Configuration of PNA-X, NVNA and X parameters

VNA

1. **S-Parameter Measurements**

PNA-X Family of Network Analyzers

- N5241A, 10 MHz to 13.5 GHz
- N5242A, 10 MHz to 26.5 GHZ
- N5244A, 10 MHz to 43.5 GHz
- N5245A, 10 MHz to 50 GHz

NVNA

2. **Harmonic Measurements**

Component Characterization - the following options are required

Option 510	Nonlinear component characterization
Option 400	4 ports, dual source test set
Option 419	4 ports, extended power range and bias tees
Option 080	Frequency offset

3. **X-Parameter Measurements**

X-Parameters

Requires component Characterization Configuration plus:

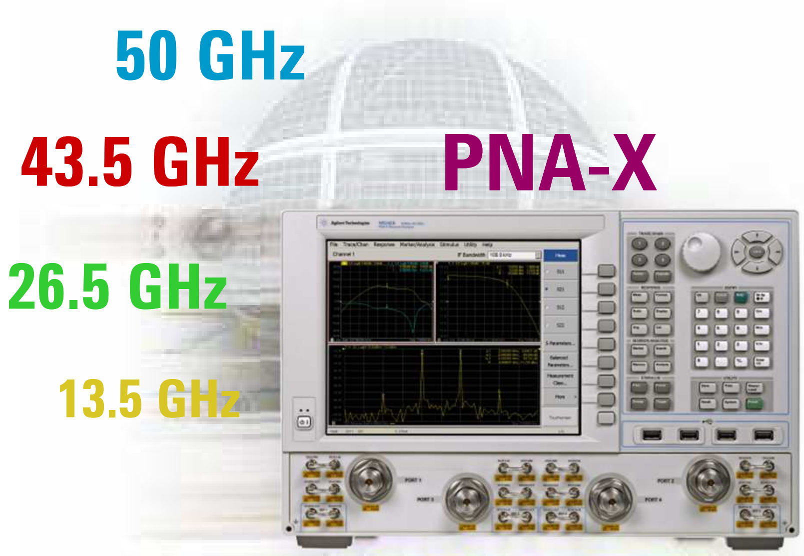
Option 514	Nonlinear X-parameters
Option 423	Internal combiner and mechanical switches

Extended Capabilities

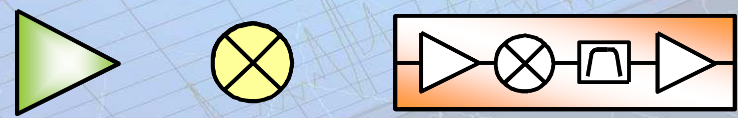
Option 520 Arbitrary load impedance X-parameters*

(*Requires Maury tuner and software and Agilent's Advanced Design System (ADS).)

Introducing the PNA-X



Agilent's Premier Performance Network Analyzer For Active Device Test



Industry-Leading Performance

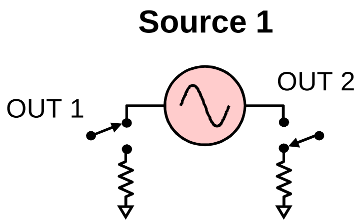
N5242A PNA-X Performance

Frequency Range	10 MHz to 26.5 GHz
IF Bandwidths	1 Hz to 5 MHz
System Dynamic Range	132 dB
Receiver Dynamic Range	130 dB
Trace Noise (1 kHz IF BW)	<0.0006 dB
Output Power	+16 dBm
Source Harmonics	-60 dBc
0.1 dB Receiver Compression	+13 dBm
Power Sweep Range (ALC)	40 dB

Product Features – Signal Sources

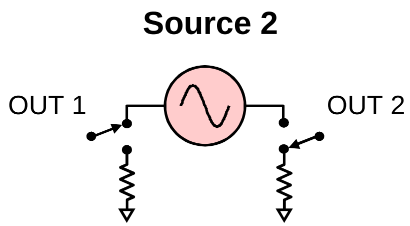
Second internal source

- Two-tone tests: intermodulation, X-param, … and more
- About 30x faster than PNA/PSG combination

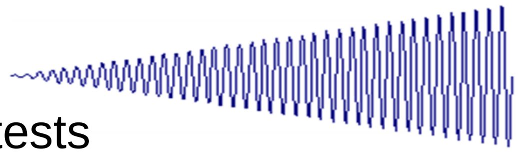


Source improvements

- Upper frequency (26.5 GHz)
- High port power (~ +16 dBm)
- Low harmonics (> -60 dBc)
  – Improves accuracy for amplifier and converter tests
  – Eliminates or reduces need for external filters



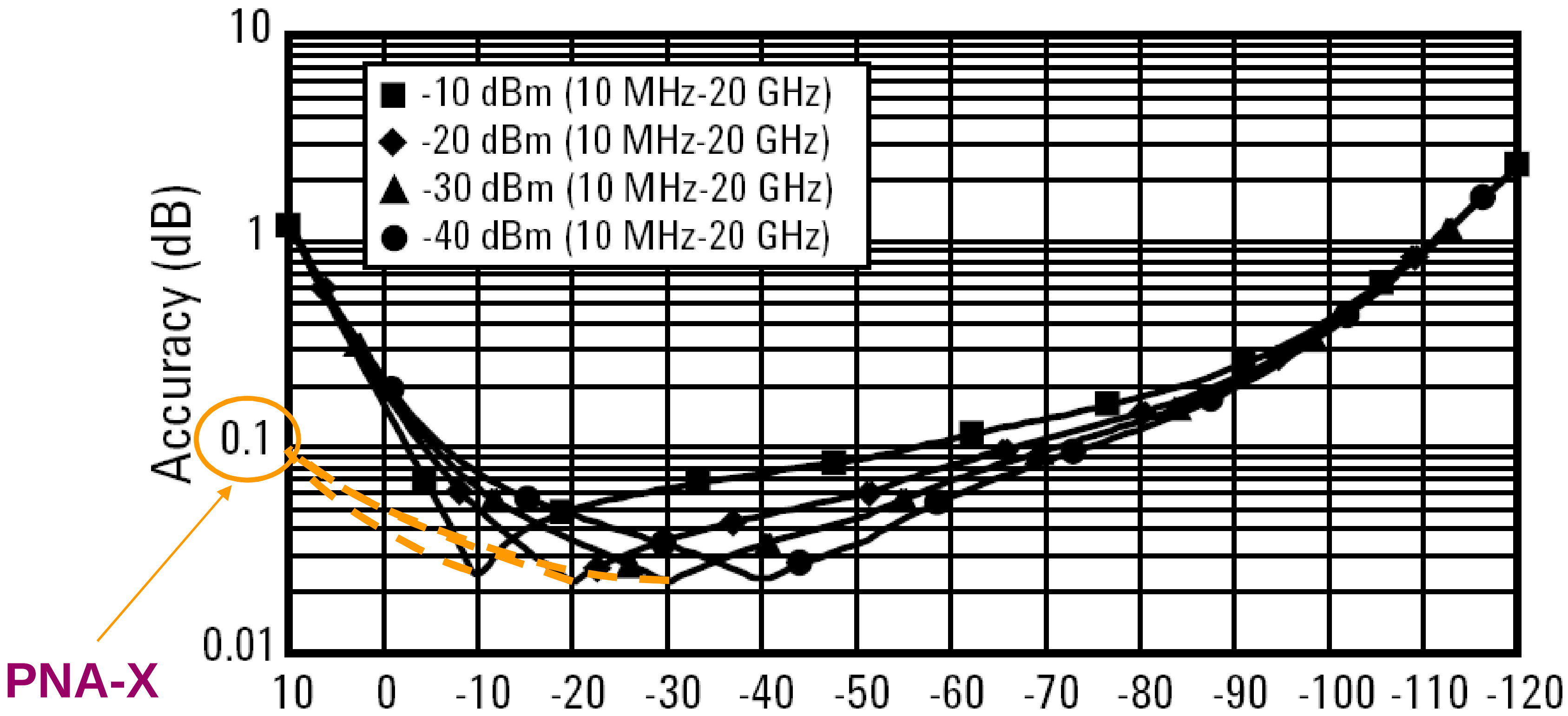
- Wide ALC range (40 dB)
  – Easily sweep power from linear to compression region
  – Increased flexibility for optimizing power for two-source tests



