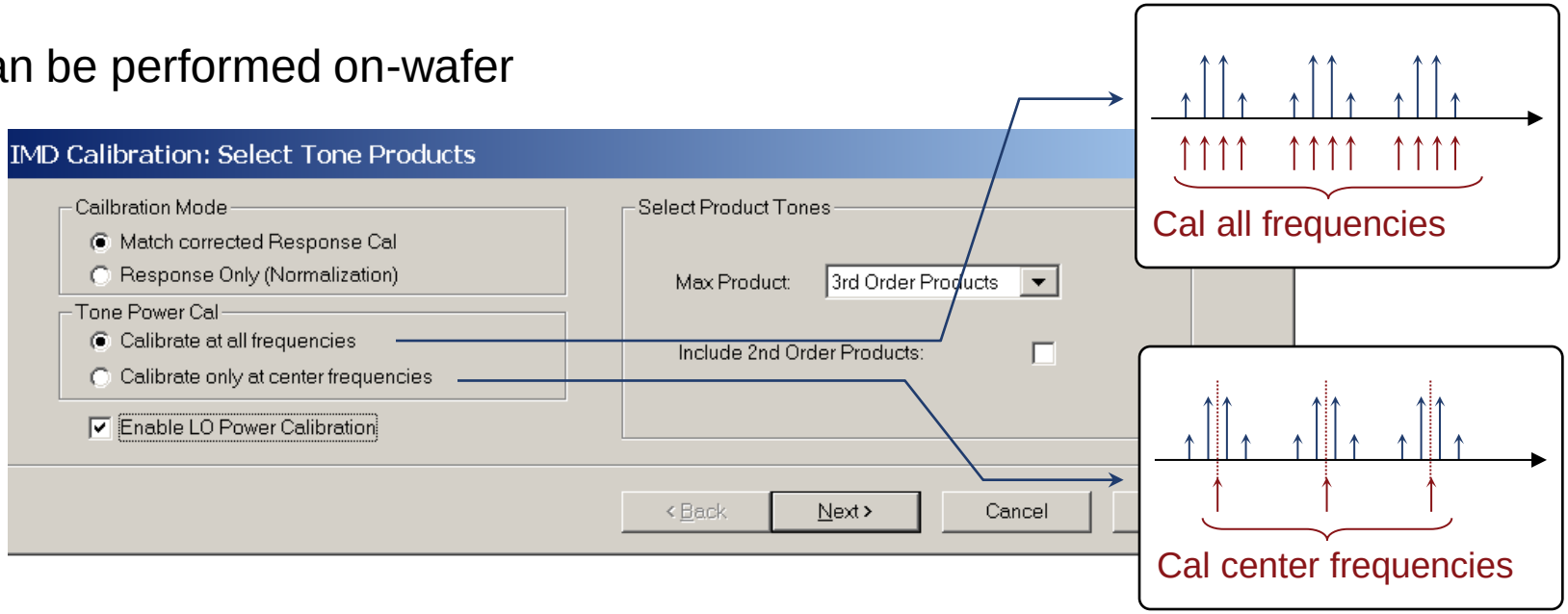
Sweep Type	Center frequency (Fc)	Tone spacing (DeltaF)	Tone Powers	LO	
Sweep Fc	Swept	Fixed	Fixed	N/A	
Sweep DeltaF	Fixed	Swept	Fixed	N/A	
Power Sweep	Fixed	Fixed	Swept (Coupled or uncoupled)	N/A	
CW	Fixed	Fixed	Fixed	N/A	
Segment	Swept (as defined on segment table)	Fixed	Fixed	N/A	
LO (IMDx)	Fixed	Fixed	Fixed	Swept	

Flexible IMD Parameters



IMD Calibration

- Guided calibration wizard steps user through calibration steps
- Very similar to GCA calibration: requires power meter and S-parameter calibration
- A couple of choices are available to trade-off calibration time with accuracy
- Match correction only available during calibration, but not during measurement
- Also can be performed on-wafer



Key Software Application

mixer/converter measurements

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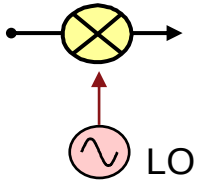
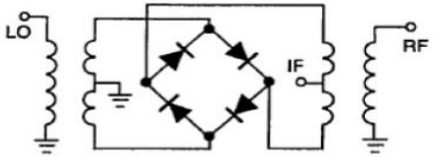
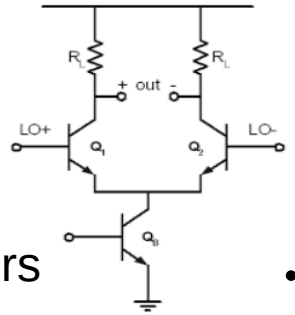
S93082A	Scalar mixer/converter measurements[1]
S93083A	Vector mixer/converter measurements[1]
S93089A	Differential I/Q device measurements

What are Mixers and Converters?

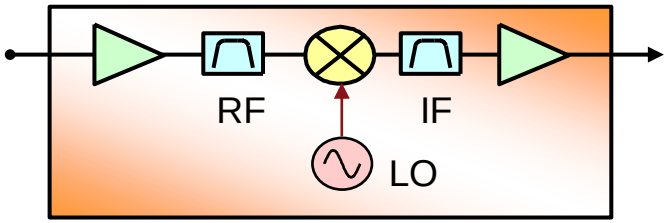
- Both provide frequency translation: $F_{out} \neq F_{in}$
- Used to translate from RF to IF (down convert) or IF to RF (up convert)
- Mixers
  - Can be passive (diodes and baluns) or active (e.g. Gilbert-cell)
  - Require an LO signal to switch diodes or transistors on and off
  - By definition, are non-linear components, but expected to behave linearly







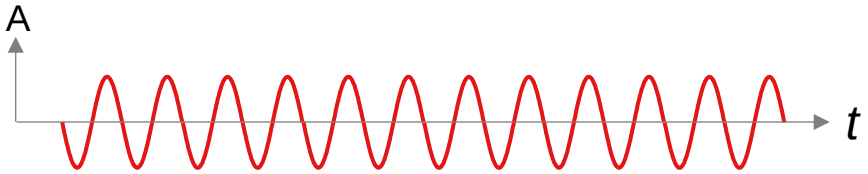
- Converters
  - Combine mixers, amplifiers and filters
  - May have single or multiple stages of conversion
  - May contain embedded LO(s)



- Both are integral components for satellite, radar, and EW systems
- Require similar tests: conversion loss/gain, group delay, port match, compression…

Understanding Phase Measurements

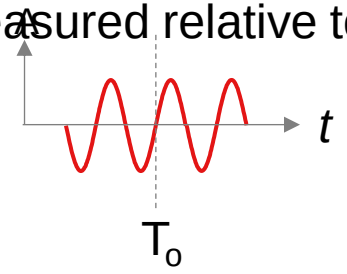
– What is the phase of this signal?

