# **R&S ZVAX-TRM** Signal Conditioning Unit
# **R&S ZVA** Vector Network Analyzers

## Systems for active device and T/R-module test

Albert Gleißner, 1EPM

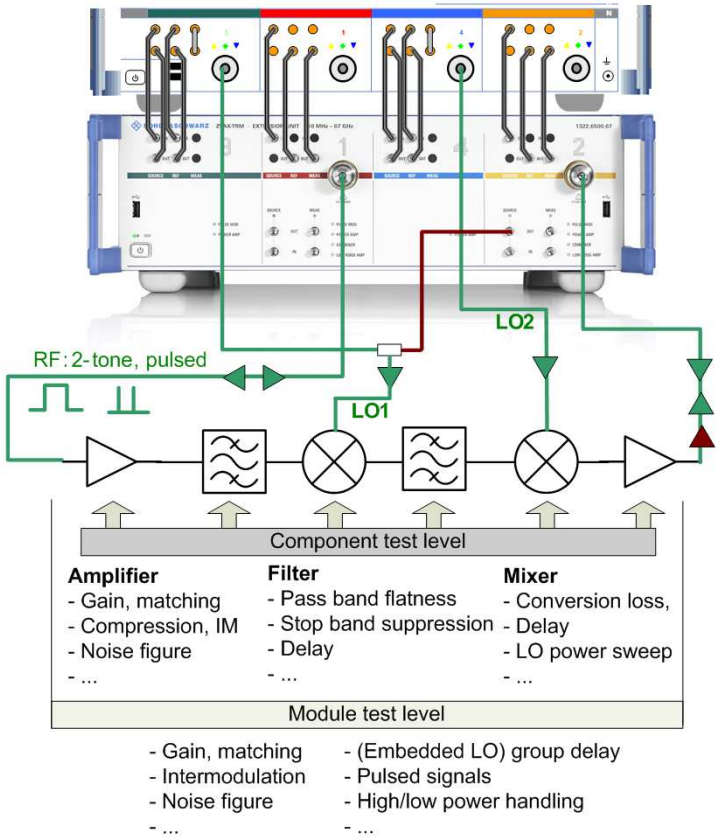




COMPANY RESTRICTED

# Receiver, Transceiver Test

- Development and production of single components
- Development and production of complete modules
- High number of test parameters
- Iterative design process



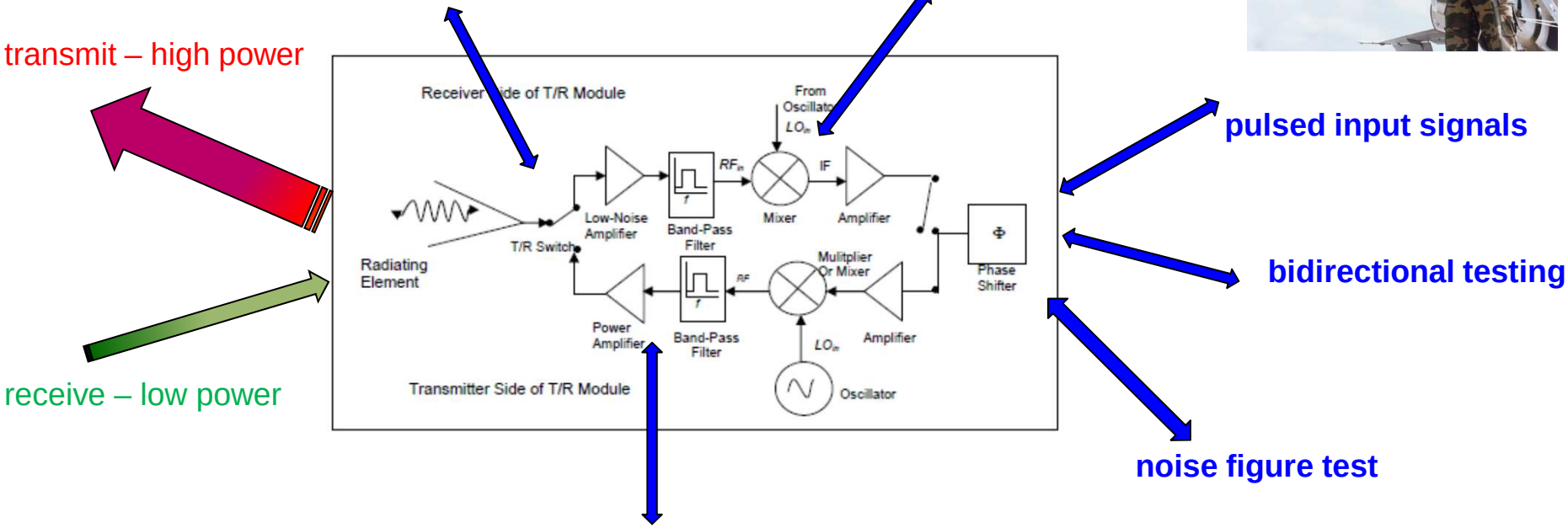
# Challanges of T/R-module characterization



**fast switching of DUT states**

**source as LO for mixer test**

transmit – high power




**pulsed input signals**

**bidirectional testing**

receive – low power

**noise figure test**

**intermodulation test**

**Main task:**
- Extensive characterization of active DUTs
- Fixed setup, mainly used in development

**Typical DUT:**
- Amplifier/LNA, mixer, modules, passive DUTs

**The solution:**
R&S ZVA
Network Analyzer



**Main features:**
- Measurement functions, e.g.:
  - S-parameter, input/output power
  - Conversion loss/gain
  - Compression, intermodulation
  - (Embedded LO) group delay
  - Pulse profile
  - Noise figure (non-frq conversion)
  - Time Domain evaluation
- Up to 4 internal sources
- Frequency range up to 67 GHz

**Benefits:**
- Extremely versatile & compact:
  A single box for a wide range of demanding applications
- High-end accuracy
- Outstanding RF performance

**Main task:**
- Full characterization with a single connection
- Extended signal conditioning, test set flexibility

**Typical DUT:**
- High power amplifier, converter, T/R-modules

**The solution:**
R&S ZVA, plus
R&S ZVAX-TRM
signal conditioning
unit



**Additional features:**
- High power test ports
- Conditioning of R&S ZVA I/O RF signals
  - Two-tone signal (for IM, embedded LO GD)
  - Pulse modulation (even bi-directional)
  - Increased output power
  - Enhanced Noise Figure capability
- Switchable signal conditioning components and I/Q paths access (booster amp, isolator etc)

**Benefits:**
- Combines extensive internal signal conditioning with flexible system extension
- Adopts the setup to the current measurement quantity without screwing of connections
- One setup – multiple measurements

**Main task:**
- Automated measurement for complete device characterization and production test

**Typical DUT:**
- T/R module, complex DUT

**The solution:**
TR Module
Test System
R&S TS6710,
consisting of:
- R&S ZVA
- Signal conditioning unit with DUT multiplexing
- R&S cTSVP for Device control
- Configurable Test SW
- DUT Power supply



**Additional features:**
- Fully automated test run incl. DUT control
- Integrated result analysis and test report
- Includes spectrum measurement with R&S ZVA or spectrum analyzer R&S FSW

