Large Signal Network Analyzer

An affordable PXI-based microwave non-linear characterization platform

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Introduction

- The goal of this research is to integrate microwave-frequency Large Signal Network Analysis capabilities with commercially available National Instruments' PXI modular instrumentation and LabVIEW environment.
- The Microwave Research Group at the University of Colorado has decades of experience in UHF through millimeter-wave transmitters, including recent X-band (10-GHz) MMIC implementations in GaN. Our aim is to extend the frequency range and capabilities of available commercial instrumentation provided by NI.
- The proposed instrumentation development will enable new types of measurements such as those required for harmonically-terminated PAs, various transmitter architectures (Doherty, outphasing and supply modulated PAs), as well as microwave transistor rectifiers. The time-domain characterization is expected to provide dramatic improvement in RF circuit design capabilities.

Calibration

LSNA calibration algorithm consists of **3 steps** at each RF frequency:

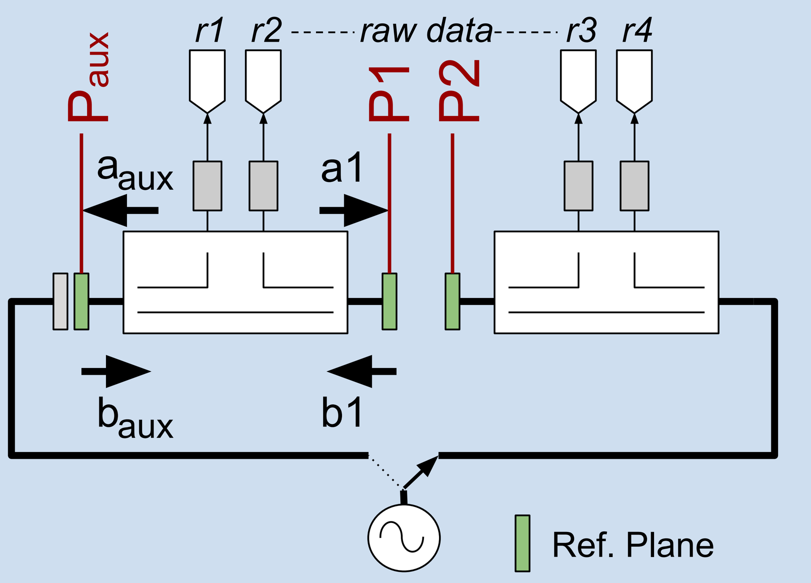
1. A relative VNA calibration creates an error-term matrix related to ports 1 and 2:

$$\begin{pmatrix} a_1 \\ b_1 \\ a_2 \\ b_2 \end{pmatrix} = K \begin{bmatrix} 1 & \beta_1 & 0 & 0 \\ \gamma_1 & \delta_1 & 0 & 0 \\ 0 & 0 & \alpha_2 & \beta_2 \\ 0 & 0 & \gamma_2 & \delta_2 \end{bmatrix} \cdot \begin{pmatrix} r_1 \\ r_2 \\ r_3 \\ r_4 \end{pmatrix}$$

2. The power calibration gives $|K|$
3. The phase calibration yields $\arg\{K\}$

Power and phase calibration are performed at an auxiliary reference plane (P_{aux}) after its own 1-port SOL coaxial calibration:

$$\begin{pmatrix} a_{aux} \\ b_{aux} \end{pmatrix} = K_{aux} \begin{bmatrix} 1 & \beta_{aux} \\ \gamma_{aux} & \delta_{aux} \end{bmatrix} \cdot \begin{pmatrix} r_1 \\ r_2 \end{pmatrix}$$



⇒ **Power** calibration at P_{aux} reference plane requires the connection of a power sensor. According to the measured value, in dBm, we can calculate $|K_{aux}|$ such as:

$$|K_{aux}| = \left| \frac{10^{(Power-10)/20}}{r_1 + \beta_{aux}.r_2} \right|$$

⇒ **Phase** calibration at P_{aux} is performed by connecting a direct receiver (e.g. r_3) at P_{aux}:

$$\arg\{K_{aux}\} = \arg\left\{ \frac{r_3}{r_1 + \beta_{aux}.r_2} \right\}$$

⇒ **Reciprocity** transfers the absolute calibration from P_{aux} to ports 1 and 2 ($P1$ and $P2$):

