RF & Microwave Components

WIDEBAND MODULATED LOAD PULL

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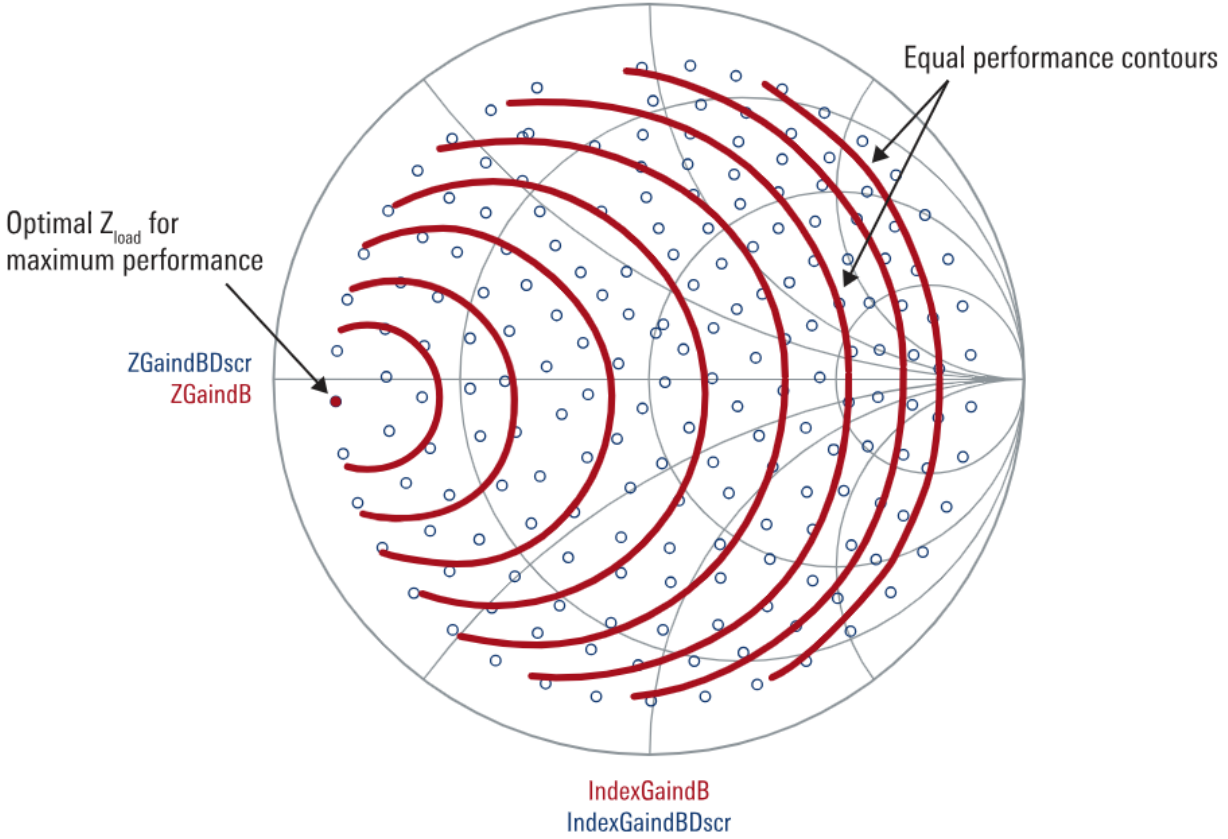
ROHDE&SCHWARZ

Make ideas real

CONTENT

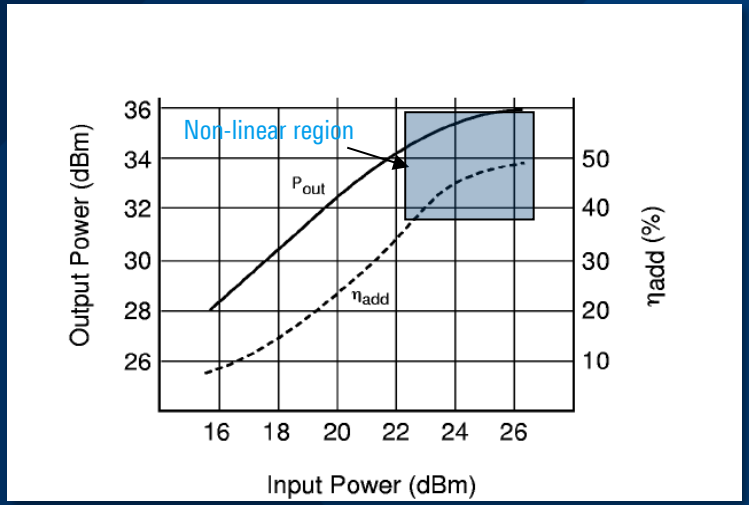
- What is load pull and why do we need it?
- Common approaches to load pull
- The new wideband modulated load pull solution
- Demo
- Summary



WHAT MAKES A PA DESIGN COMPETITIVE IN THE MARKET?

