Satellite Test

STRIKING FEATURES OF THE R&S ZNA TO SUCCESSFULLY CHARACTERIZE SATELLITE AND HIGH-GAIN RECEIVERS

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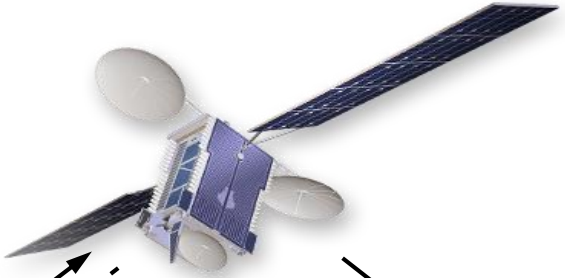
SATELLITE SYSTEM



satellite

uplink

downlink

transmitting station

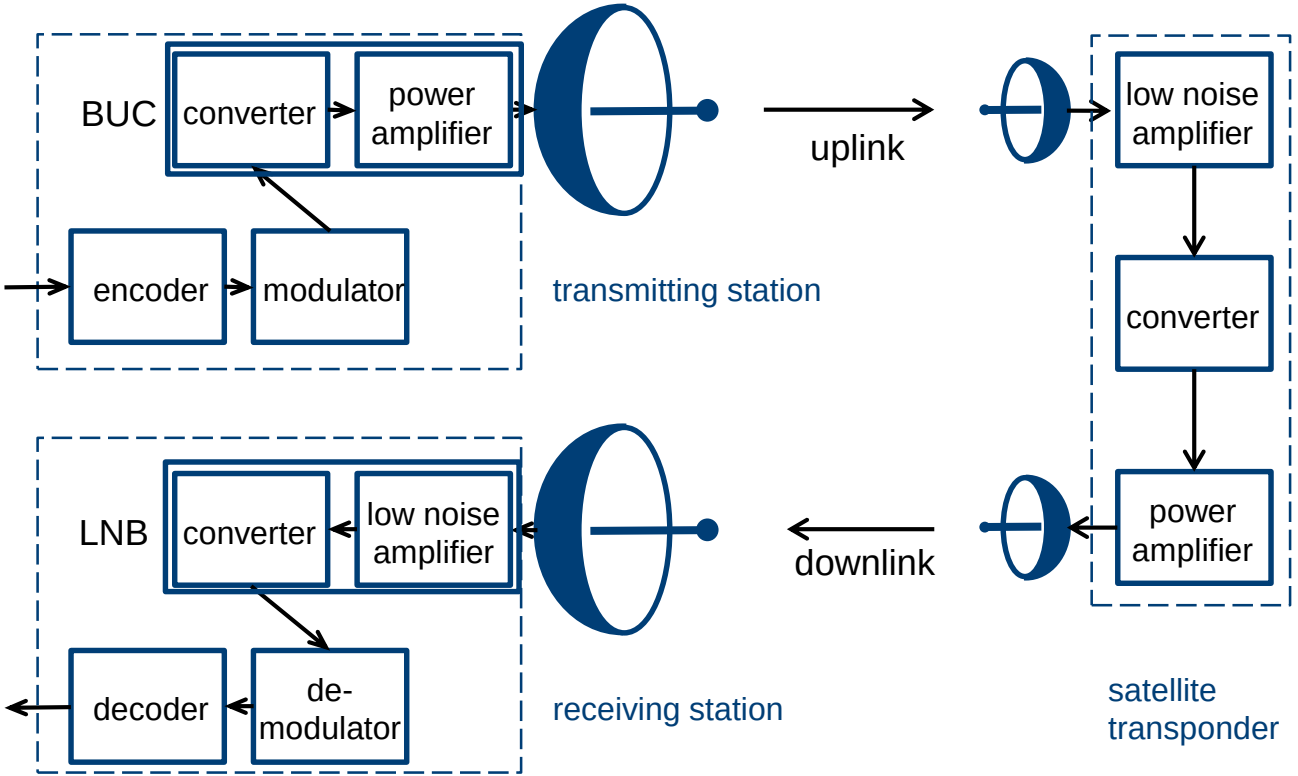
Carrier to noise ratio:

$$\frac{C}{N} = \frac{P_{EIRP}}{L_{FS} k B_w} \frac{G_{RX}}{T_S}$$

$$T_S = T_0 (F_N - 1)$$

receiving station

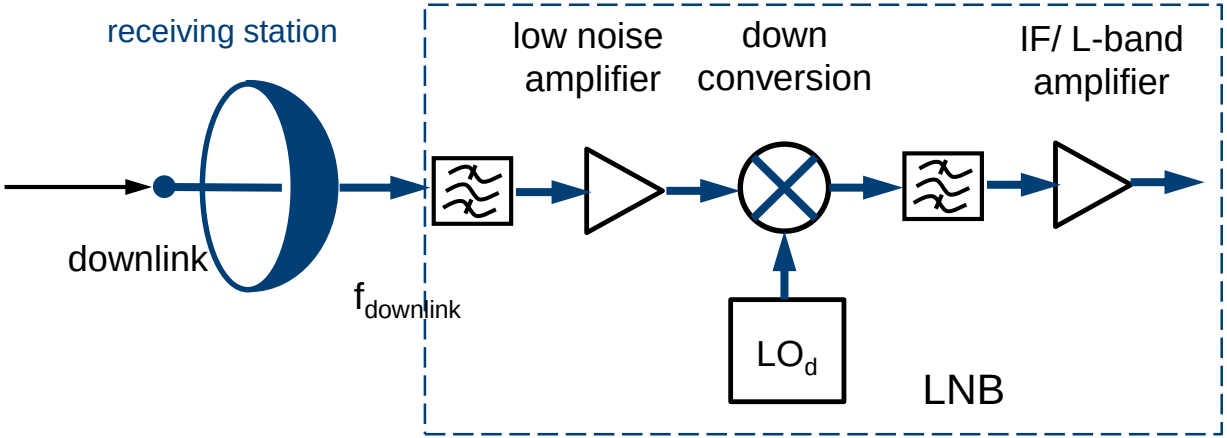
SATELLITE SUBSYSTEMS



SATELLITE SUBSYSTEMS – RECEIVING STATION

⇒Receiver requirements and tests

- Noise figure
- Group delay
- Sensitivity
- Selectivity
- Intermodulation
- Demodulation
- Symbol error rate



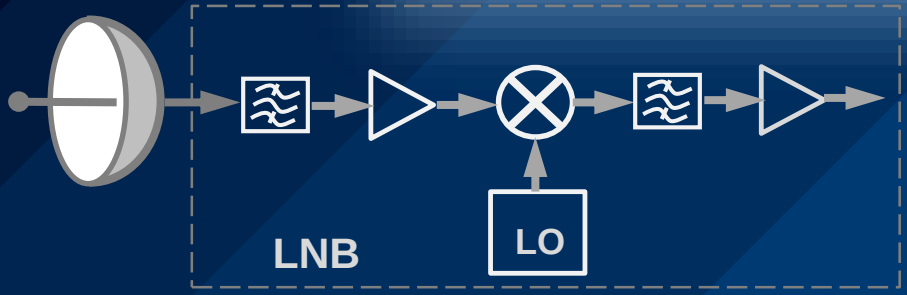
Ku band: 10.7 GHz –11.75 GHz
or 11.8 GHz–12.75 GHz

950 MHz–2150 MHz

LO_d =9.75 GHz (HB), 10.6 GHz (LB)

VECTOR NETWORK ANALYZERS
R&S ZNA26
R&S ZNA43

How to characterize satellite and high-gain converters: R&S ZNA features and benefits