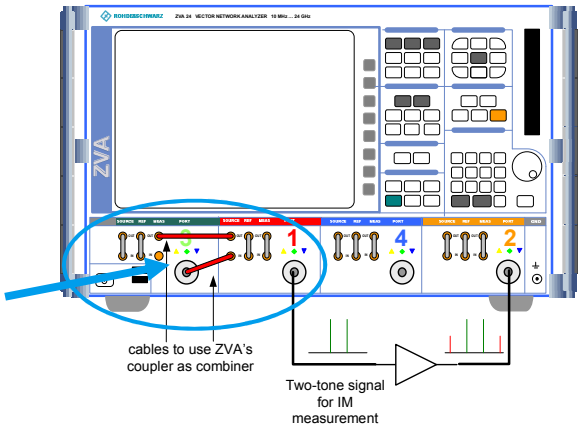
**Benefits:**
- High test speed based on R&S experience
- Optimized test routines with source code
- Customized adaptations
- Local support and adaptation


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# R&S ZVA single box solution

## Example configuration and test parameters

- **Amplifier measurements**
  - S-parameters: Matching, Gain (mag & phase)
  - Compression (power sweep)
  - Intermodulation (2-tone signal with internal sources & coupler)
  - Hot S22 (reverse matching with input stimulation signal)
  - …

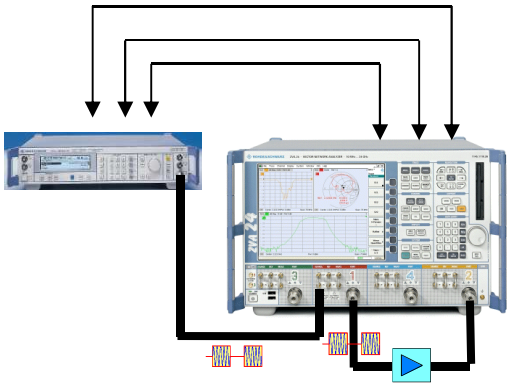


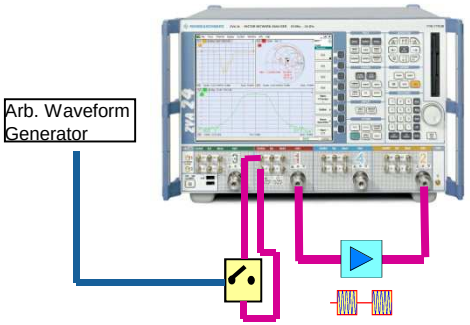

- **Mixer measurements**
  - 2-port VNA with ext src, or 4-port ZVA with 2 or 4 sources
  - Conversion gain
  - RF, LO crosstalk
  - Group delay
  - ….

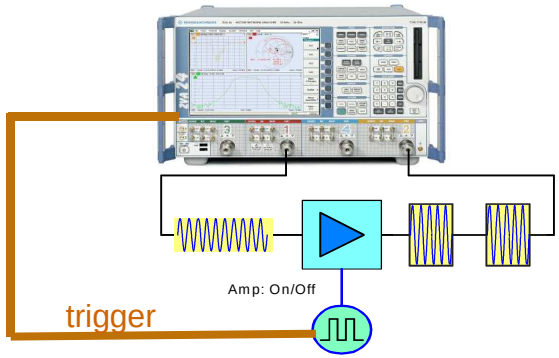
- **Potential complementary instrumentation:**
  - NRP power meter for Pcal and power measurement
  - Pre-amps, attenuators
  - …

# R&S ZVA single box solution
# Pulse generation

- Generation of pulsed signal
  - Signal generator with pulsed option
  - Pulse modulator (with wave form generator)
  - Pulsed DUT supply power
- Signal fed to front of coupler
- Pulsed reference signal
- Calibrated S11 and S21 measurements
- Frequency and power sweep possible

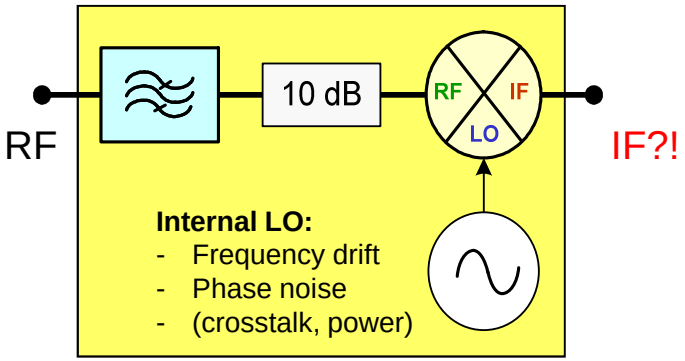




# Embedded LO group delay:
# What is a Mixer / Converter with out LO Access

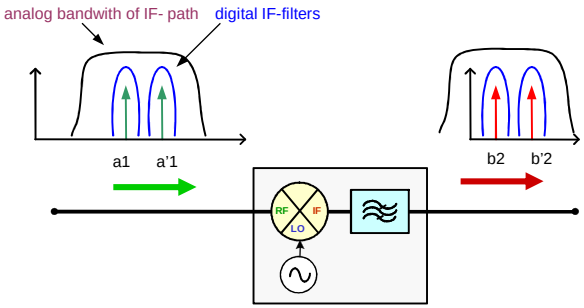
- Typically converter are used for up- and down-links of satellites
- The LO is not accessible, often also the reference signal is not available
- Group delay is the key parameter for low bit error rate for data transmission
- Challenges
  - Internal LO frequency drift → IF drift
  - Internal LO phase affects IF phase & DUT delay
  - Internal LO phase noise decreases system performance



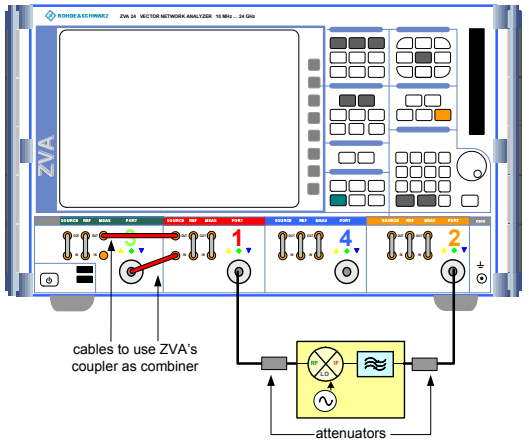
# Group Delay Measurement of Mixers without LO Access with ZVA-K9

- Stimulation of DUT with two carriers a1 and a'1 (= a1 +Δf)
- Measurement of phase difference of the input signals (φ a1 - φ a'1), using unique *digital dual receiver architecture* of the ZVA.
- Phase shift of φ b2 and φ b'2 due to the phase response of the DUT
- Measurement of phase difference of the output signals (φ b2 - φ b'2)