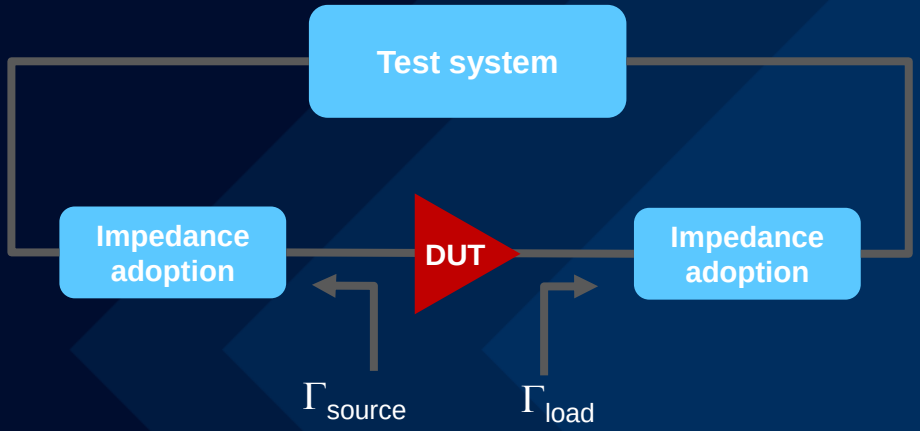
- **Energy efficiency or PA Efficiency** is the key performance differentiator in many industries.

- PAs are operated in non-linear modes (compression) for maximum output power
  - Small signal S-Parameters aren't valid
  - But we can still measure vector wave quantities (a1, b1, a2, b2)



WHY LOAD PULL?

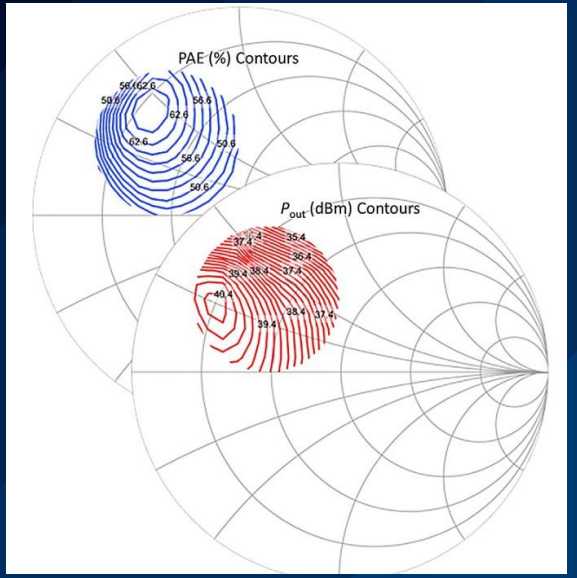
- Active devices:
  - **Different characteristics with different impedances**
  - **Performance prediction across impedances is not possible**
- Load Pull: presenting different impedances to DUT

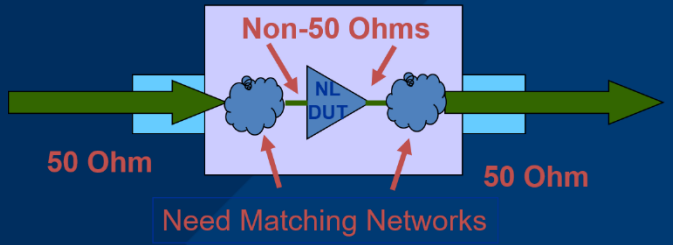


WHY LOAD PULL?

- Validation of devices with different impedances to ensure proper performance in varying conditions
  - Max power, gain, efficiency, harmonics, intermodulation, NF, EVM, ACLR, … all depend on impedance
  - Contour plots show equal performance on Smith chart

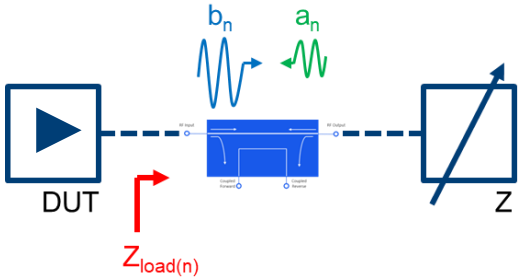
- Raw PA die and MMICs are non-50Ω devices
  - PA input and output are low impedance (usually less than 10 Ohms)
  - Matching networks are required – It's a 50Ω world
- Modelling
- PA optimization incl. harmonics, 2nd & 3rd typically



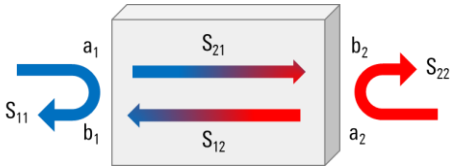


LOAD PULL BASICS

- Impedance as seen by the device – load means on the output



- Remember: S parameters
  - a-waves: to device
  - b-waves: from the device
  - S11 = Forward reflection coefficient (input match)
  - S22 = Reverse reflection coefficient (output match)
  - S21 = Forward transmission coefficient (gain or loss)
  - S12 = Reverse transmission coefficient (isolation)