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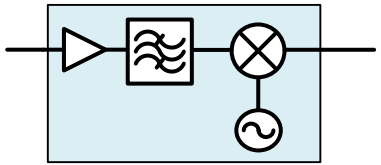
SATELLITE RECEIVER & CONVERTER TESTING AGENDA

- **Agenda**
  - Challenges of high-gain sat-converter characterization
  - R&S ZNA solution: details of related specifications, functions & options
  - Exemplary measurement & test results
  - Summary

  - exemplary DUT:
    Ku-band satellite down link receiver (LNB)

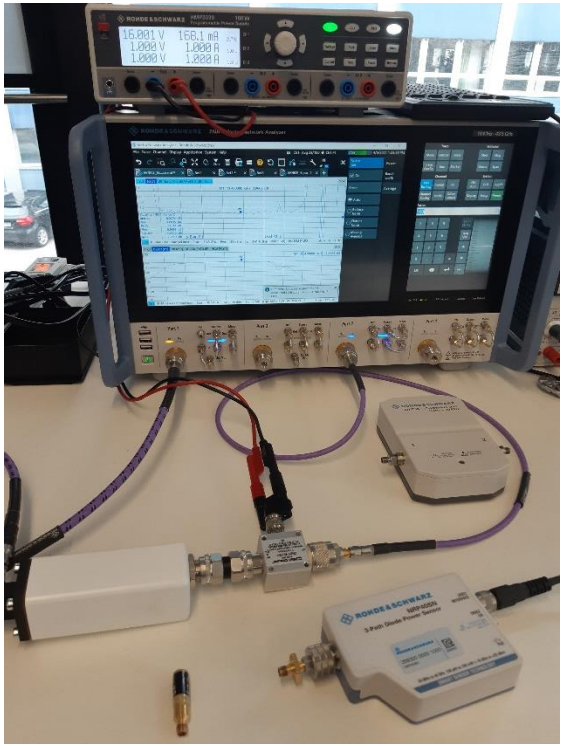


Embedded LO satellite down converter
- ✓ Frequency conversion with embedded LO
- ✓ Filter characteristics
- ✓ High-gain / low stimulus power
- ✓ Gain, matching, GDL, NF, IM, leakage, ...

SATELLITE RECEIVER & CONVERTER TESTING EXAMPLE: KU-BAND LNB

- **DUT specifications & characteristics**
  - Input frequency: 10.95 GHz to 11.7 GHz
  - LO internal 10 GHz
  - Gain 60 dB
  - Compression level ~ -55 dBm
  - Noise figure 0.8 dB
- Wave guide input: coax-to-wave-guide adapter
- Supply voltage +12 V to +24 V
  DC bias at output

- **Test equipment**
  - ZNA26/43 with 4 ports, 2 sources
  - Calibration unit or Cal kit, match, attenuator