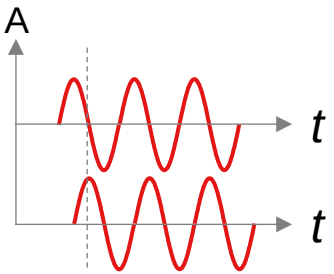


– Absolute phase doesn't exist!

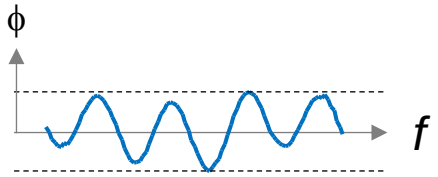
– Phase is always measured relative to something

- Time reference

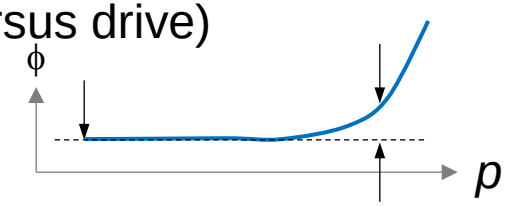




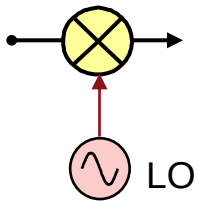
- Another signal of identical frequency (incident signal or from reference mixer)



- Straight line or parabola (e.g. deviation from linear phase)
- An arbitrary trace point (AM to PM conversion, phase versus drive)

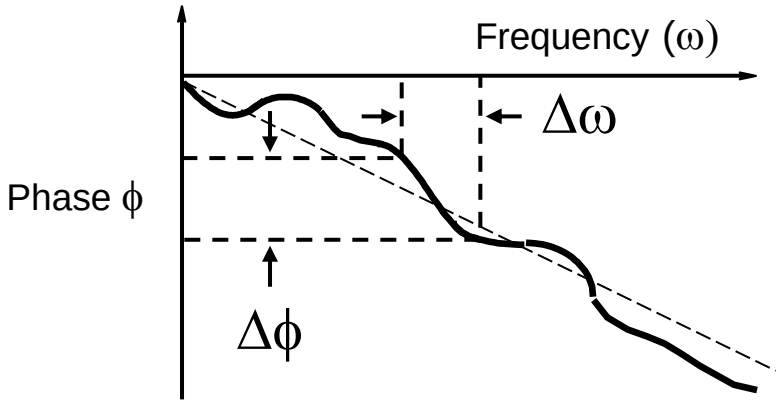


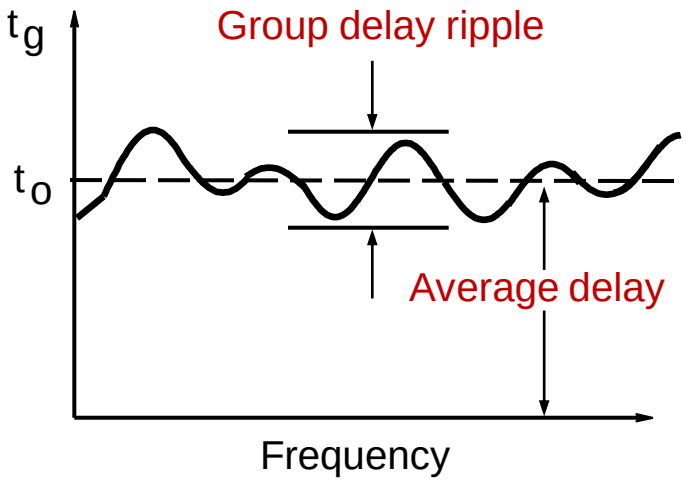
- Mixer output phase depends on phase of input and LO signals



Understanding Group Delay

Requires phase versus frequency





Group Delay (t_g) =

$$\frac{-d\phi}{d\omega} = \frac{-1}{360^{o}} * \frac{d\phi}{df}$$

ϕ in radians

ω in radians/sec

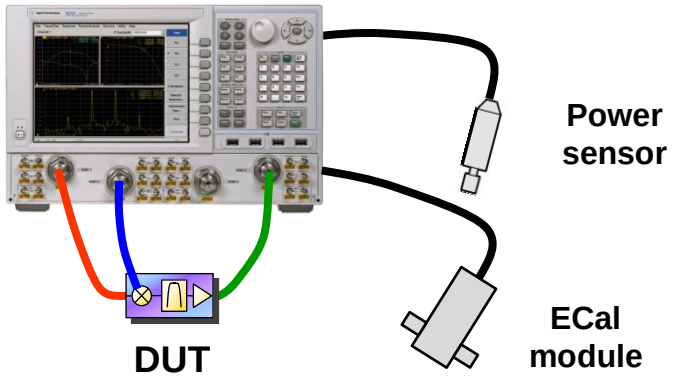
ϕ in degrees

f in Hertz ($\omega = 2\pi f$)

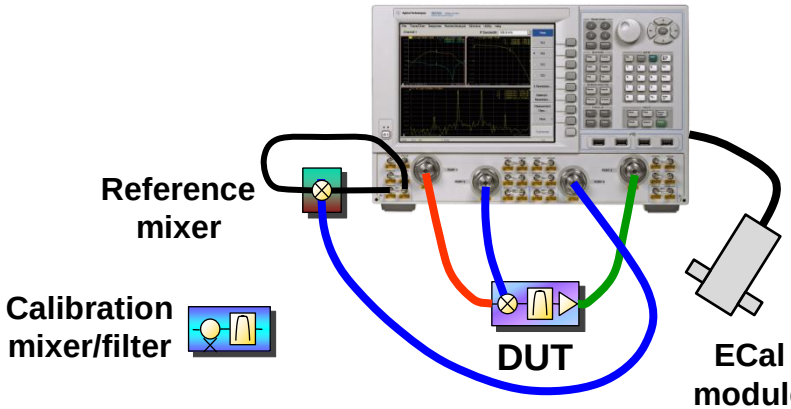
- Calculated from phase versus frequency response
- Group-delay ripple indicates phase distortion
- Average delay indicates electrical length of DUT
- Aperture ($\Delta\omega$) of measurement is very important