- $\Delta\varphi = (\varphi\ b2 - \varphi\ b'2) - (\varphi\ a1 - \varphi\ a'1)$

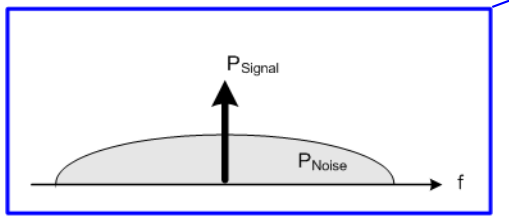


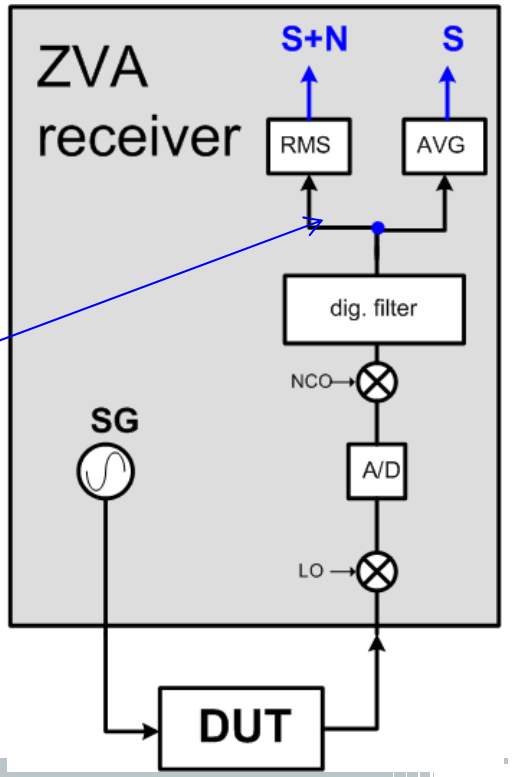

$$\tau = \frac{-1}{360°} \bullet \frac{\Delta\varphi}{\Delta f}$$



# Noise Figure Measurement with R&S®ZVA

- Based on power calibration
  - No noise source required
- Independent on used test ports
  - Measures Noise Figure in any direction
- Uses RMS and AVG detector



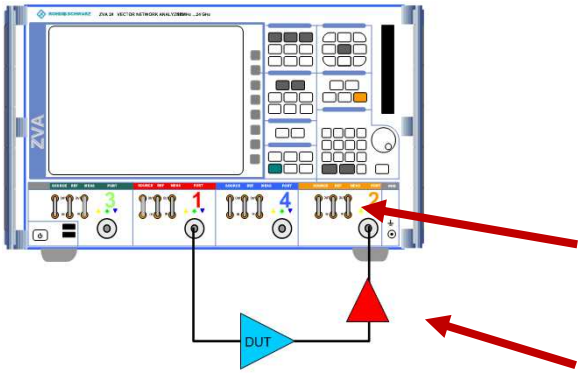

- RMS detector signal + noise
- AVG detector signal only

# Noise Figure Measurement with R&S®ZVA

Noise Figure Calculation:

$$NF_{DUT} = 10\log\left(\frac{SNR_{input}}{SNR_{output}}\right)$$

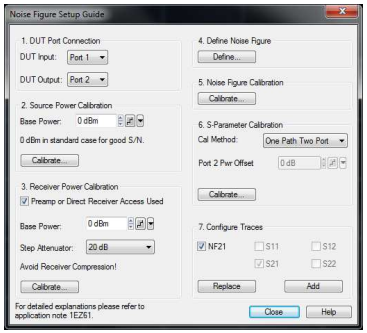
$$= \underbrace{10\log\left(\frac{P_{signal_{input}}}{P_{noise_{input}}}\right)}_{:=CAL\ data} - \underbrace{10\log\left(\frac{P_{signal_{output}}}{P_{noise_{output}}}\right)}_{:=NF\ meas}$$




Setup depends on ZVA receiver NF, frequency, DUT gain & DUT NF:

- Use of direct channel access

- Additional test set components required (Mostly pre-amplifier in receive path, Filters with f>24 GHz, …)

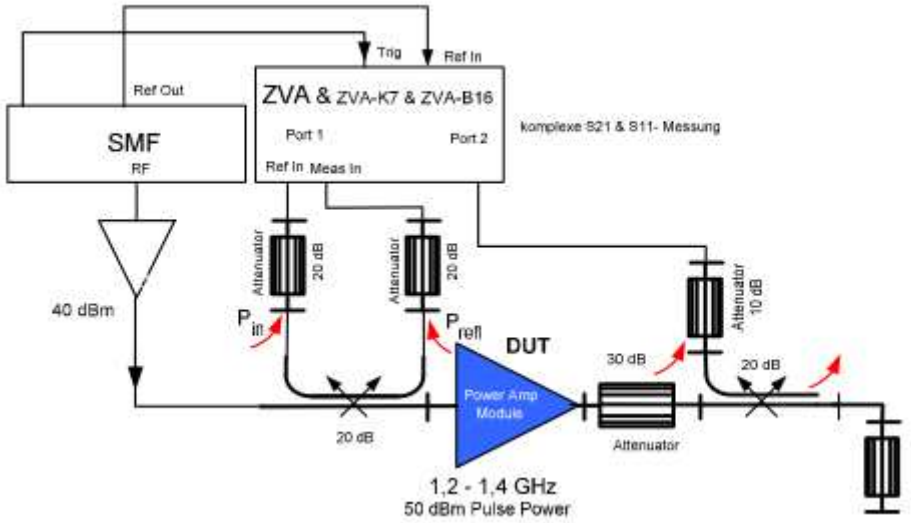


# R&S ZVA single box solution

## Example configuration and test parameters

- High power testsetups
  - DUT requires stimulation power
    > ZVA output power
  - Measurement power
    > ZVA port/input distortion power

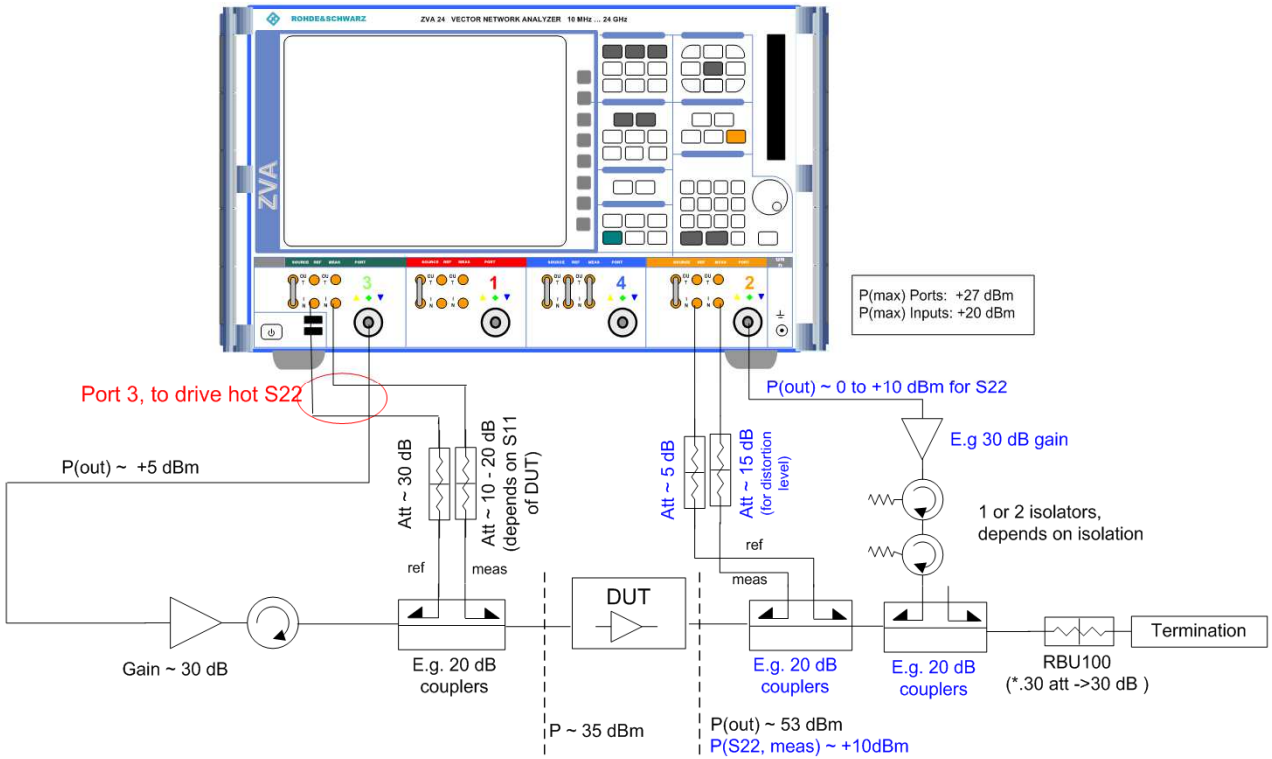
- Possible requirements
  - Internal step attenuators
  - Direct channel access
  - High power coupler(s)
  - External (fixed) attenuators
  - Isolators