CHALLENGES OF HIGH-GAIN DUT CHARACTERIZATION

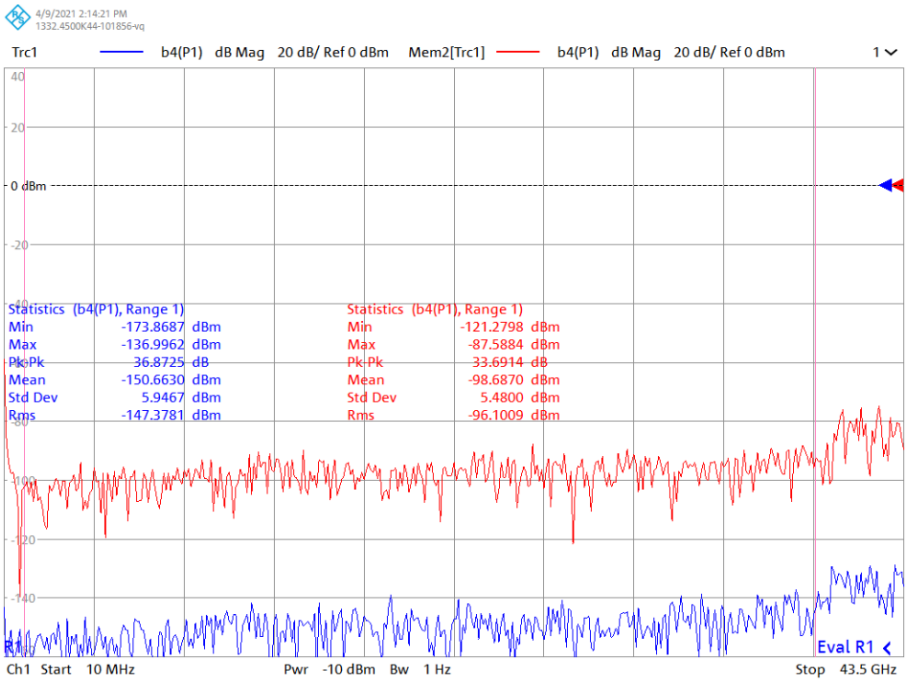
- Very low stimulus level of ~-70 dBm
  - System error correction & absolute power calibration
  - S11 (ie. a1 & b1) at low stimulus power
  - Long term stability
- Frequency converting DUT with Embedded LO
  - LO frequency offset lacking of LO synchronization
  - Overcoming LO drift for S-parameters, group delay test
- Wide scope of VNA functionality and measurement quantities
  - S-parameters (matching, conversion gain), absolute power (leakage)
  - Noise figure, Group delay, Compression, Intermodulation
  - Use of direct src/rec access, monitor access, combiner, pre-amps, ...

LOW POWER STIMULATION & S11

SENSITIVITY

- **Maximum sensitivity: -151 dBm (typ)**
  - @ 1 Hz IFBW
  - Direct channel access / reversed coupler
  - Receiver step att in 0 dB position
- **Typical application case: ~ -110 dBm**
  - IFBW = 1 kHz
  - Using test port: coupler loss ~ 10 dB
- **Uncertainty estimation**:
  - S/N with 15 dB DUT matching:

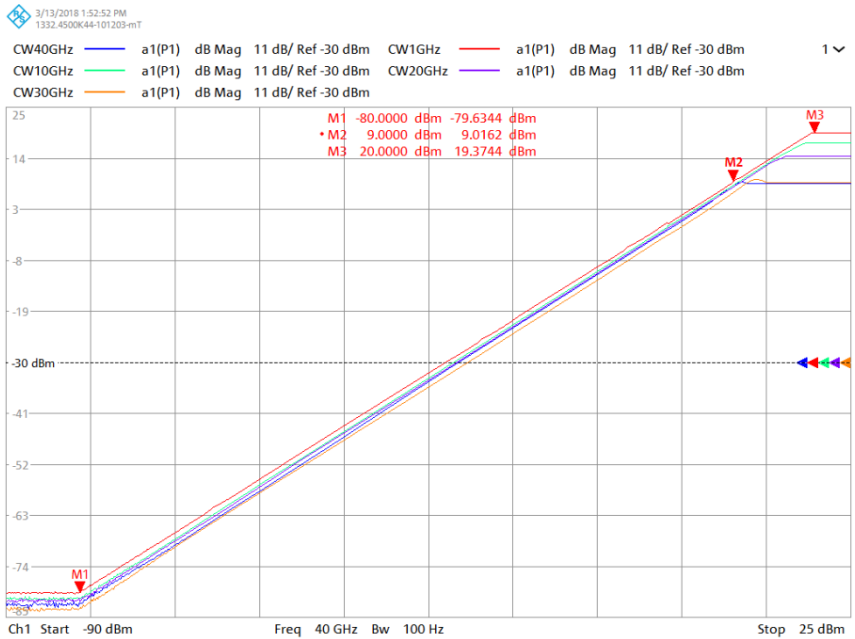
    -75 dBm - 15 dB = - 90 dBm
  - Sensitivity @ 1kHz = 110 dB
  - S/N = 20 dB → ±0.85 dB uncertainty