Measuring Phase for Mixer/Converter Test

- Different measurement classes required for different measurements
- Most widely used is SMC+Phase
  - Used to be that SMC was magnitude only, and VMC was required for phase
  - Later, phase capability was added to SMC
  - SMC+Phase used for deviation from linear phase and absolute group delay
- VMC useful for phase shifters or comparing phase/delay among DUTs
- DIQ or FOM useful for comparing phase between multiple channels or paths



Scalar Mixer/Converters (SMC)



Vector Mixer/Converters (VMC)

SMC+Phase Calibration Choices for Phase/Delay

– Choice 1: Mixer with known delay

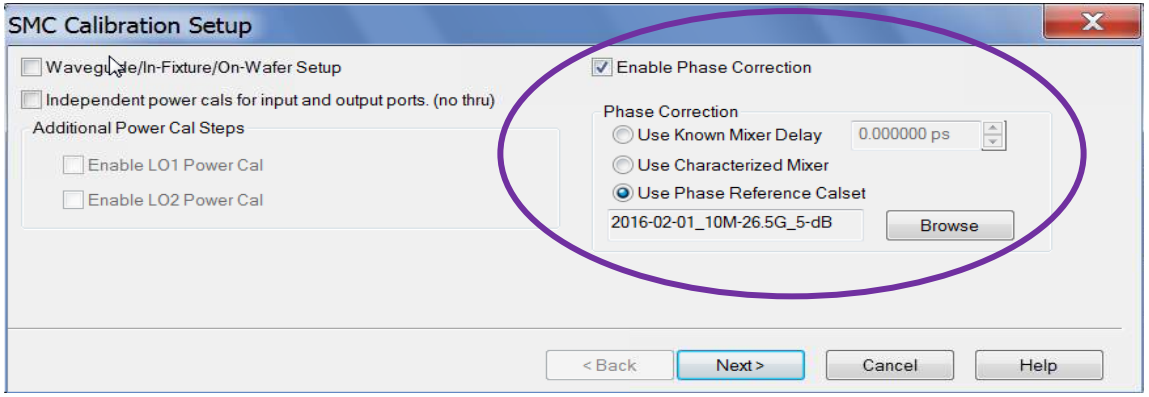
- Uses fixed value of delay (average of mixer delay versus frequency)
- Delay can be determined from educated guess, simulation, or measurement

– Choice 2: Characterized mixer

- Uses actual delay data versus frequency
- Uses same characterization method as VMC (based on reflection measurements)
- Requires reciprocal mixer, plus filter for selecting desired conversion product

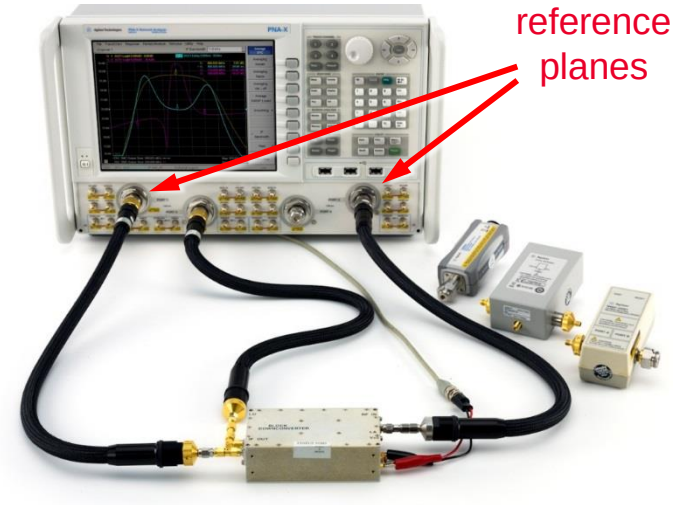
– Choice 3: Comb generator

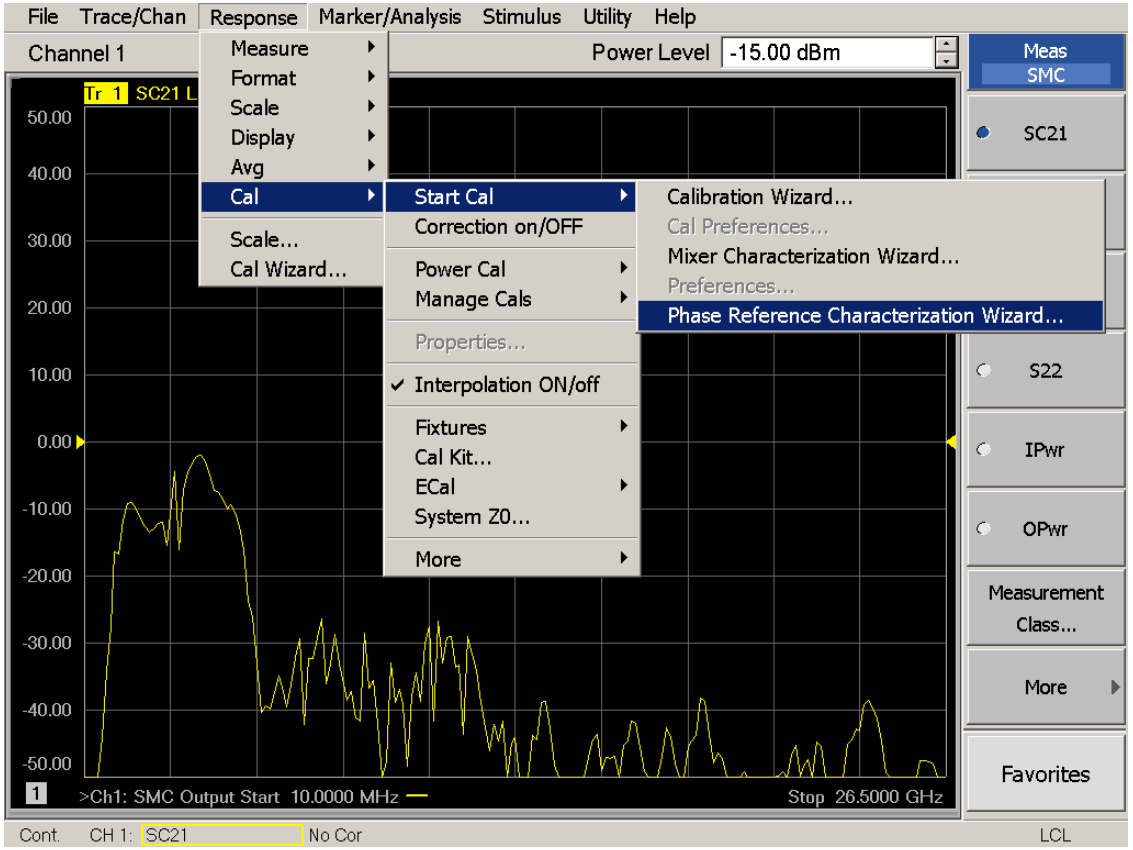
- Uses a two-tier approach, where tier one is a power plus phase calibration
- Second tier typically requires S-parameter calibration only



