Extending Vector Network Analyzers ....

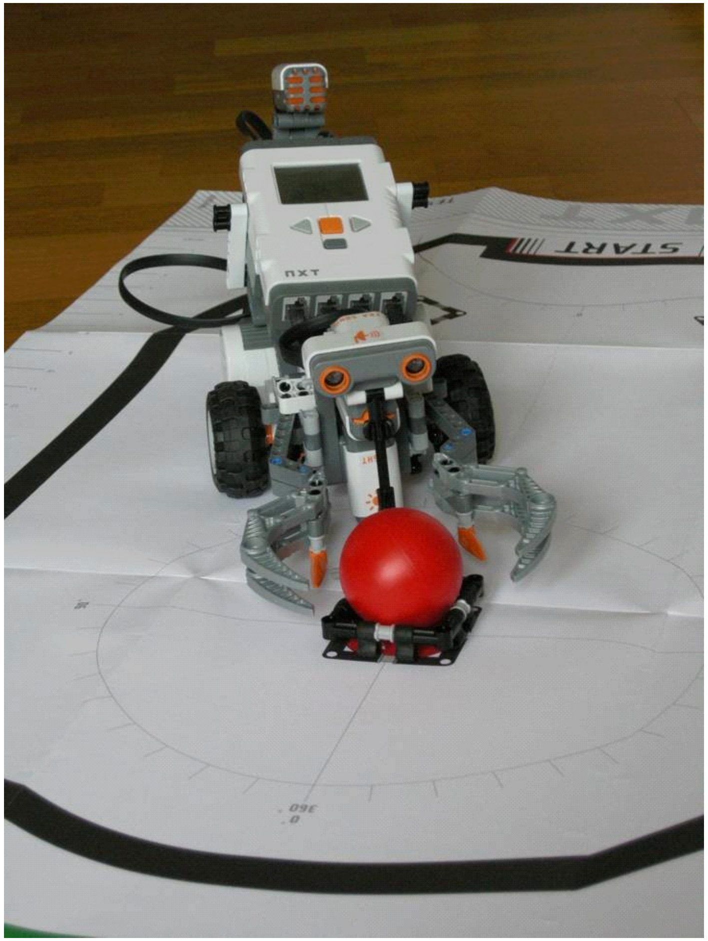
- Characterization of diodes, transistors and amplifiers -

- in frequency and time domain -

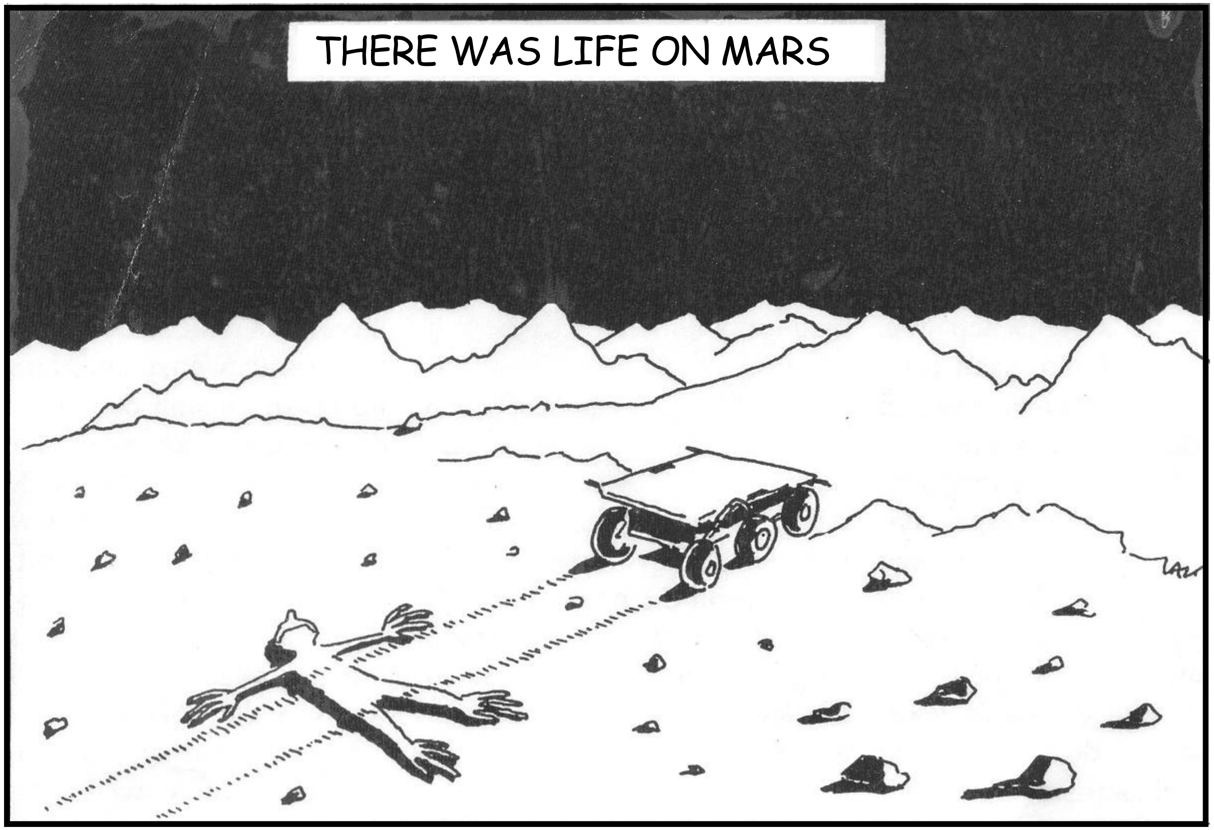
NMDG Engineering

Leading beyond S-parameters

A little story



A little story



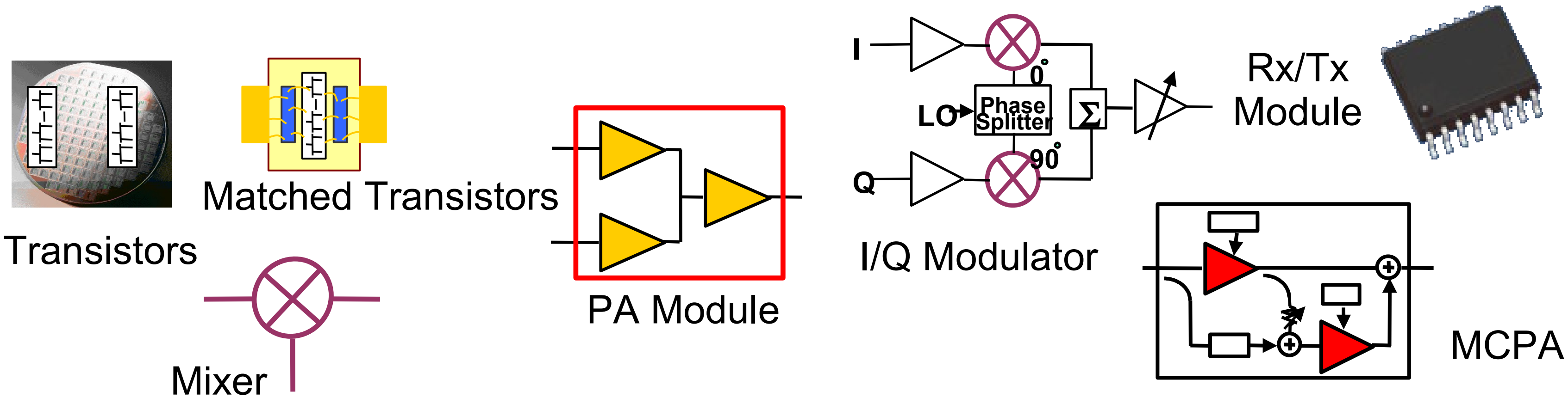
Agenda

- Why extending vector network analyzers?
- Large-Signal Network Analysis
- Commercial Solutions
- Theory of Operation of VNAPlus
- Capabilities of VNAPlus
- Applications
  - Breakdown effects
  - Model verification in ADS
  - In-circuit Probing
- VNAPlus and “Sensing Tuner”: a new frontier
- Conclusions

Design Challenge

"Customers are demanding more capabilities/performance from their devices at lower cost"

- Designers are looking for better and faster methods of characterizing their components

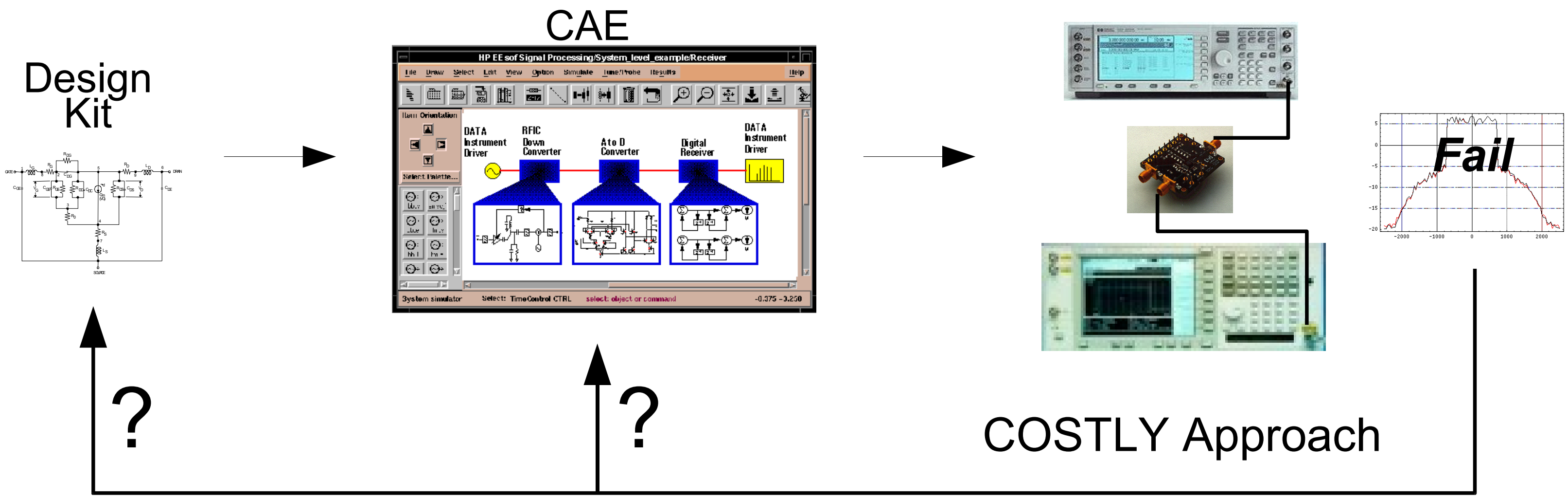


Demands translate to greater design complexities

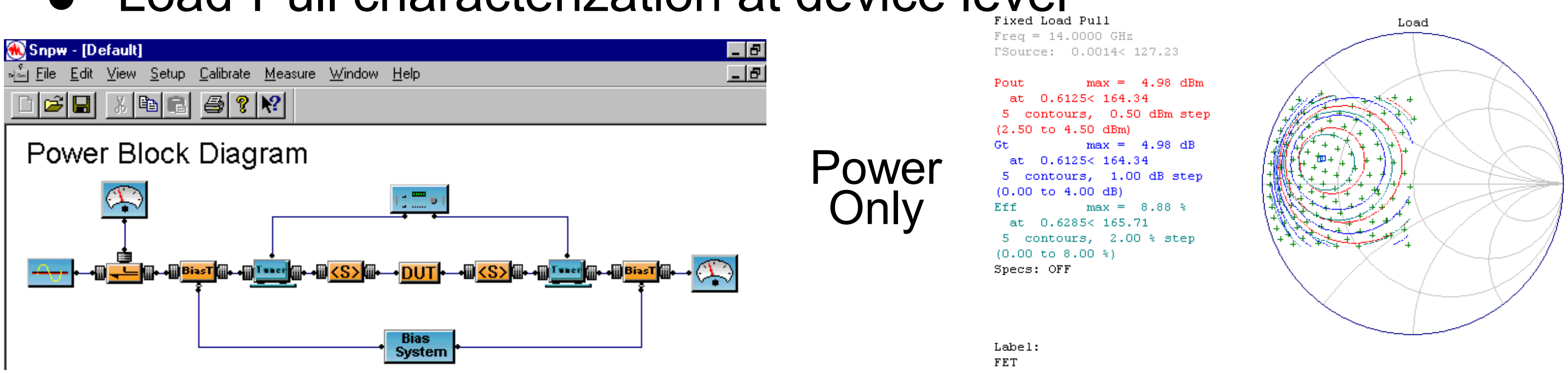
- More complex modulation schemes
- Higher power efficiency requirements
- Improved linearity

Model Verification Techniques

- Design, manufacture and test under realistic conditions



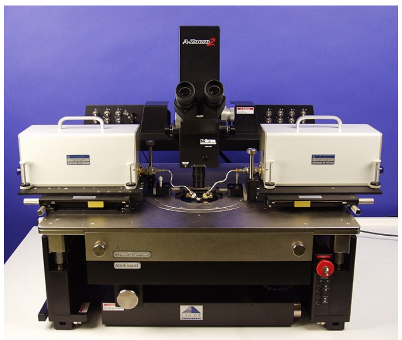
- Load-Pull characterization at device level

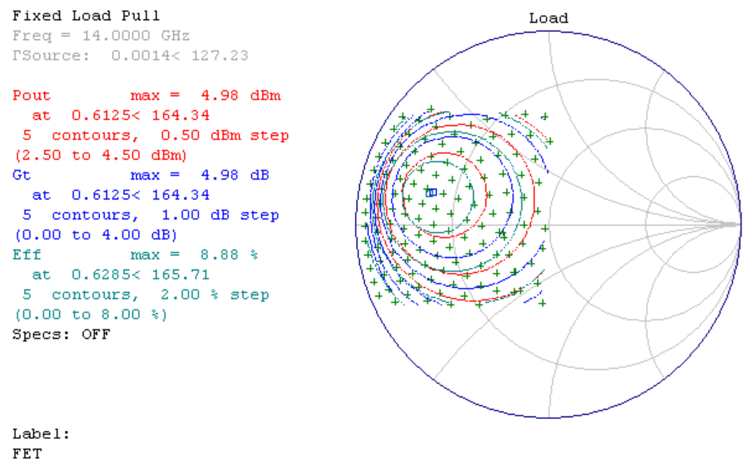


"What happens at the transistor?"