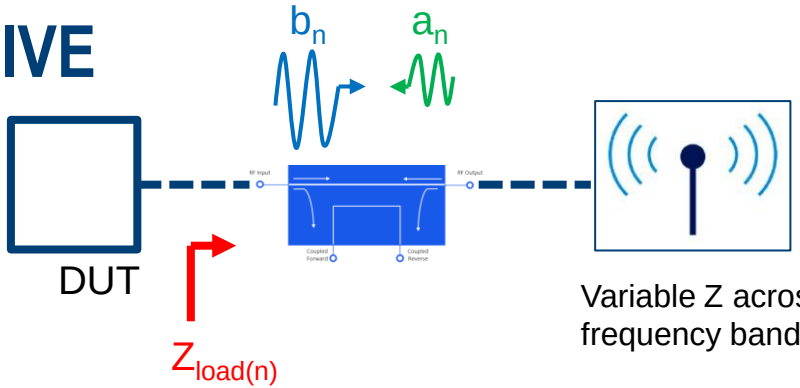
$S_{11} = b_1/a_1$
$S_{21} = b_2/a_1$
$S_{12} = b_1/a_2$
$S_{22} = b_2/a_2$

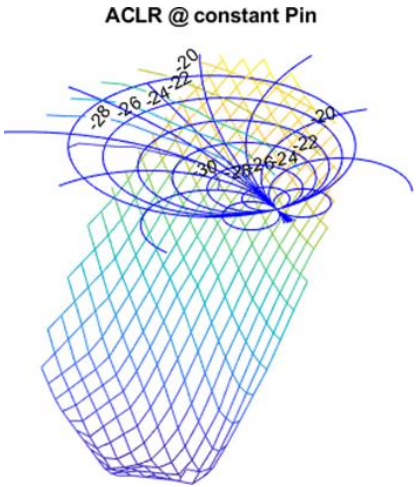
WHY LOAD PULL
A DUT APPLICATION PERSPECTIVE

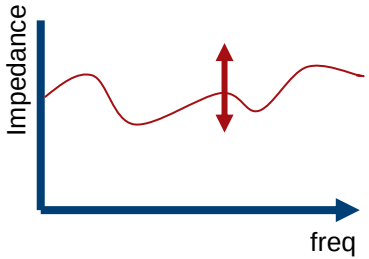
- One RF chain
  - wide RF frequency range
  - multiple RF bands in communication systems

- *Nominal* 50 Ohm world, *but* impedance is varying across frequency, e.g. antenna structure
  - Amplitude and phase variance