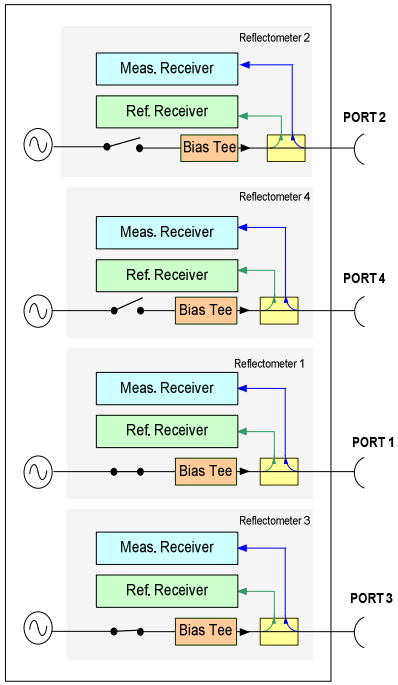
# R&S ZVA single box solution

## Example configuration and test parameters

- High power testsetups
- Example:
  - +35 dBm stimulation power
  - DUT gain 18 dB
  - P(DUT out) = 53 dBm

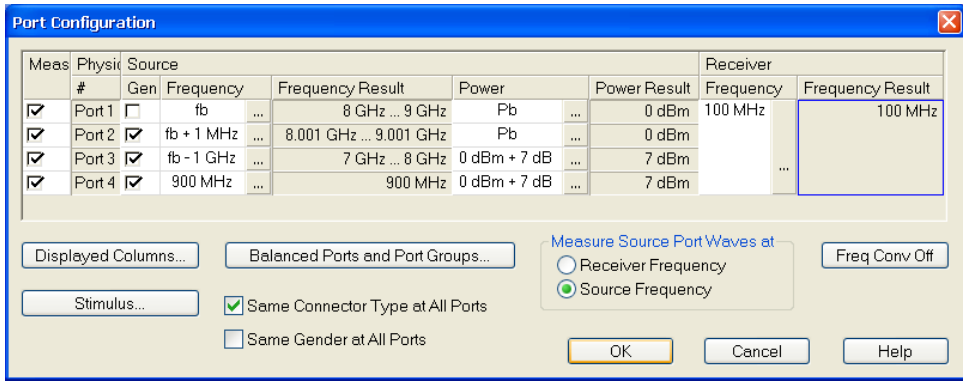


# Four Internal Sources



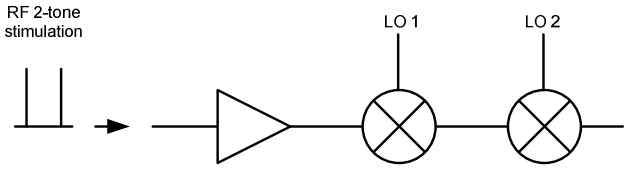

- Individual settings for power, frequency, activation (on/off)
- Phase locking possible (generator mode)

| Nr of sources | 2-port | 4-port | 4-port (4 src model) |
|---|---|---|---|
| ZVA8 | 1 (*.08) | 2 (*.10) | --- |
| ZVA24 | 1 (*.24) | 2 (*.26) | 4 (*.28) |
| ZVA40 | 1 (*.40/43) | 2 (*.42/45) | 4 (*.48) |
| ZVA50 | 1 (*.50) | 2 (*.52) | --- |
| ZVA67 | 2 (*.02) | --- | 4 (*.04) |

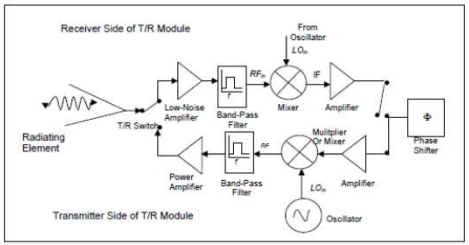


# Four Internal Sources

- **Application: Devices with 2 mixers**
  - Double converting receivers (two mixer stages)




  - T/R-Modules with seperate mixers for Tx and Rx path




- **Alternative: external sources**
  - Instrumentation effort, needs more space
  - Additional control cables and configuration effort
  - Slower (remote control)
  - Mostly not all sweep modes supported, less flexible
  - Additional programming effort

# Summary: R&S ZVA „single“ Box Solution

- Characterization of active devices, receiver, T/R-modules possible

- Typical possible measurements:
  - S-parameters (matching, [conversion] gain)
  - Absolute high- and low power (Input/Output power)
  - Compression, intermodulation, harmonics
  - (group) delay, even with LO embedded in the DUT
  - Pulsed measurements
  - Noise figure

# Summary: R&S ZVA „single“ Box Solution

- Drawbacks
  - External instrumentation and accessories required (lumped elements)
    - Pulse generation → requires signal generator, external pulse modulators
    - High stimulation power → requires output pre-amplifier
    - Power (> +23 dBm) → external high power test setup
    - Noise figure → requires receiver NF pre-amplifier, filters (with f>24 GHz)
    - Intermodulation → requires auxiliary cables for 2-tone signal
    - Embedded LO GD → requires auxiliary cables for 2-tone signal
  - Reconfiguration & reconnection required (time consuming, error prone, no automization)
  - No multiport system
  - No automized control (e.g. for phase shifters, or production)

**Main task:**
- Extensive characterization of active DUTs
- Fixed setup, mainly used in development

**Typical DUT:**
- Amplifier/LNA, mixer, modules, passive DUTs

**The solution:**
R&S ZVA
Network Analyzer



**Main features:**
- Measurement functions, e.g.:
  - S-parameter, input/output power
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  - (Embedded LO) group delay
  - Pulse profile
  - Noise figure (non-frq conversion)
  - Time Domain evaluation
- Up to 4 internal sources
- Frequency range up to 67 GHz

**Benefits:**
- Extremely versatile & compact: A single box for a wide range of demanding applications
- High-end accuracy
- Outstanding RF performance