Phase Reference Characterization Wizard (Tier 1)

- Performed at VNA test ports to eliminate adverse cable effects
- Typically done over full frequency range of instrument
- Due to stability of instrument, can be done infrequently
- Includes power calibration (using power sensor)

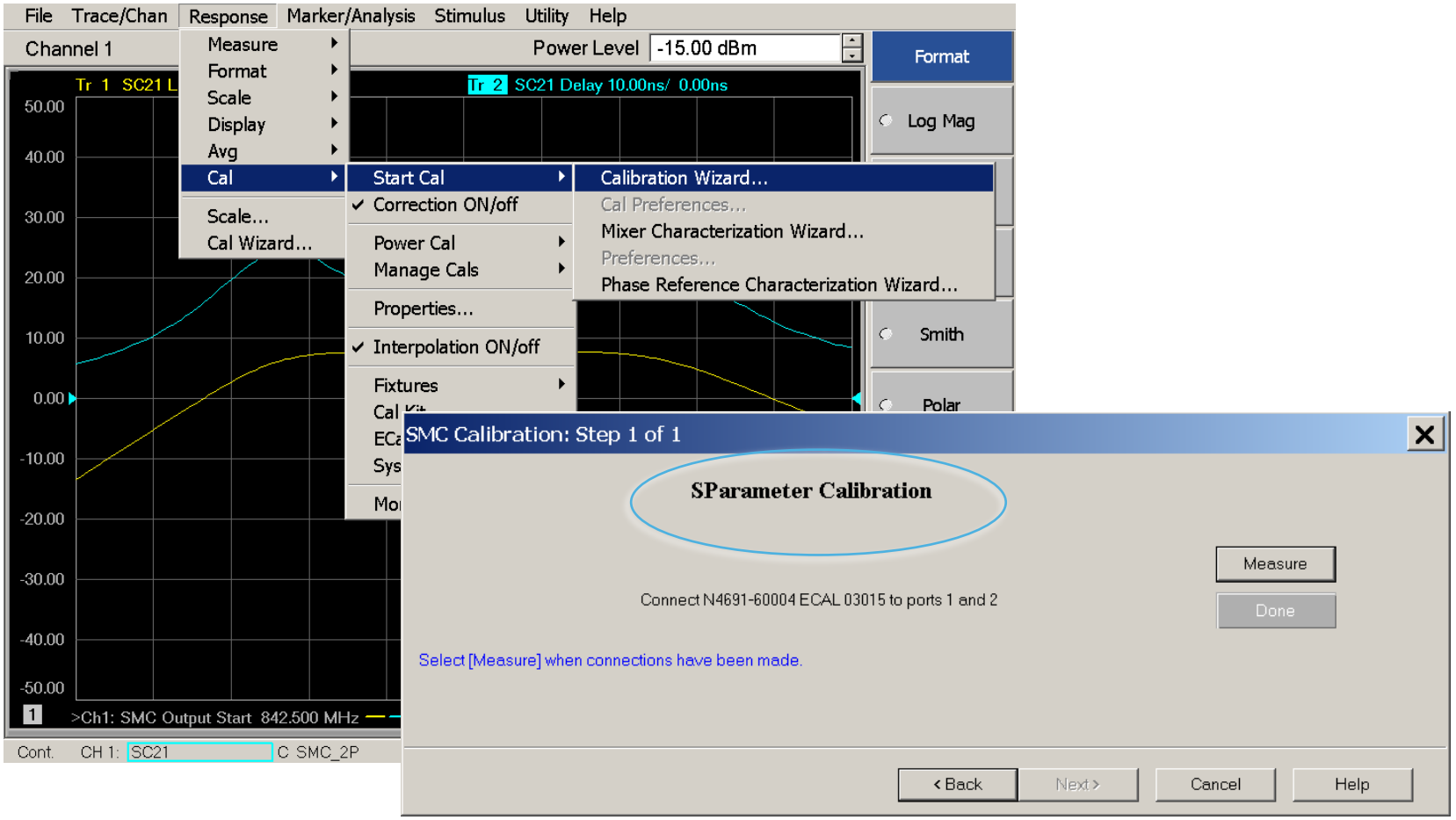




SMC+Phase Calibration Wizard (Tier 2)

– S-parameter calibration only, at end of cables or probes

– One-step cal if ECal connectors match those of DUT



Key Software Application

Differential I/Q device measurements

SW Appl.	Description
S93007A	Automatic Fixture Removal[1]
S9309xxA	Spectrum analysis (up to 90 GHz)
S93093A	Spectrum analysis up to 120 GHz
S93094A	Spectrum analysis beyond 120 GHz
S93029A	Noise figure measurements[1,2]
S93086A	Gain-compression measurements [1]
S93087A	Intermodulation Distortion Measurements
S93082A	Scalar mixer/converter measurements[1]
S93083A	Vector mixer/converter measurements[1]
S93089A	Differential I/Q device measurements

Differential and I/Q Devices Application

Option 089 / S93089A

– Combines source phase-control with receiver frequency-offset mode

– Provides accurate phase control of multiple sources, eliminating the need for hybrid couplers and baluns

