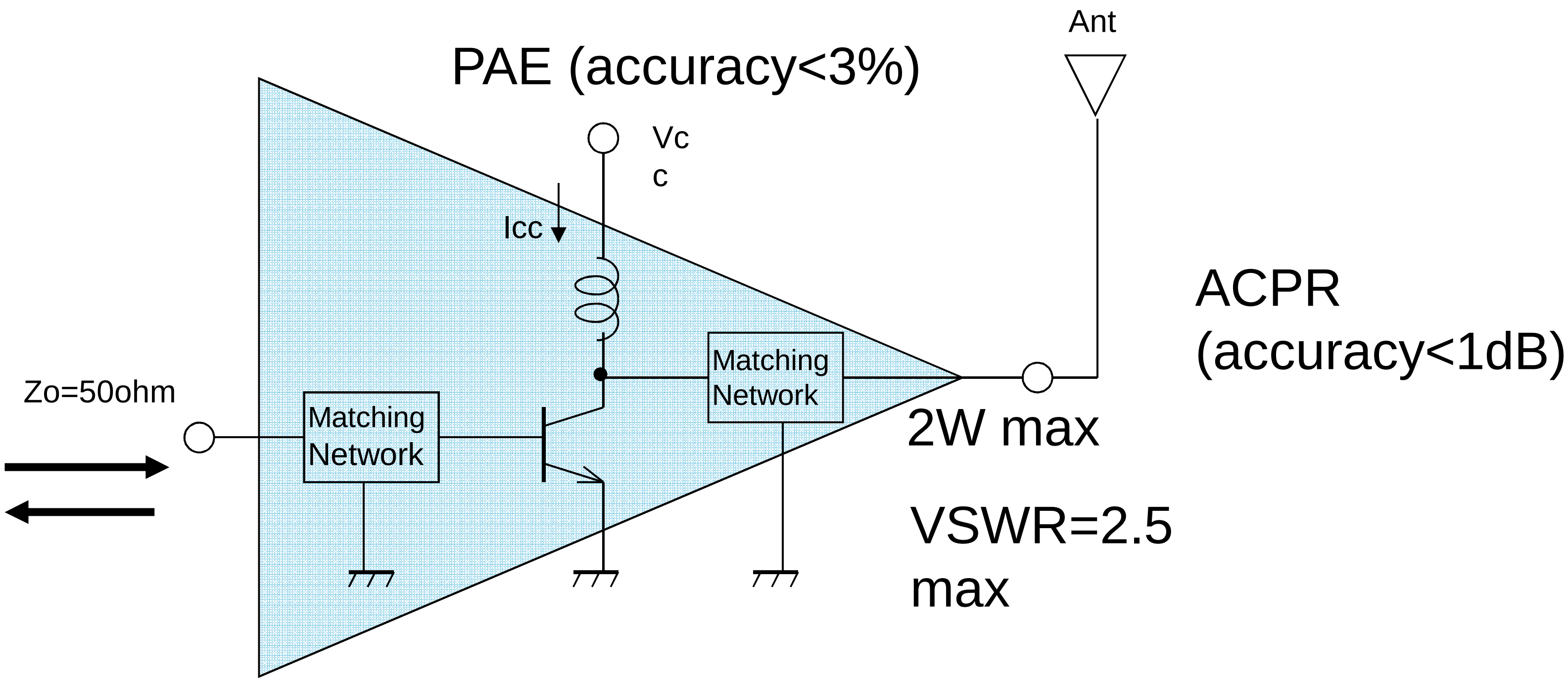
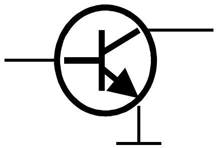
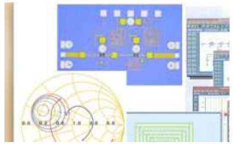
How do I optimize desired Amplifier Specifications?



PAE= Power Added Efficiency
ACPR= Adjacent Channel Power Ratio
VSWR= Voltage Standing Wave Ratio

Evolution of the Tools & Measurements





Patchwork → **S-Parameters** → **S-Parameters + Figures of Merit** → **NVNA + X-Parameters**

TOOLS:
SS & Oscilloscope
Grease pens and
Polaroid cameras
Slotted line
Power meter