**Main task:**
- Full characterization with a single connection
- Extended signal conditioning, test set flexibility

**Typical DUT:**
- High power amplifier, converter, T/R-modules

**The solution:**
R&S ZVA, plus
R&S ZVAX-TRM
signal conditioning
unit



**Additional features:**
- High power test ports
- Conditioning of R&S ZVA I/O RF signals
  - Two-tone signal (for IM, embedded LO GD)
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TR Module
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- Signal conditioning unit with DUT multiplexing
- R&S cTSVP for Device control
- Configurable Test SW
- DUT Power supply

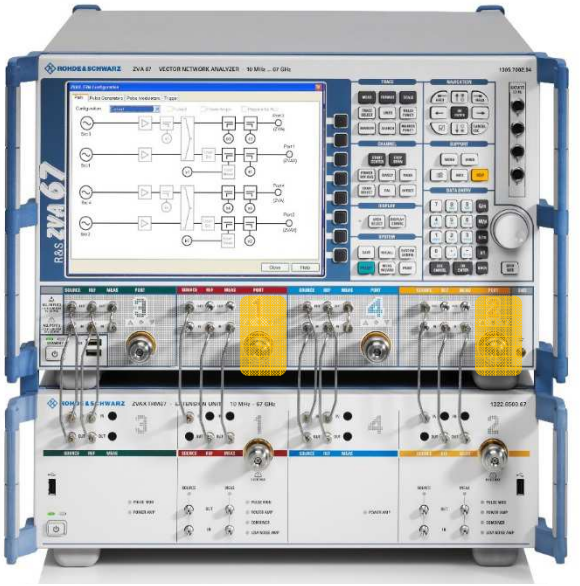


**Additional features:**
- Fully automated test run incl. DUT control
- Integrated result analysis and test report
- Includes spectrum measurement with R&S ZVA or spectrum analyzer R&S FSW

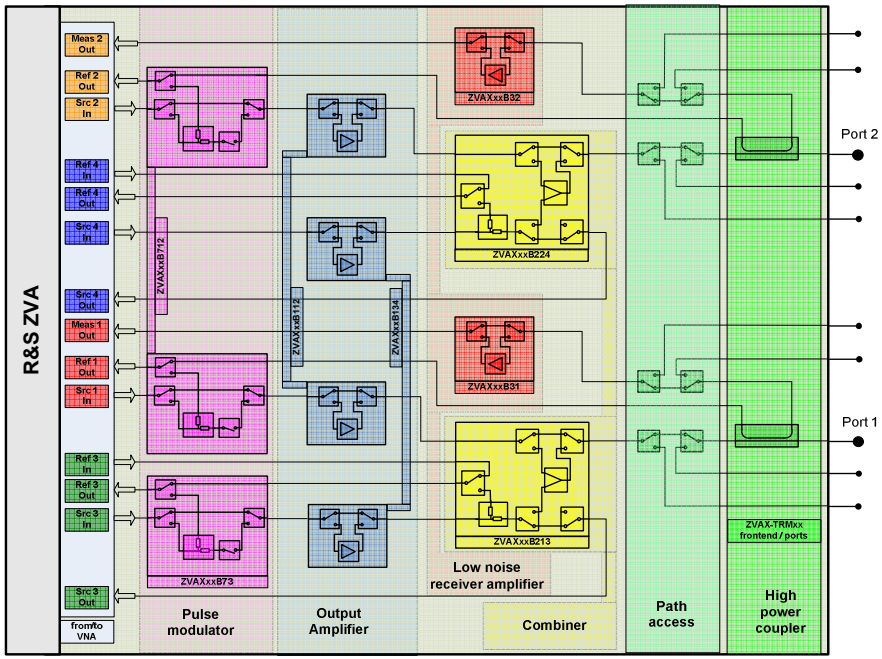
**Benefits:**
- High test speed based on R&S experience
- Optimized test routines with source code
- Customized adaptations
- Local support and adaptation

# R&S®ZVAX-TRM + R&S®ZVA

- R&S®ZVAX-TRMxx, with xx: 24, 40, 50, 67 GHz
- Base unit, tailorable with options
  - Base unit with high power couplers, path access as standard
- Can be combined with any 2-port or 4-port R&S®ZVA24/40/50/67 ZVT: RF connection cables to be designed and provided individually
- 4-port R&S®ZVAs with 4 sources offer maximum flexibility
- Control by R&S®ZVA via USB

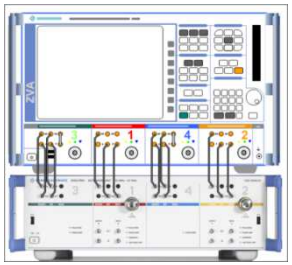


# R&S®ZVAX-TRM + R&S®ZVA



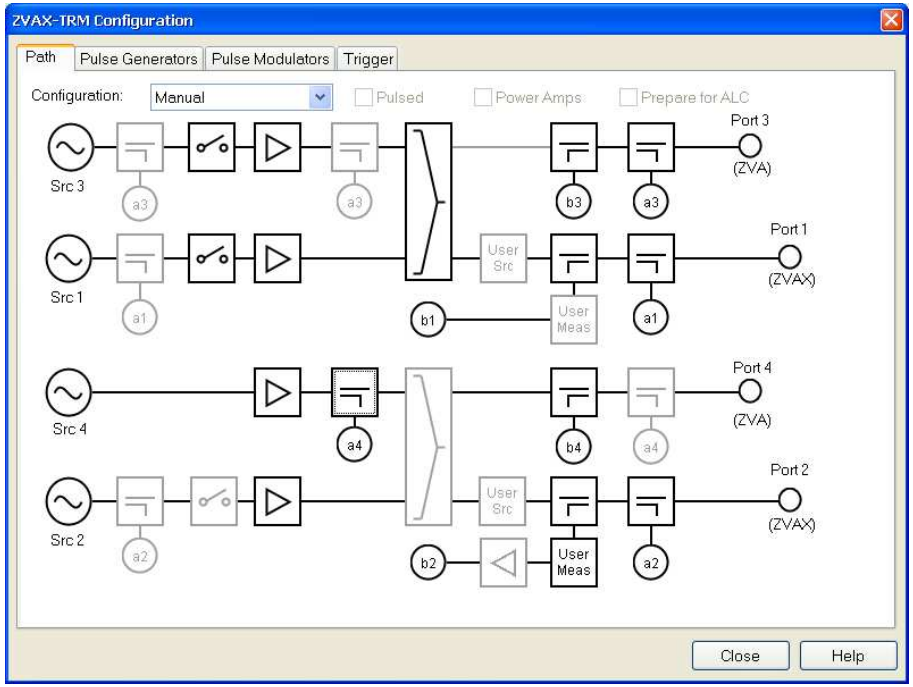

Extends R&S®ZVA with:

- Pulse modulators
- Output amplifiers
- Combiners
- Receiver amplifiers
- Accesses to source and receiver paths
- High-power couplers