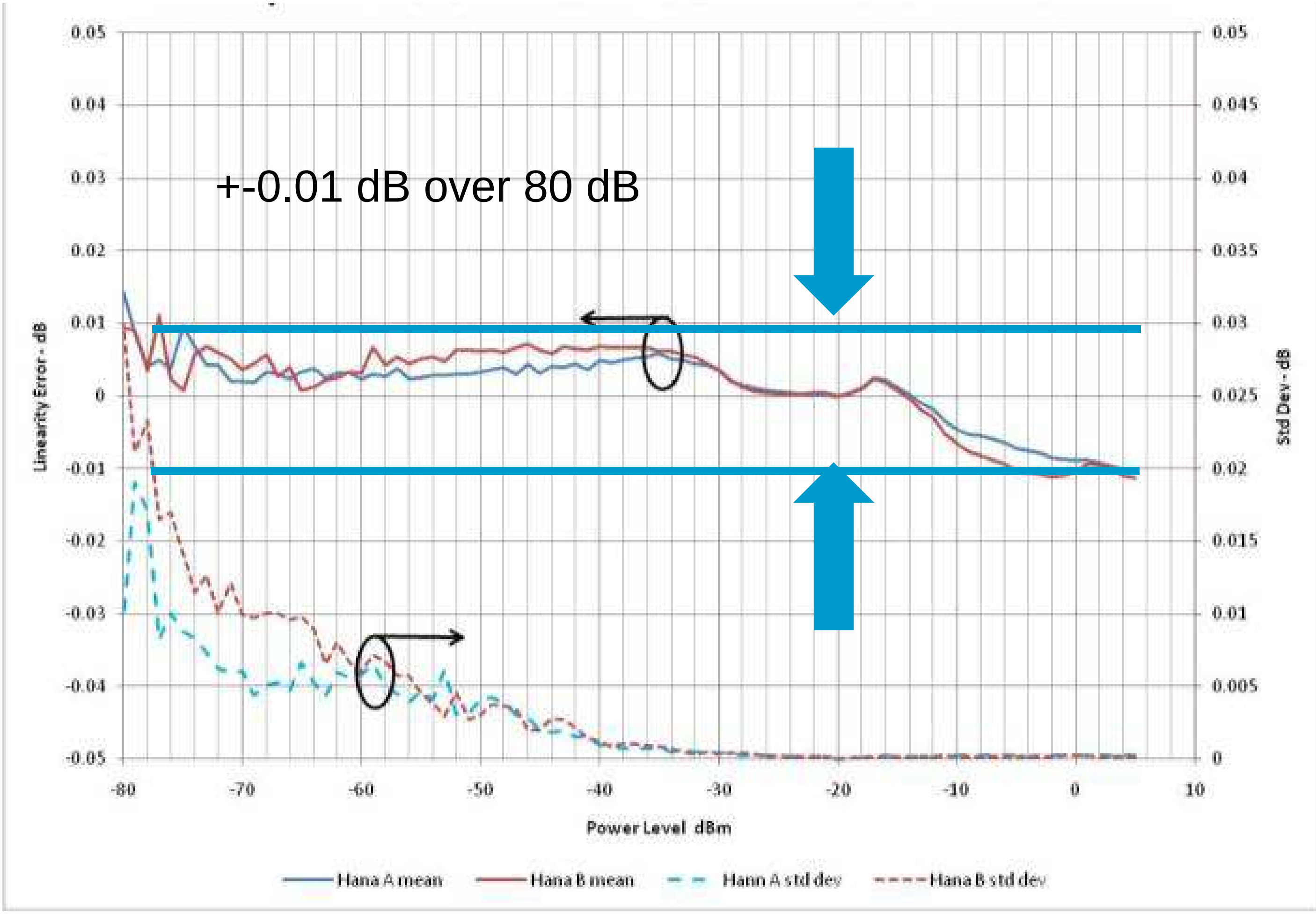
Product Features – Receivers

Outstanding receiver compression (0.1 dB comp: +12 dBm)

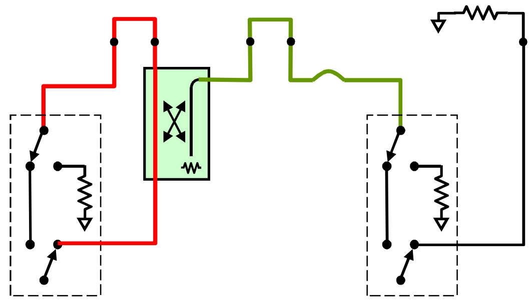
- Improves dynamic linearity when measuring amplifiers
- Improves gain-compression accuracy



PNA-X receiver linearity: Most accurate receiver in the world!



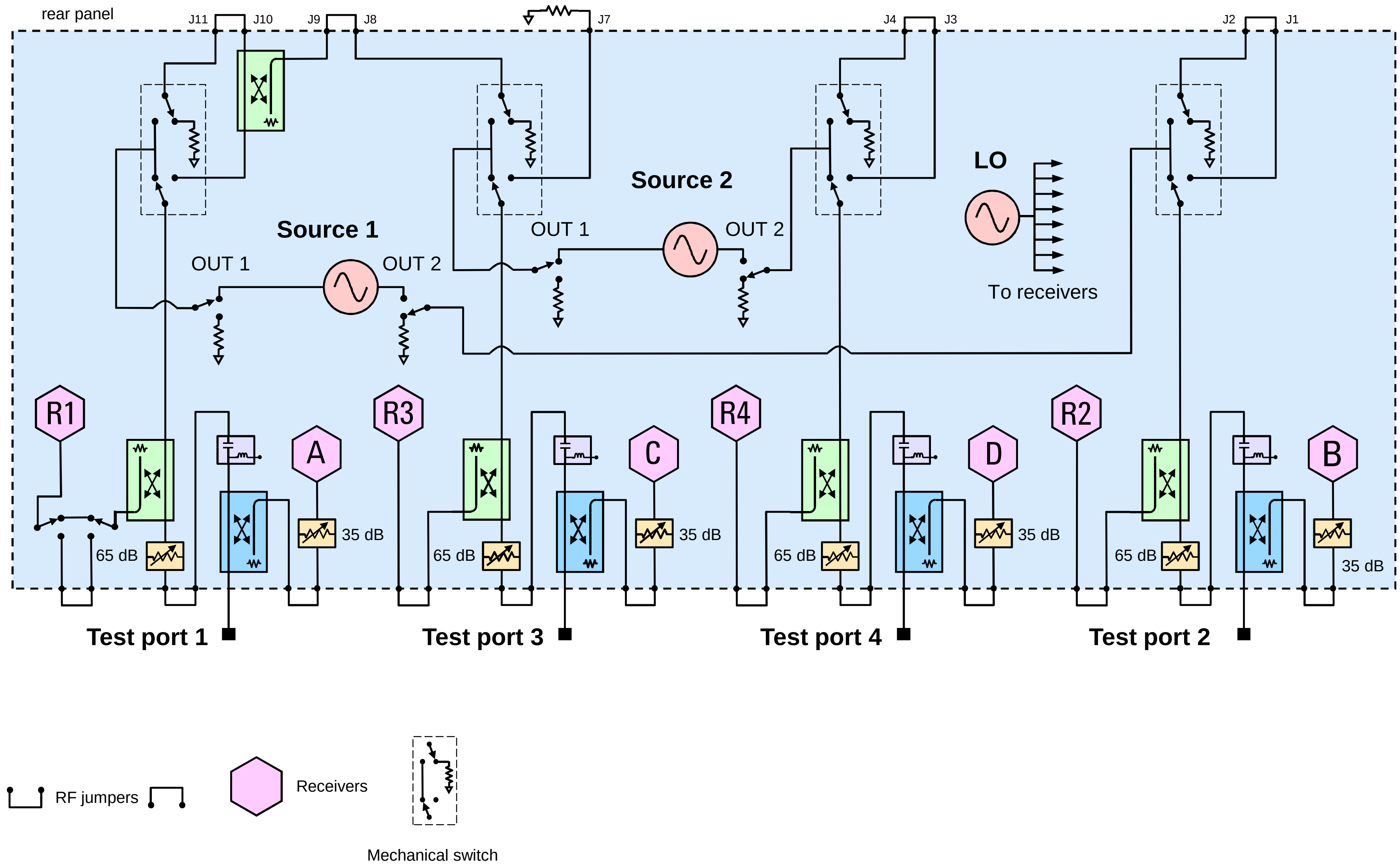
Product Features – Test Set



Flexible signal routing

- **Internal signal combiner**
  - Use for IMD, Hot S22, X-param, phase vs drive measurements
  - Easily switch between one and two source measurements
- **Front panel jumpers** to access couplers and receivers
  - Add high-power components for power amplifier measurements
  - Add reference mixer for mixer/converter measurements
- **Rear-panel signal routing** with mechanical switches
  - Add signal-conditioning hardware like filters, amplifiers
  - Add other test equipment to extend suite of measurements