Direct design techniques

- Source- and load-pull- characterization
  - Absence of good models
  - Difficult to extract good model parameters
  - Mainly power information

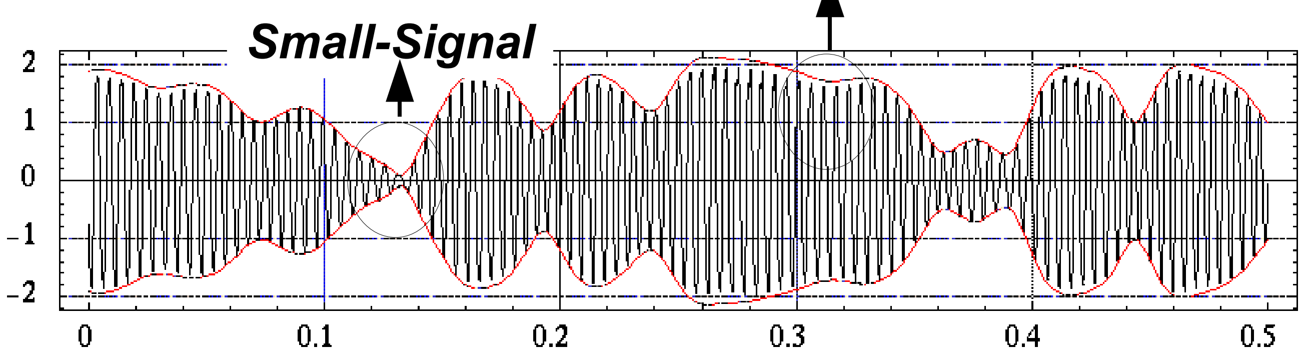




"For each input power"

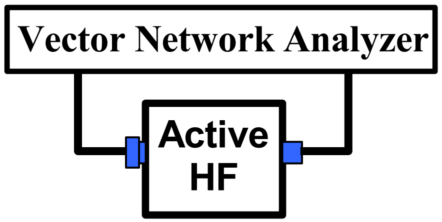
- <u>But:</u> What under modulation stimulus?

Large-Signal

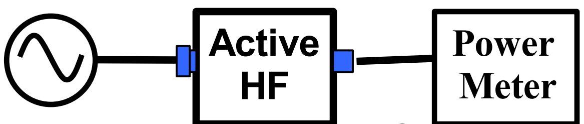


Component Characterization

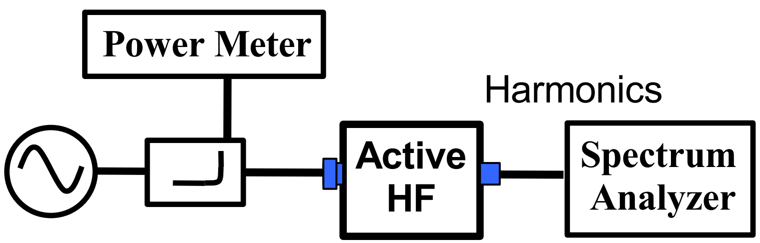
50 Ohm Termination



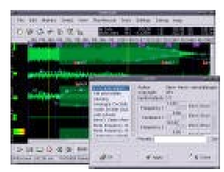
Linear
S-parameters

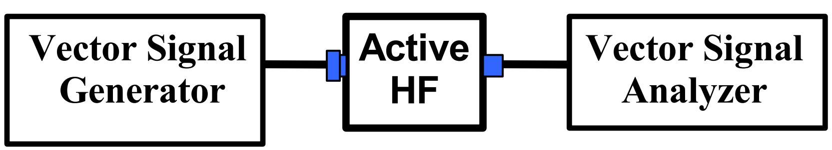


Compression



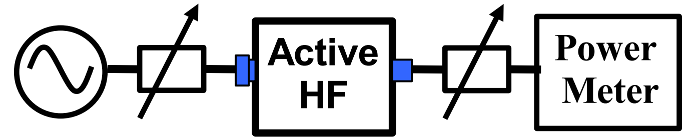
Harmonics



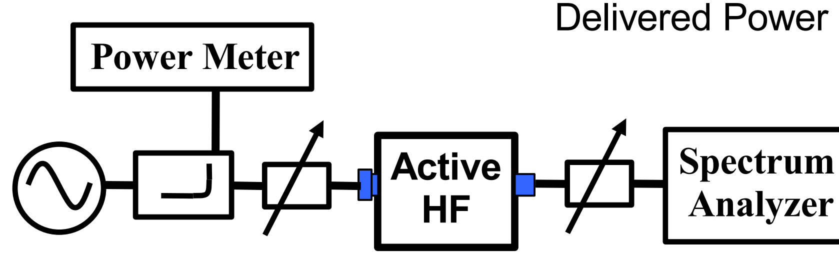


Spectral Regrowth

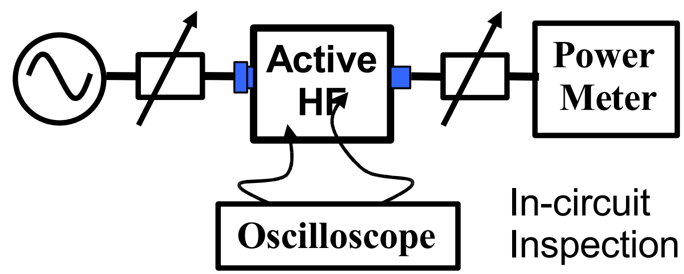
Source and Load Tuning



Compression
Delivered Power



Harmonics

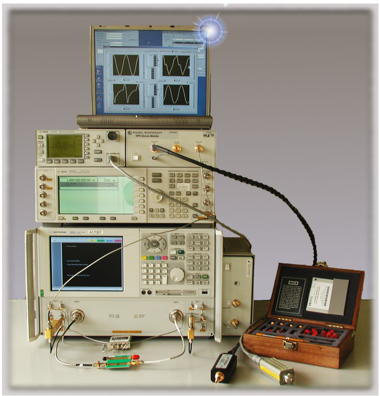


In-circuit
Inspection

Different Setups
for different aspects
without systematic approach

How to help the circuit designers,
needing good models?

Extending a vector network analyzer with VNAPlus



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Measuring directly

accurately and completely

the true nonlinear behavior

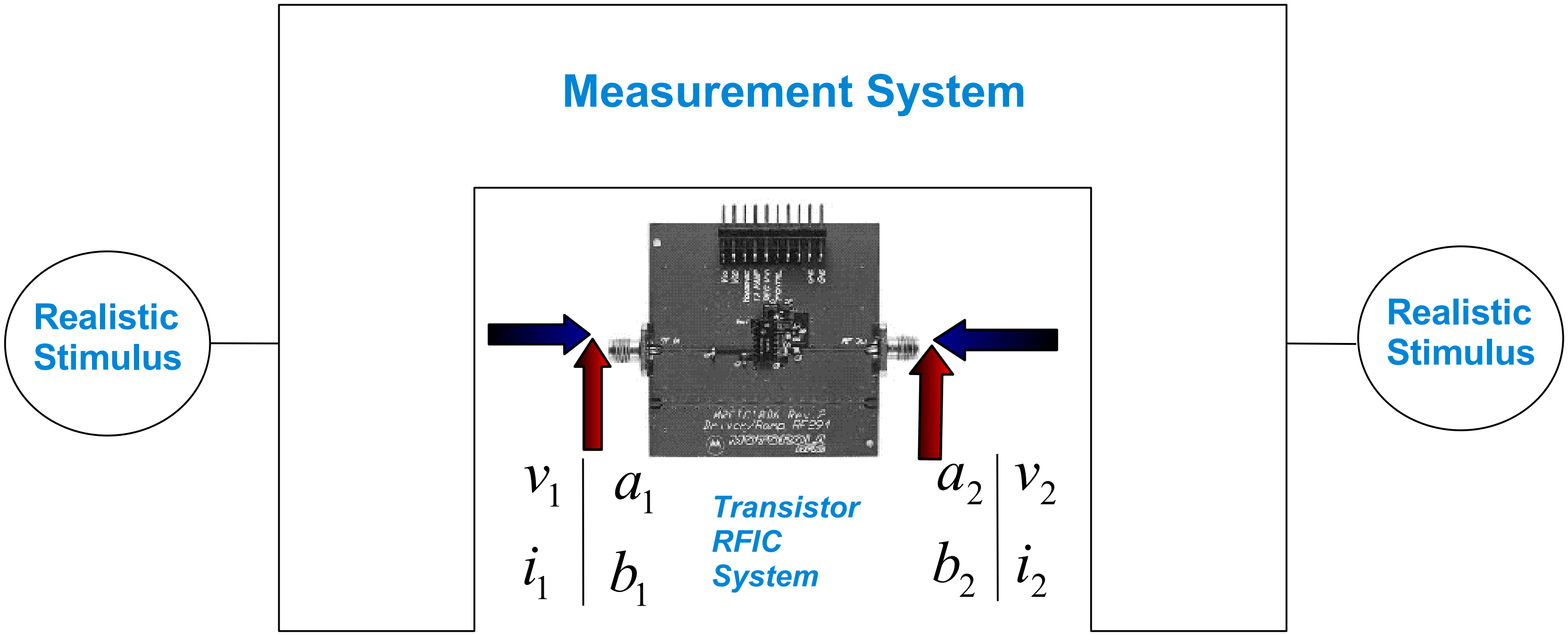
under realistic conditions

at the device level

Based on Large-Signal Network Analyzer Technology

A Large-Signal Network Analyzer

"Complete insight in large-signal behavior"



- **Representation Domain**
  - **Frequency (f)**
  - **Time (t)**
  - **Freq - time (envelope)**

- **Physical Quantity Sets**
  - **Travelling Waves (A, B)**
  - **Voltage/Current (V, I)**