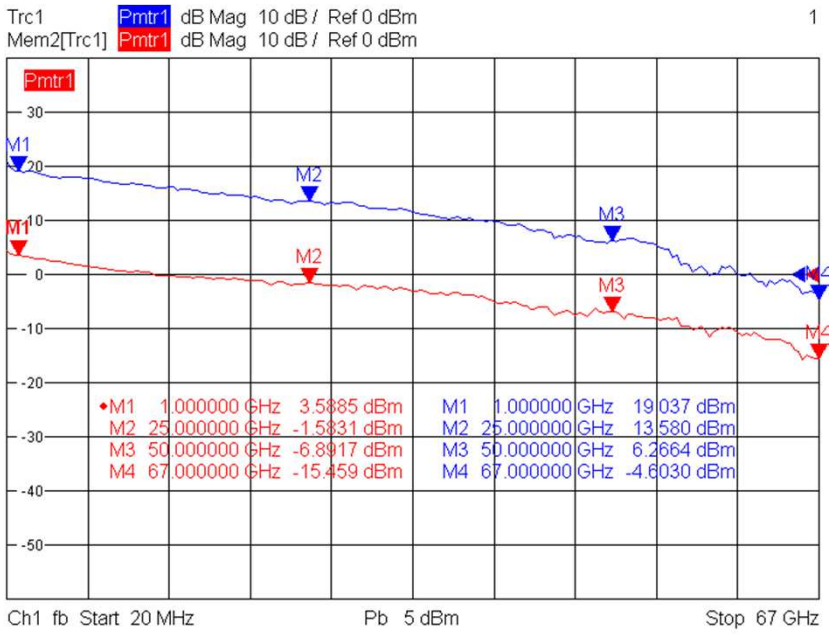


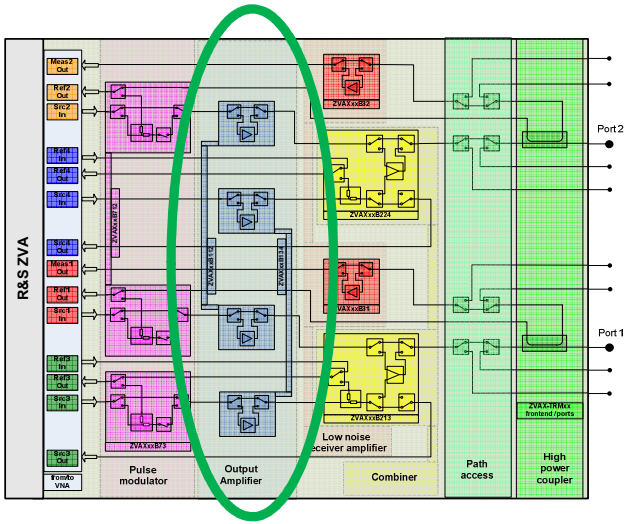
# Intuitive User Interface

- Controlled directly via R&S®ZVA user interface, or remote control



# Output Power at R&S®ZVAX-TRM Port

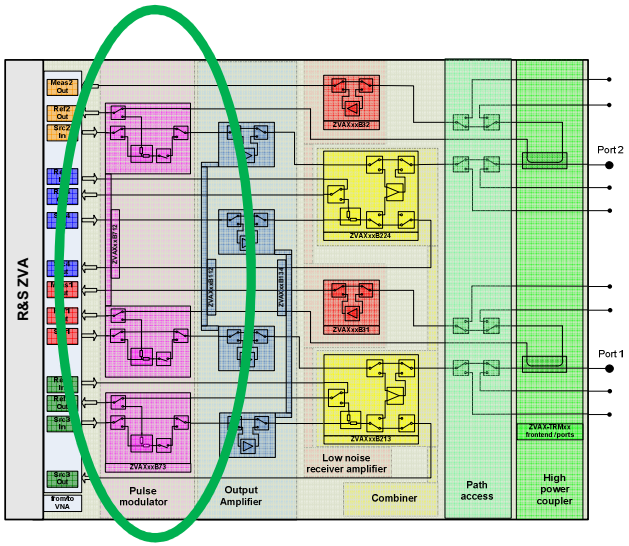


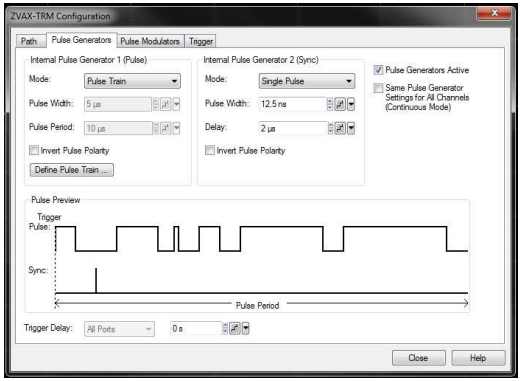

- Unique output power combined with extensive signal conditioning
- Output amplifier option R&S®ZVAXxxB112, B134
- Output power at R&S®ZVAX-TRM port comparable to VNA test port

# Generation of Pulsed Signals

- Pulse modulators for Port 1, Port 2 and Port 3
  - Bidirectional pulsed measurements
  - Pulsed 2-tone measurements

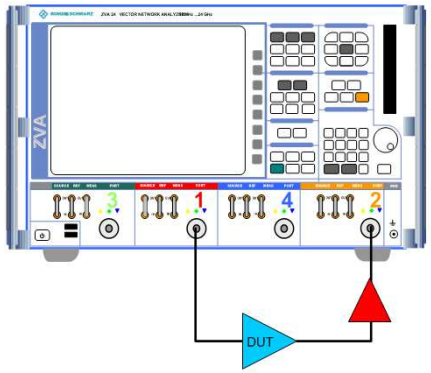


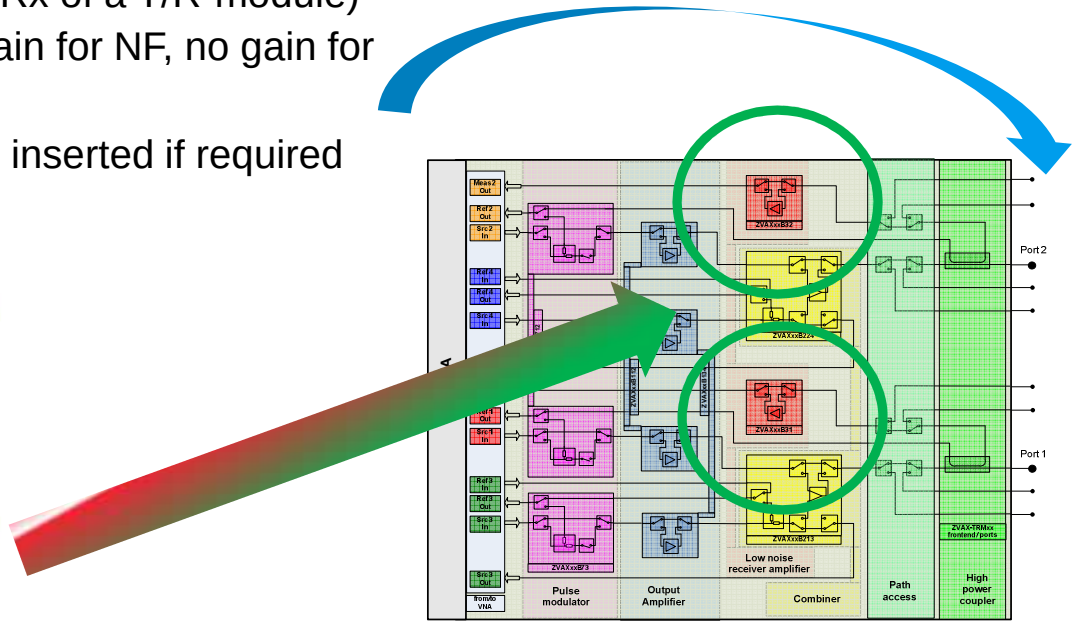

- Controlled by R&S®ZVA internal or external pulse generators
- Min pulse width 12.5 ns
- Generation of single pulses, periodical pulses and pulse trains