4-Port 26.5 GHz PNA-X Options 419, 423

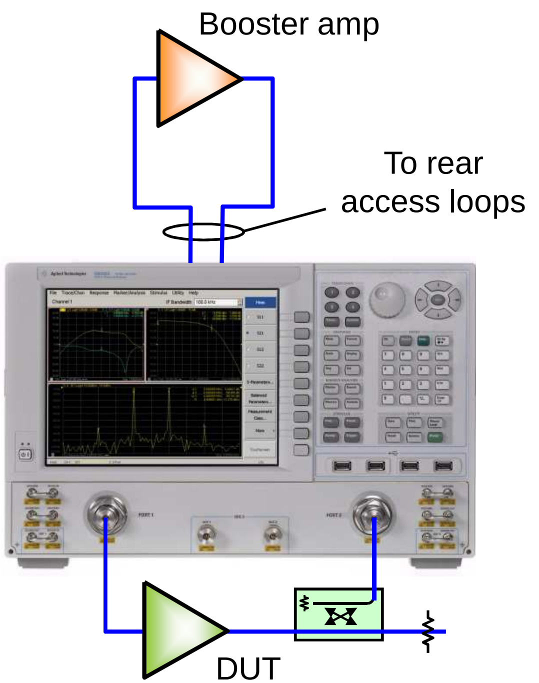


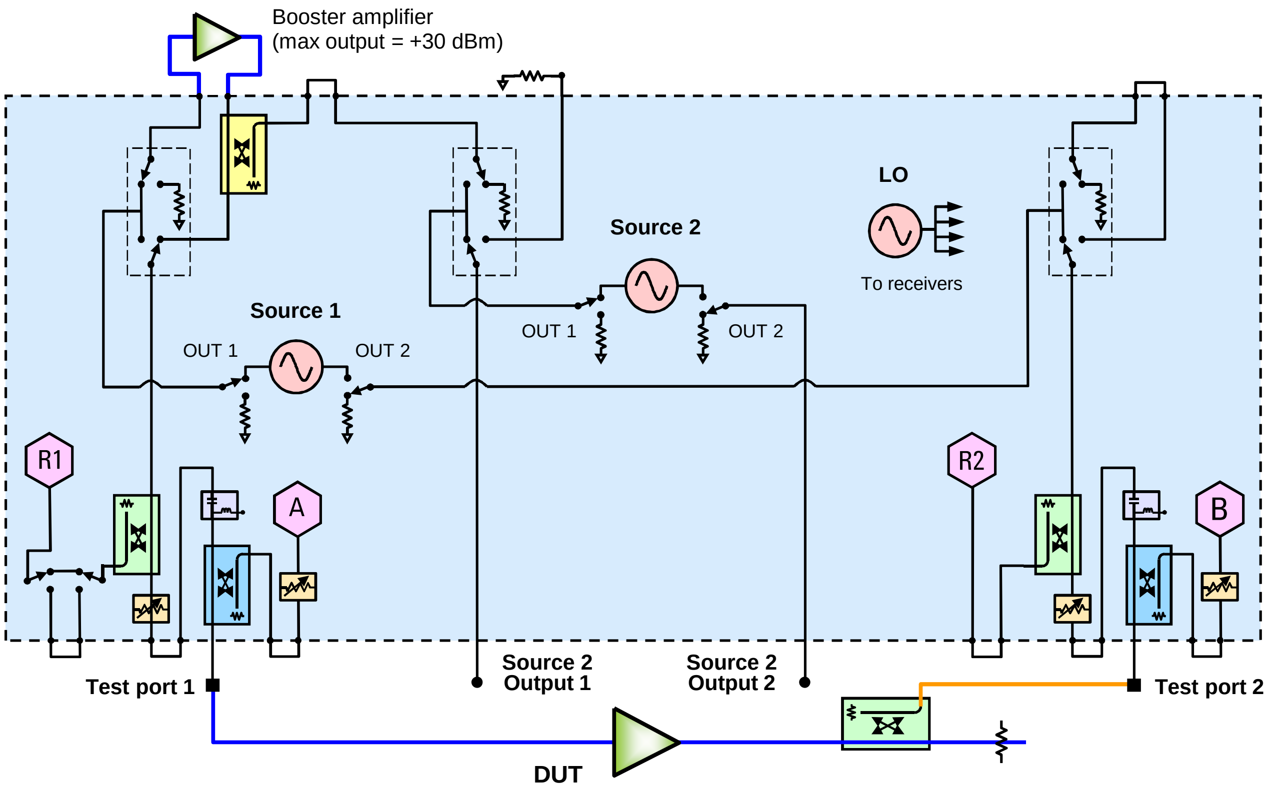
Rear Access Loops and Internal Switches

Add signal-conditioning hardware

Example 1:

Switch between normal path and high-power path

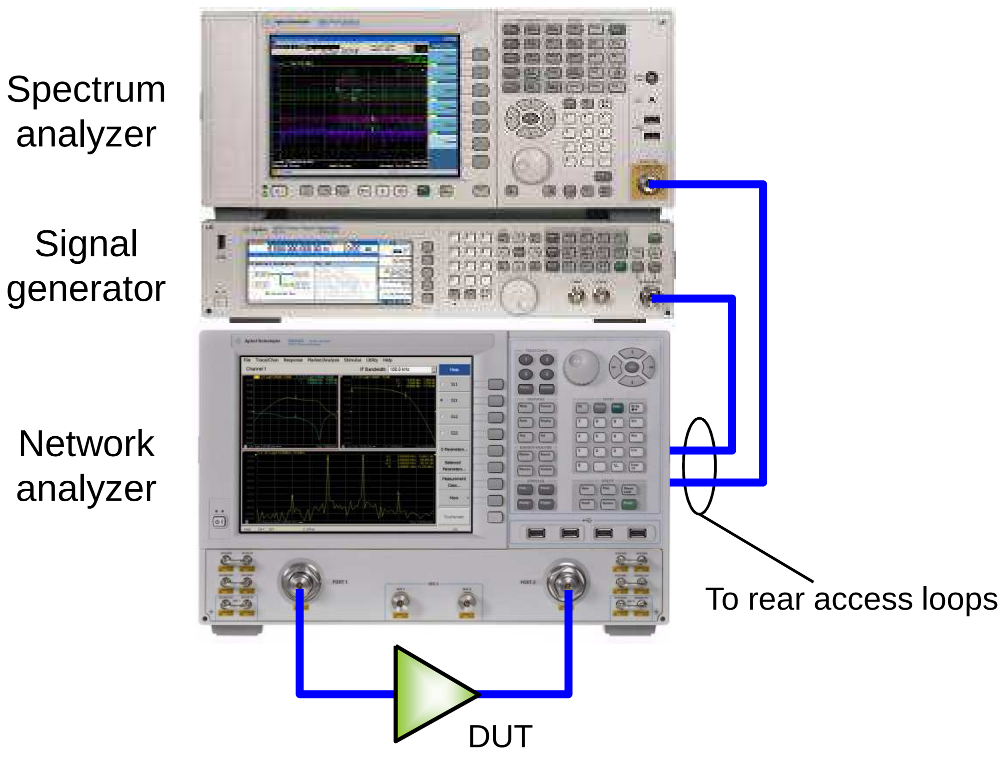


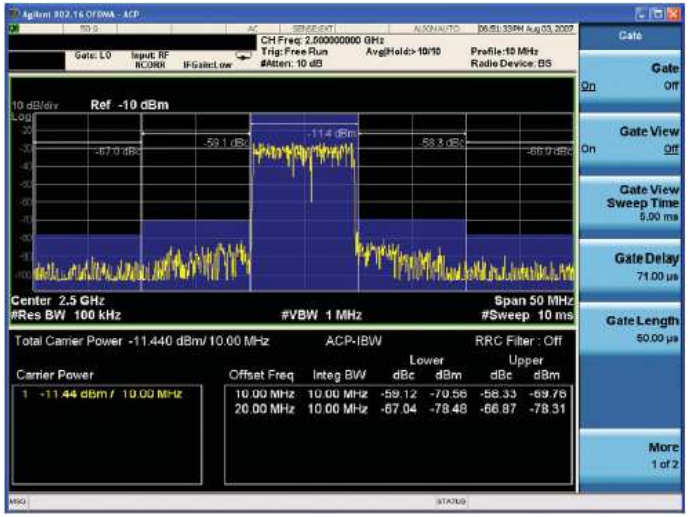


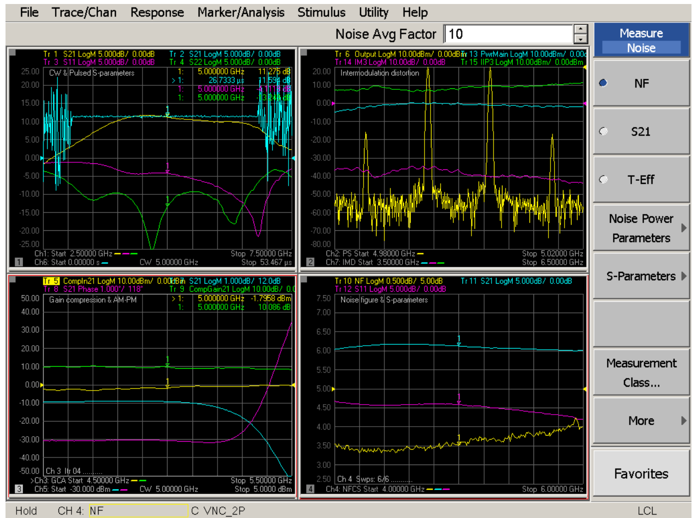
Extending Test Suite With Other Instruments