- Ensure PA behavior in final design

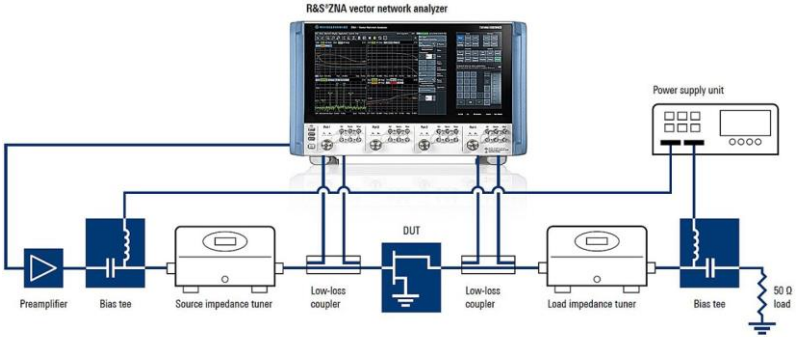




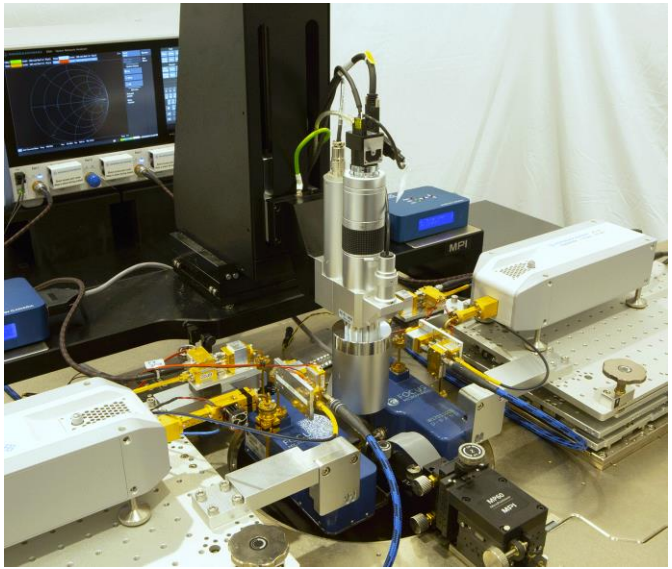


TRADITIONAL LOAD PULL APPLICATION BASED ON VNA

- Basic principle with impedance tuners



- Often seen in on-wafer applications



3 DIFFERENT LOAD PULL APPROACHES

Passive LP

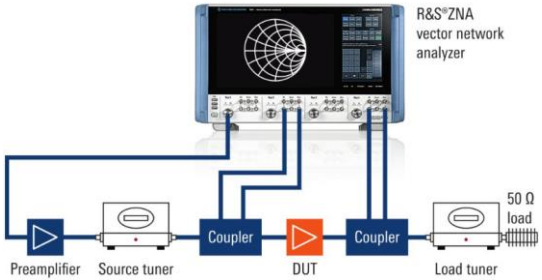
- Traditional
- VNA and tuner based

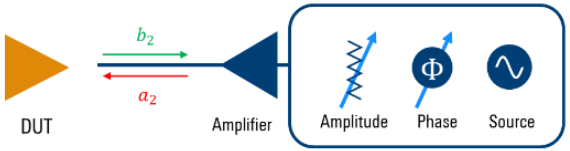
Active LP

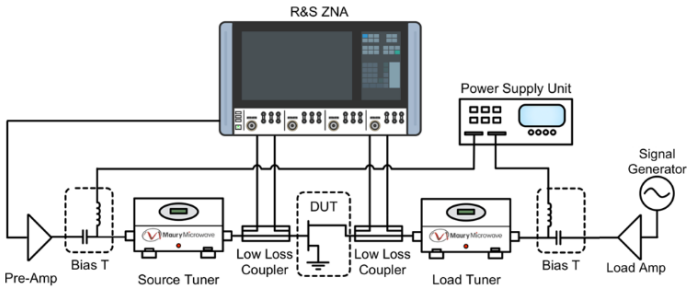
- Active creation of reflection signal
- Wider drive range
- Faster

Hybrid LP

- Best of both worlds
- Pre-matching with passive tuner
- But most complex







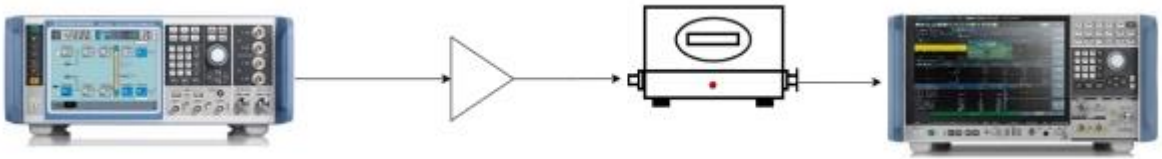
COMMON MODULATED LOAD PULL

Wideband modulated load pull solution

MODULATED LOAD PULL

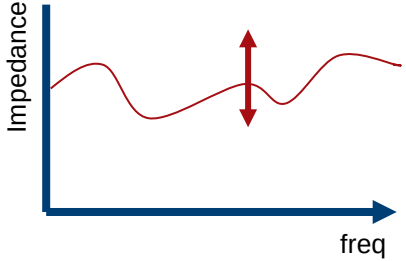
- Validate modulation characteristics under different impedances
- Every RFFE vendor validates the RF frontend for different impedances
- Wide frequency coverage of antenna
  →impedance variation
  →tests from 1/3 of 50 Ohm to 3x 50 Ohm

- Common method: passive tuner inserted to test setup

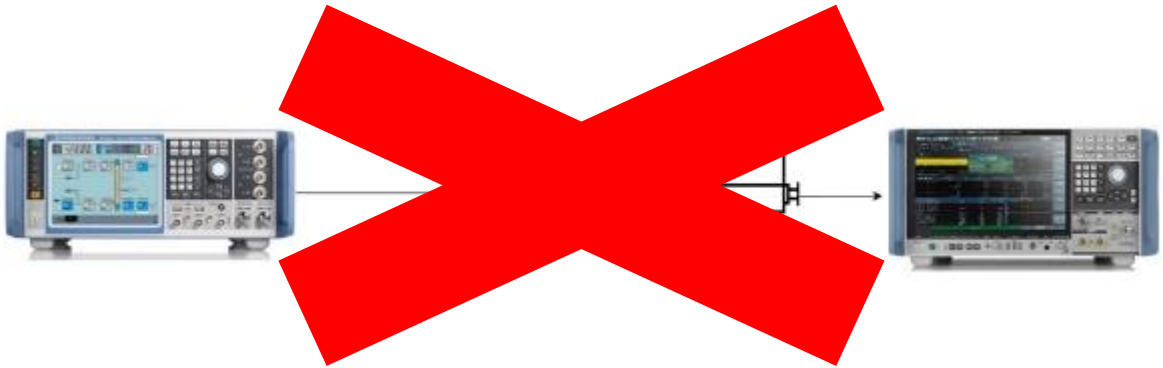


MODULATED LOAD PULL

- Group delay of tuner in amplitude and phase
  - Neglectable for narrowband use
  - PROBLEM for 100 MHz and beyond