# Noise figure measurement

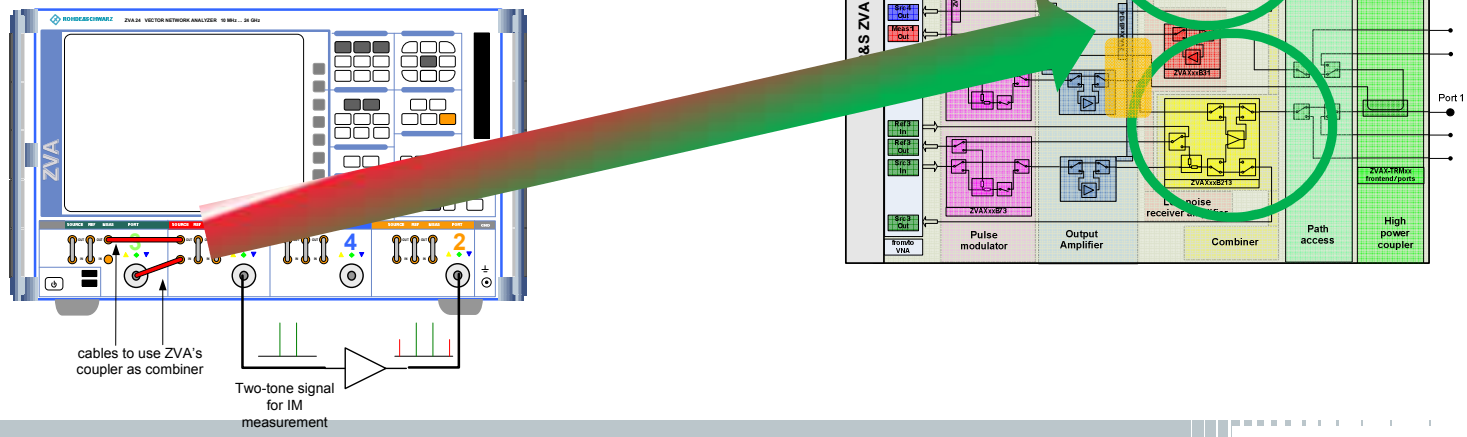
- Receiver pre-amp integrated
  - At Port 1 & Port 2 (e.g. Tx and Rx of a T/R-module)
  - Switchable (switchable: high gain for NF, no gain for other measurements)
  - 40 dB gain, attenuators can be inserted if required



# Two tone signal: Embedded LO & IM

- Combiners for two tone signal integrated
  - Switchable (activation if required)
  - Support of
    - IM measurement
    - embedded LO group delay



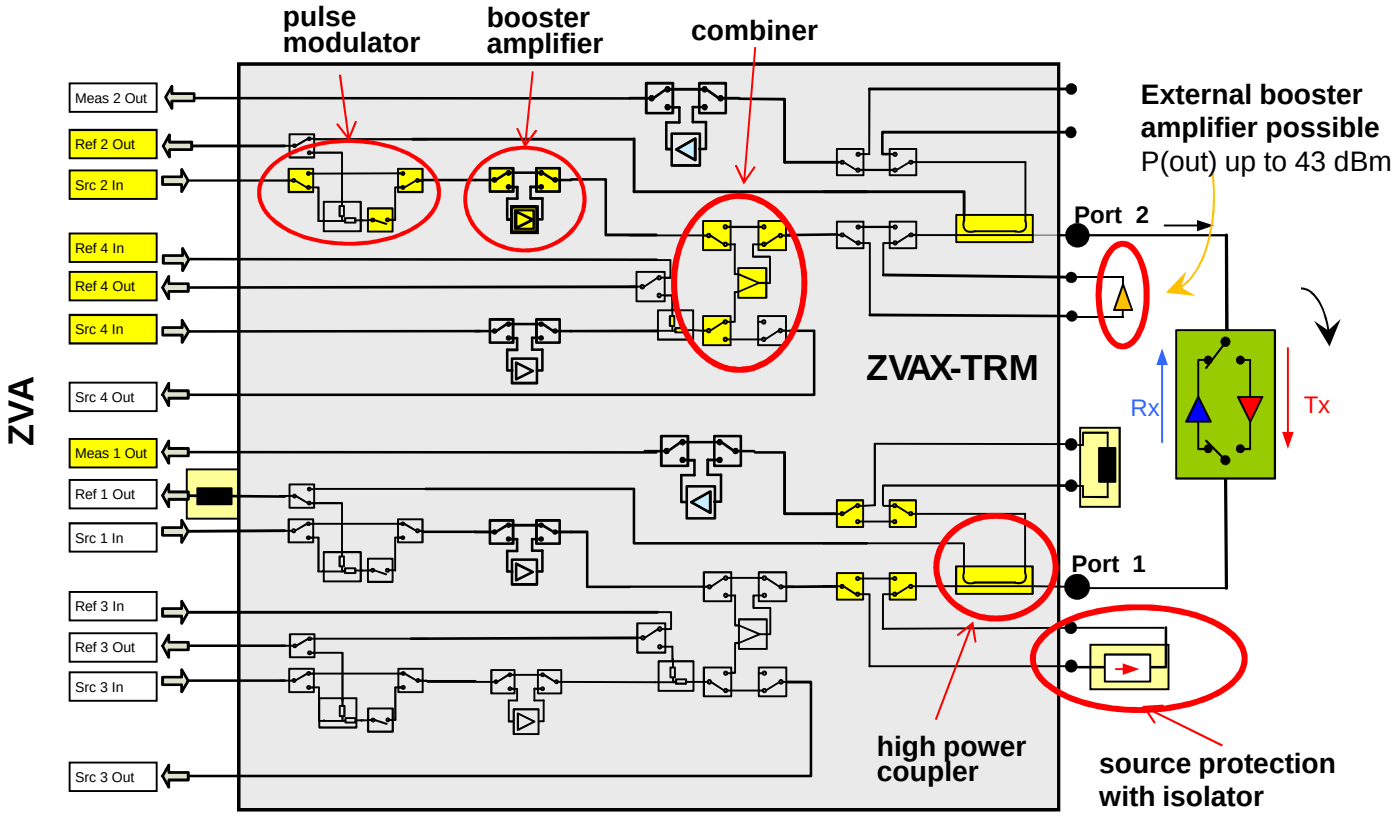
# R&S ZVAX-TRMxx
# T/R-module Test
# -
# Setup & measurement examples

# Typical Measurement Tasks for T/R-Module Test

## Transmit path Tx

- High input power
- High power handling up to 43 dBm
- Generation of pulsed signals
  - Measurement in pulsed mode versus frequency, power and time
- Transmission (mag / phase) & reflection
- $P_{out}$ versus $P_{in}$
- Intermodulation test with 2-tone signal