Example 2:

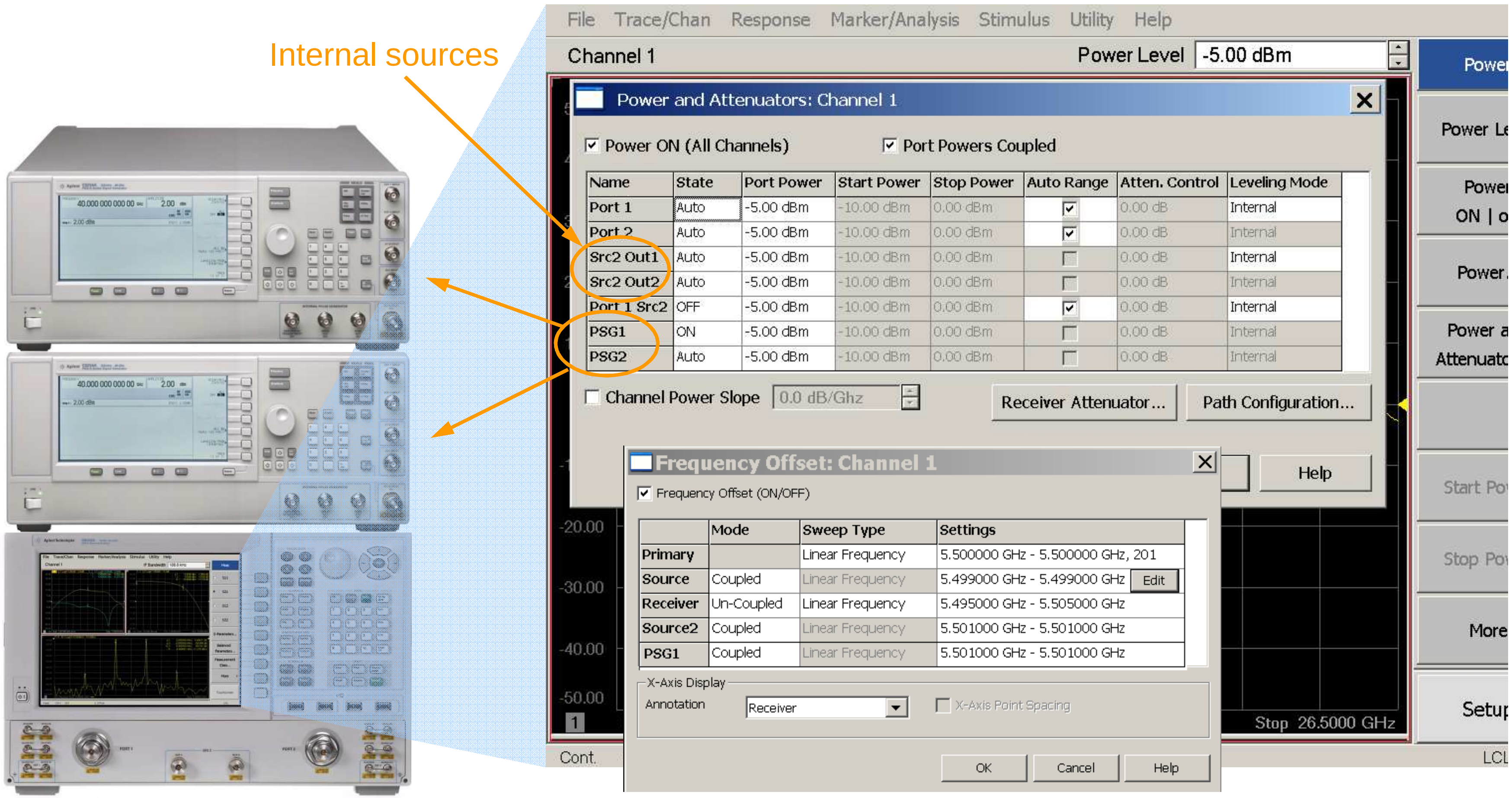
Switch between network analyzer and external source/analyzer combination for ACPR testing with digital modulation



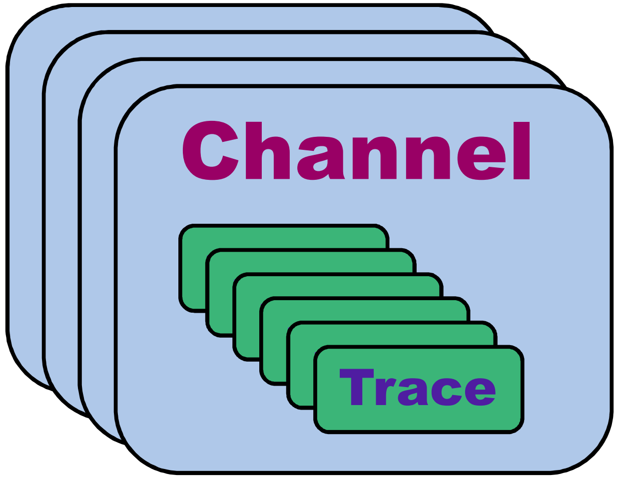




Easy Control of External Signal Sources



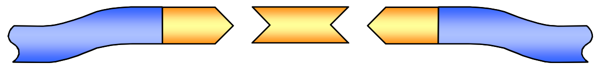
Product Features - General



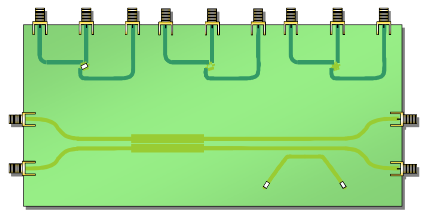
Common PNA features

- Flexible channels, traces, windows
- Open Windows® architecture
- LAN, GPIB, USB connectivity
- Built-in HELP system

Advanced calibrations



- Unknown through, QSOLT, offset load
- Data-based with weighted-least-squares
- Automatic port extensions
- Match-corrected mixer calibrations
- ECal electronic calibration