- **Analysis**

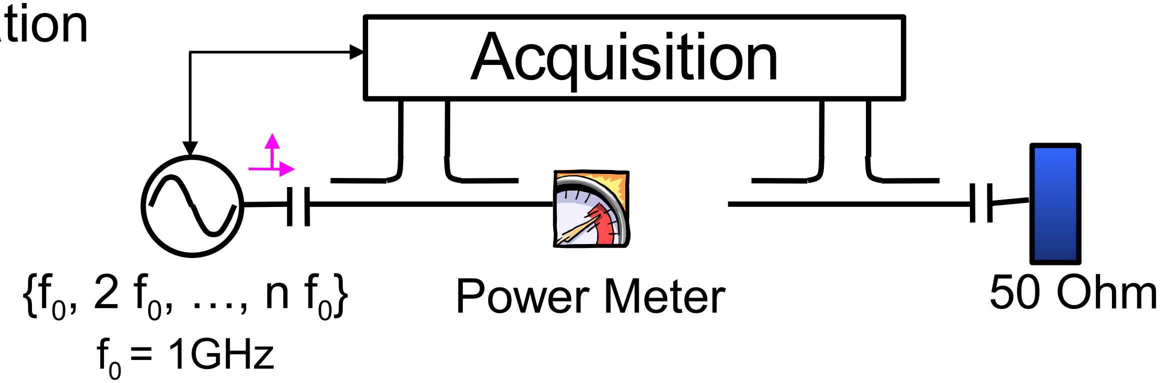
$$g(v_1, v_2, i_1, i_2, t \mid f) = 0$$

$$h(v_1, v_2, i_1, i_2, t \mid f) = 0$$

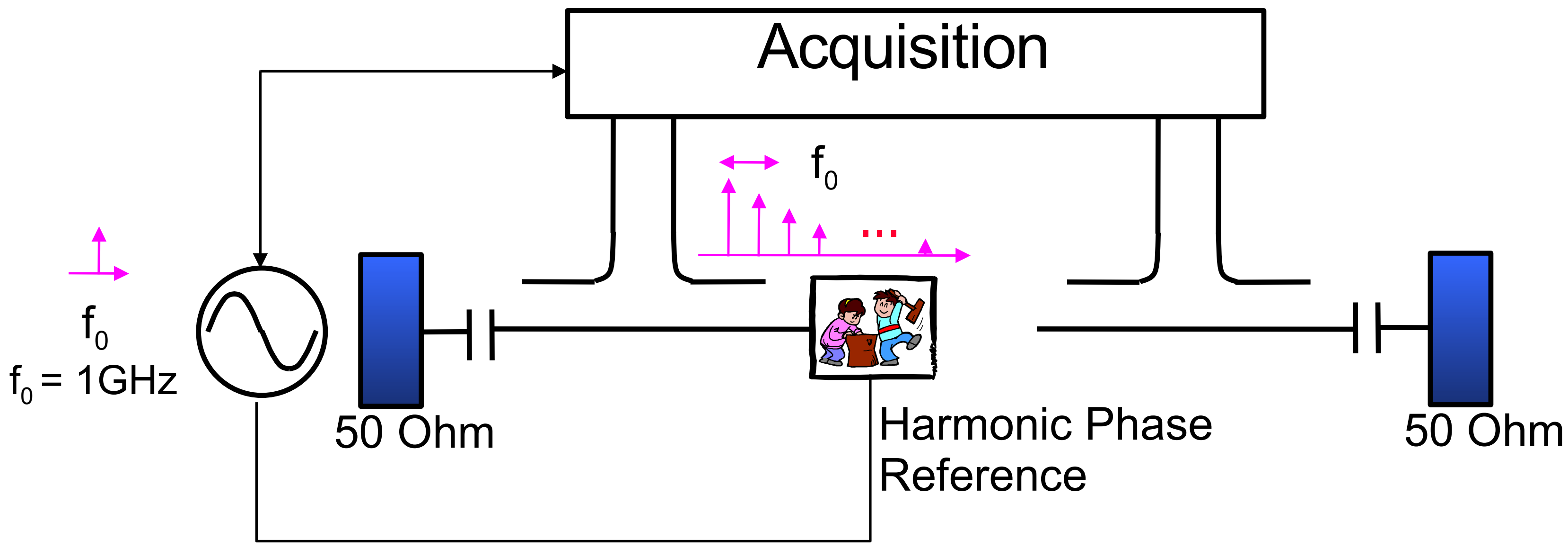
Characterization

Calibration technique

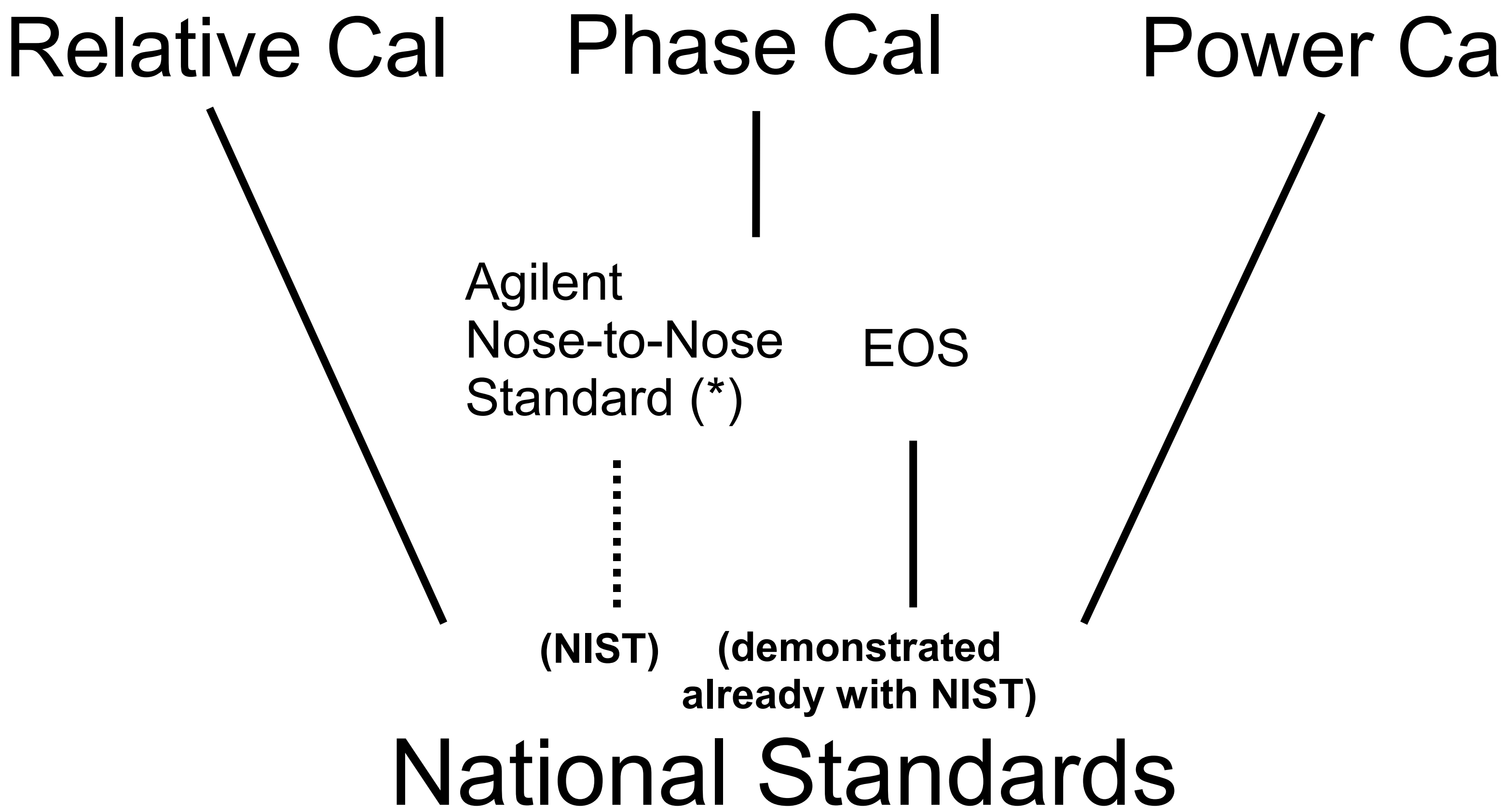
- Relative calibration, similar to VNA calibration
  - SOLT, TRL, LRRM ...
- Absolute calibration
  - Power



  - Phase



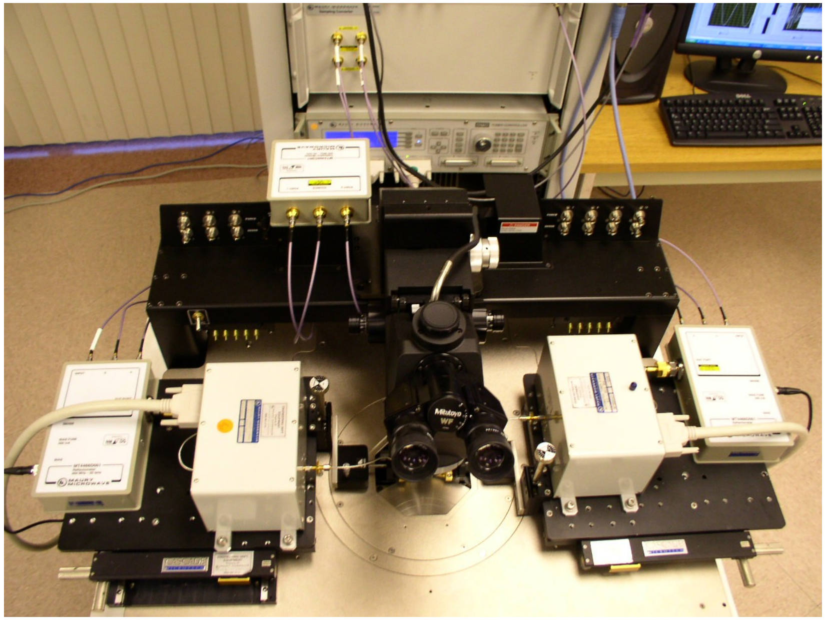
Measurement Traceability



(*) Licensed to Maury and NMDG

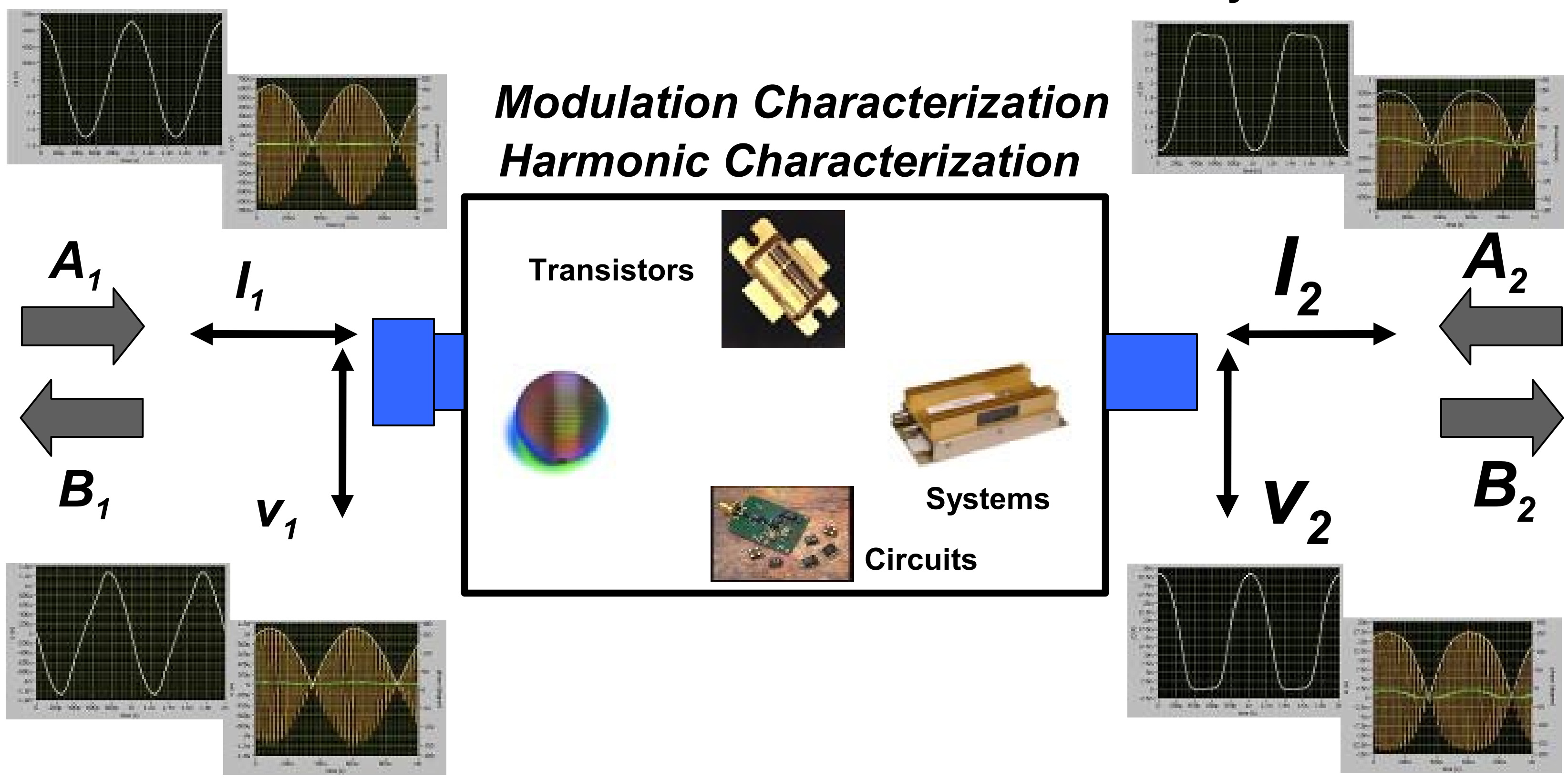
MT4463A - 20 GHz

MT4463B - 50 GHz



MT4463 measures...

Accurately
Completely
In a traceable way



In following domains

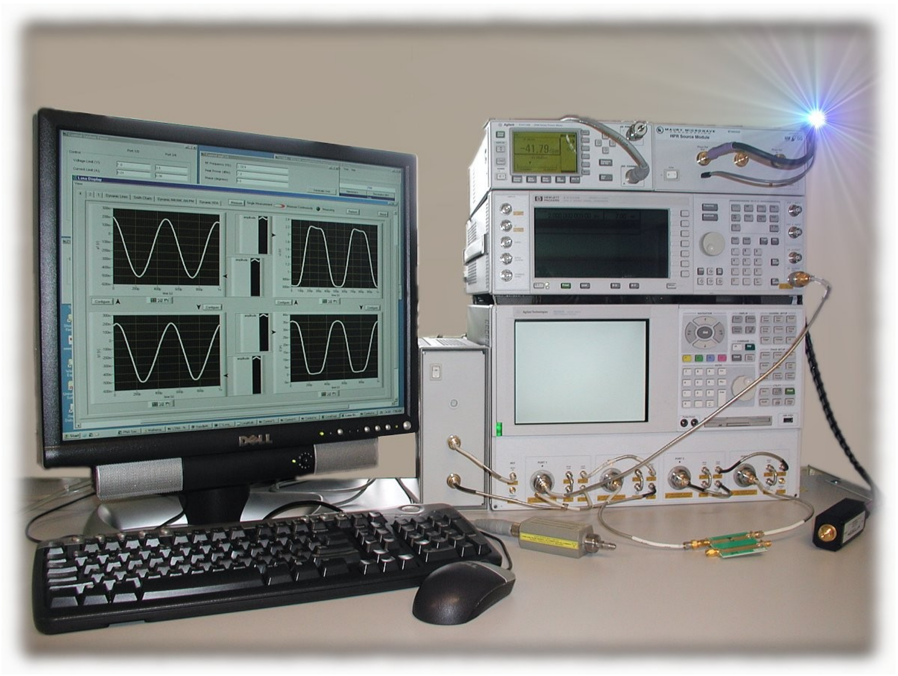
Frequency domain
Frequency - time domain
Time domain

Compatible with Simulation Tools

Under realistic conditions

Continuous wave
Periodic Modulation
Source and Load Tuning

VNAPlus

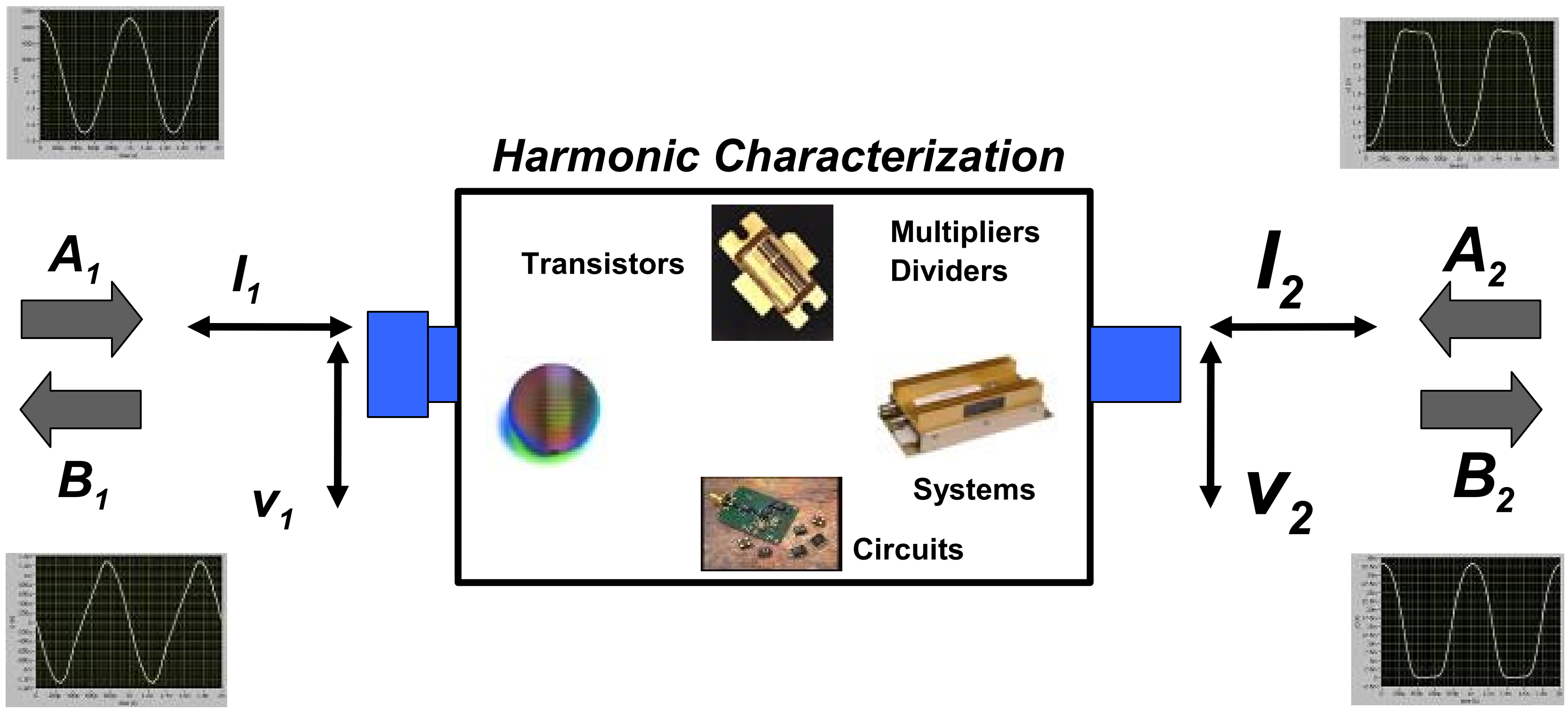


Requires: **Agilent N5230A or Agilent E836X Opt 080 + config. Test set**
Synchronizer, enabling nonlinear time domain characterization
External synthesizer with frequency range, covering the application needs
3.5 mm Calibration kit
Power meter, for power calibration
Harmonic Phase Reference, for phase calibration

VNAPlus measures...