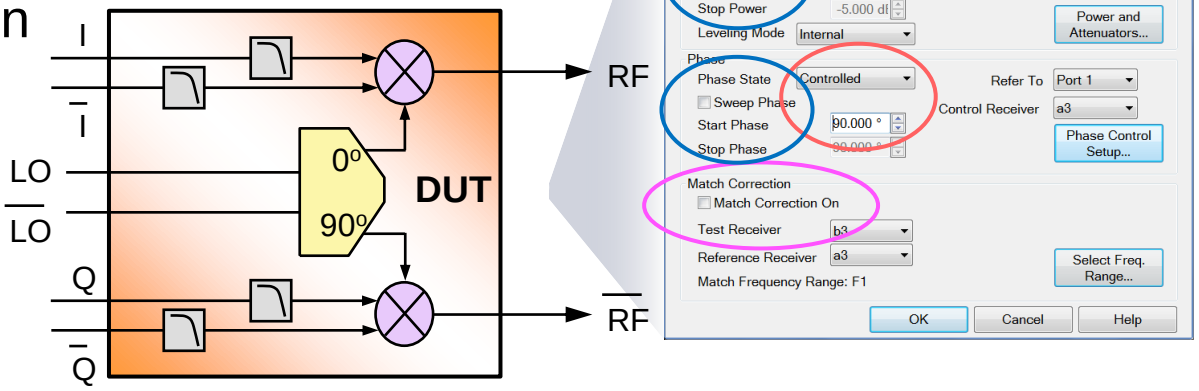
– Tunes receivers to arbitrary set of output frequencies

– Sweeps frequency, phase, or power

– Performs match correction

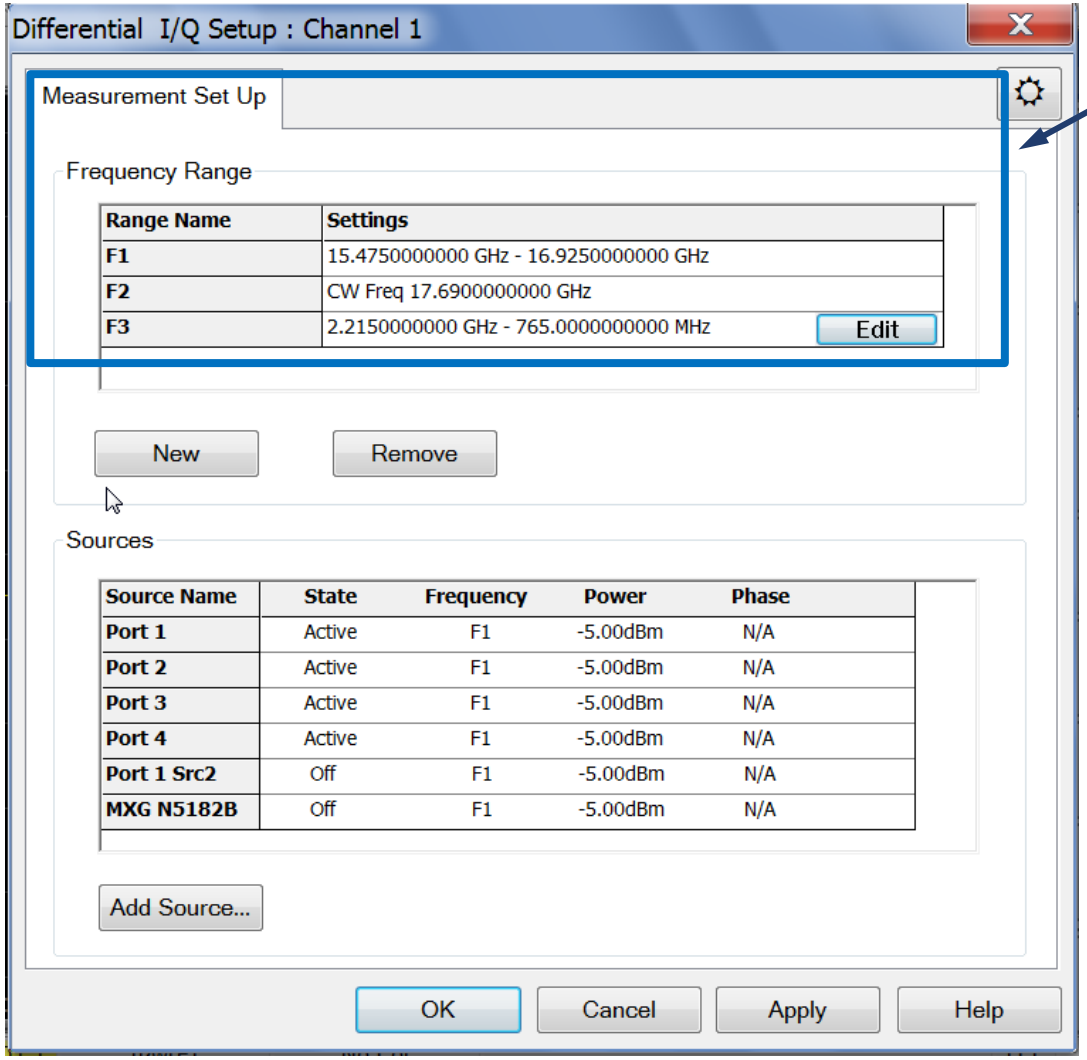
– Defines user parameters

– Controls external RF, ARB, and DC sources



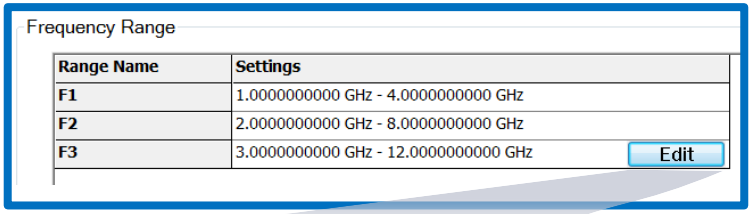
Step 1: Define Frequency Ranges

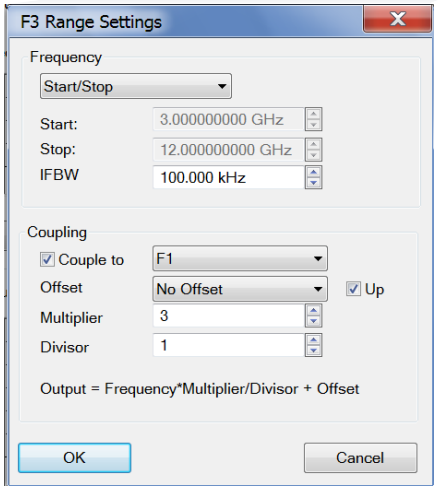
Ranges need to cover source and receiver frequencies