Remote programming

- Code compatible with current PNAs
- SCPI, COM, DCOM interface

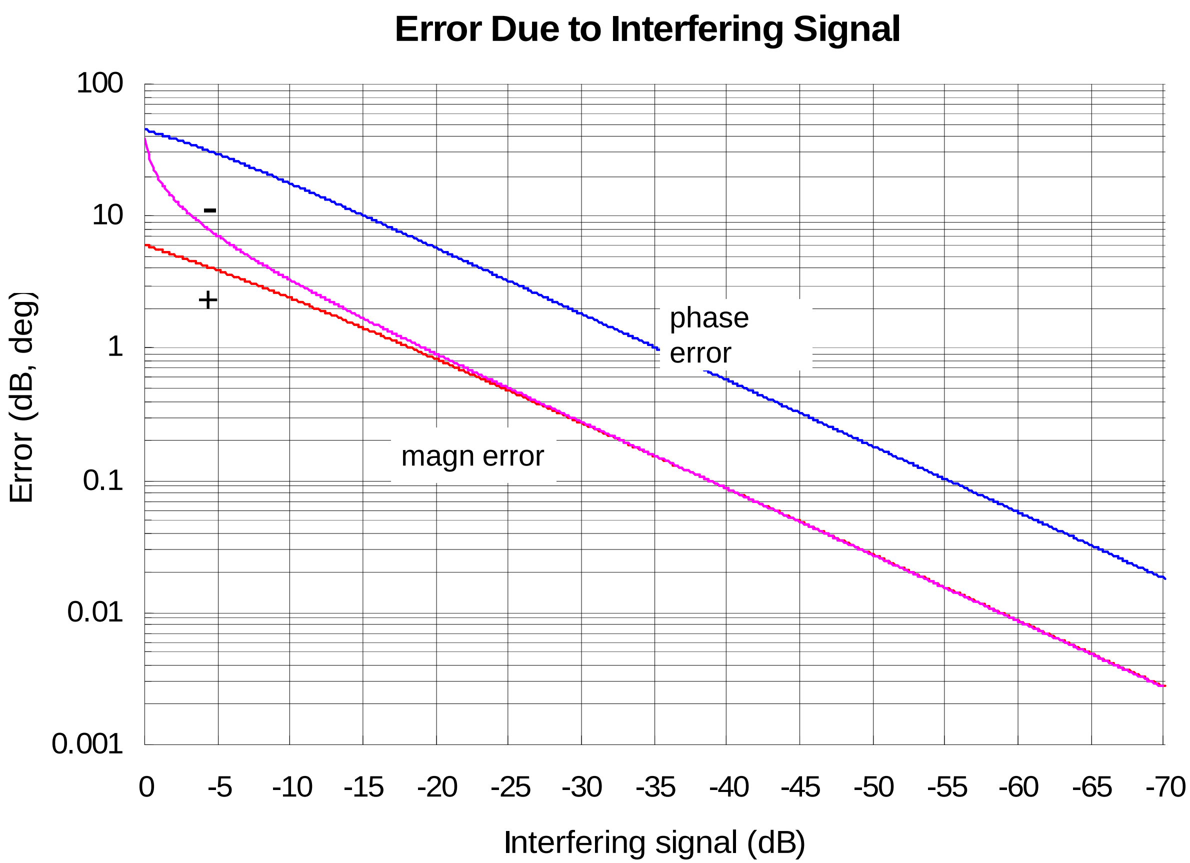
Microsoft COM
Component Object Model

Demonstration 1/3

PNA-X performance and GUI

- Trace Noise
- Dynamic Range
- Receiver Leveling
- …

Dynamic Range and Accuracy

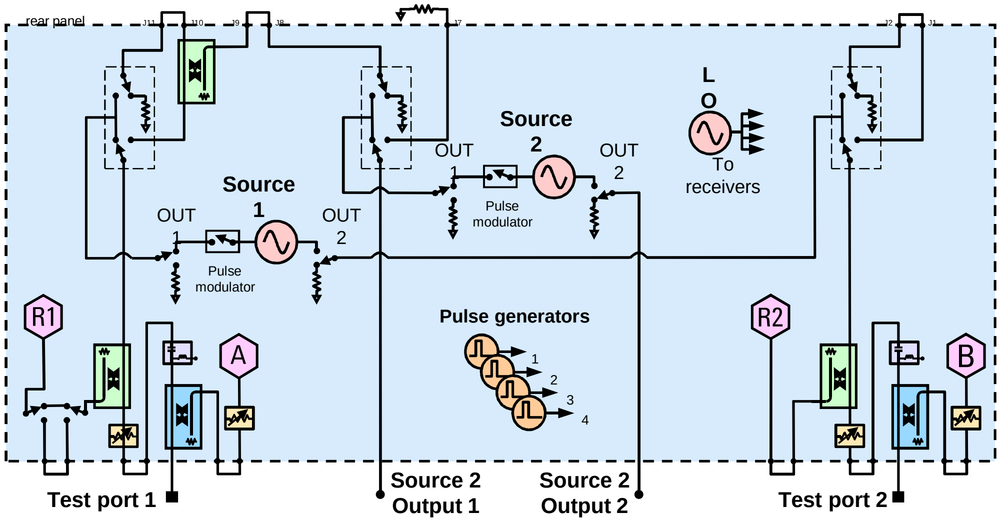


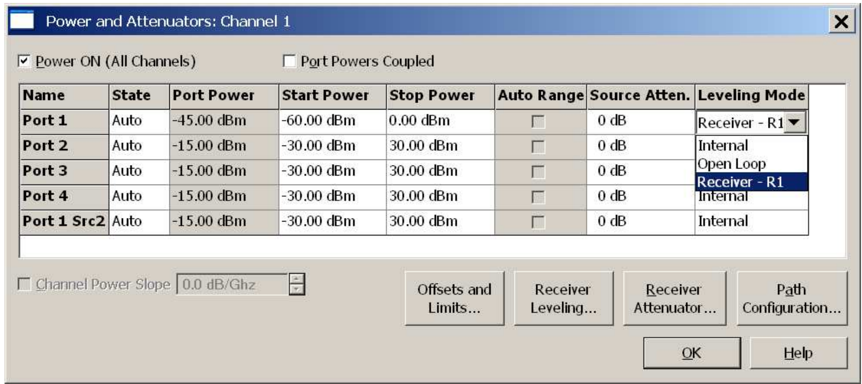
Dynamic range is very important for measurement accuracy!

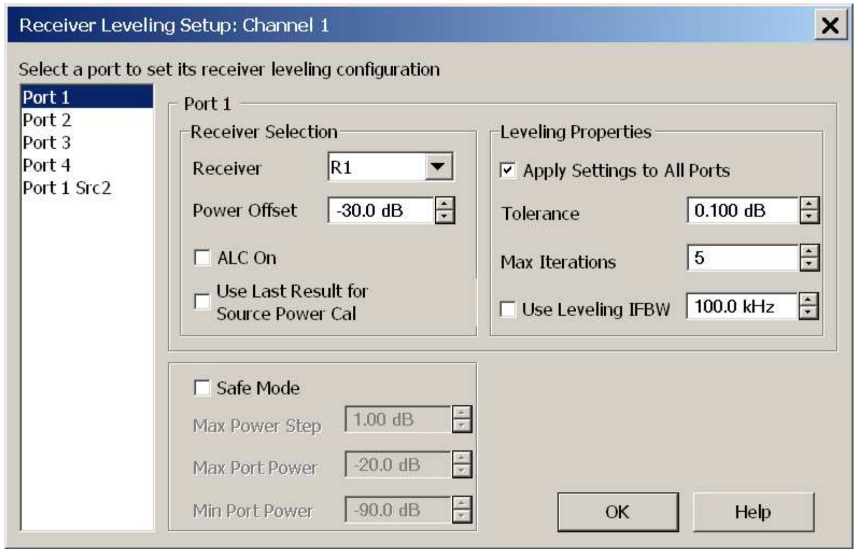
It depends on IFBW!!!

Receiver Leveling – What Is It?

- A new source power leveling mode
- Uses any one of receivers as a detector
- Can use different receivers for different source ports
- Can be used with any sweep types
- Available in Standard, GCA, IMD and FCA measurement classes

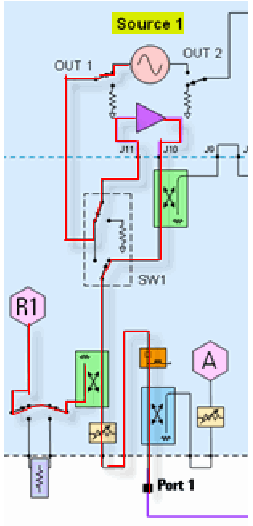


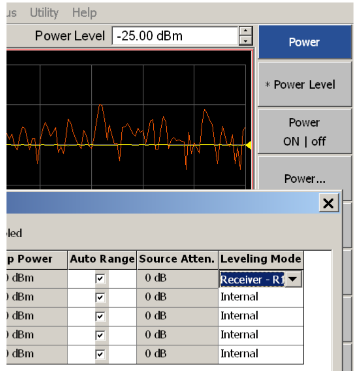


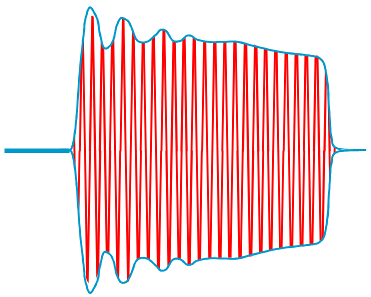


Receiver Leveling – When Is It Useful?

- Corrects short term drift errors when using external components
- Improves source accuracy at low power level
- Improves source linearity performance
- Extend minimum source power level
- Expand power sweep range up to 60 dB
- Enables power-leveled pulsed-RF measurements
- Enables power-leveled mmW measurements







Demonstration 2/3

Amplifier Test Methodology

- Pretest: Simple characterization to understand the measurement requirements of the amplifier

- Setup: Optimize the setup of the measurement to fit the needs and attributes of the Device Under Test (DUT)