Accurately

In a traceable way



In following domains

Frequency domain

Time domain

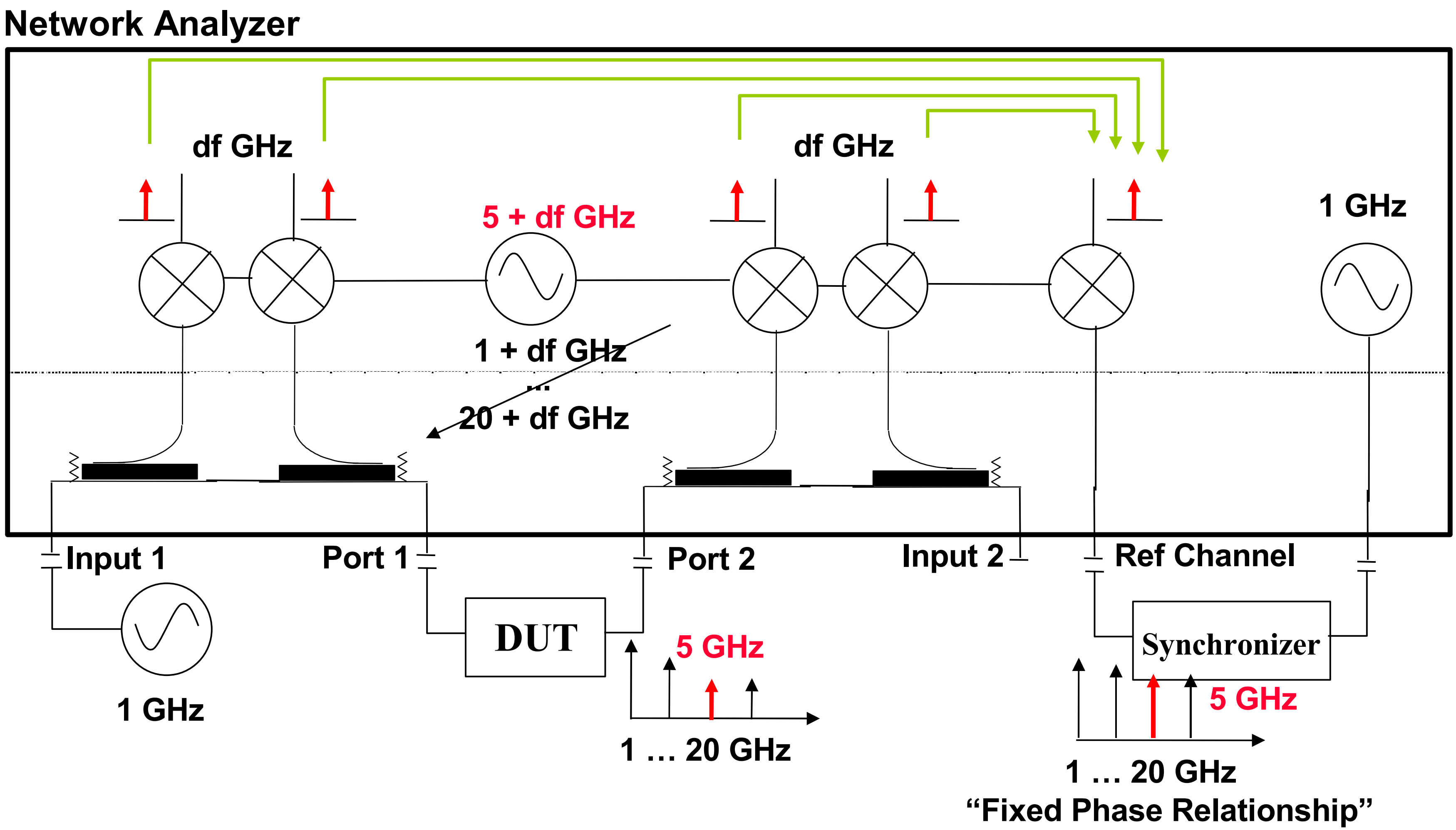
Compatible with Simulation Tools

Under realistic conditions

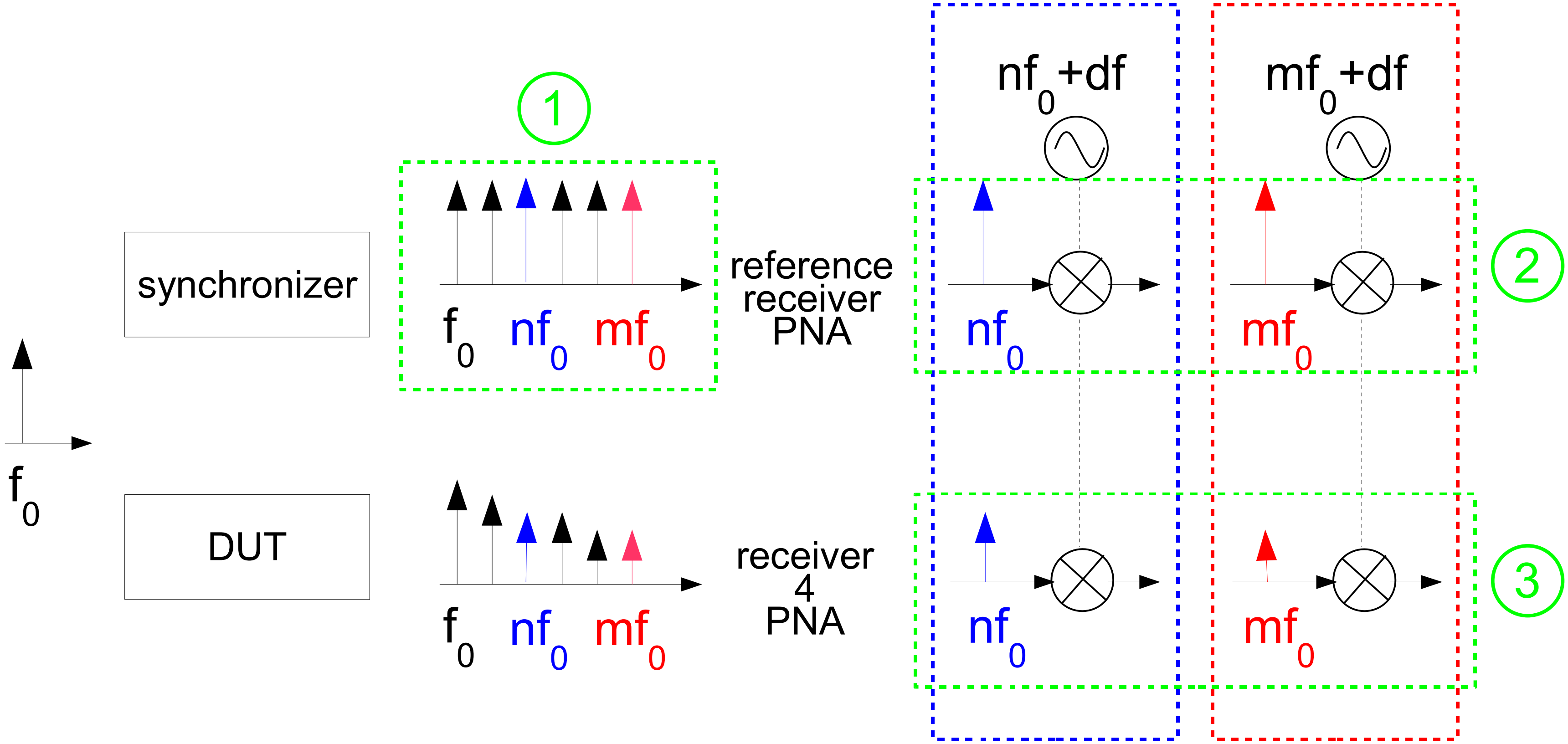
Continuous wave

Non 50 Ohm environment [Source and Load Tuning]

VNAPlus: Theory of Operation



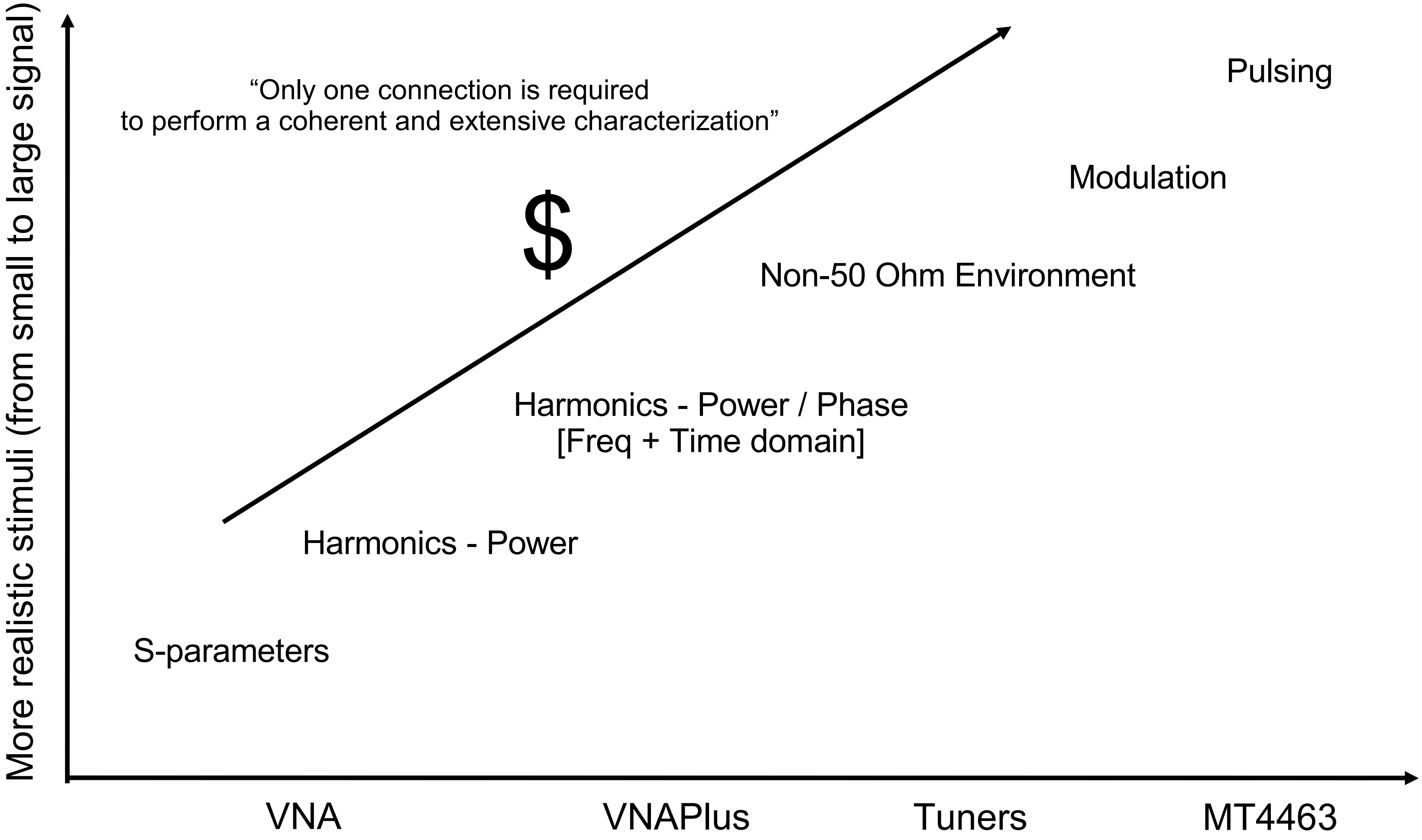
VNAPlus: Theory of Operation



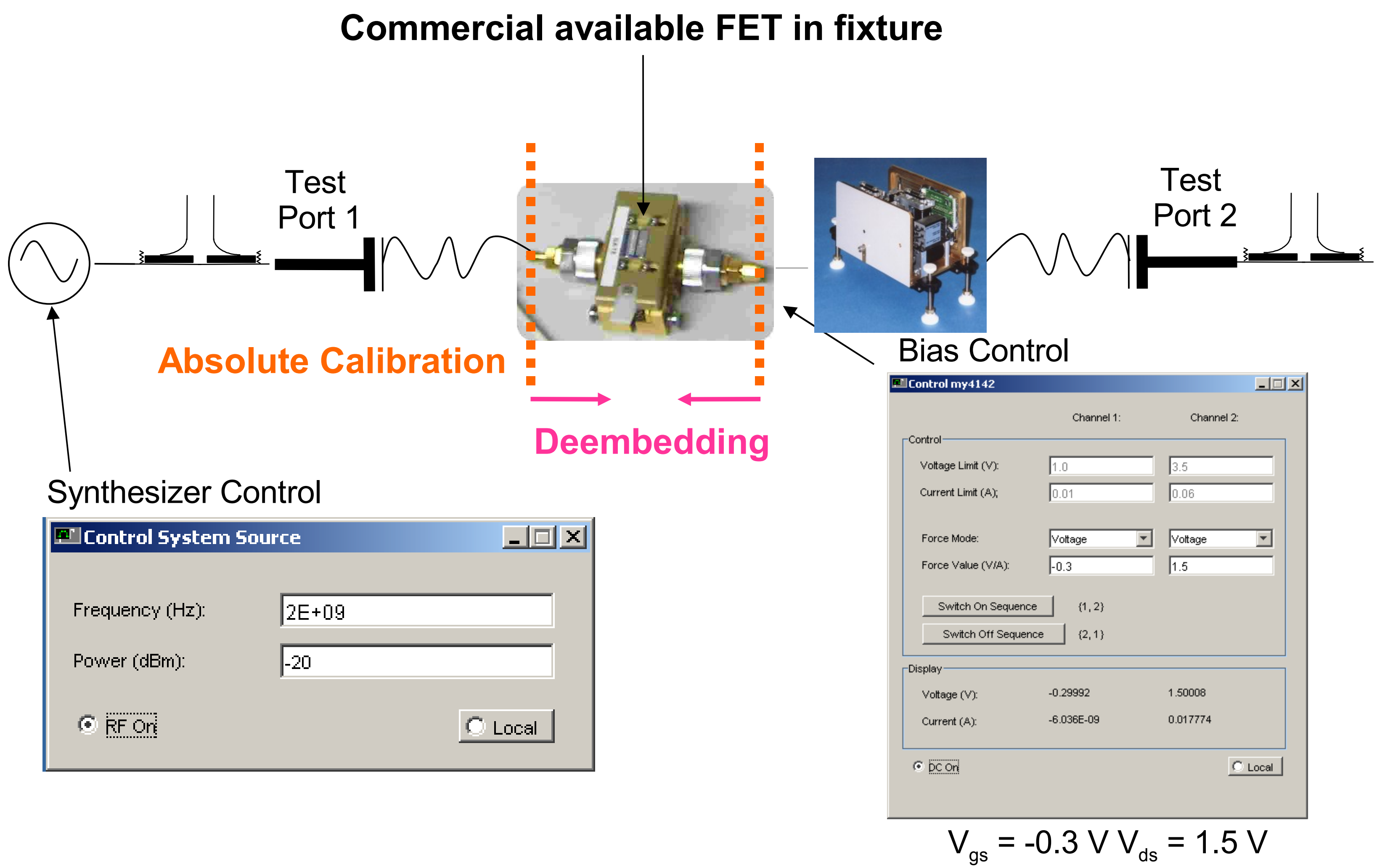
phase consistency between harmonics in ① ② ③

phase consistency between receivers by simultaneous measurement one frequency at the time