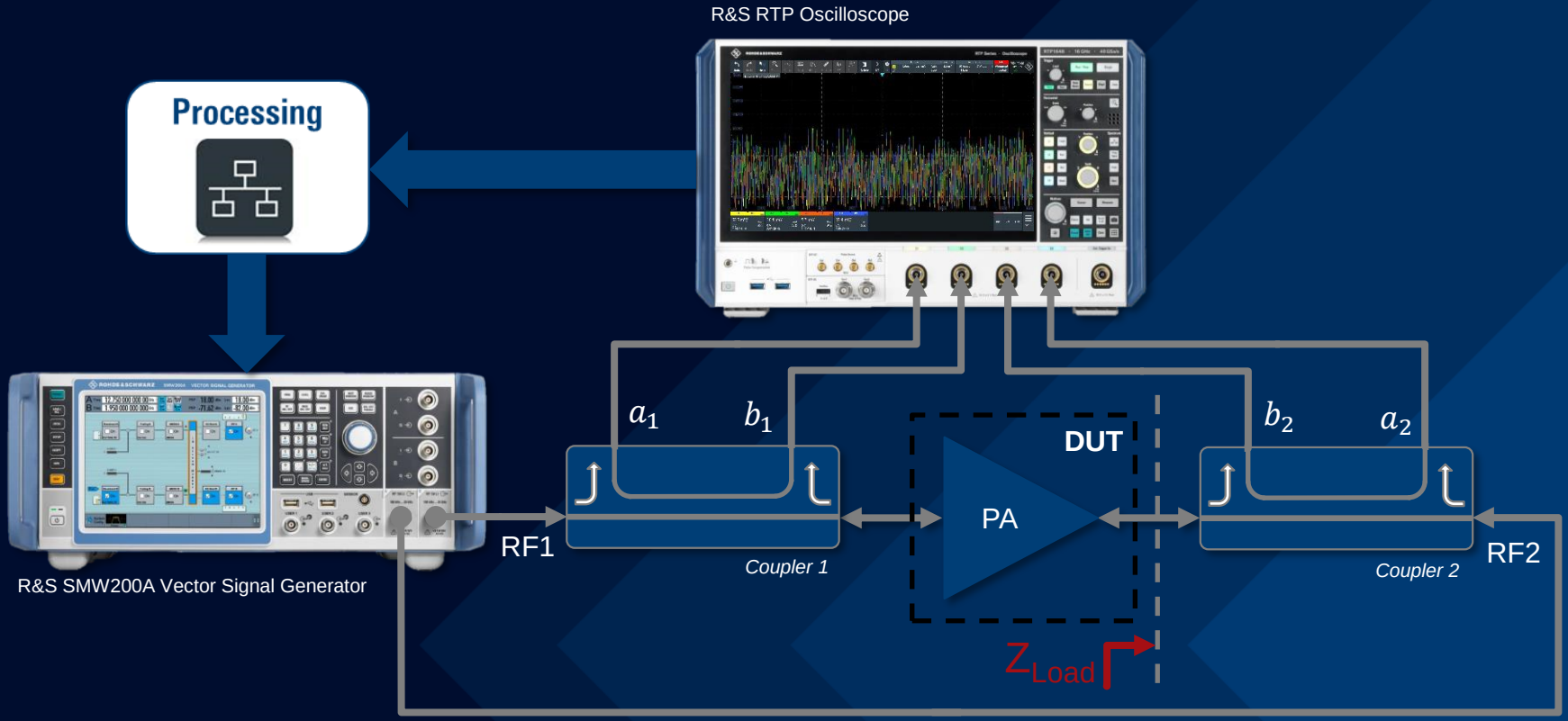
- New solution needed!