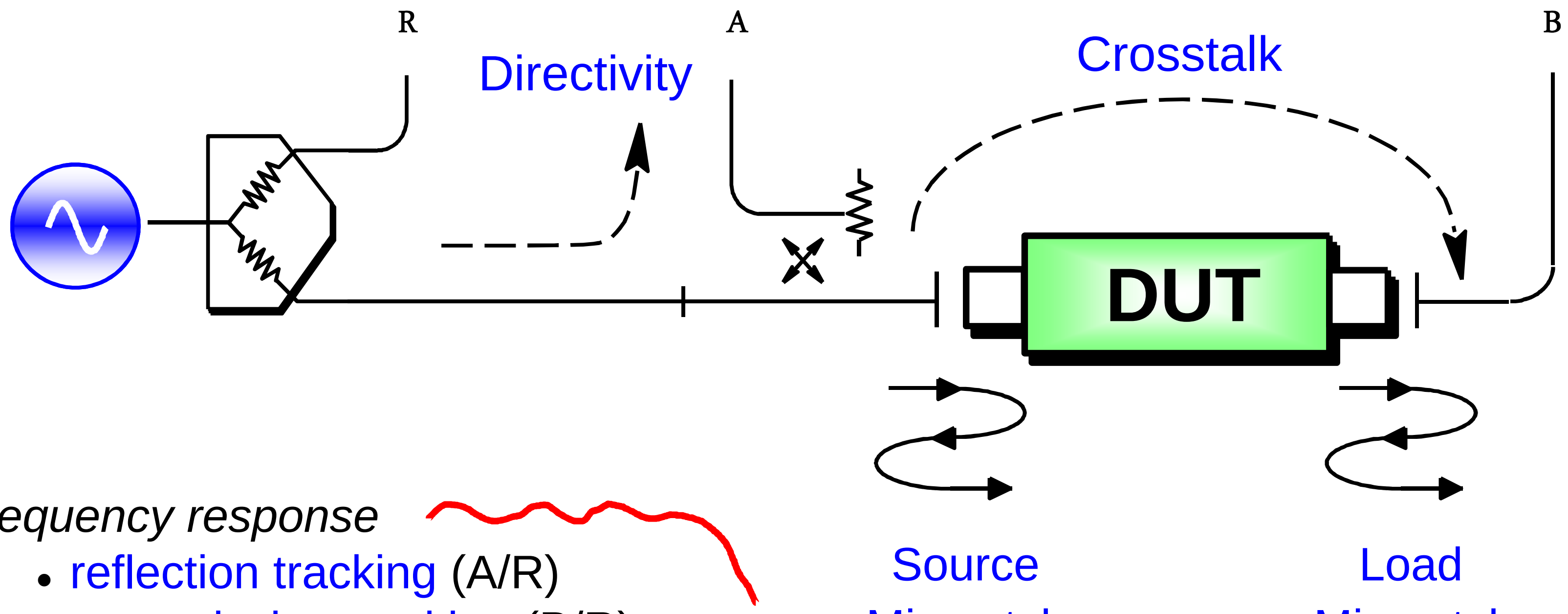
- Calibration: Understand and choose methods that improve the accuracy of the measurements

- Measurement: Acquire the data in the most effective way

- Analysis: Apply post measurement algorithms to display the data in convenient and effective ways

- Data Save: Save the results in formats most convenient for offline analysis and use

Systematic Measurement Errors



Frequency response

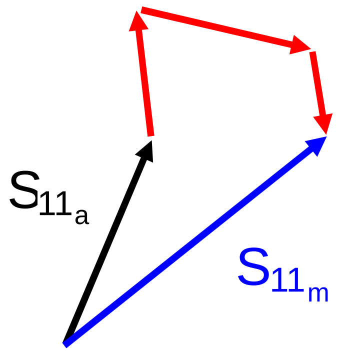
- reflection tracking (A/R)
- transmission tracking (B/R)

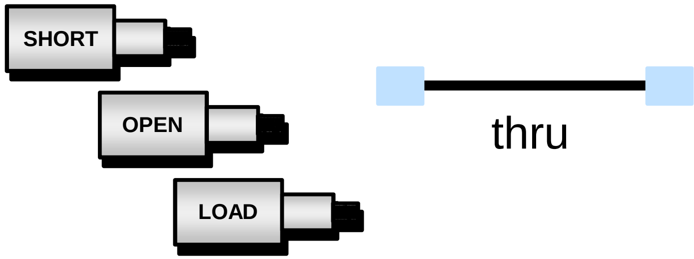
Six forward and six reverse error terms yields 12 error terms for two-port devices

Types of Error Correction

- **response (normalization)**
  - simple to perform
  - only corrects for tracking errors
  - stores reference trace in memory, then does data divided by memory

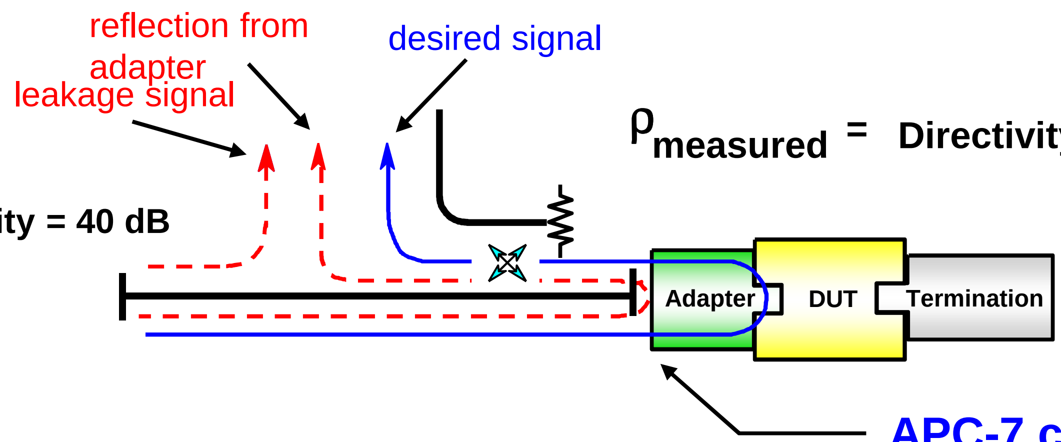
- **vector**
  - requires more standards
  - requires an analyzer that can measure phase
  - accounts for all major sources of systematic error





Adapter Considerations

Coupler directivity = 40 dB



$$\rho_{measured} = \text{Directivity} + \rho_{adapter} + \rho_{DUT}$$

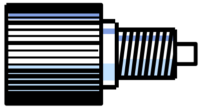
DUT has SMA (f) connectors

APC-7 calibration done here

Worst-case
System Directivity

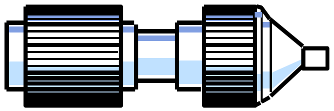
Adapting from APC-7 to SMA (m)

28 dB



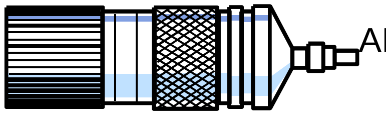
APC-7 to SMA (m)
SWR:1.06

17 dB



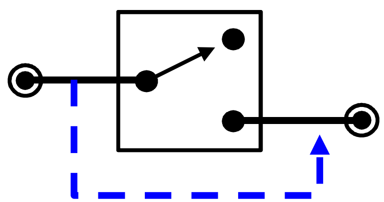
APC-7 to N (f) + N (m) to SMA (m)
SWR:1.05 SWR:1.25

14 dB

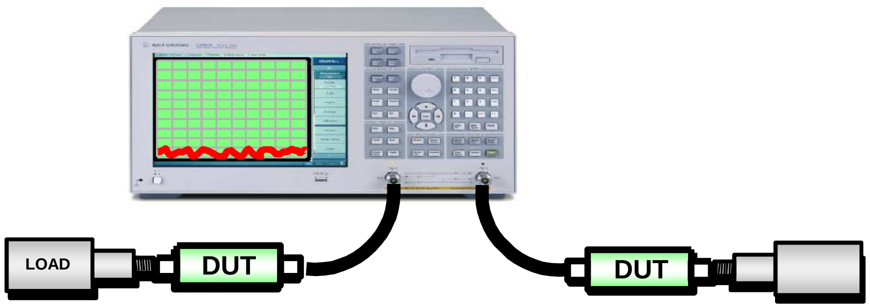


APC-7 to N (m) + N (f) to SMA (f) + SMA (m) to (m)
SWR:1.05 SWR:1.25 SWR:1.15

Crosstalk: Signal Leakage Between Test Ports During Transmission



- Can be a problem with:
  - high-isolation devices (e.g., switch in open position)
  - high-dynamic range devices (some filter stopbands)
- Isolation calibration
  - adds noise to error model (measuring near noise floor of system)
  - only perform if really needed (use averaging if necessary)
  - if crosstalk is **independent** of DUT match, use two terminations
  - if **dependent** on DUT match, use DUT with termination on output



Performing the Calibration: SOLT

Two most common types of calibration: SOLT and TRL

- Both types remove all the systematic error terms
- Type and definition of calibration standards are different

SOLT

- Basic form uses short, open, load, and known-thru standards
- Advanced forms use multiple shorts and loads, unknown thru, arbitrary impedances (ECal)
- Uses the 12-term error model

Advantages:

- Easy to perform
- Applicable to a variety of environments (coaxial, fixture, waveguide…)
- Provides a broadband calibration

Performing the Calibration: TRL

Basic form: thru, reflect, line standards

Advanced forms: TRM, LRM, LRM+, LRL, LRRL, LRRM…

Uses a 10-term error model

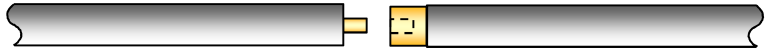
Advantages

- Uses standards that are easy to fabricate and have simpler definitions than SOLT
  - Only need transmission lines and high-reflect standards
  - Required to know impedance and approximate electrical length of line standards
  - Reflect standards can be any high-reflection standards like shorts or opens
  - Load not required; capacitance and inductance terms not required
- Potential for most accurate calibration (depends on quality of transmission lines)
- Commonly used for in-fixture, on-wafer and waveguide environments

Calibrating Non-Insertable Devices

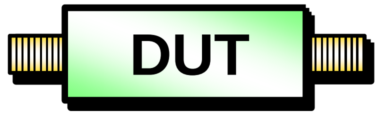
When doing a through cal, normally test ports mate directly

- cables can be connected directly without an adapter
- result is a zero-length through



What is an insertable device?