All-in-one with one calibration



From small - signal to large - signal with ONE connection



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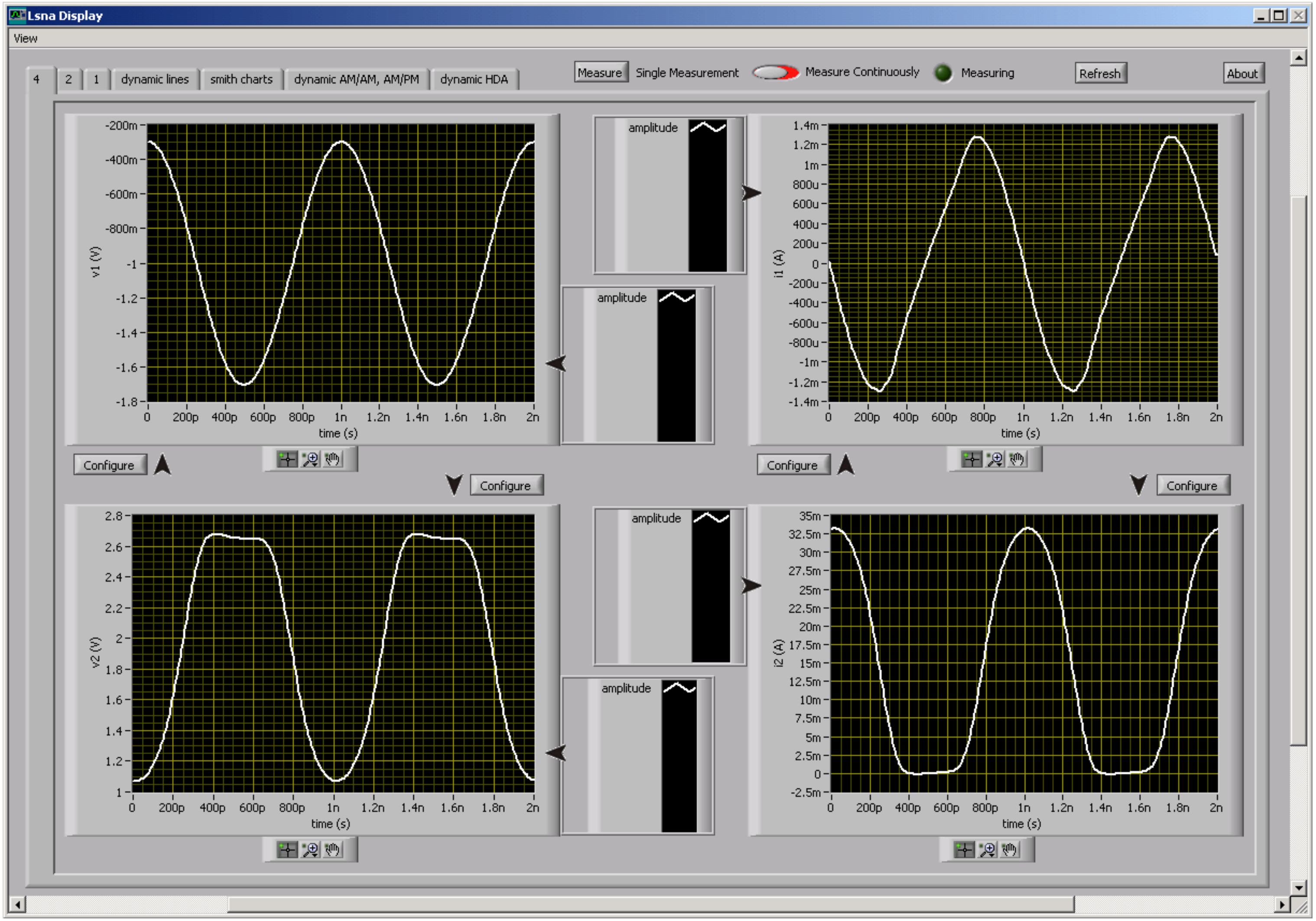
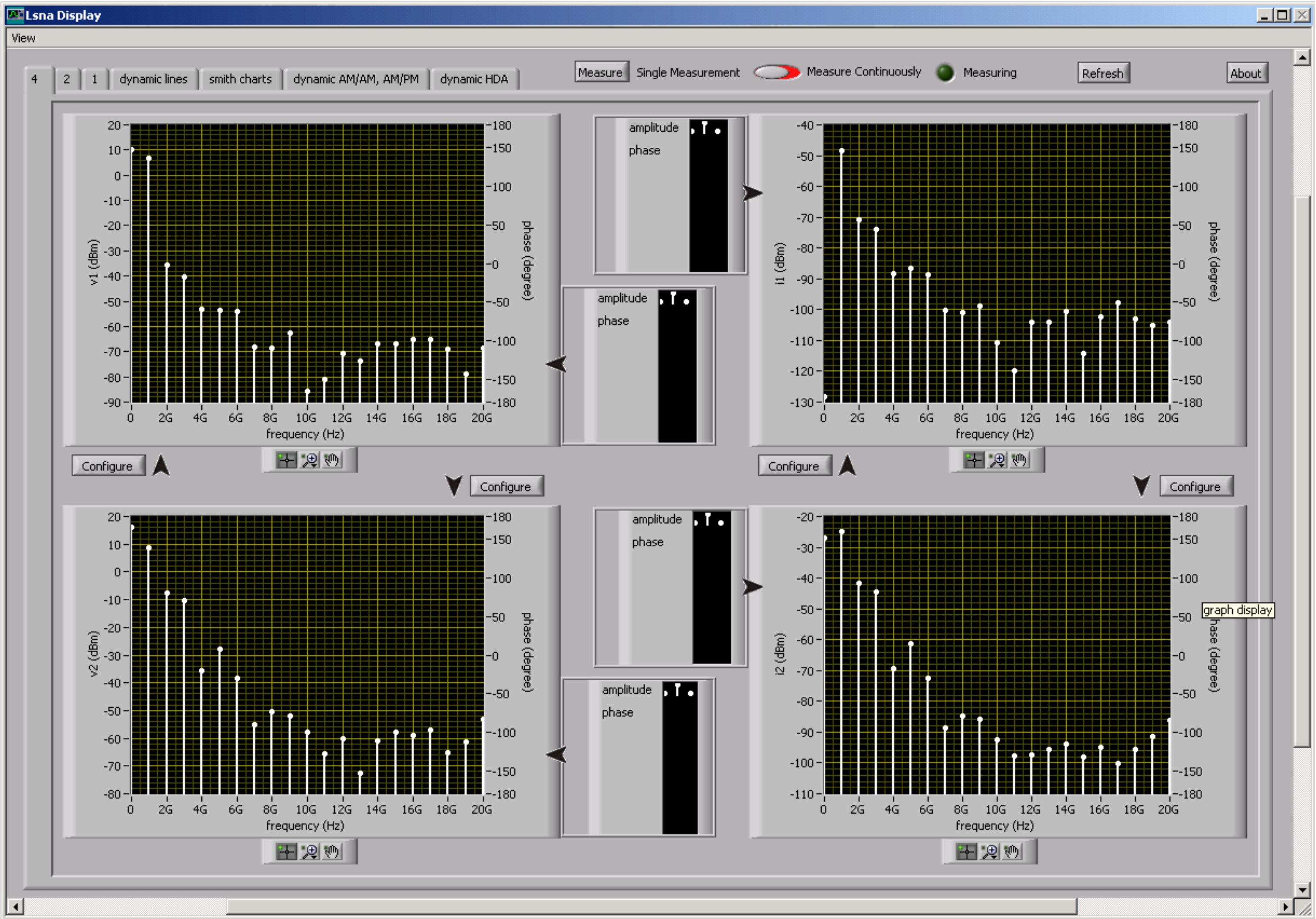
NMDG Engineering
Leading beyond S-parameters

Large-Signal Measurements - CW - Voltage/Current



Time domain

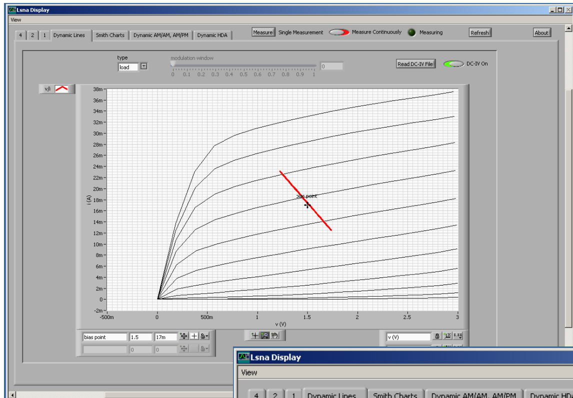
Large-Signal Measurements - CW - Voltage/Current