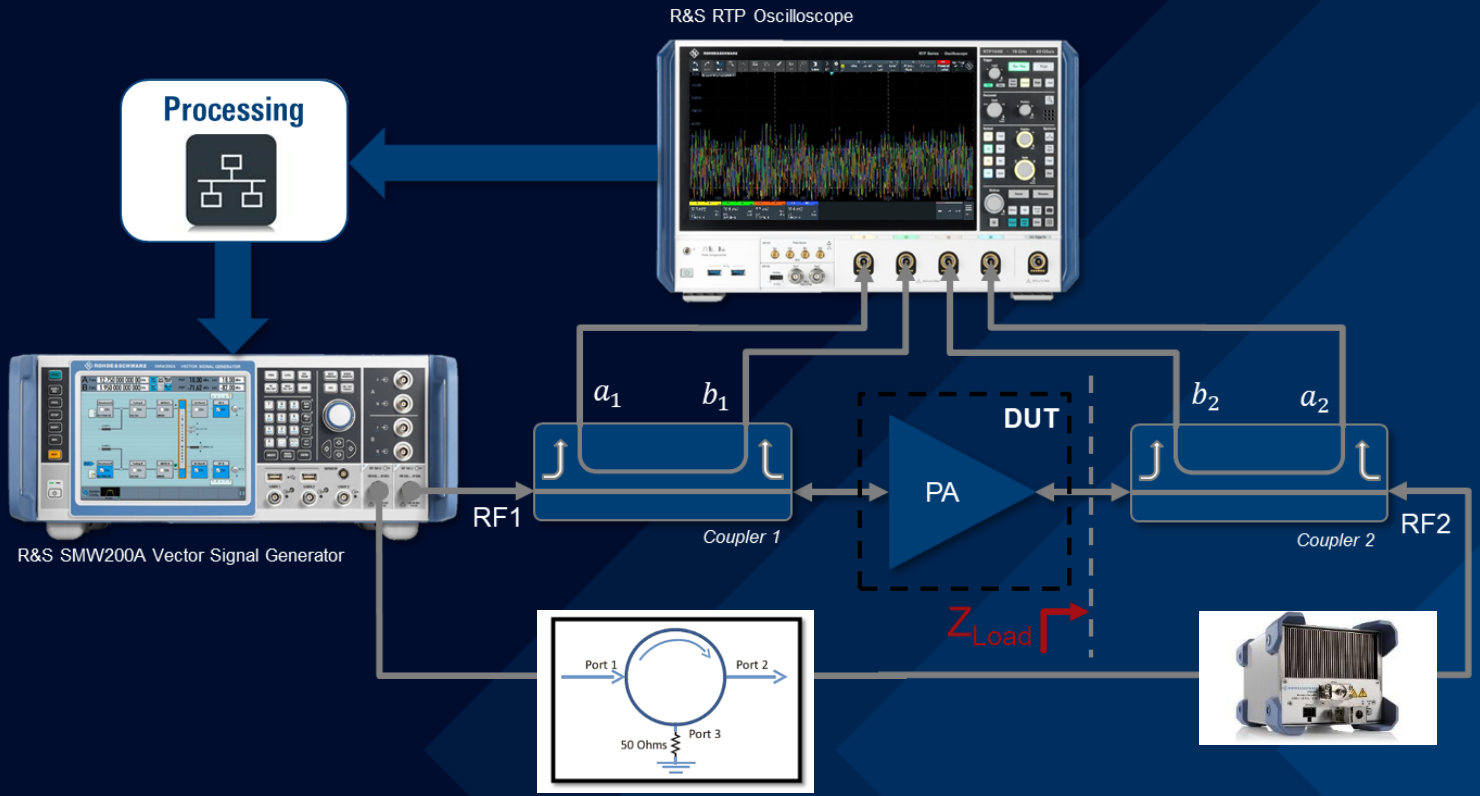
R&S® wideband modulated load pull solution