- has same type of connector, but different sex on each port
- has same type of sexless connector on each port (e.g. APC7)

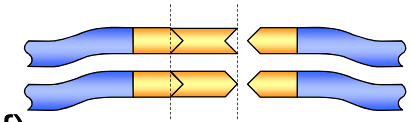


What is a non-insertable device?

- one that cannot be inserted in place of a zero-length through
- has same connectors on each port (type and sex)
- has different type of connector on each port (e.g., waveguide on one port, coaxial on the other)

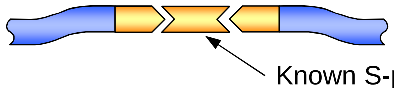
Compromises of Traditional Non-Insertable Methods

Swap equal adapters



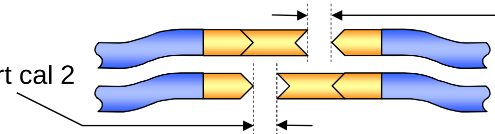
- Need phase matched adapters of different sexes (e.g., f-f, m-f)
- Errors introduced from loss and mismatch differences of adapters

Use characterized thru



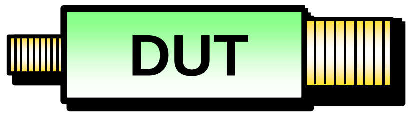
- Two-step process (characterize thru, then use it during calibration)
- Need a non-insertable cal to measure S-parameters of characterized thru

Perform adapter removal cal



- Accurate but many steps in calibration (need to do two 2-port calibrations)

Add adapters after cal, then, during measurement…



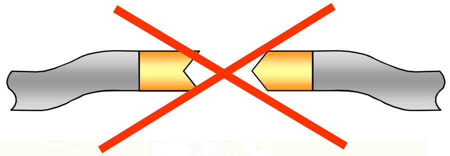
- Use port extensions – doesn't remove adapter mismatch effects
- De-embed adapters (S-parameters known) – similar to characterized thru

Unknown Thru Calibration

The "Unknown Thru" technique is…

Used when a "flush" (zero-length or mate-able) thru cannot be used or when using a flush thru would cause measurement impairment

A refinement of SOLT calibration



Also called short-open-load-reciprocal-thru (SOLR)

Unknown Thru technique eliminates need for…

Matched or characterized thru adapters

Moving or bending test cables

Works great for many component measurement challenges…

Non-insertable devices

Mechanically difficult situations

Multiport devices

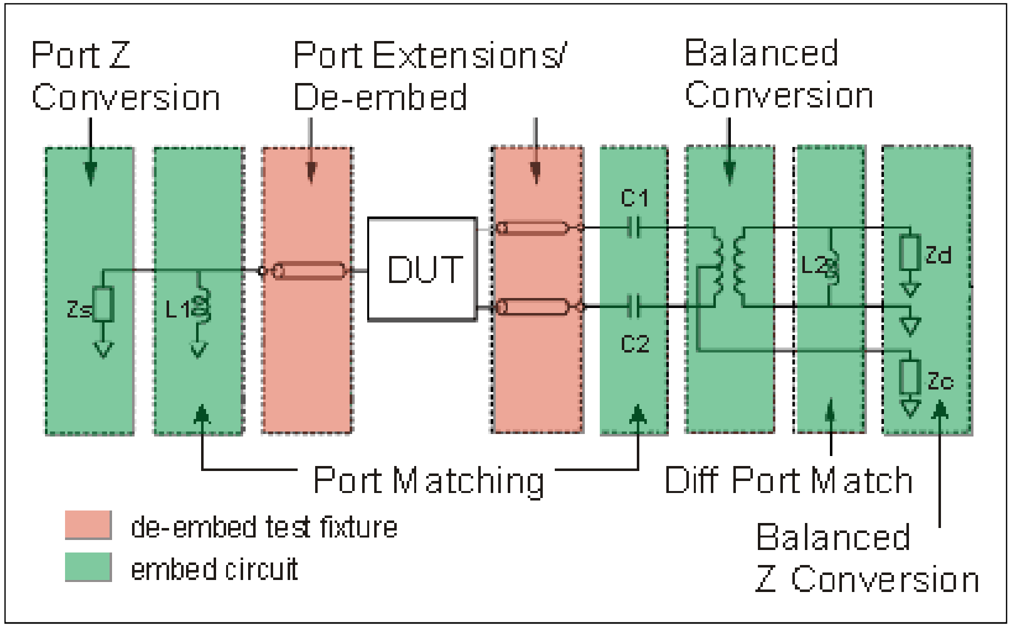
Order of Fixturing Operations

First, single-ended functions are processed in this order:

- Port extensions
- 2-port de-embedding
- Port Z (impedance) conversion
- Port matching / circuit embedding
- 4-port network embed/de-embed

Then, balanced functions are processed in this order:

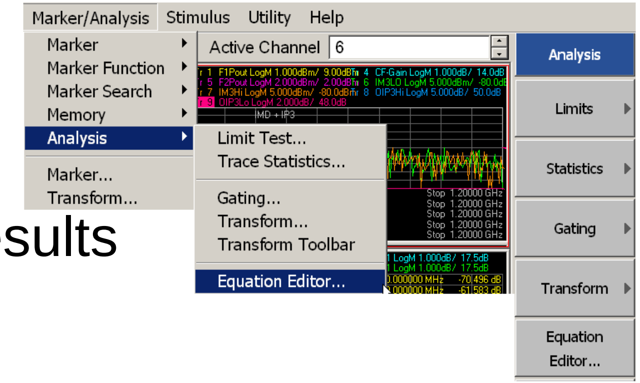
- Balanced conversion
- Differential- / common-mode port Z conversion
- Differential matching / circuit embedding



Example circuit simulation

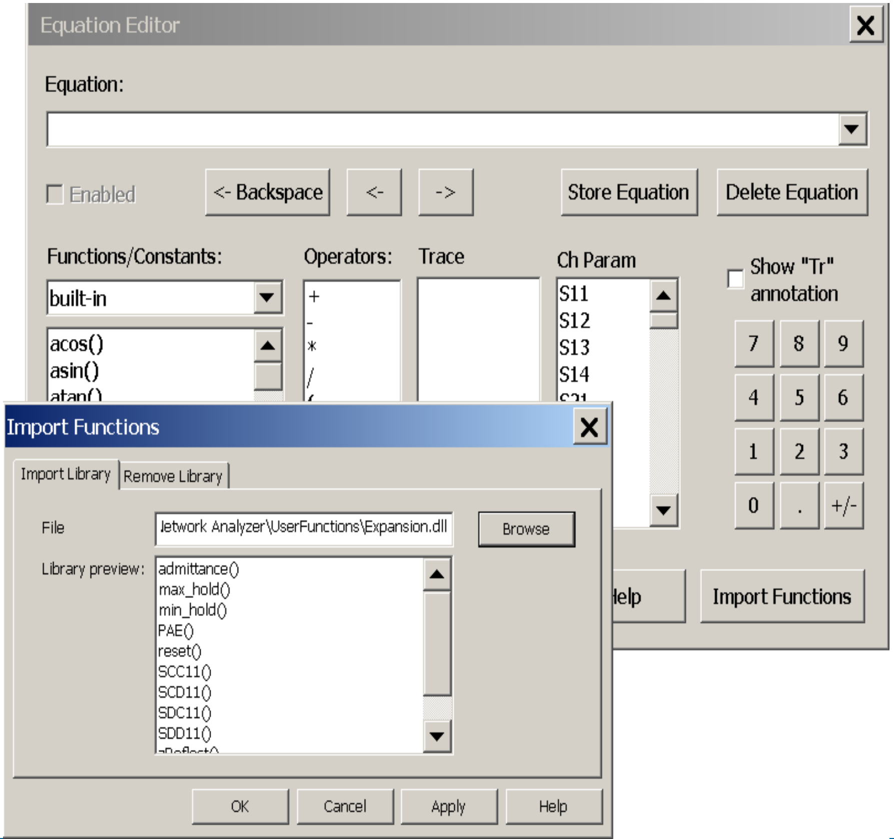
Equation Editor

If You Can't Measure it, Compute It!!