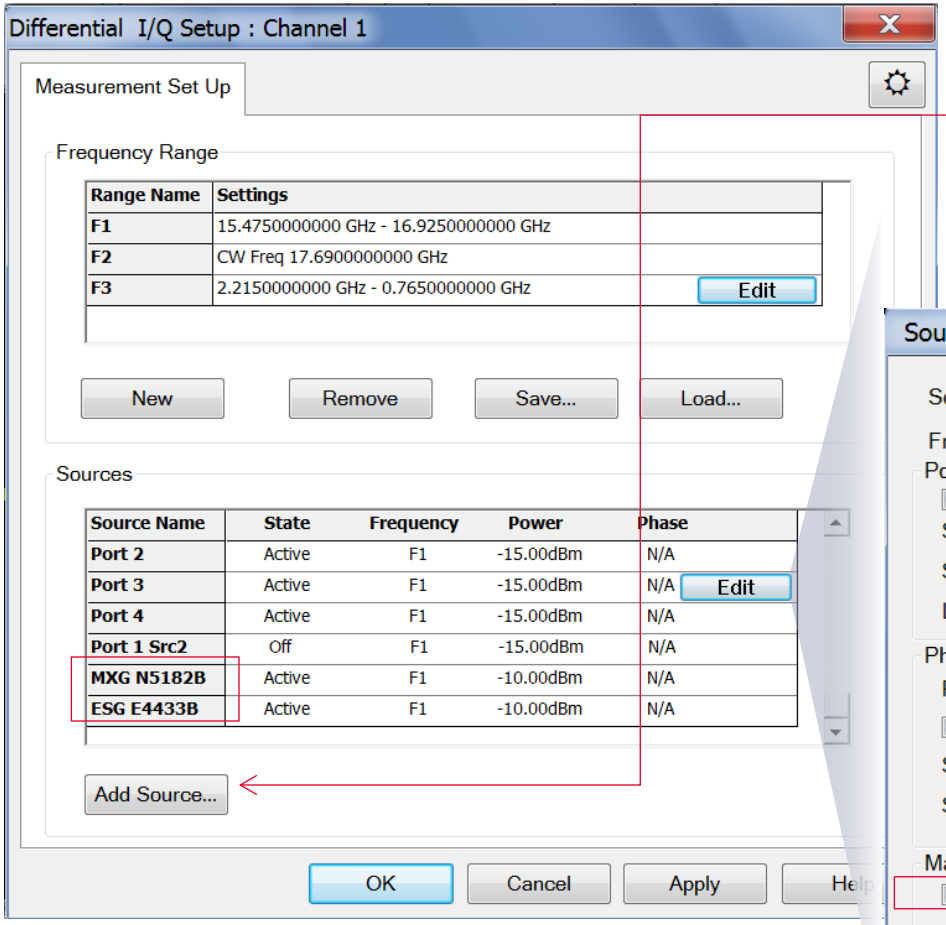
Mixer measurements:
RF, IF, LO

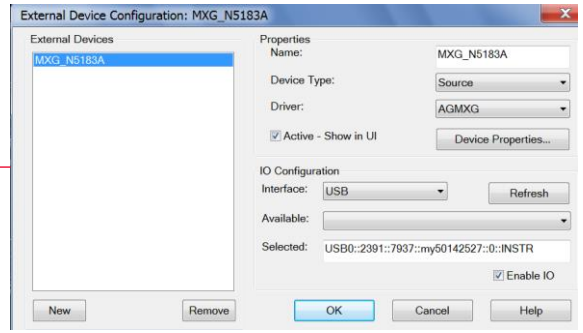
Differential amplifier:
Input, harmonics