MEASUREMENTS:
Bode plots
Gain
SWR
Scalar network analyzers
Y & Z parameters

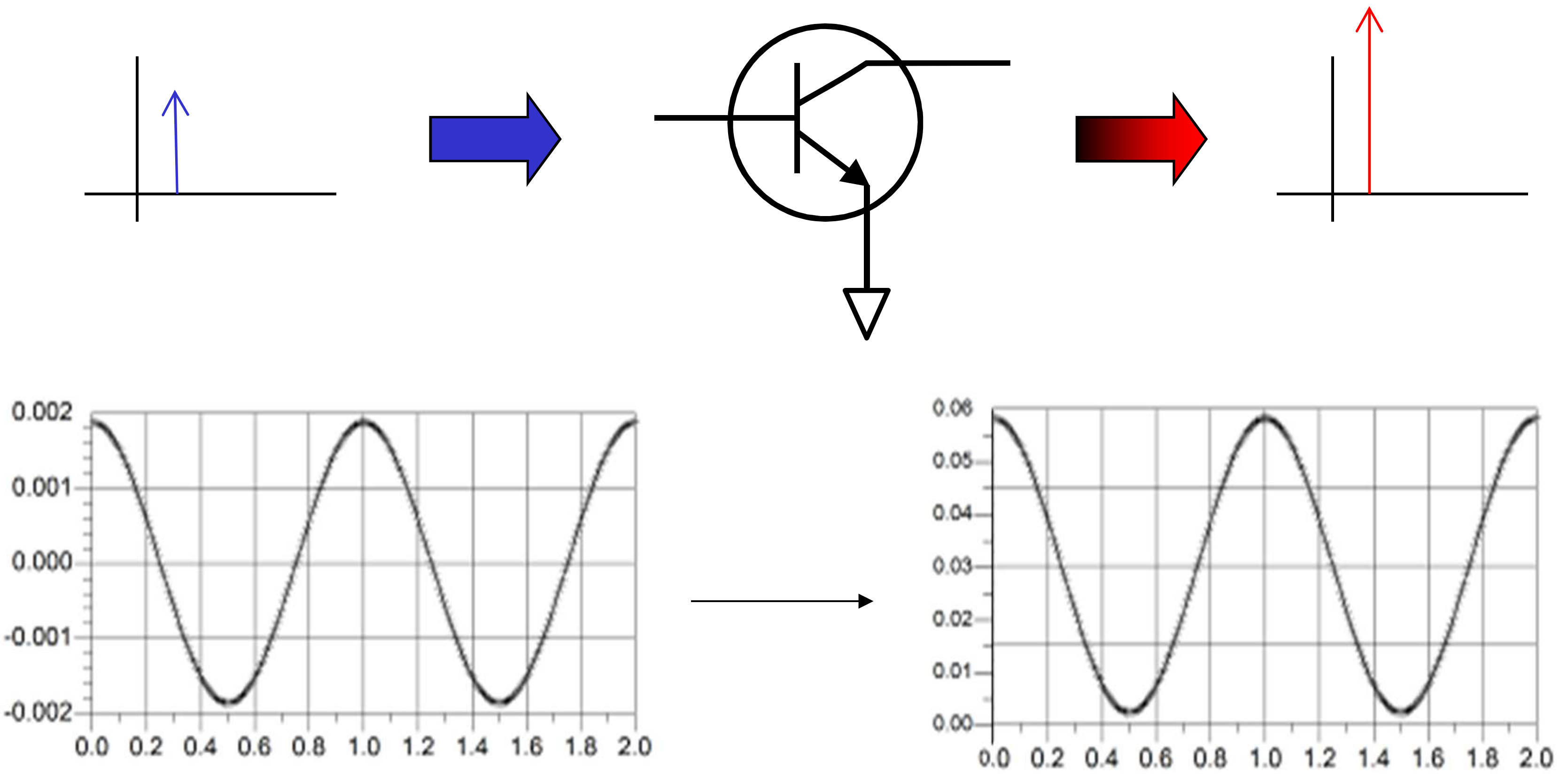
TOOLS:
Vector Network
Analyzer

MEASUREMENTS:
Gain
Input match
Output match
Isolation
Transconductance
Input capacitance

TOOLS:
NA
SA/SS/NFA
Power meter
Oscilloscope
DC Parametric Analyzer

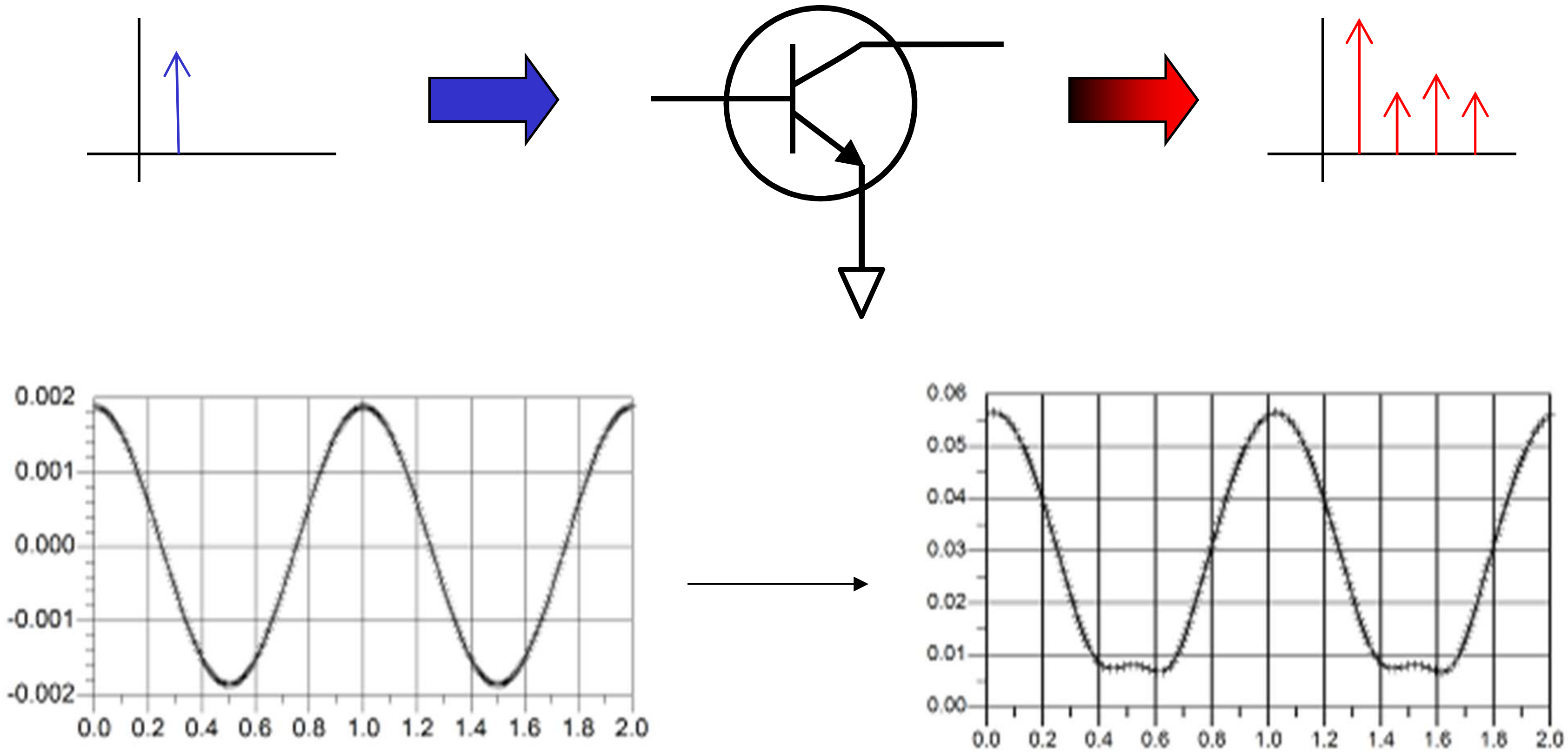
MEASUREMENTS:
Gain compression, IP3, IMD
PAE, ACPR, AM-PM, BER
Constellation Diagram, EVM
GD, NF, Spectral Regrowth
ACLR, Hot “S22”