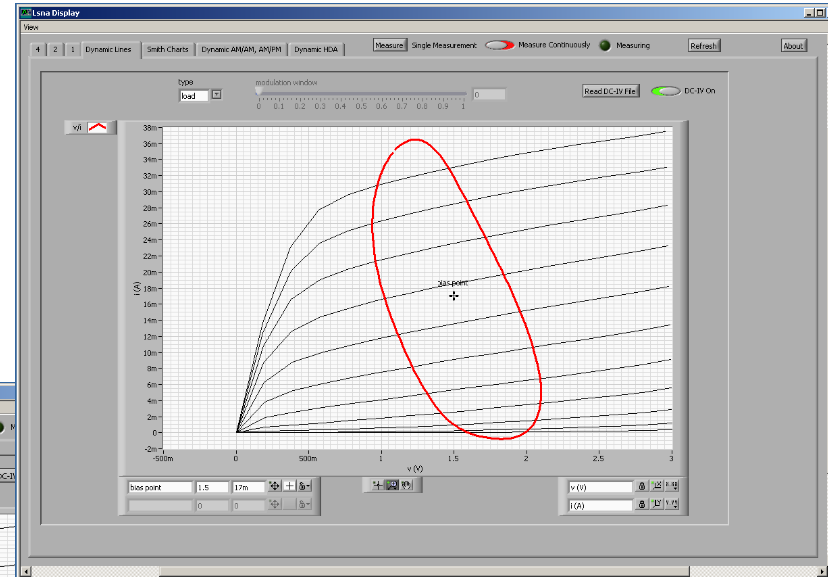


Frequency domain

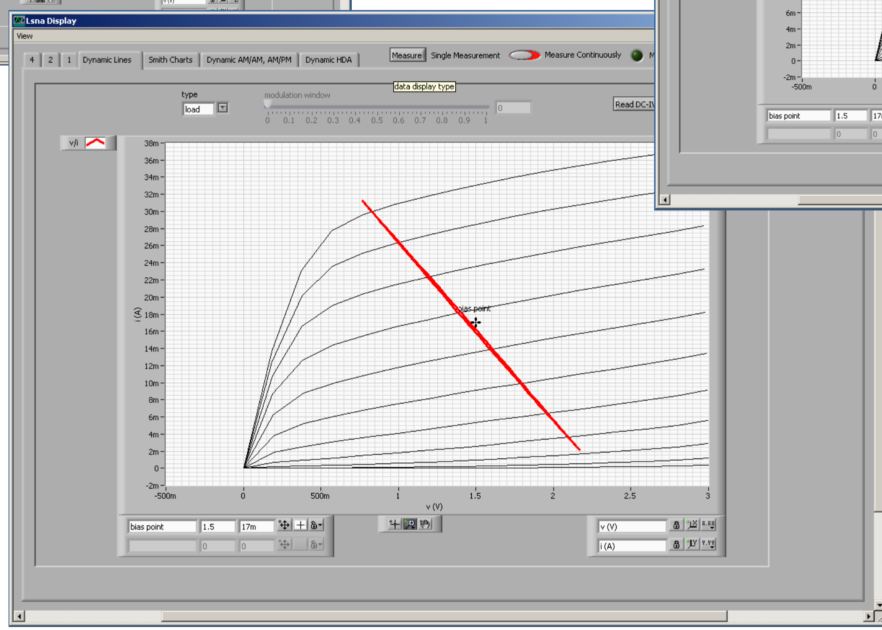
DC-IV curve and load line

Small-signal - 50 Ohm Termination



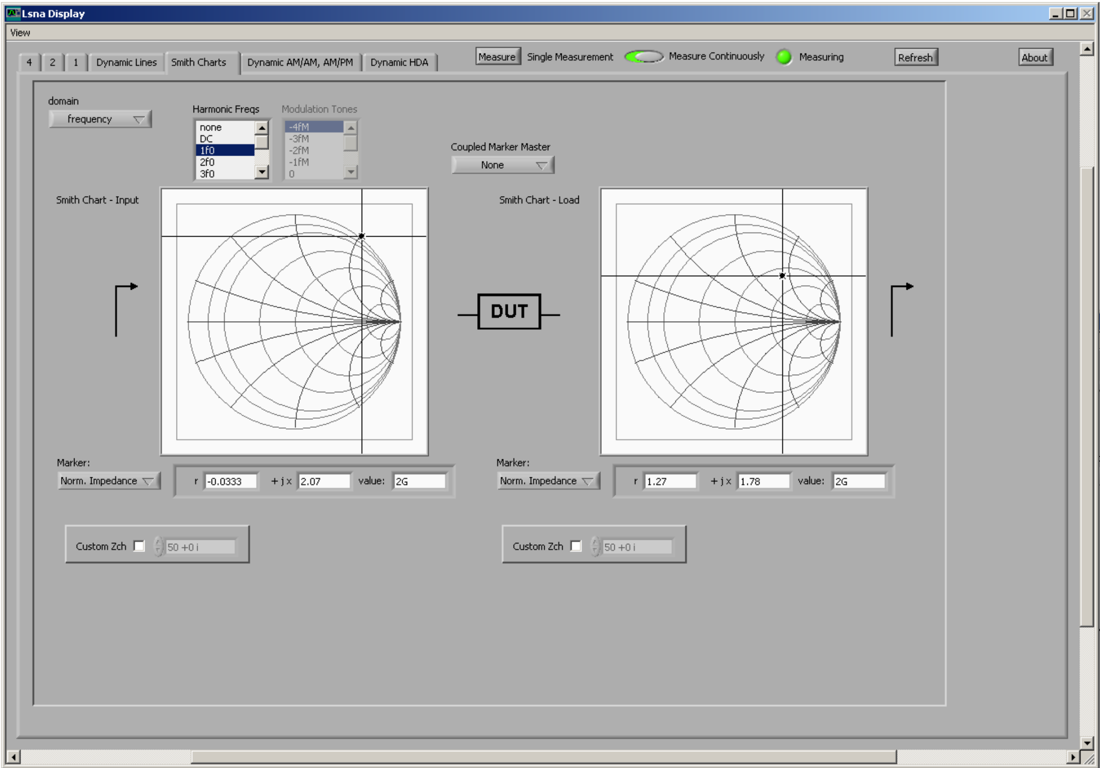


Large-signal - non-50 Ohm Termination

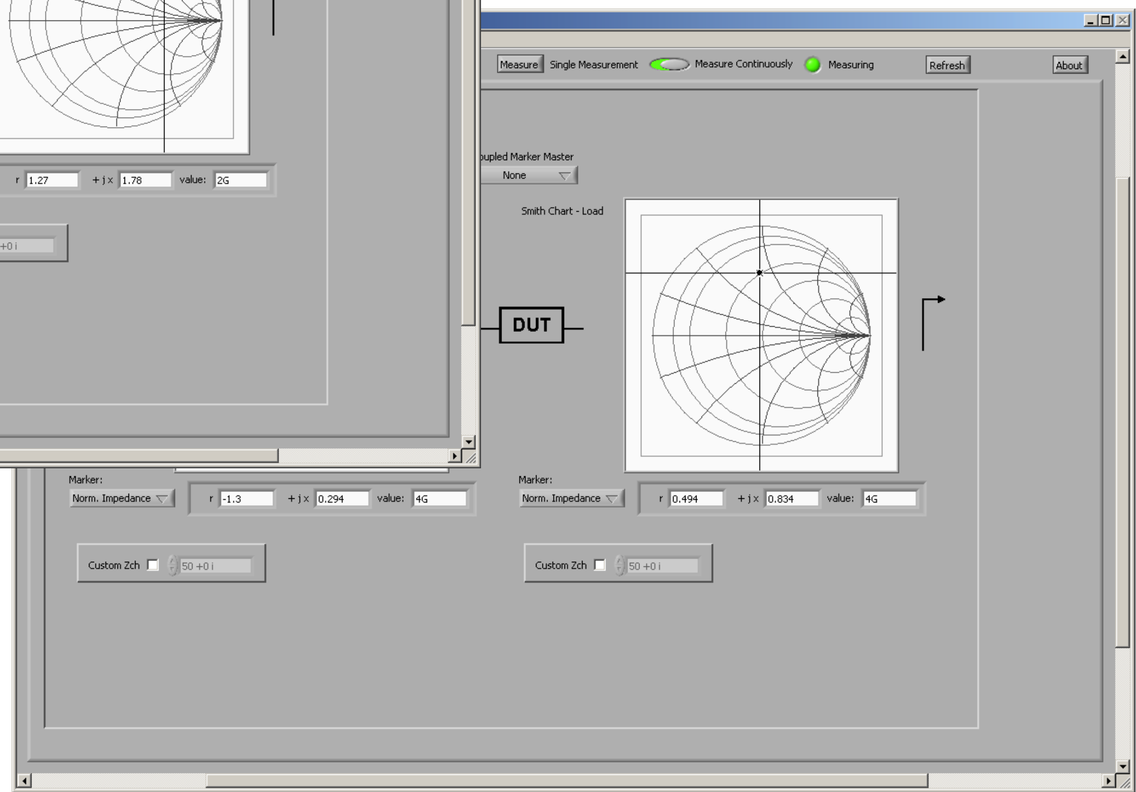


Large-signal - 50 Ohm Termination

Input and Load impedance under CW

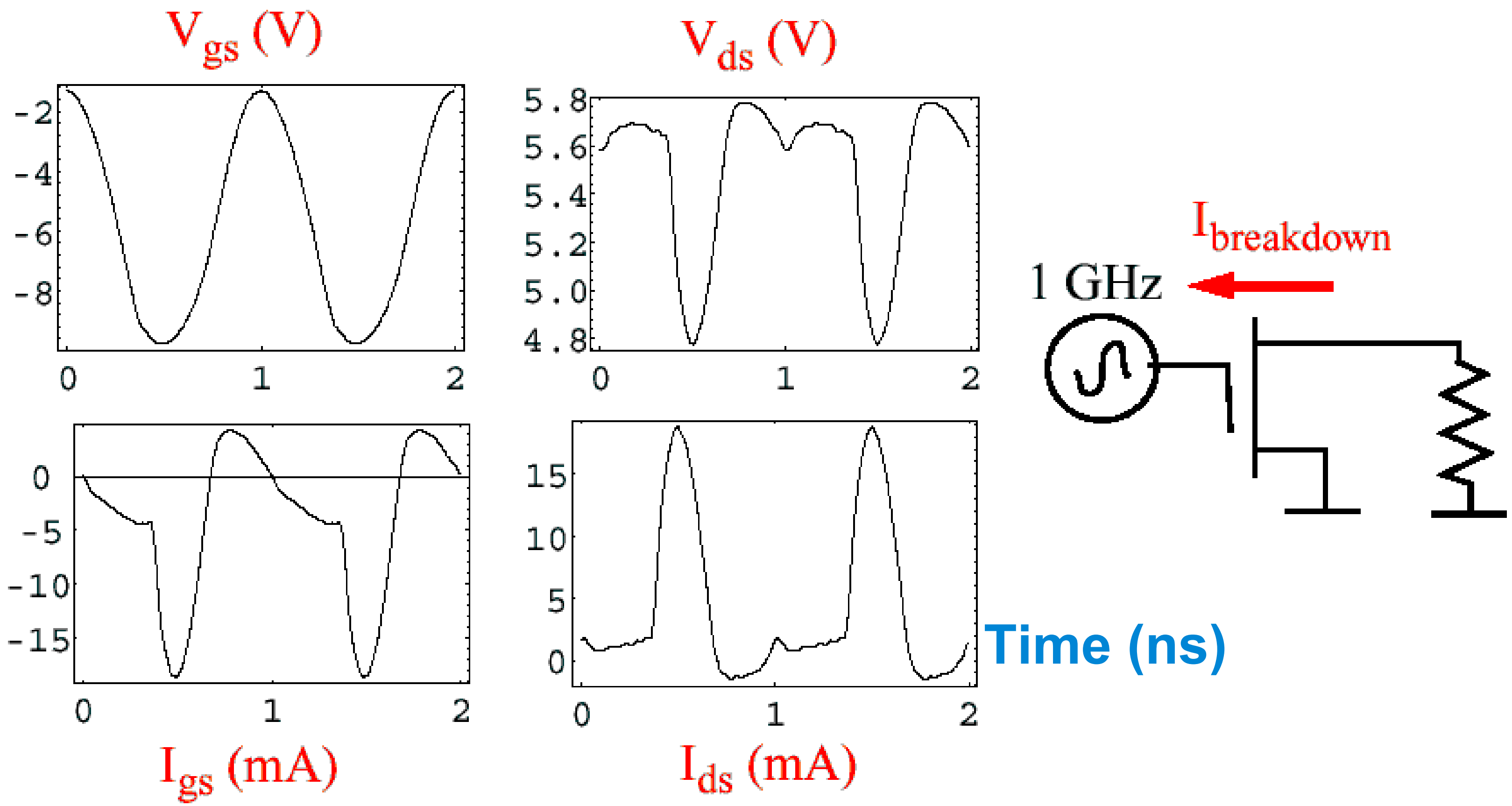


Impedance at 2nd harmonic non-50 Ohm Termination



Impedance at fundamental non-50 Ohm Termination

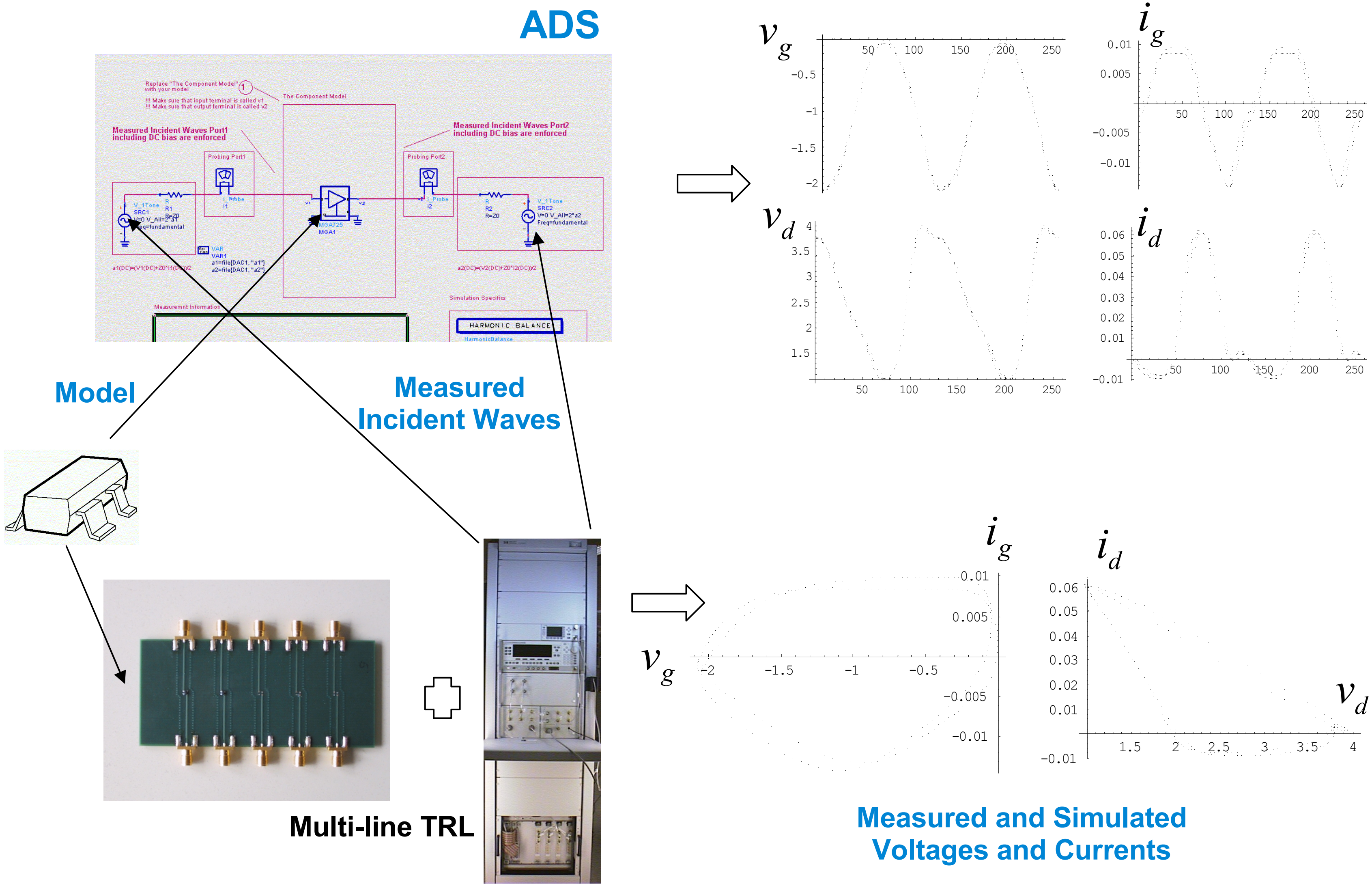
Application #1: Gate-Drain Breakdown Current



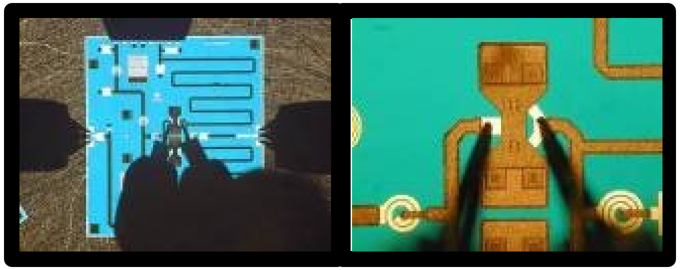
° TELEMIC / KUL

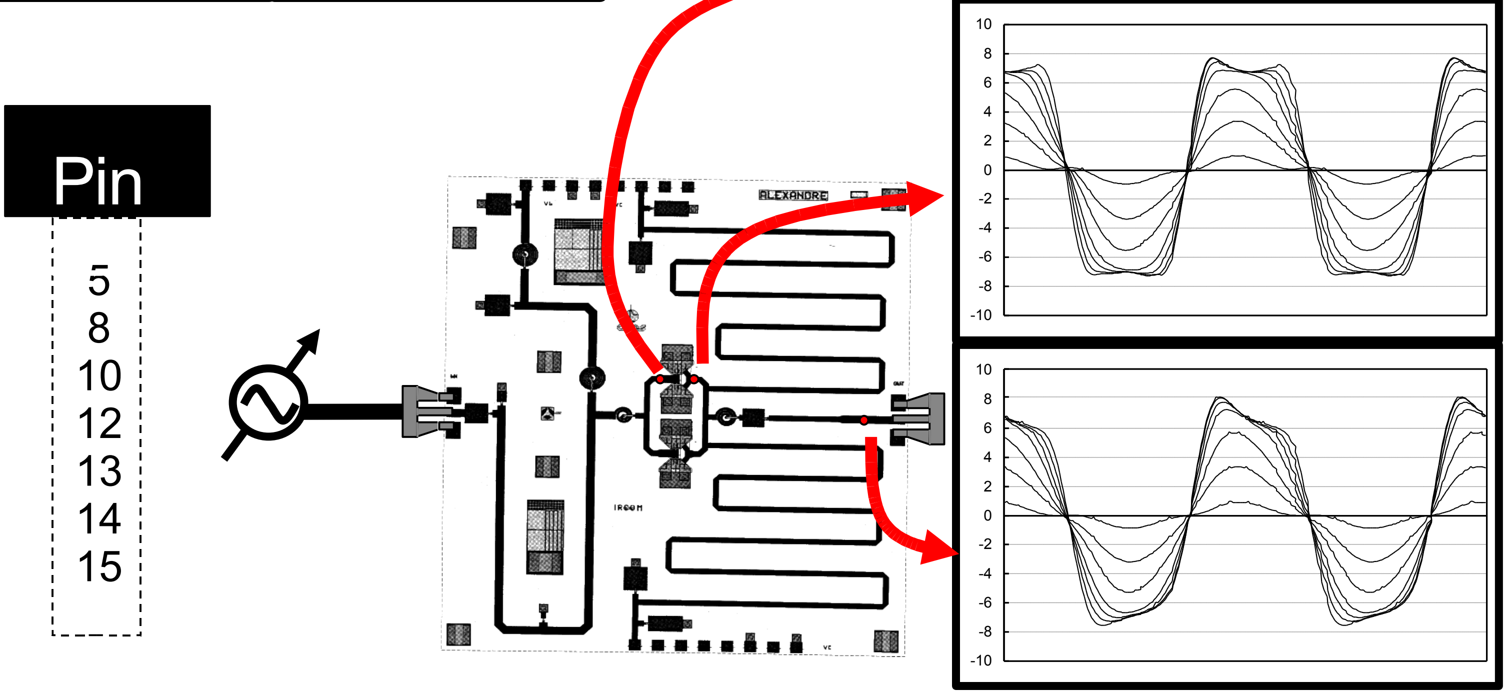
° transistor provided by David Root, Agilent Technologies - MWTC