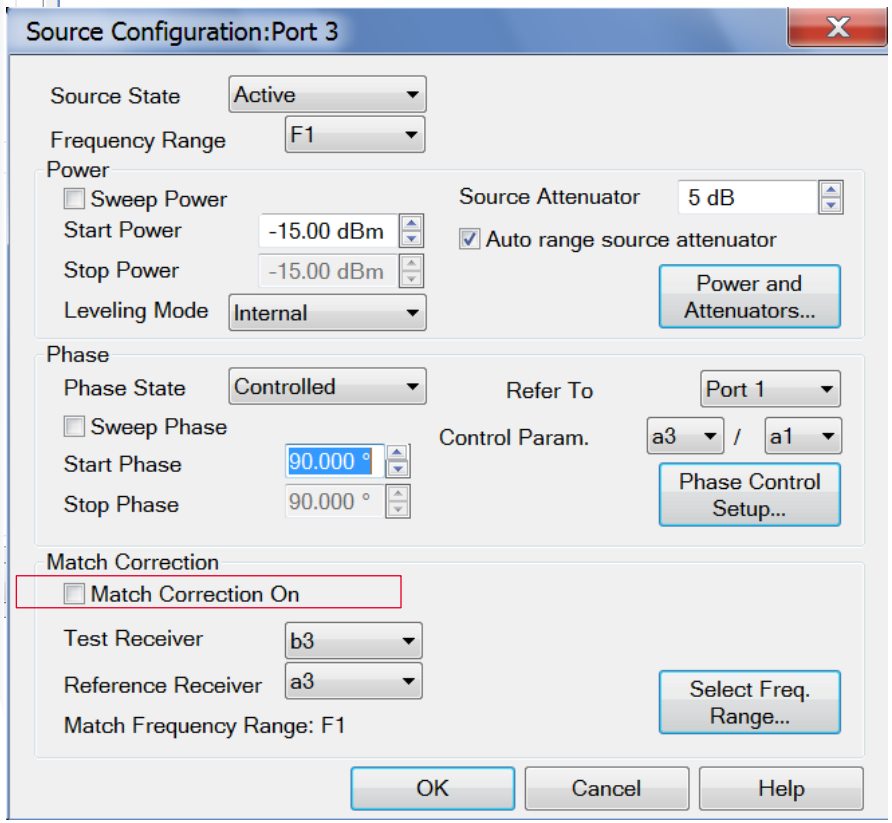




Step 2: Define Controlled Sources

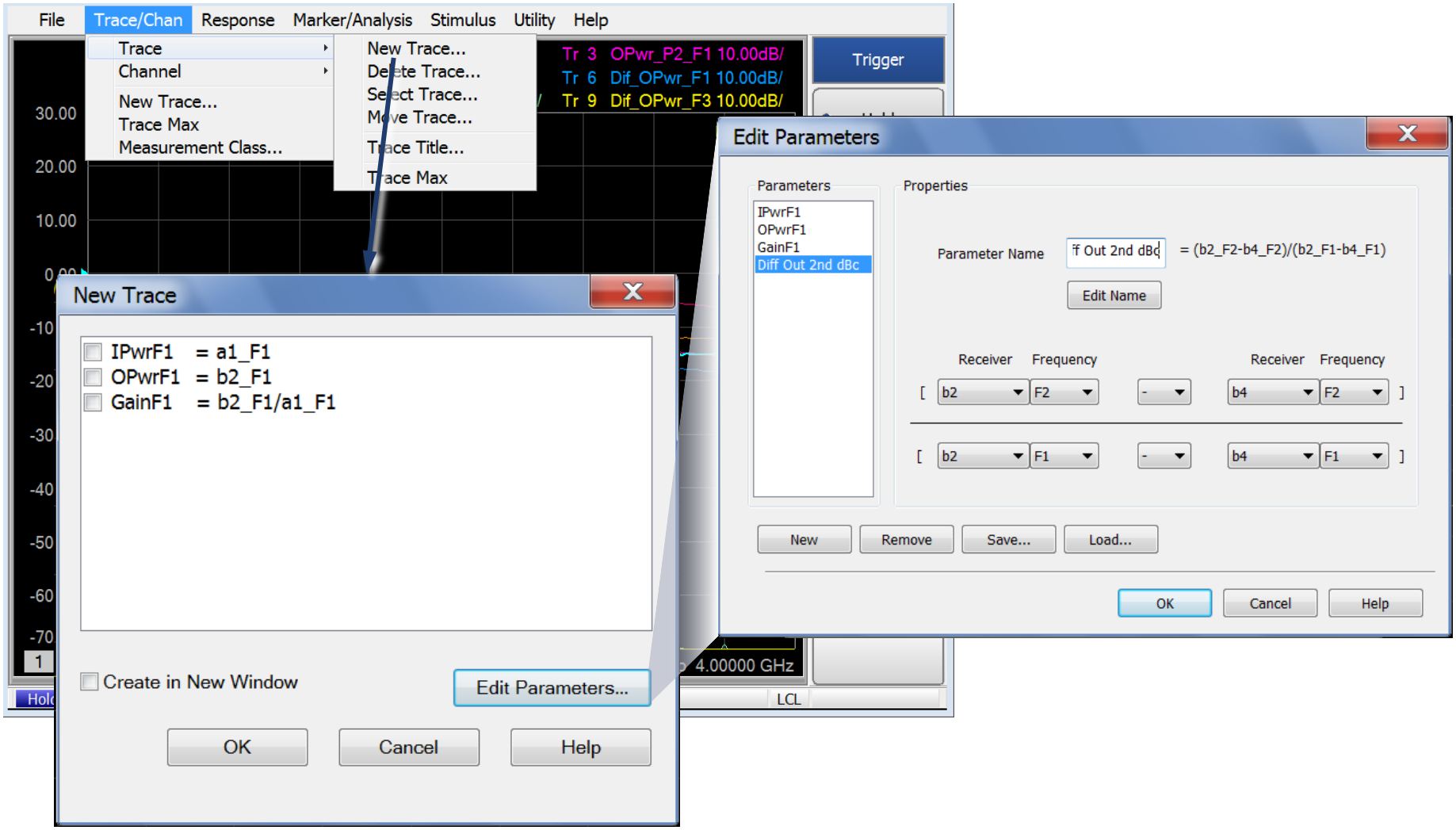




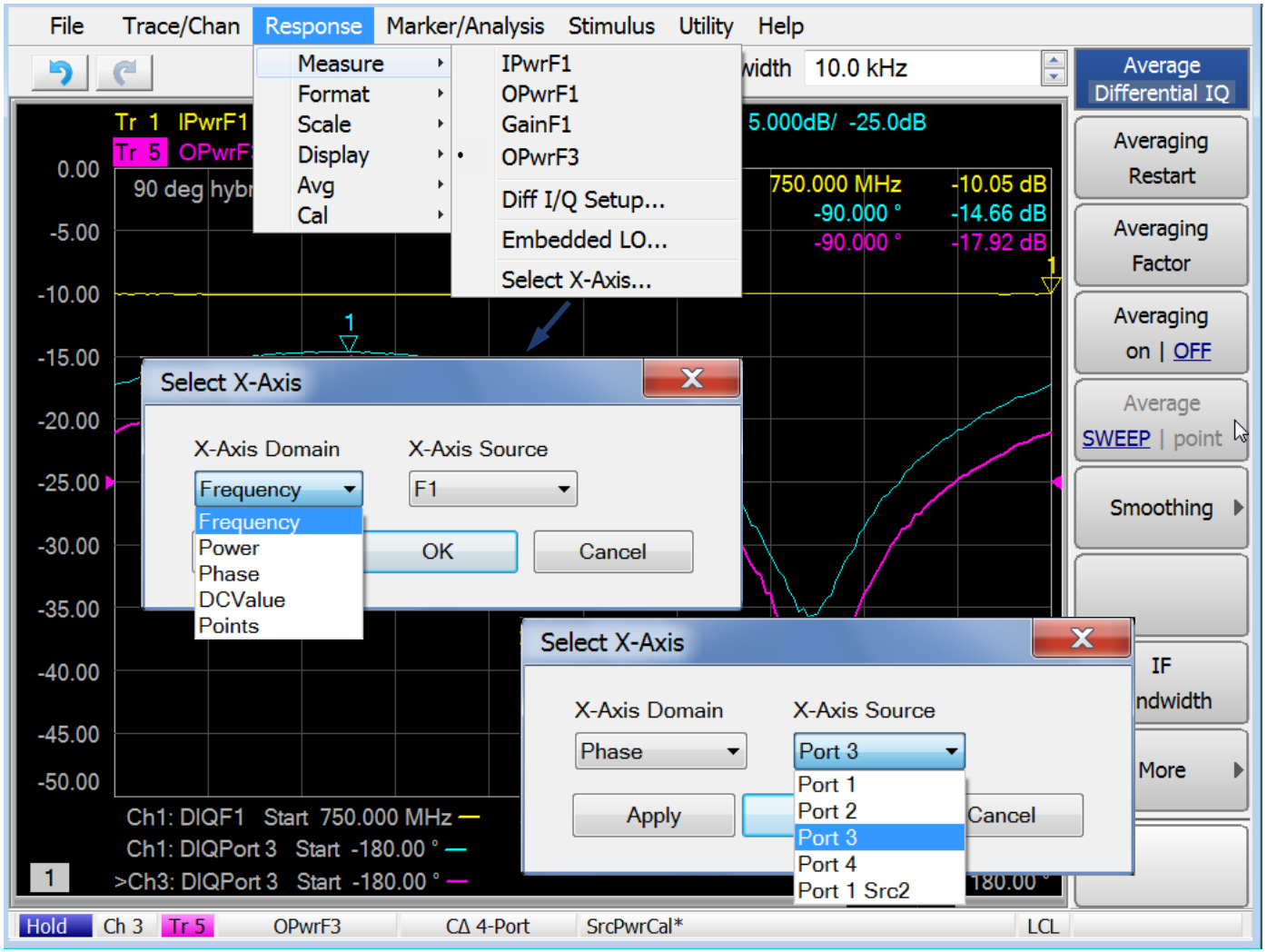


Note: do not manually set Port 1 to zero degrees. It will get set automatically when configured as the reference port.

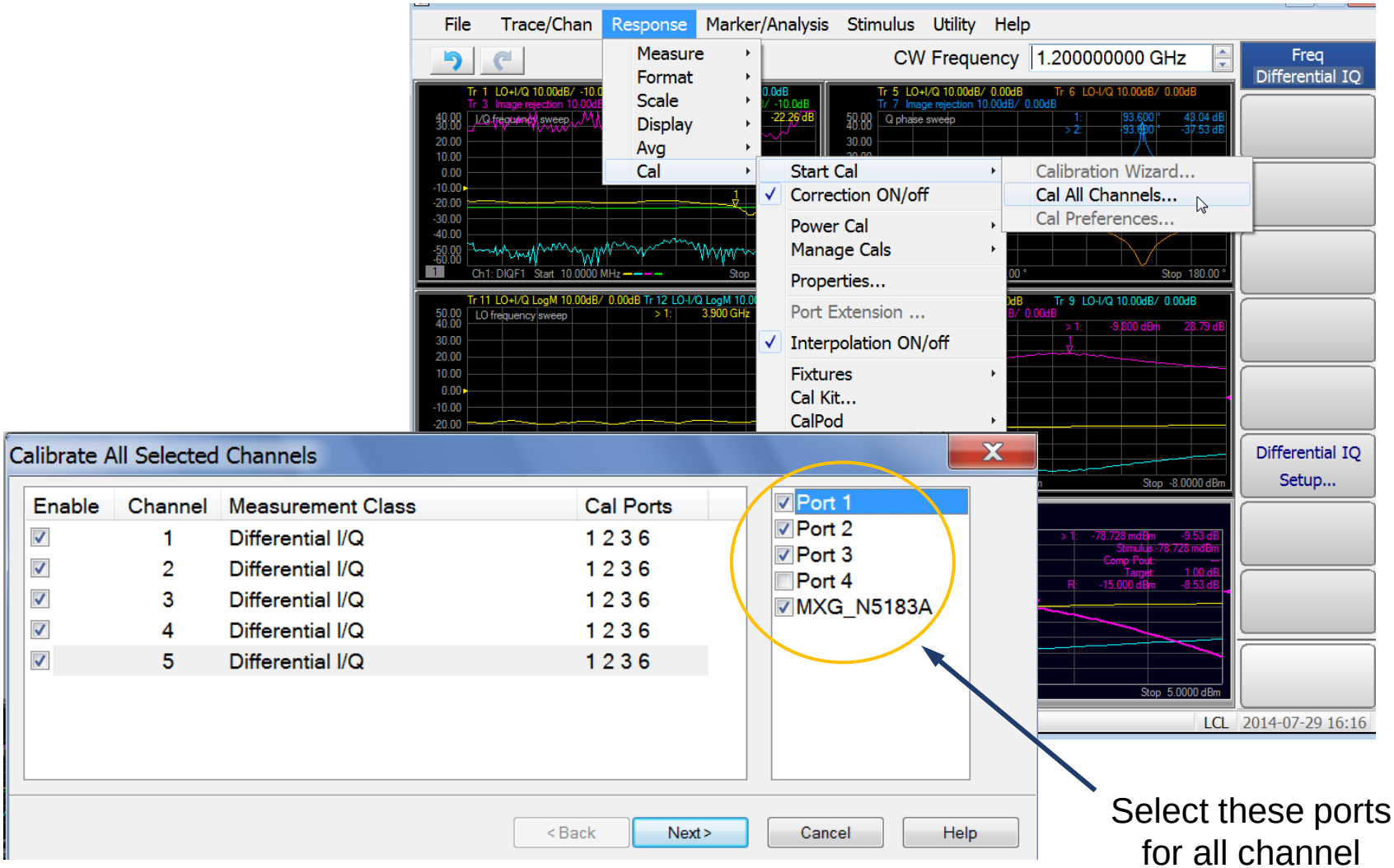
Step 3: Define Trace Parameters



Step 4: Define X-Axis



Step 5: Calibrate All Channels Using “Cal All”



Select these ports for all channel

Summary

- Provide easier access to accurate, repeatable measurements at ever-higher frequencies and wider bandwidths.
- Delivers metrology-grade precision that ensures unparalleled system-level performance.
- Characterize and optimize new-generation devices from 900 Hz to 120 GHz
- PNA-X offers a unique combination of hardware and software that is well suited to the needs of A/D supply chain customers measuring active devices
- Innovations in measurement science and calibration give big competitive advantage
- Flexibility and range of applications and measurements means setup complexity

Thank You

Questions ?

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KEYSIGHT TECHNOLOGIES

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