Measurements on Linear Components

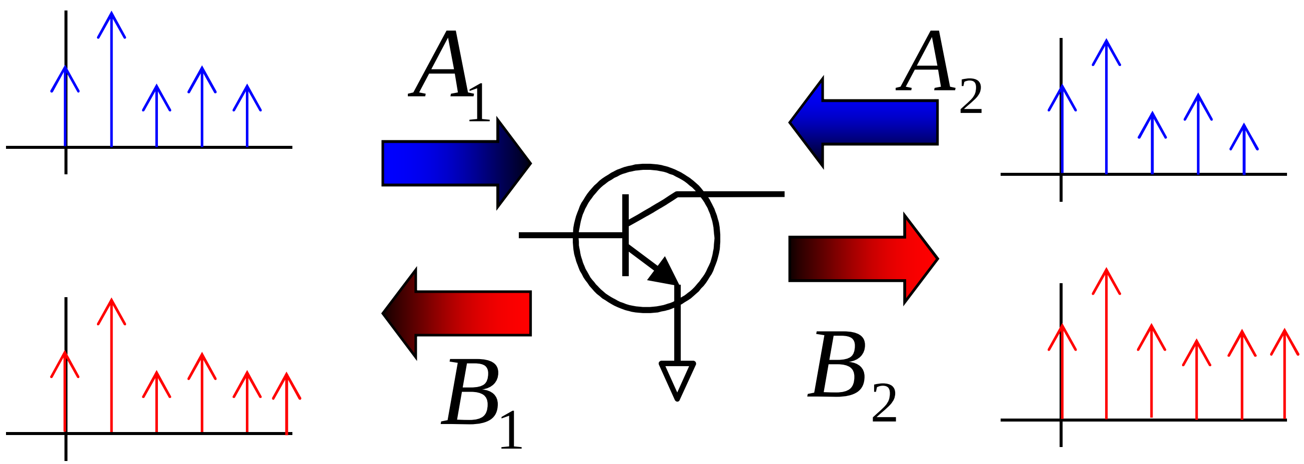


All measurements at same frequency as stimulus

Measurements on Nonlinear Components

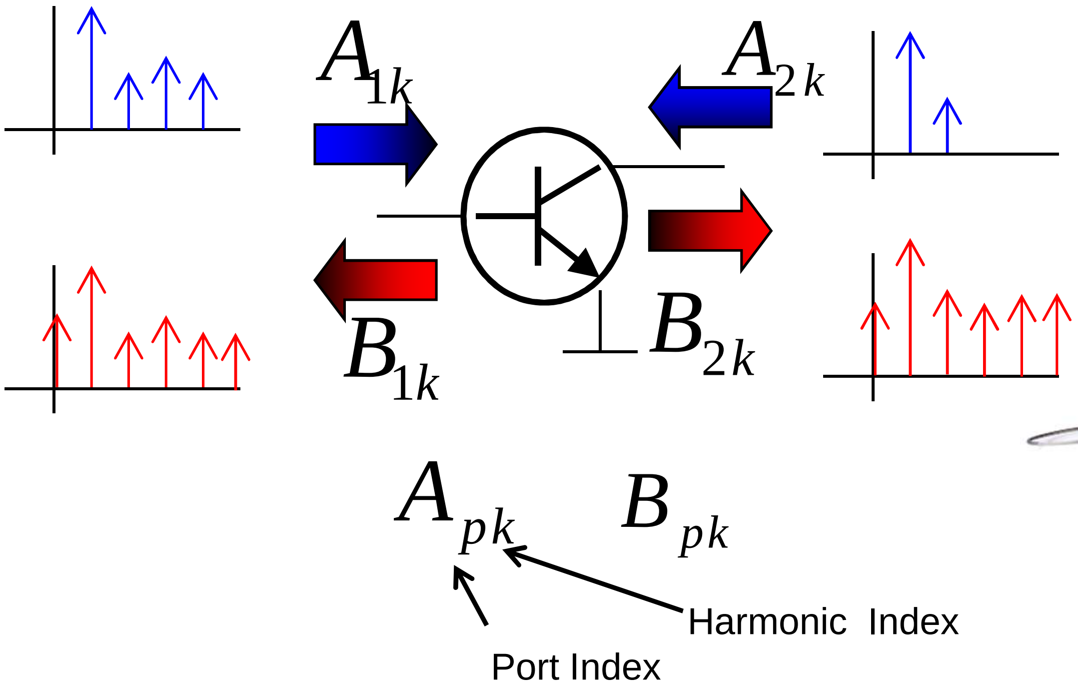


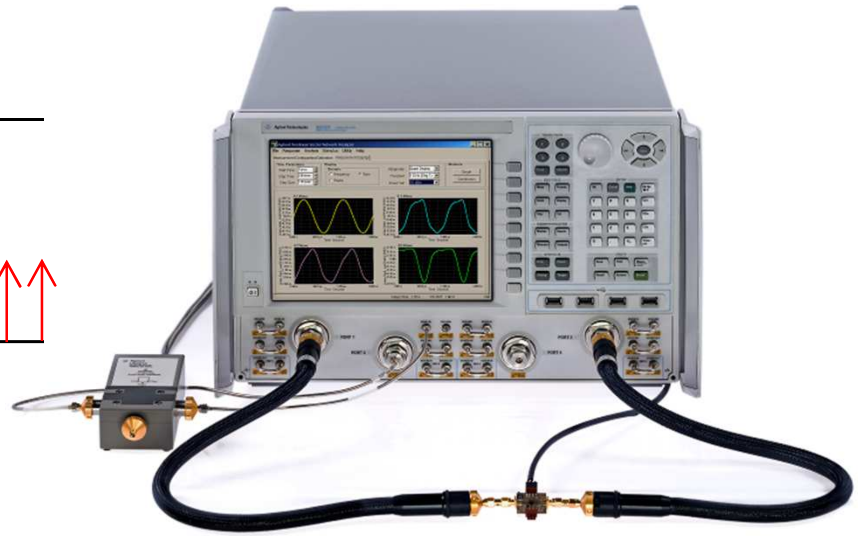
It’s Really Even More Complex

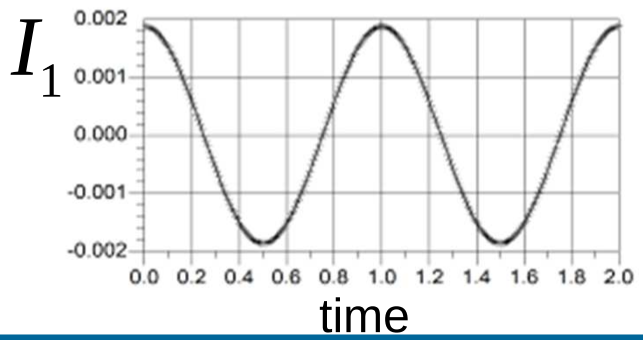


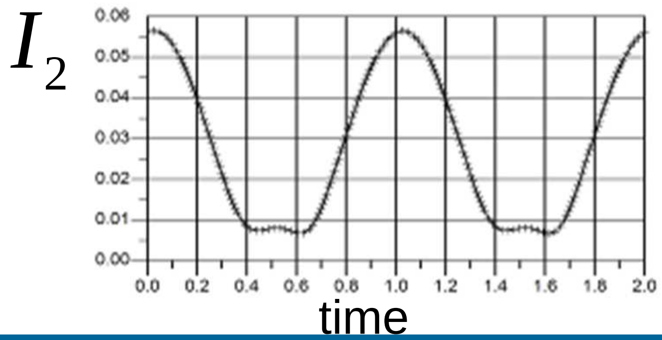
NVNA measurements

– complex spectra and time domain waveforms

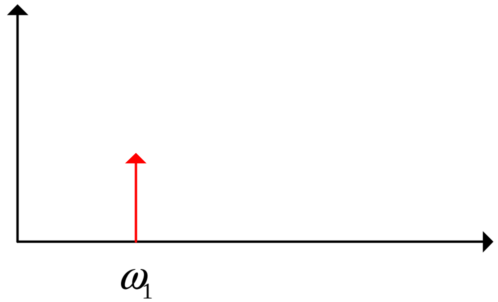


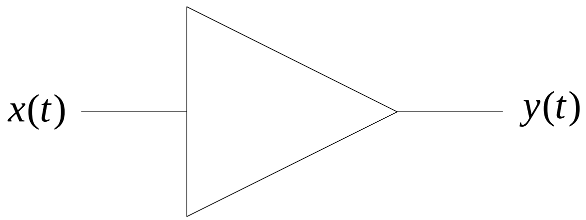


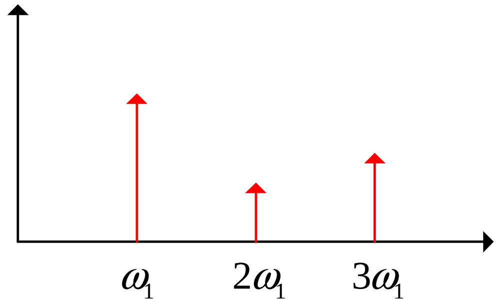




Nonlinearities







$$x(t) = Ae^{j(w_0 t + \phi_0)}$$

$$\begin{aligned} y(t) &= a_0 + b_0 e^{j\theta_{b0}} x(t) \\ &+ c_0 e^{j\theta_{c0}} x(t)^2 \\ &+ d_0 e^{j\theta_{d0}} x(t)^3 \end{aligned}$$

$$\begin{aligned} y(t) &= a_0 + b_0 e^{j\theta_{b0}} \left[Ae^{j(\omega_0 t + \phi_0)} \right] \\ &+ c_0 e^{j\theta_{c0}} \left[A^2 e^{j2(\omega_0 t + \phi_0)} \right] \\ &+ d_0 e^{j\theta_{d0}} \left[A^3 e^{j3(\omega_0 t + \phi_0)} \right] \end{aligned}$$