Application #2: Model Verification in CAE tool



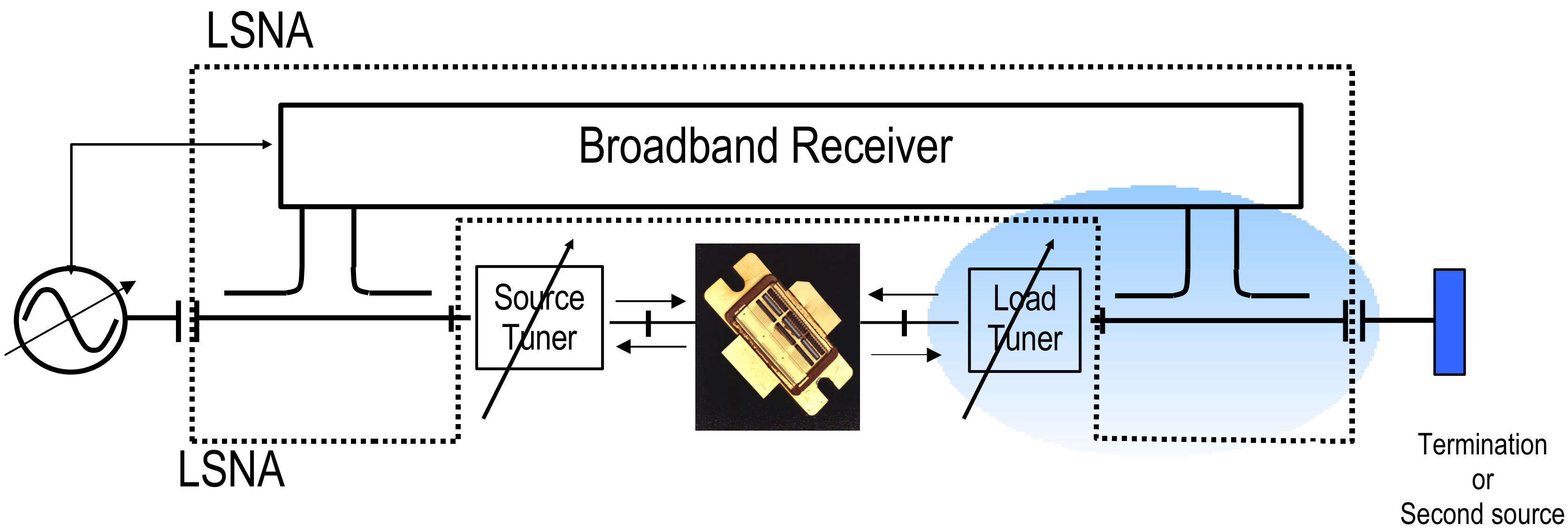
Application #3:
In-Circuit coherent and calibrated HF Signal Probing(*)





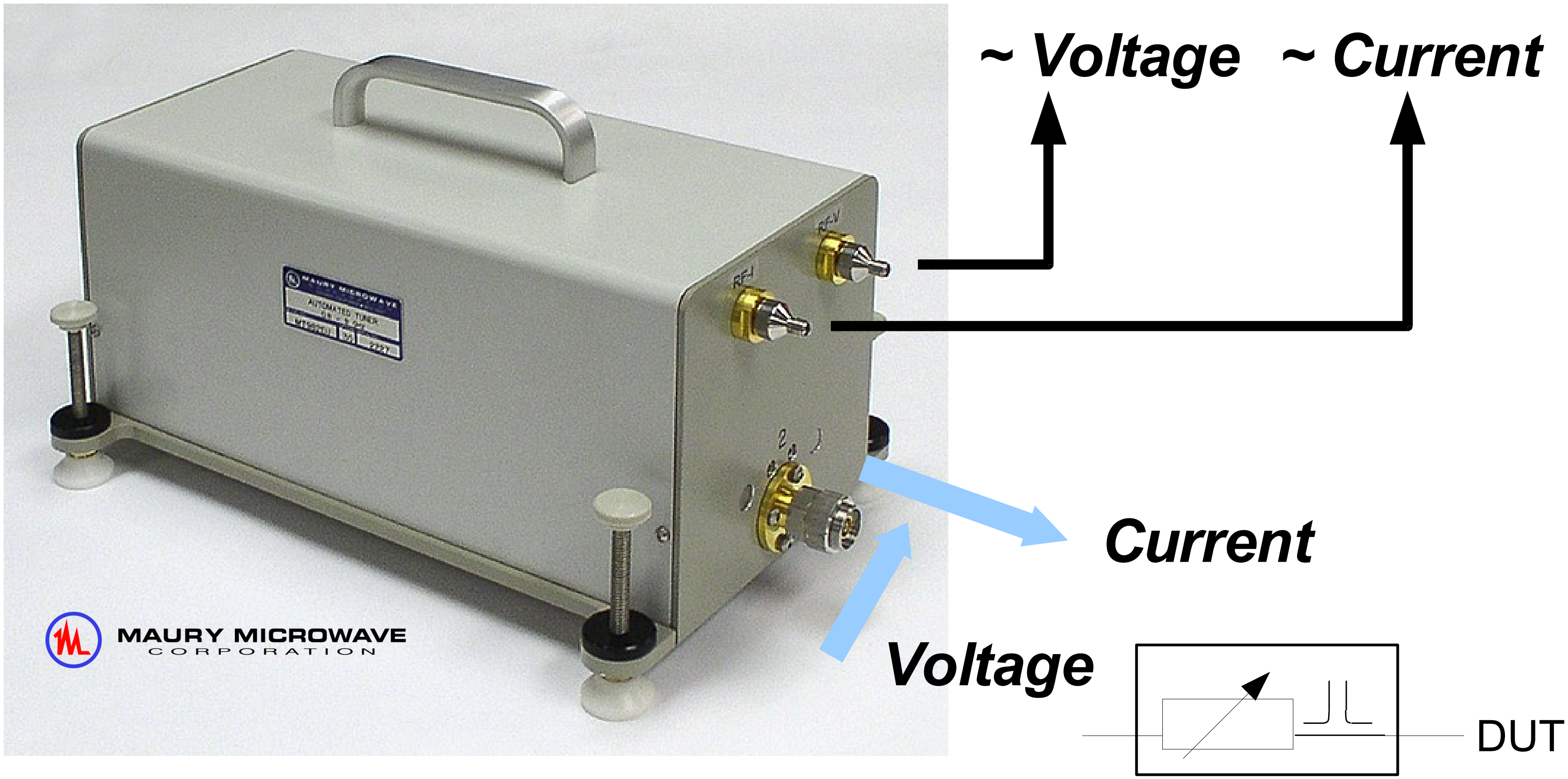
(*) With courtesy of CNES and IRCOM

LSNA and tuners: synthesizing high reflections



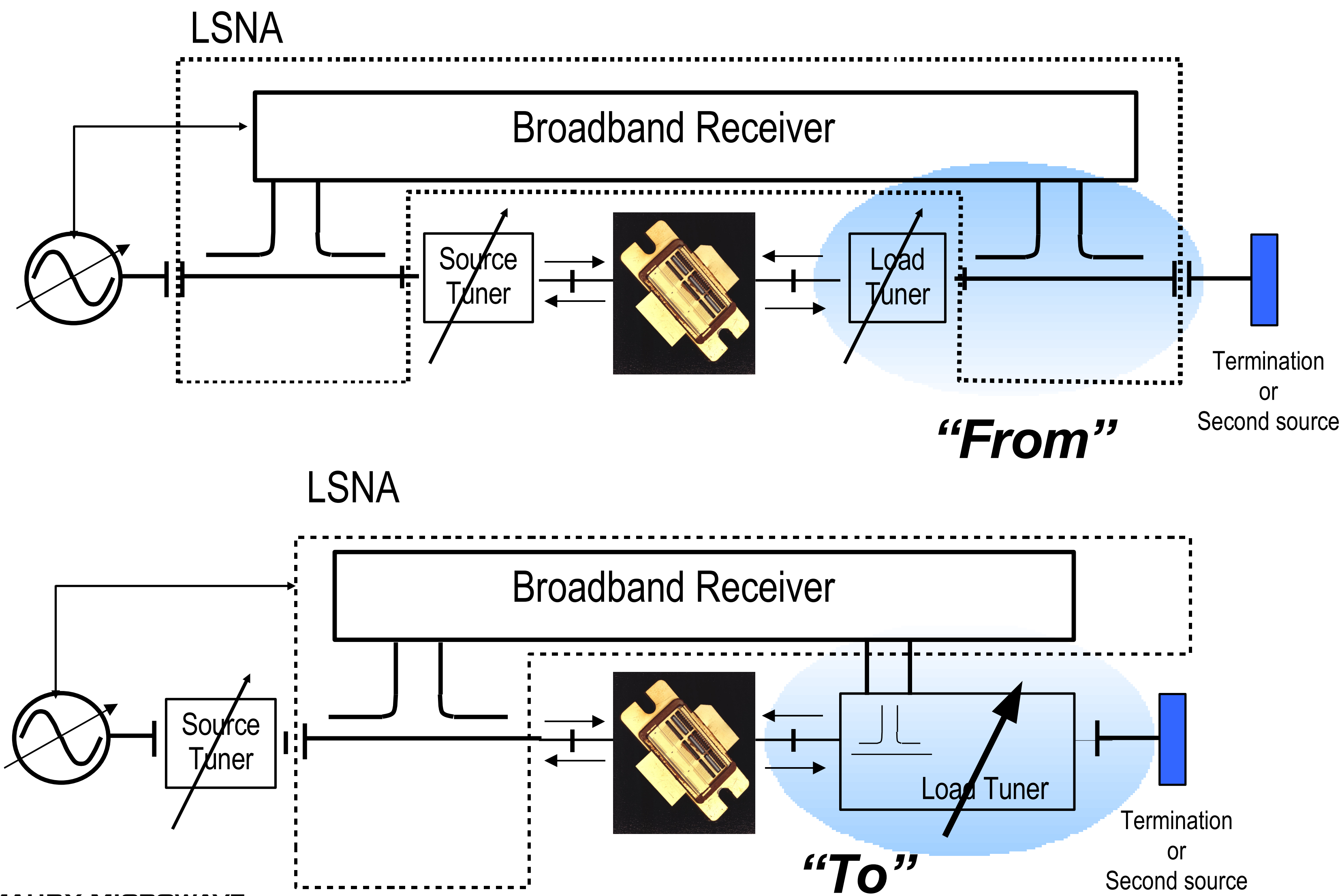
- need for adapting de-embedding as function of tuner position
- ill-conditioned situation in case of high reflections (typ. at harmonics)

Maury introduces the “Sensing Tuner”



The Sensing Tuner “probes” incident / reflected waves or voltages and currents close to the device under test with a minimal insertion loss

LSNA and the Sensing Tuner



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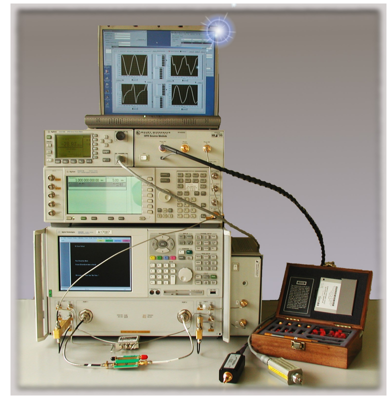


or

=

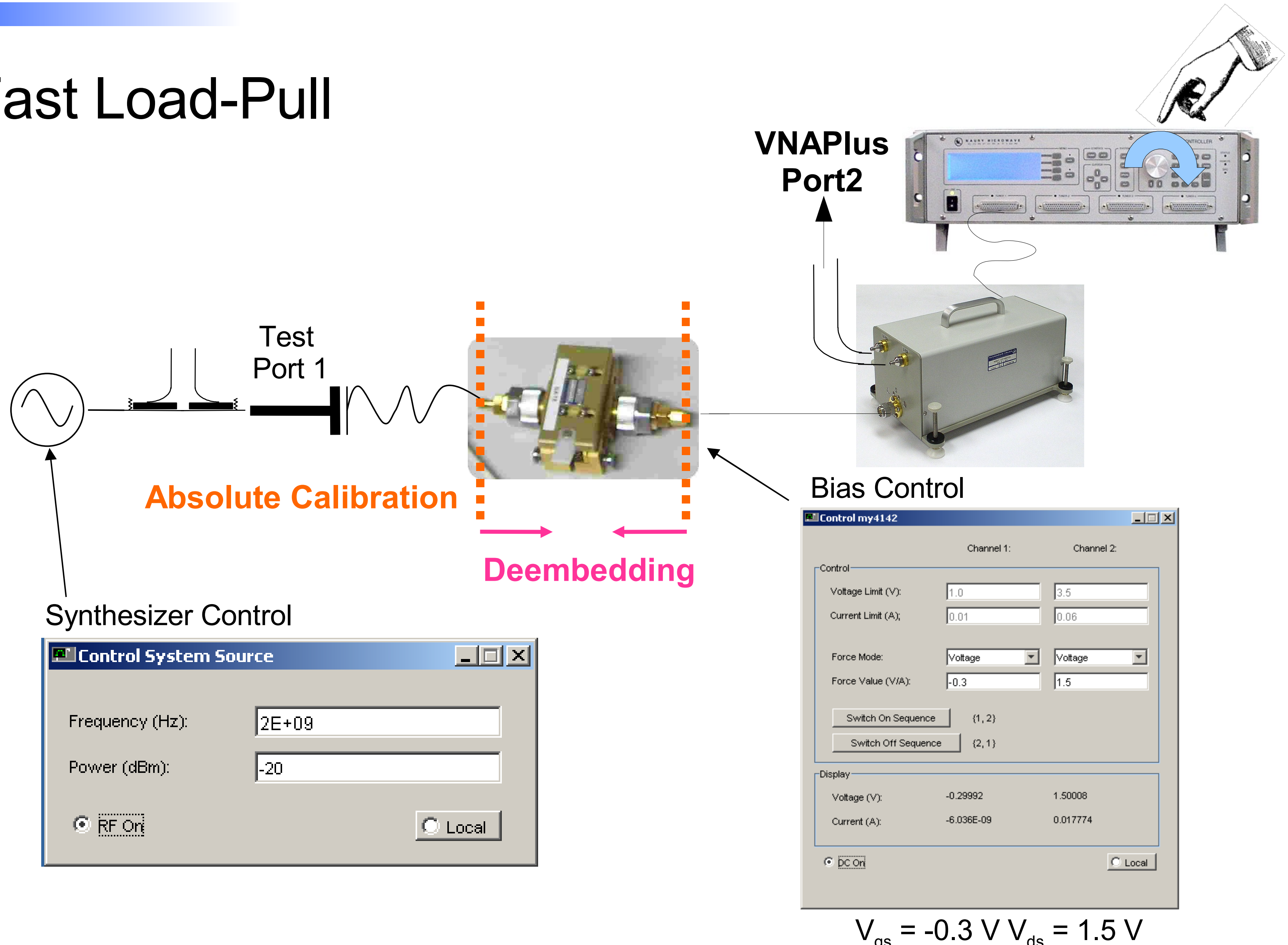
A Winning Team with many advantages

A new Frontier in the Load-Pull world

Advantages

- Ready to measure in minutes instead of hours
  - Tuners don't need to be characterized
  - Only standard LSNA calibration and possibly de-embedding is required
- Tuning resolution determined by tuner, not by its characterization
- Improved measurement accuracy
  - Measurement accuracy is set by calibration accuracy
  - No cumulation of errors by combining S-parameter blocks
- Finding optimal operating conditions in less than a minute
- Complete load-pull in a few minutes
- Harmonic load-pull and waveform engineering becomes easy