$$K = \pm\sqrt{1/Det\{[M]\}}$$

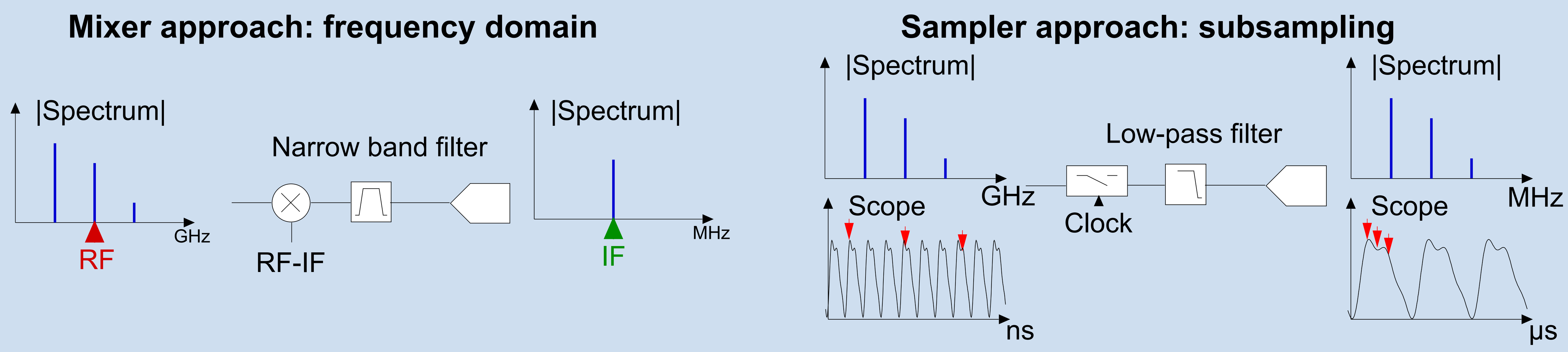
with

$$M = \begin{bmatrix} 1 & \beta_1 \\ \gamma_1 & \delta_1 \end{bmatrix} \cdot \left[K_{aux} \cdot \begin{bmatrix} 1 & \beta_{aux} \\ \gamma_{aux} & \delta_{aux} \end{bmatrix} \right]^{-1}$$

Time-domain instrumentation for non-linear devices

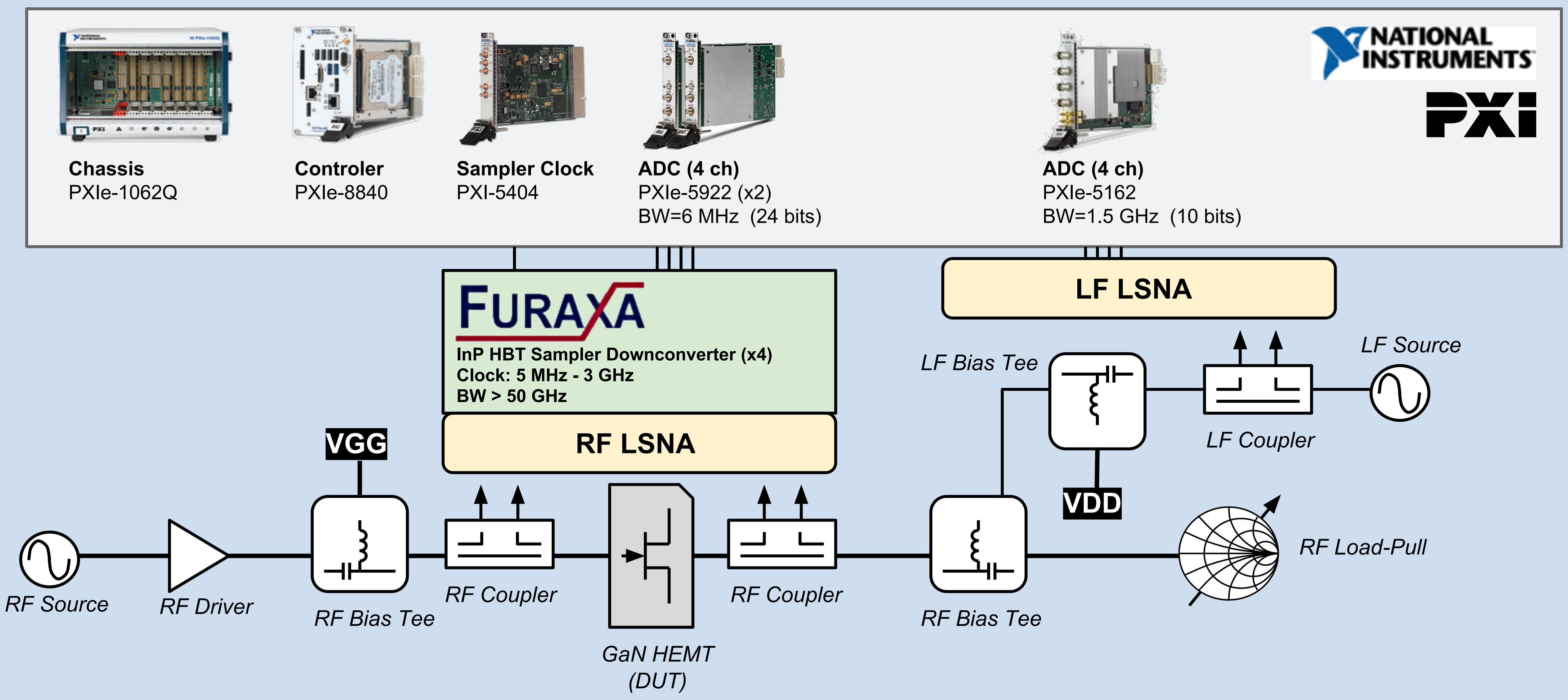
Name	Manufacturer	Receivers	Availability
MTA (requires two synchronized)	HP	Sampler	Discontinued
LSNA	Agilent	Sampler	Discontinued
PNA-X + Nonlinear option	Agilent	Mixer	\$\$
ZVA + Nonlinear option	Rohde and Schwarz	Mixer	\$\$
SWAP X-402	VTD	Sampler	Discontinued

Receiver: Mixer vs. Sampler



Measurement Setup for Envelope Tracking Application

The setup includes **two LSNAs simultaneously**. One is dedicated to RF (sampler based down-conversion), the other one samples directly the LF stimulus. The purpose is to investigate **low-frequencies** S_{22} of the DUT under RF large signal conditions.



Low-frequency measurement of drain supply envelope-bandwidth impedance for supply-modulated PAs

Conclusion

This new project will enable a new RF measurement capability by enabling an instrument that currently does not exist on the market. Some additional benefits include:

- frequency range extension of NI RF instrument products currently available;
- sampler architecture offers a unique multi-scale time analysis possibility (e.g. signal and carrier domains);
- can be implemented with various ADCs and downconverters (e.g. THAs);
- 100% LabVIEW environment;
- goal is to offer open-source LabVIEW software for user measurement flexibility.

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