The Need for Phase

Cross-Frequency Phase

- Notice that each frequency component has an associated static phase shift. Each frequency component has a phase relationship to each other.

$$y = a_0 + b_0 e^{j\theta_{b0}} \left[A e^{j(\omega_0 t + \phi_0)} \right] + c_0 e^{j\theta_{c0}} \left[A^2 e^{j2(\omega_0 t + \phi_0)} \right] + d_0 e^{j\theta_{d0}} \left[A^3 e^{j3(\omega_0 t + \phi_0)} \right]$$

Why Measure This?

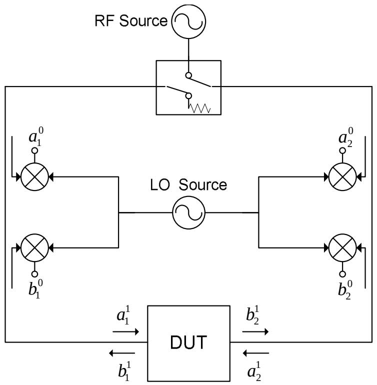
If we can measure the absolute amplitude and cross-frequency phase we have knowledge of the nonlinear behavior such that we can:

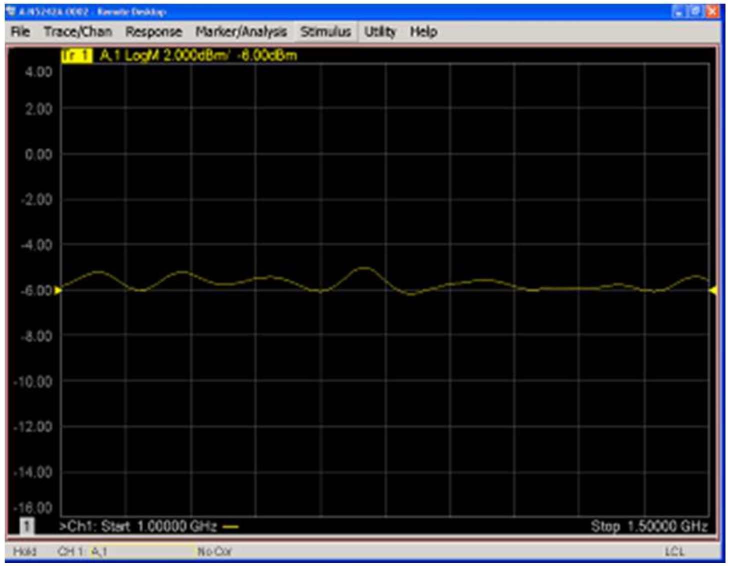
- Convert to time domain waveforms.
- Measure phase relationships between harmonics.
- Generate model coefficients.
- Frequency converters

Measuring Unratioed Measurements on PNA-X

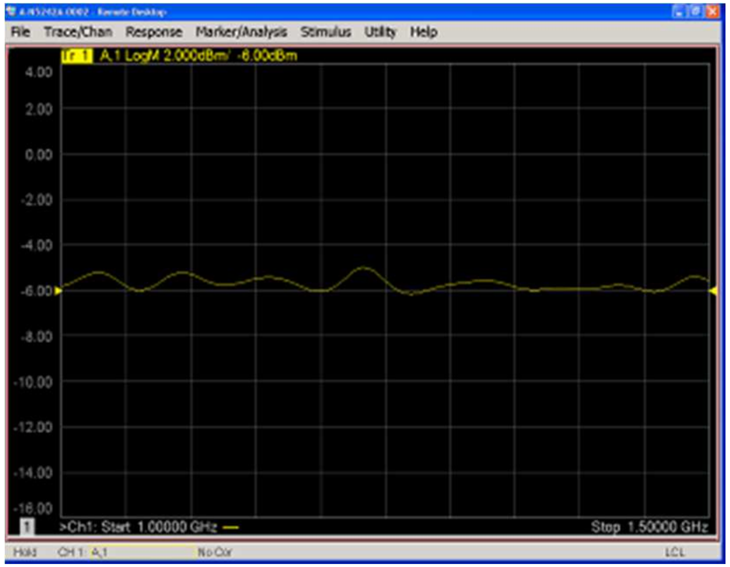
Unratioed Measurements – Amplitude

- Works fine.
- Ever tried to measure phase across frequency on an unratioed measurement?