NEW WIDEBAND MODULATED LOAD PULL SOLUTION

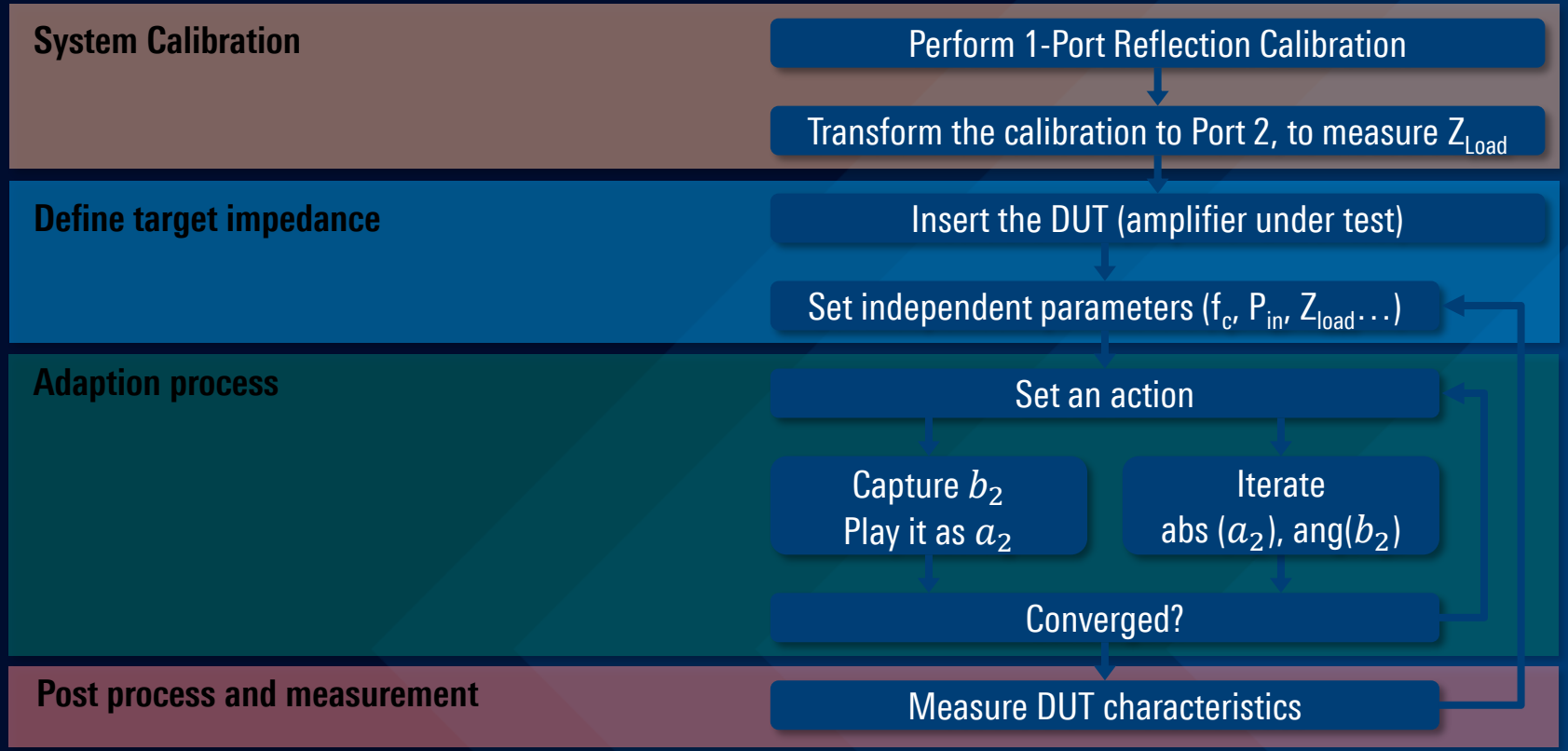
THE PROPOSED MEASUREMENT SETUP …



MEASUREMENT SETUP … IMPROVED PERFORMANCE

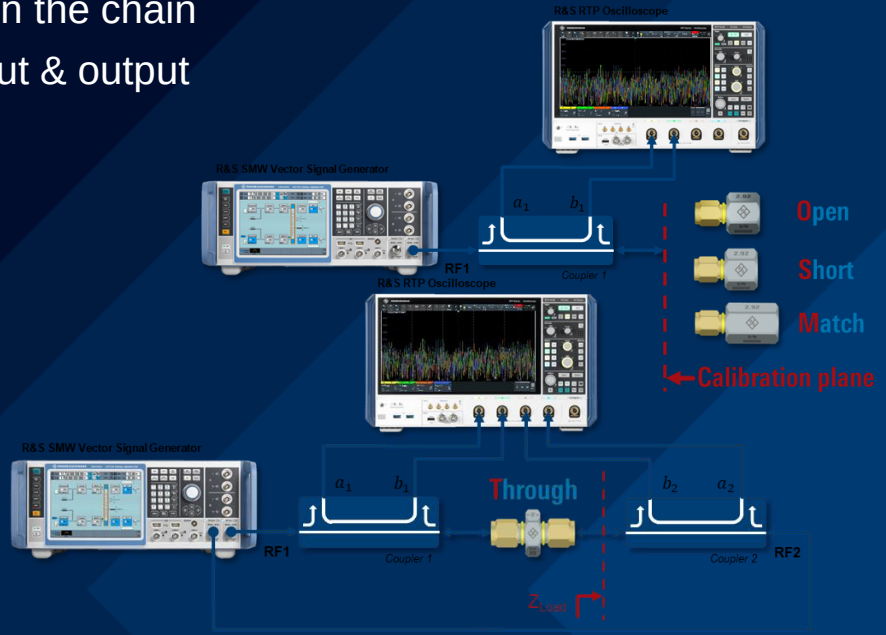


SYNTHESISING ARBITRARY LOAD IMPEDANCE UNDER MODULATION CONDITIONS

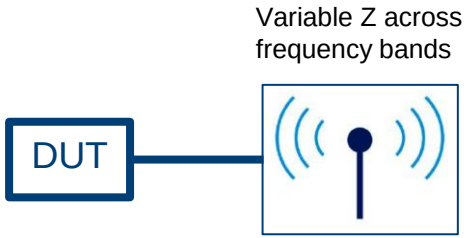


SOME WORDS ON THE CALIBRATION

- There is no VNA like measurement w/o proper calibration!
- Calibration to include driver or amplifier in the chain
- Need impedance calibration on DUT input & output
- 2 step approach
  - OSM calibration on DUT input plane
  - Transfer to DUT output side