# Tests of the Tx Path

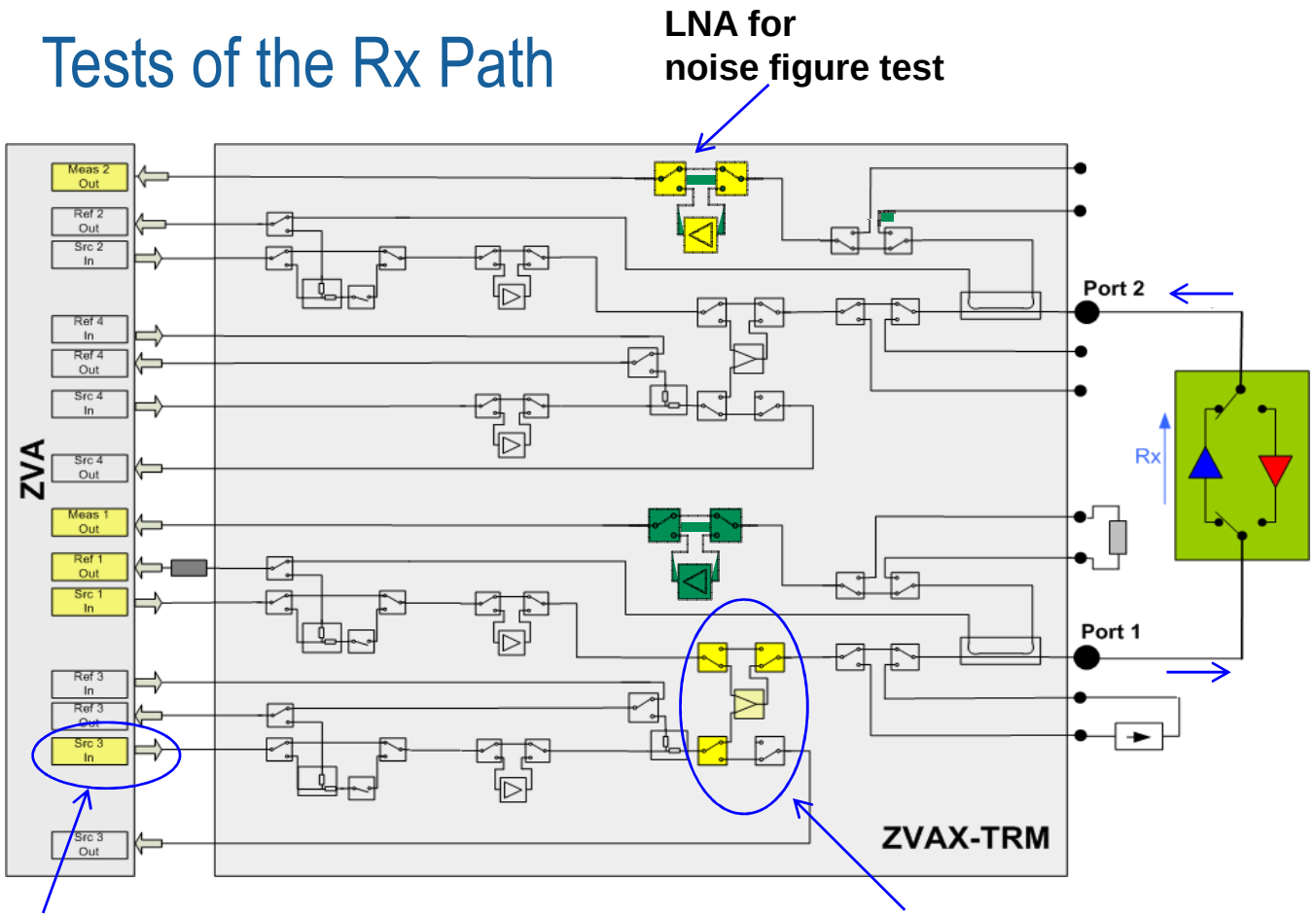


# Typical Measurement Tasks for T/R-Module Test

Receive path Rx:

- Measurement in CW or pulse mode
- Transmission and reflection
- Noise figure
- Intermodulation test with 2-tone signal
- In case of frequency conversion
  - Conversion loss with or w/o LO access
  - Requires additional source(s)

# Tests of the Rx Path



# Summary: R&S®ZVAX-TRM & R&S®ZVA

- Complete characterization of active devices and T/R-modules with a single connection
  - All quantities possible with ZVA single box solution
  - **Unique system compactness with integrated and switchable components:**
    - Pulse modulators [no external signal generator]
    - Combiner [2-tine signal for IM and embedded LO GD – switchable as required]
    - Output amplifier [high output power even with comprising test setup]
    - Receiver pre-amplifier [NF measurements]
    - Switchable path access & high power couplers [high and low power w/o reconnection]
    - Unique performance and flexibility with R&S®ZVA with 4 sources
  - **Signal conditioning separated from ZVA base unit**
    - High RF performance of ZVA base unit unaffected w/o ZVAX-TRM unit
      - High output power, dynamic, sensitivity stability of basic VNA
    - One ZVAX-TRM can be used with several ZVA
    - Uncoupling of high power part protects ZVA
    - ZVA available even in case ZVAX-TRM is at service



# Summary: R&S®ZVAX-TRM & R&S®ZVA

- **Drawbacks**
  - **No multiport system**
  - **No automized test set control (e.g. pre-amplifier, path switching)**
  - **No automized and DUT control (e.g. phase shifters, switchable DUT gain)**
  - **No automized test sequences in production**
  - **No data recording, test protocol**
  - **….**



**Main task:**
- Extensive characterization of active DUTs
- Fixed setup, mainly used in development

**Typical DUT:**
- Amplifier/LNA, mixer, modules, passive DUTs

**The solution:**
R&S ZVA
Network Analyzer



**Main features:**
- Measurement functions, e.g.:
  - S-parameter, input/output power
  - Conversion loss/gain
  - Compression, intermodulation
  - (Embedded LO) group delay
  - Pulse profile
  - Noise figure (non-frq conversion)
  - Time Domain evaluation
- Up to 4 internal sources
- Frequency range up to 67 GHz

**Benefits:**
- Extremely versatile & compact: A single box for a wide range of demanding applications
- High-end accuracy
- Outstanding RF performance

**Main task:**
- Full characterization with a single connection
- Extended signal conditioning, test set flexibility

**Typical DUT:**
- High power amplifier, converter, T/R-modules

**The solution:**
R&S ZVA, plus
R&S ZVAX-TRM
signal conditioning
unit



**Additional features:**
- High power test ports
- Conditioning of R&S ZVA I/O RF signals
  - Two-tone signal (for IM, embedded LO GD)
  - Pulse modulation (even bi-directional)
  - Increased output power
  - Enhanced Noise Figure capability
- Switchable signal conditioning components and I/O paths access (booster amp, isolator etc)

**Benefits:**
- Combines extensive internal signal conditioning with flexible system extension
- Adopts the setup to the current measurement quantity without screwing of connections
- One setup – multiple measurements

**Main task:**
- Automated measurement for complete device characterization and production test

**Typical DUT:**
- T/R module, complex DUT

**The solution:**
TR Module
Test System
R&S TS6710,
consisting of:
- R&S ZVA
- Signal conditioning unit with DUT multiplexing
- R&S cTSVP for Device control
- Configurable Test SW
- DUT Power supply



**Additional features:**
- Fully automated test run incl. DUT control
- Integrated result analysis and test report
- Includes spectrum measurement with R&S ZVA or spectrum analyzer R&S FSW

**Benefits:**
- High test speed based on R&S experience
- Optimized test routines with source code
- Customized adaptations
- Local support and adaptation


COMPANY RESTRICTED

# End