Sweep 1



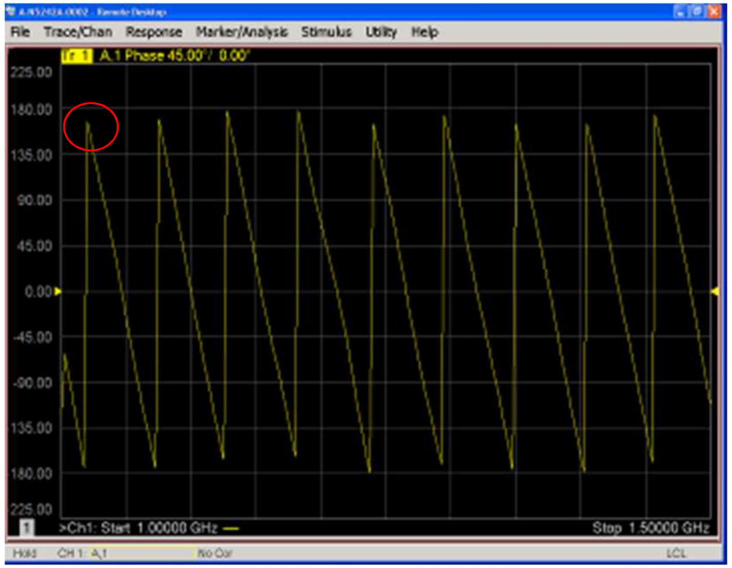
Sweep 2

Measuring Unratioed Measurements on PNA-X

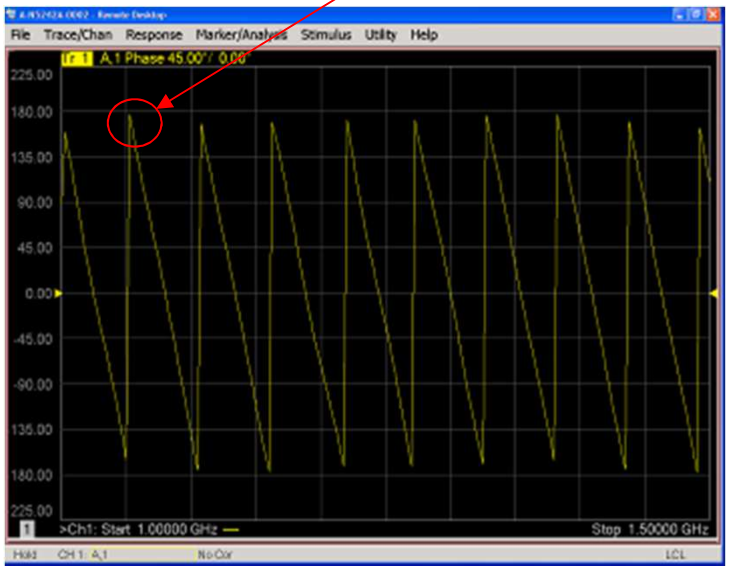
Unratioed Measurements – Phase

- Phase response changes from sweep to sweep. As the LO is swept the LO phase from each frequency step from sweep to sweep is not consistent. This prevents measurement of the cross-frequency phase of the frequency spectra.

Phase Shifted



Sweep 1

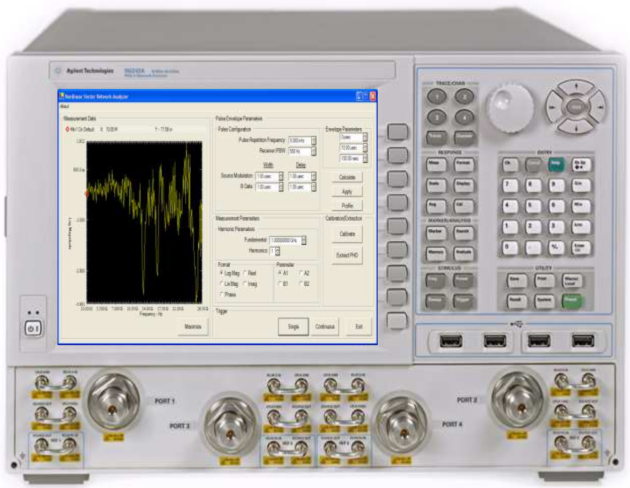


Sweep 2

NVNA System Configuration

Vector (amplitude/phase) corrected nonlinear measurements

PNA-X Network Analyzer



Amplitude Calibration

Vector Calibration

Phase Calibration

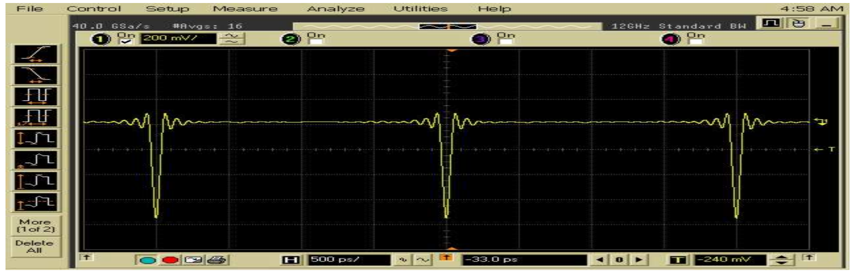
Phase Reference

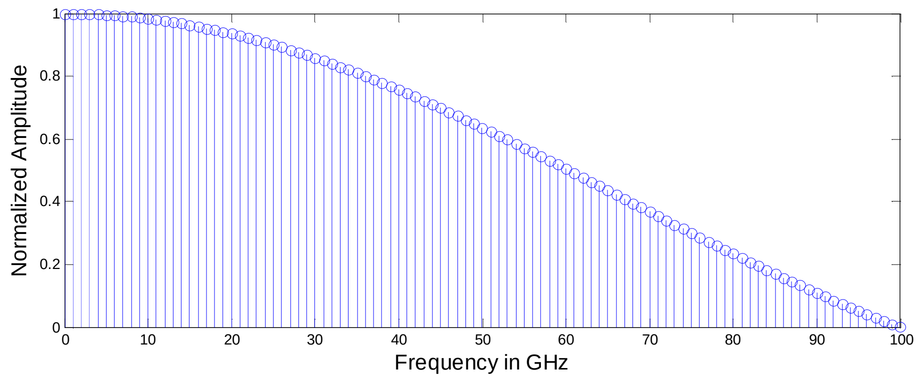
Agilent Proprietary Calibrated Phase Reference