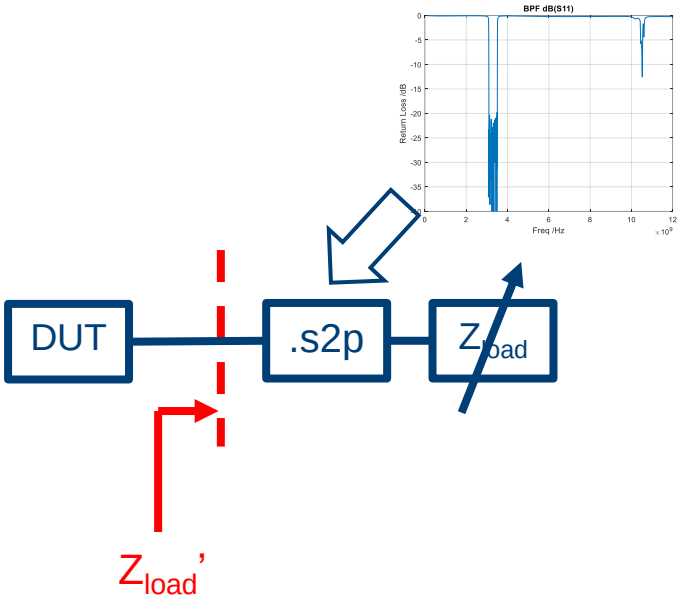


DISPERSIVE IMPEDANCE & S2P DEEMBEDDING



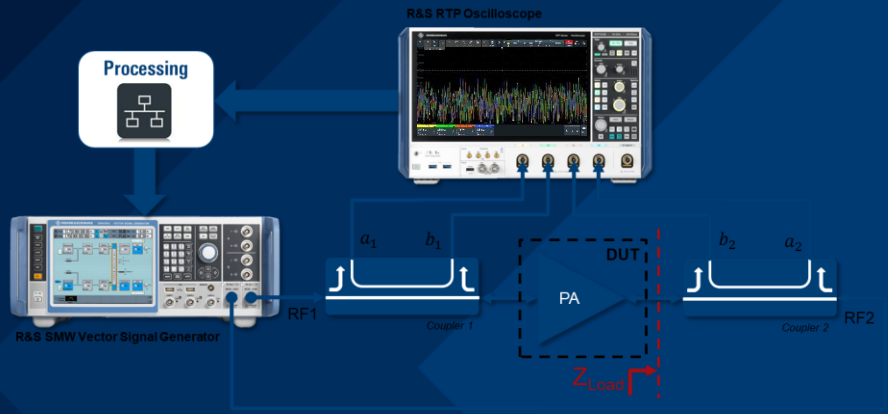
- Dispersive Load: Load S1P file for Z_{load}

- What if there is any device between PA and the antenna?
- Shift Z_{load}, plane by applying a S2P file representing candidate networks
- Potential use cases:
  - Filter
  - Matching network
  - Tuner for hybrid load pulling



BENEFIT FROM THE R&S MODULATED LOAD PULL SOLUTION

1. Speed
   - Example: 1300 impedance states & measurements take all night with other approaches, now only 1h
2. Advantage in accuracy and speed over tuners, plus true Time-Domain measurements
3. Based on two main general-purpose instruments
   - which can also be re-used for different applications
4. Flexibility in the setup
   - commercially modular + capable to adapt to third party components

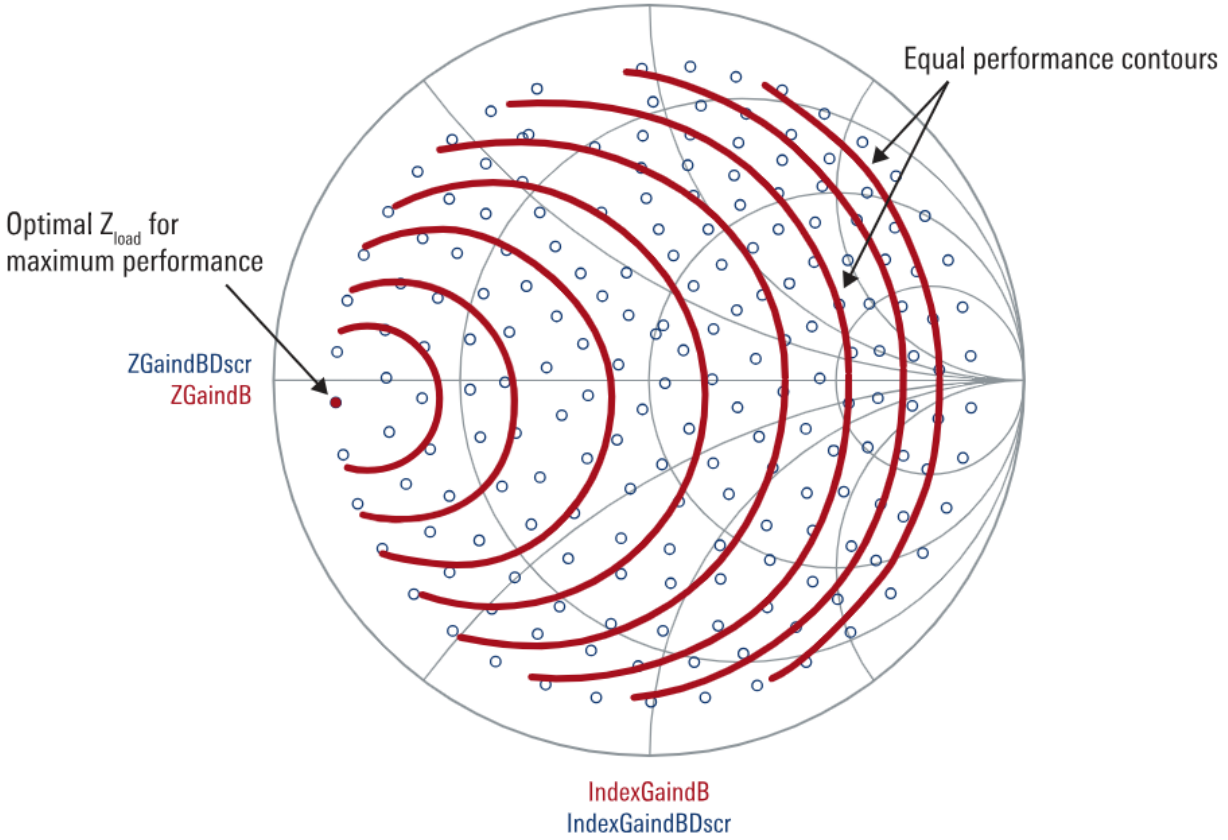


R&S® wideband modulated load pull solution

RTP-K98 SOFTWARE SOLUTION INTRODUCTION AND DEMO

SUMMARY

- Turnkey solution for modulated PA validation across impedance
- Use of common lab instruments allows reuse
- High speed impedance tuning supports fast measurements
- Standard compliant testing incl DPD or ET supported



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