Powerful and convenient tool to add computation results as a new trace to your measurement display.

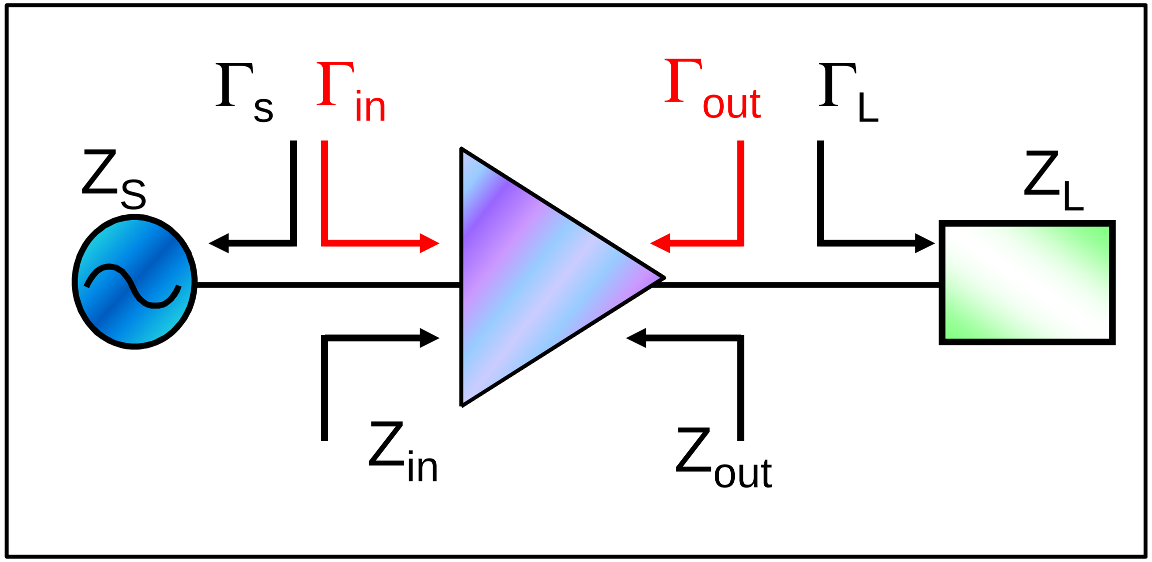
- Equations can be based on any combination of existing traces or underlying channel parameters or memory traces along with any user defined constants.
- You can use any of the basic operators or choose from an extensive library of functions and standard constants.
- Equations can be stored for later use.
- Import your own compiled library of functions



K-Factor, Stability

Oscillation possible when | Γ_{in} | or | Γ_{out}| > 1 (negative resistance)

Unconditional stable when Re{Zin} & Re{Zout} for all passive Zs & ZL



K-Factor, Stability

Unconditional stable when…

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|} > 1$$

…and

$$\Delta = |S_{11}S_{22} - S_{12}S_{21}| < 1$$

…at each frequency

All 4 S-parameters required

Use higher power for reverse measurements

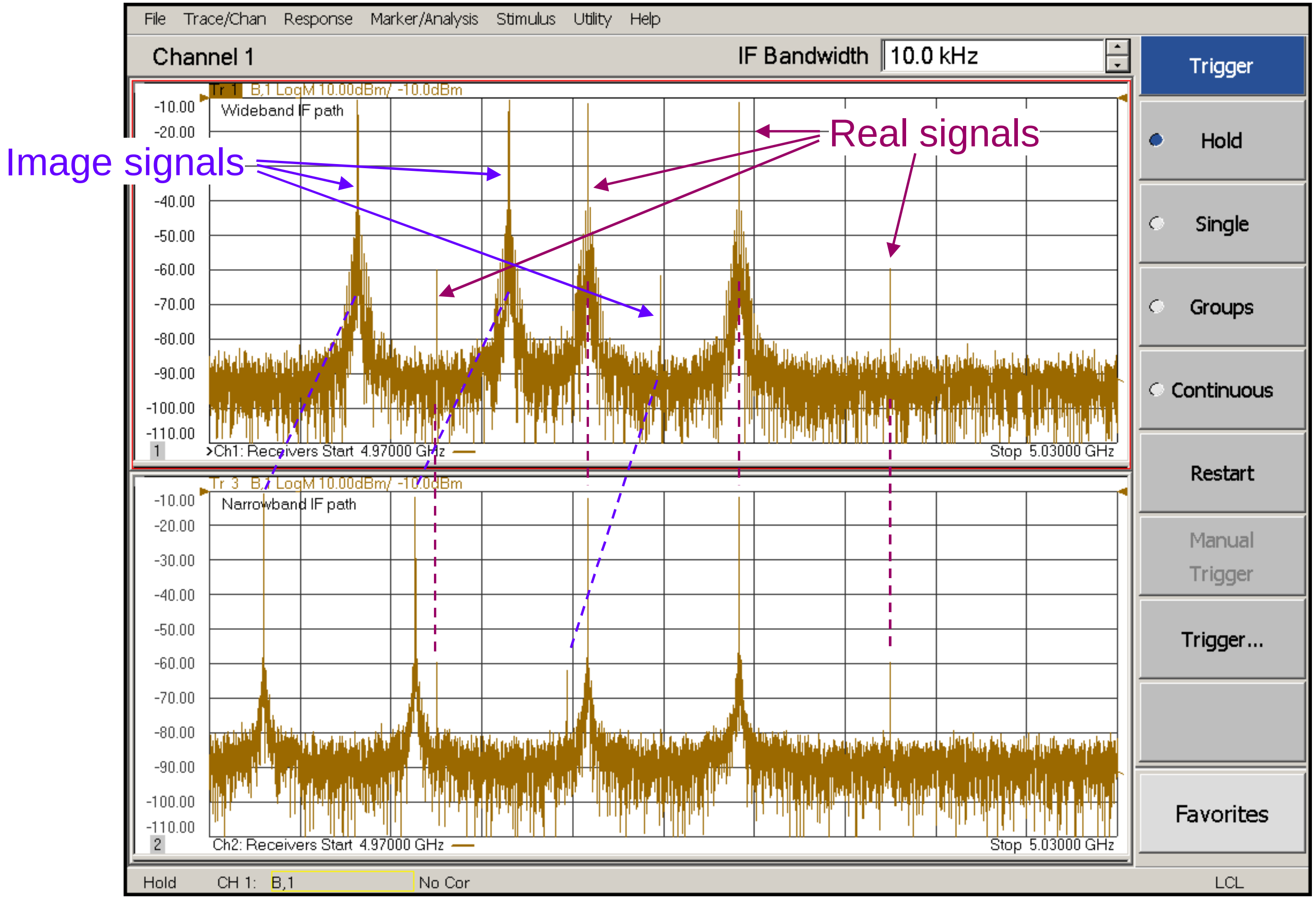
Demonstration 3/3

Advanced features

- Frequency Offset
- Spectrum view, Images!
- Path Configuration
- Hot S22
- …

Example of IF shift using FOM

Wideband IF path = 7.606 MHz
Narrowband IF path = 10.7 MHz



Special cases for high gain devices

For high gain devices (**more than 40 dB**), special care in the S-parameter cal is needed to avoid noise related issues

By default, the reverse power is set to the source power

- In high gain devices the source power is very low
- Often, port 2 padding is needed to reduce power from the amplifier
- **This makes the reverse measurement very noisy**
- Noise in the reverse measurements <u>show up in S11 and S21 through the full 2-port</u> error correction math

Follow the earlier guidelines, and set the Port 2 power higher than the Port 1 power by just less than the gain of the amplifier

Special cases for high power devices

For devices needing higher drive power, use the “loops” on the rear of the PNA-X to add a **booster amplifier**

Because this comes before the R-channel, you can use the R-channel and **Rx Leveling to compensate for amplifier drift**

Maximum input power is +30 dBm to the rear panel

External padding and maybe external coupling might be needed on port 2. Max port 2 power is +30 dBm (+43 with option H85).

Protecting the Device: Global Power Limit

Global Power Limit sets **a limit on the source port power**

Power Level is referred to the port, and **does not include any external amplifiers or pads**. Offsets will change the source setting by the offset value

One set, the output power will not exceed the limit regardless of any remote-software or front panel entries. Locking the limit will not let front-panel users override the setting without unlocking it from a software command

Changing power ranges after calibration

Might be necessary to evaluate a wide range of input powers

Nominal values are compensated, but fine-grain response is not compensated for

Moving **from 0 dB attenuation** to any other can cause **substantial change** (up to 0.5 dB)

Moving **from non-zero attenuation** to another non-zero is **usually better response**

Changing source power (ALC power) is always OK.