X-Parameter extraction source

Phase Reference- Frequency & Time domains

Agilent Calibrated Phase Reference



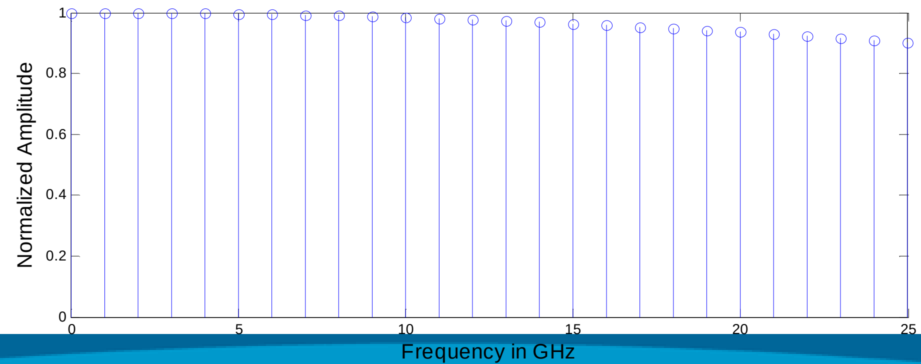


Drive phase reference with a F_{in}

Get $n*F_{in}$ at the output

Example:

- Stimulate DUT with 1 GHz input stimulus
- Measure harmonic responses at 1, 2, 3, 4, 5 GHz.



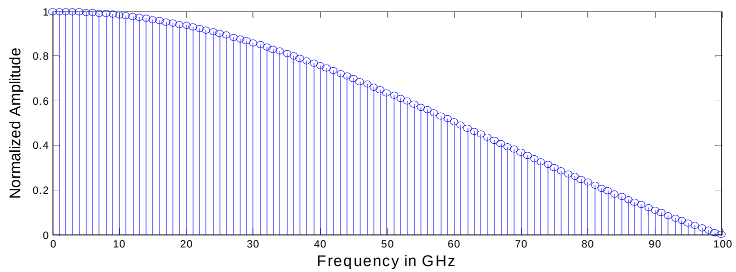
NVNA System Configuration
-Phase Reference

Agilent's new IC based phase reference is superior in all aspects to existing phase reference technologies.

Agilent Calibrated Phase Reference

Advantages:

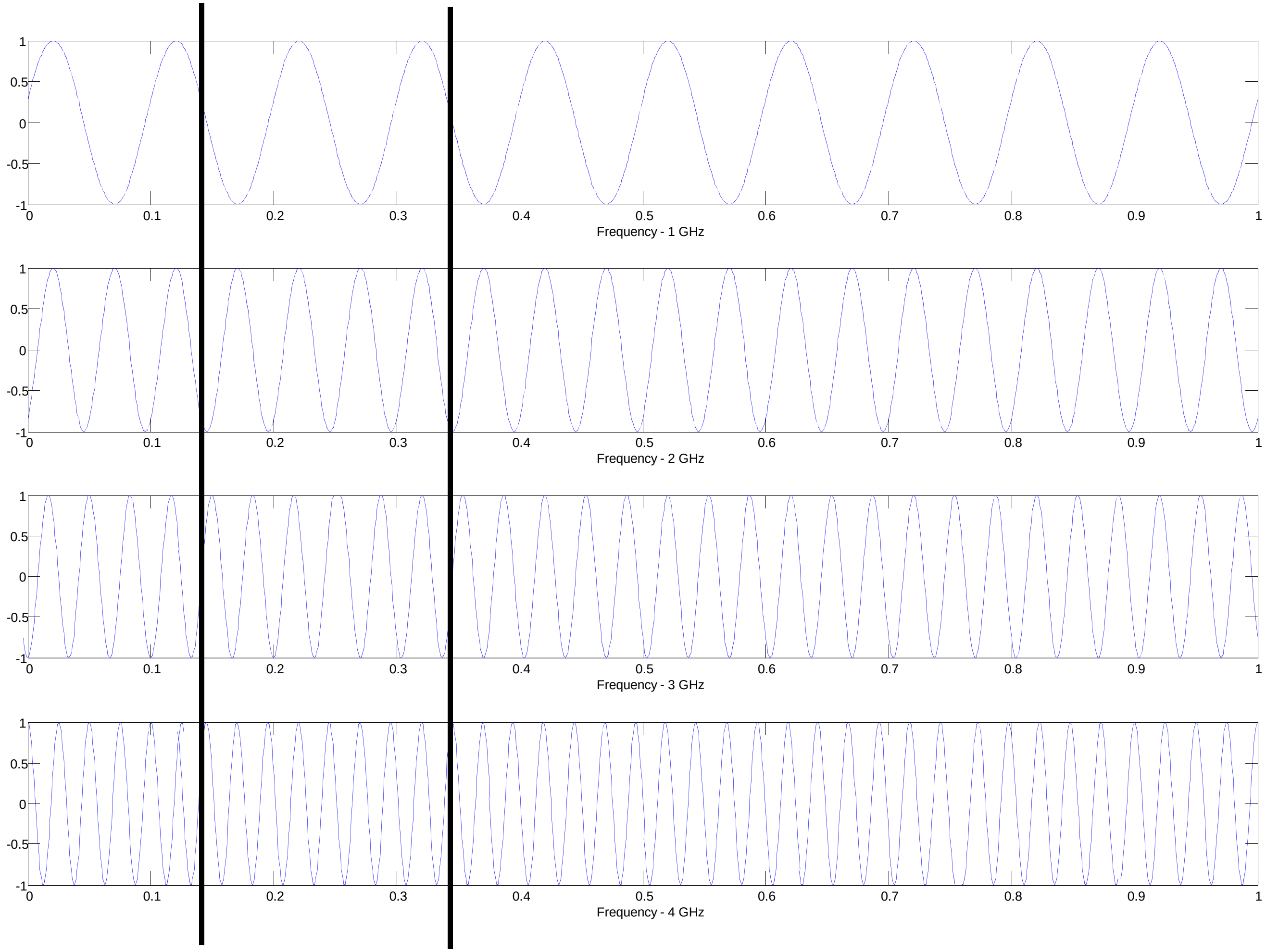
- Lower temperature sensitivity
- Lower sensitivity to input power
- Smaller minimum tone spacing (< 10 MHz vs 600 MHz)
- Lower frequency (< 10 MHz vs 600 MHz)
- Much wider dynamic range due to available energy vs noise



NVNA System Configuration

-Phase Reference

If we were to isolate a few of the frequencies we would see that the phase relationship remains constant versus input drive frequency and power (at least on Agilent one).