Fast Load-Pull



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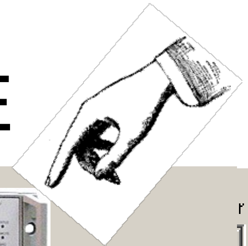
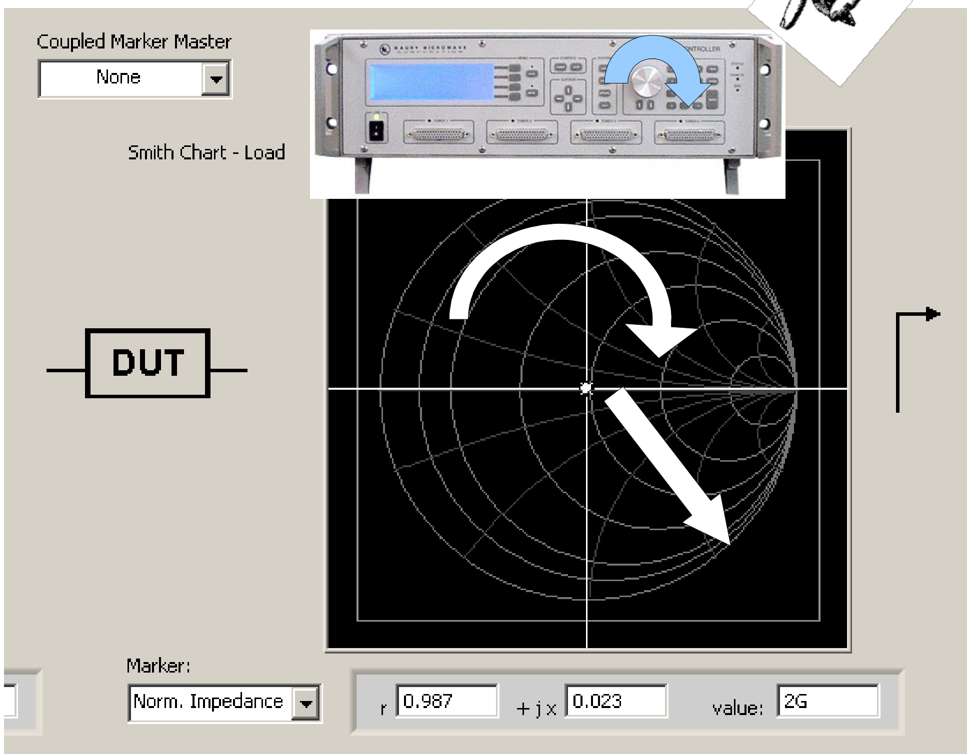
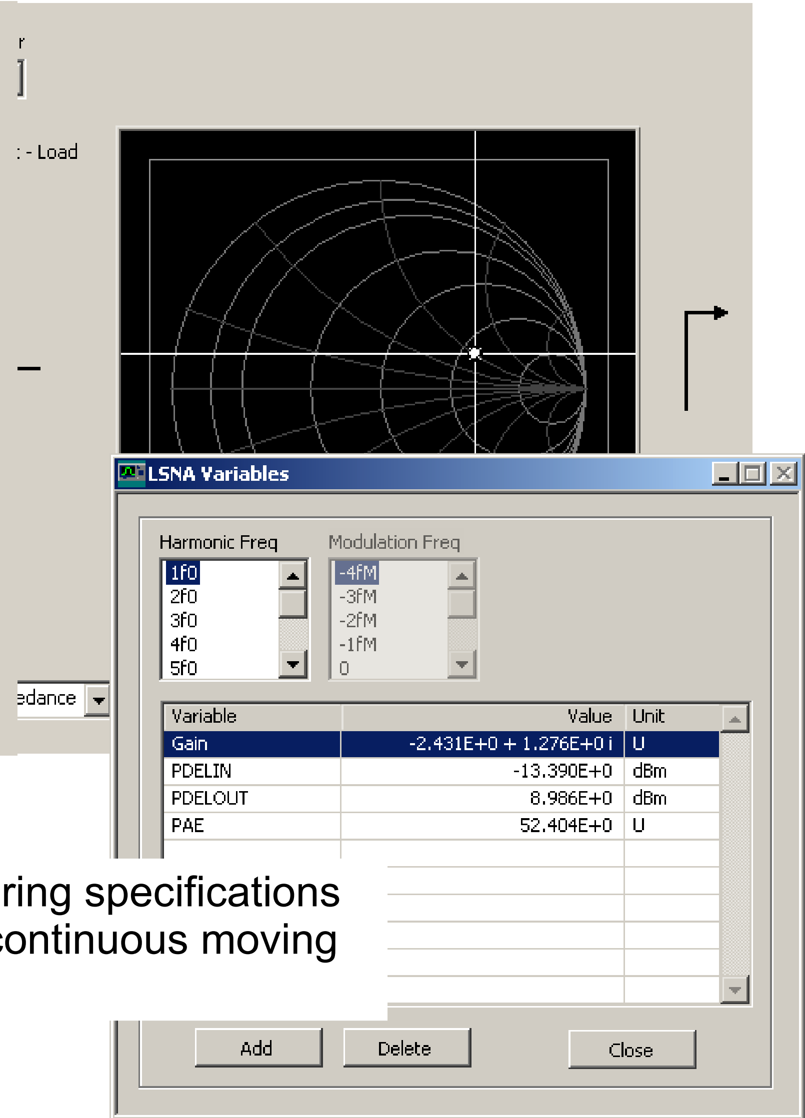
Tuning to optimal PAE in 45 Seconds



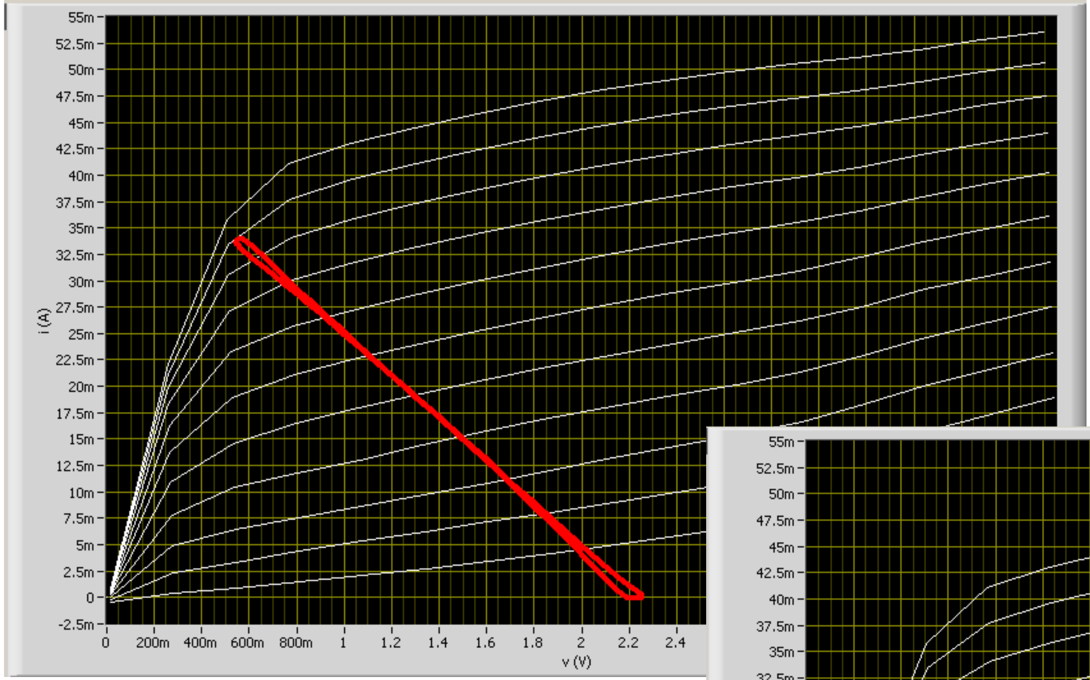




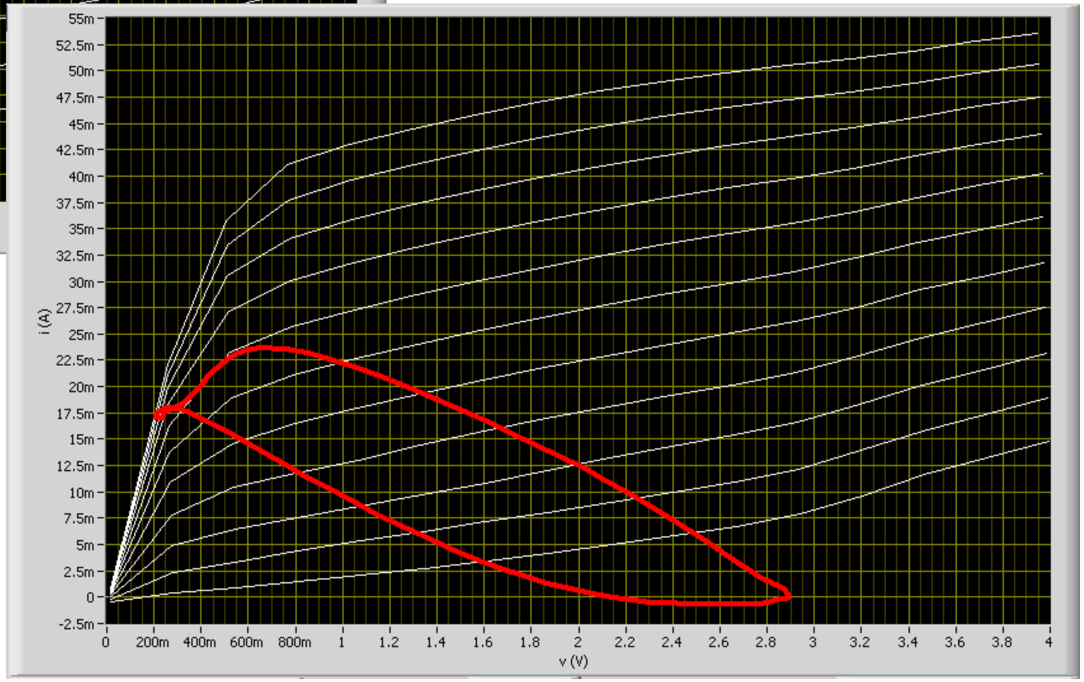
PAE: from 39 to 52%

Monitoring specifications while continuous moving tuners

Dynamic Load-Line



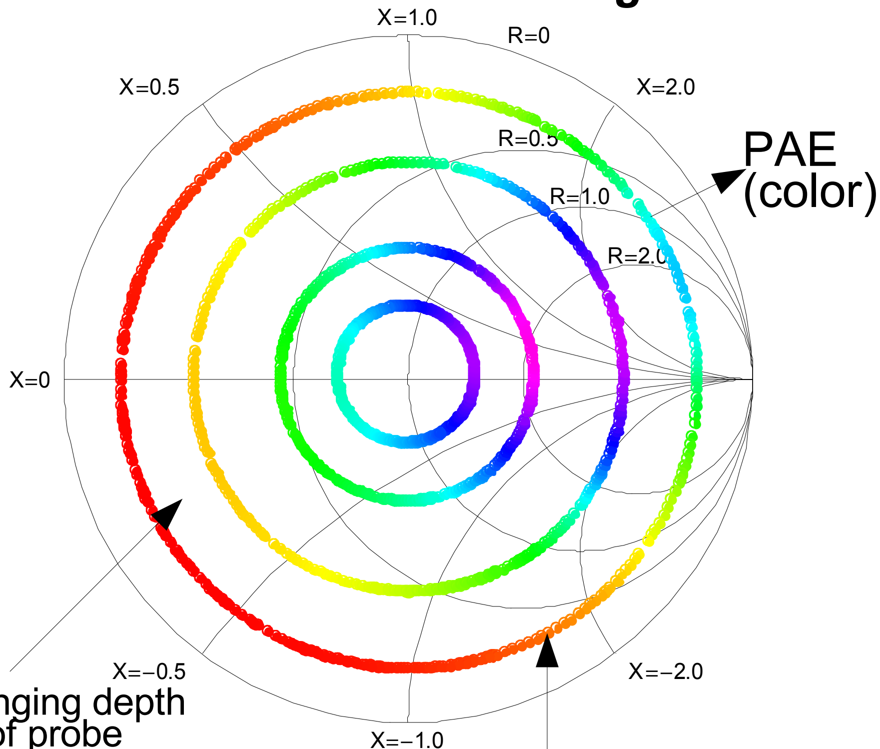
PAE: 39%



PAE: 52%

Load-Pull in less than 3 Minutes

Smith Chart Coverage



PAE Contours

Changing depth of probe

Moving carriage while measuring continuously with LSNA results in a very dense reflection "circle" where the complete V/I behavior was measured

Conclusion

- Large-signal network analysis provides a uniform way to characterize the input - output behavior of nonlinear HF components under almost realistic conditions
- Incremental investment allows harmonic component characterization in time and frequency domain with a vector network analyzer in a non-50 Ohm environment
- The “Sensing Tuner” and VNAPlus: FAST, SIMPLE, ACCURATE
- For sales information

  www.bsw-ag.com

  www.amska.se
- For technical information

info@nmdg.be

www.nmdg.be

http://www.maurymw.com/contact_us/contact_us.htm

www.maurymw.com

A little story