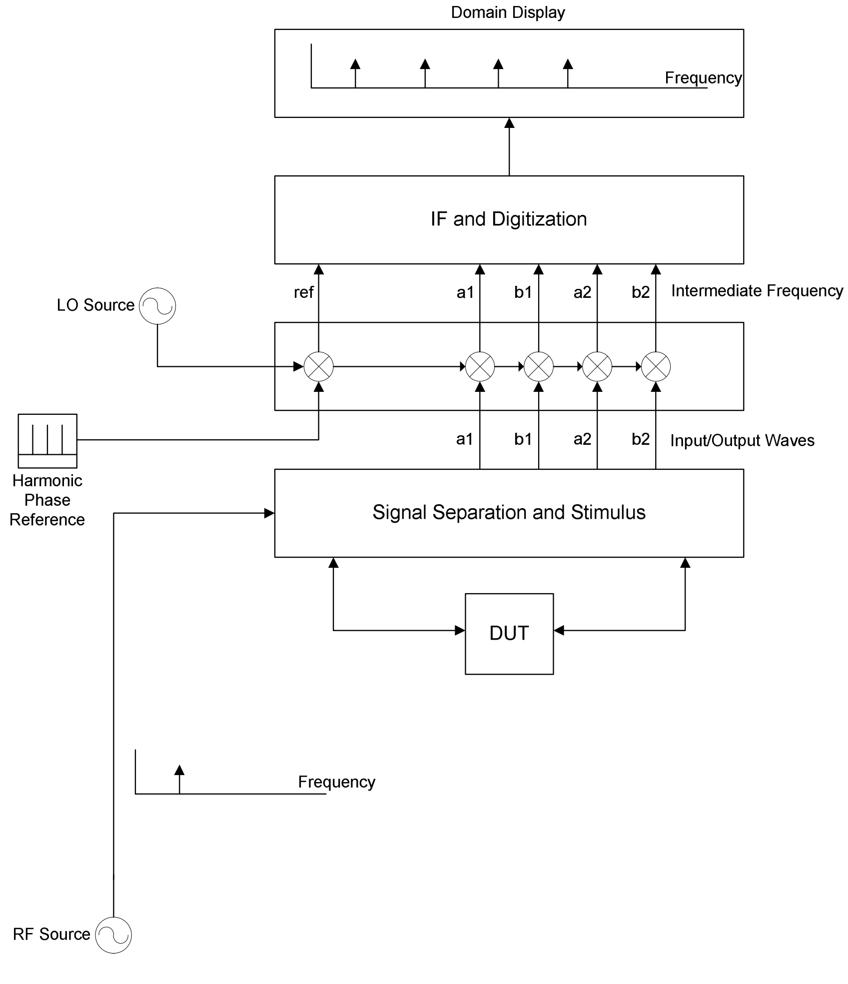
NVNA Hardware Configuration

Generate Static LO

Since we are using a mixer based VNA the LO phase will change as we sweep frequency. This means that we cannot directly measure the phase across frequency using unratioed (a1, b1) measurements.

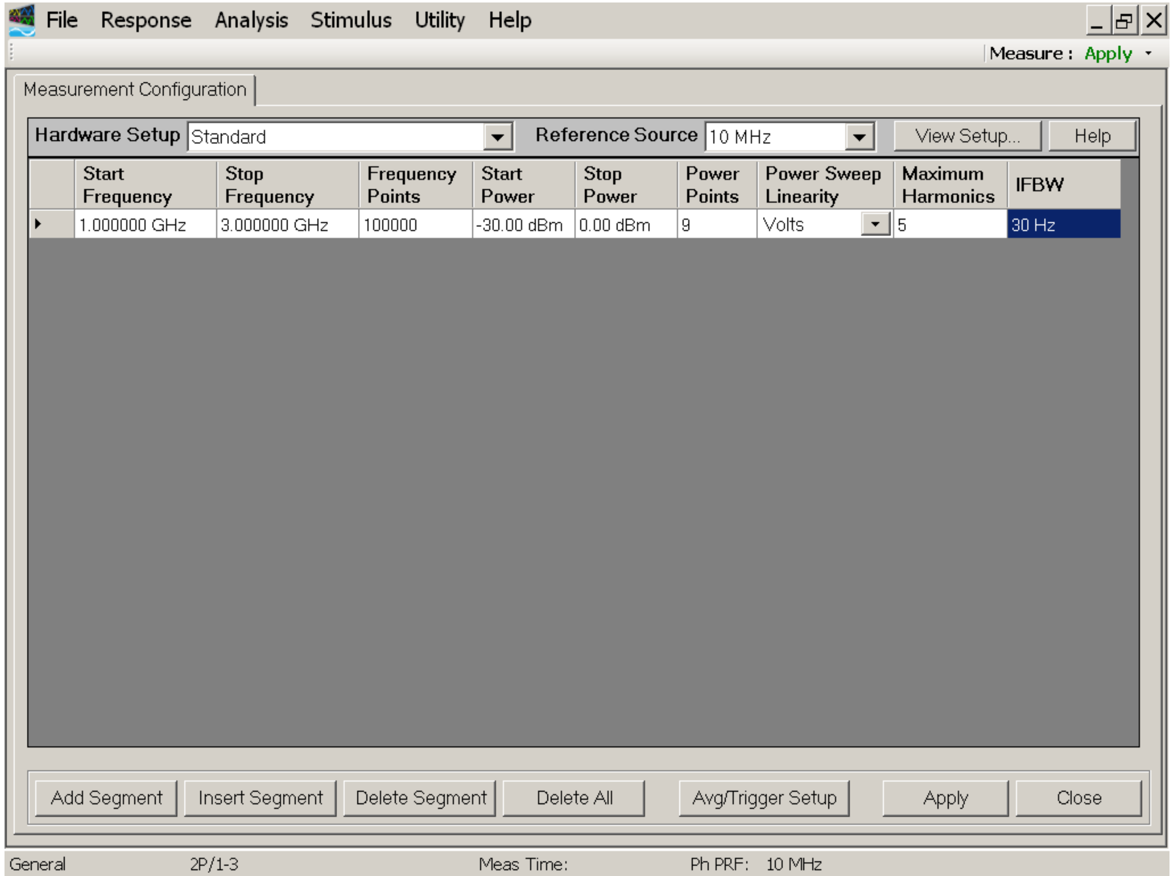
Instead…ratio (a1/ref, b2/ref) against a device that has a constant phase relationship versus frequency. A harmonic phase reference generates all the frequency spectrum simultaneously.

The harmonic phase reference frequency grid and measurement frequency grid are the same (although they do not have to be generally). For example, to measure a maximum of 5 harmonics from the device (1, 2, 3, 4, 5 GHz) you would place phase reference frequencies at 1, 2, 3, 4, 5 GHz.



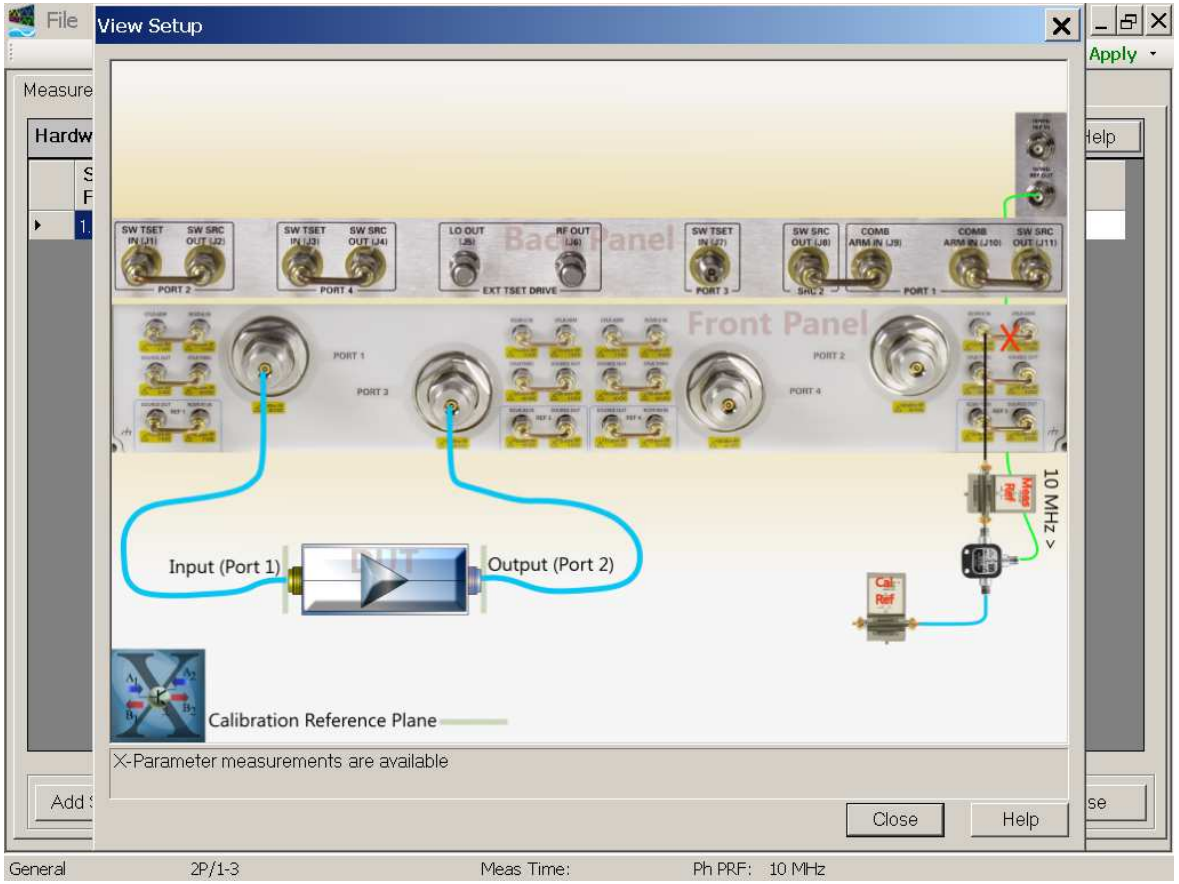
Nonlinear VNA Measurements

Stimulus/Response Setup 1/2



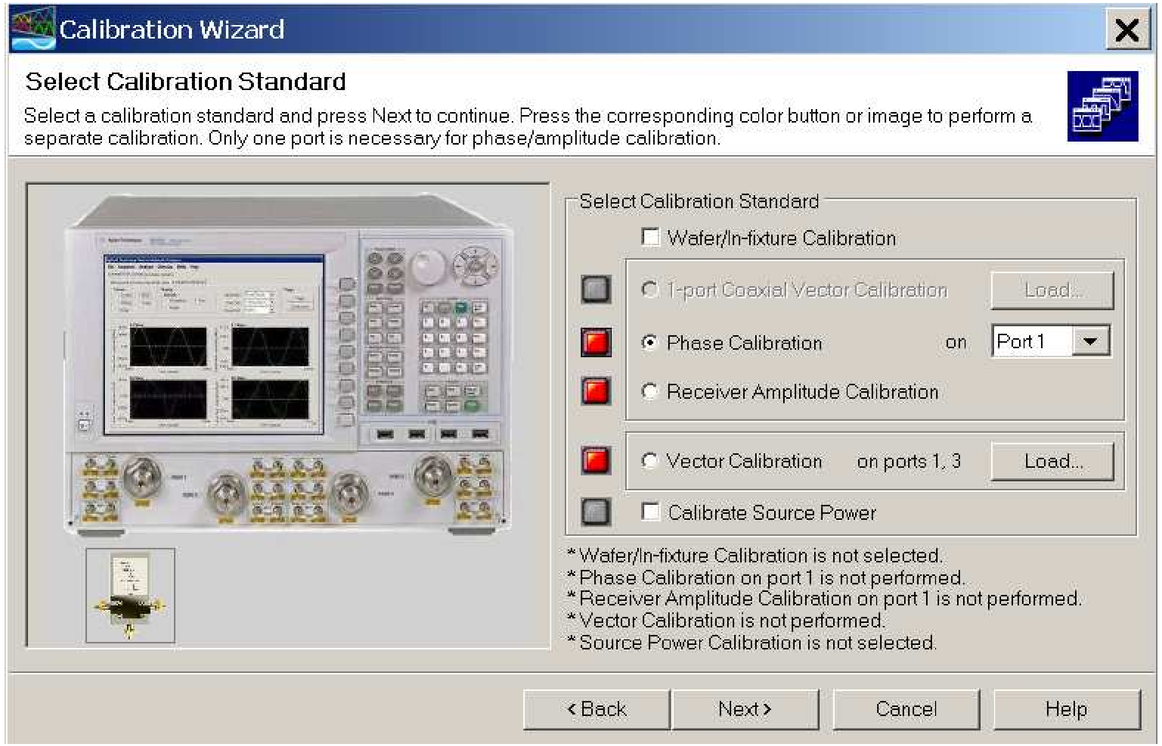
Nonlinear VNA Measurements

Stimulus/Response Setup 2/2



Nonlinear VNA Measurements

Guided Calibration Wizard



Nonlinear VNA Measurements

Measurement Display