- → ZNA sensitivity crucial, further improvements possible (30 dB internal pre-amp)

LOW POWER STIMULATION & S11
POWER SWEEP RANGE & ATTENUATORS

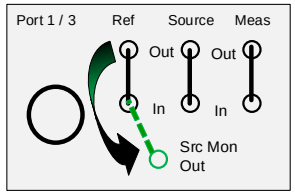
- Power sweep range
  - Electronic controllable power
  - e.g ZNA43:
    - P(min,el) = -80 dBm
    - P (max, el) ~ +6 dBm to +20 dBm
    - Sweep range ~90 dB to 100 dB
- Mechanical step attenuators
  - 0 dB to 70 dB /10 dB
- (Reference) receiver linearity
  - in -50 dBm to 0 dBm:
  - 0.03 dB (typ)

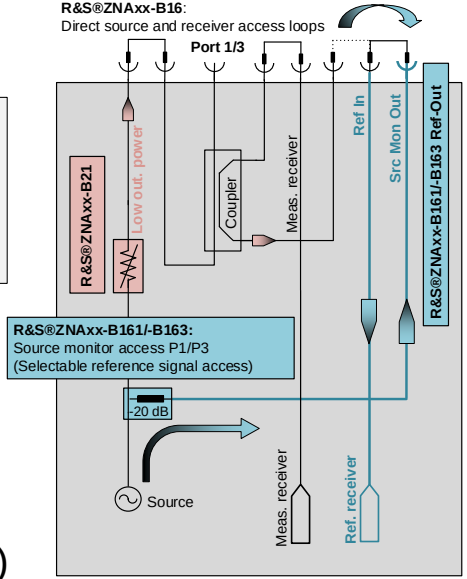


➢ Highly accurate control of a very wide power range

LOW POWER STIMULATION
OPTION ZNAXX-B163 (HANDLING OF A LOW REFERENCE SIGNAL)

- Options ZNA26/43-B161 (P1) -B163 (P1 & P3)
  - *Purpose*: reference signal to be picked up before or after the step attenuator
  - *Consists in*: Internal splitter and additional front panel connector
  - *Activation*: Swap of B16 front panel jumper





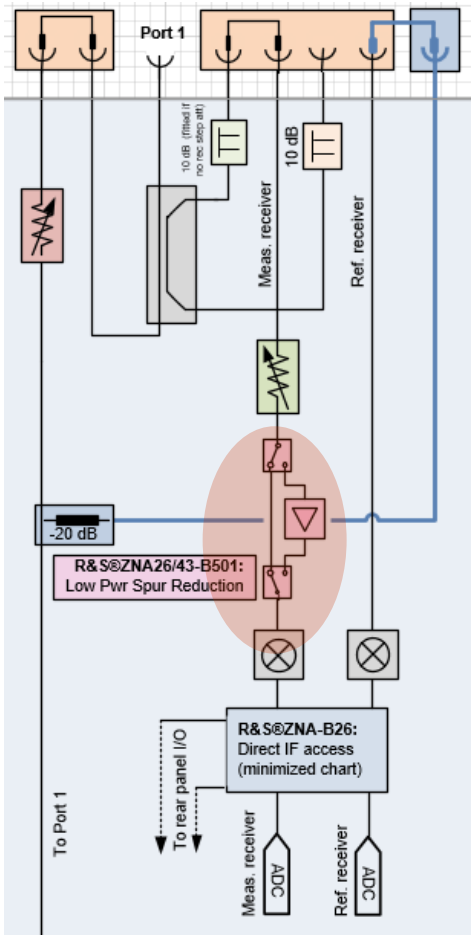
- Application: handling of very low power (a1 and a3 reference signal)
  - „Medium“ electronic power from the source (eg: -35 dBm)
  - Additional attenuation by step attenuator (eg: 40 dB → -75 @DUT)
  - Fairly high power in the reference channel (eg: -55 dBm)
  - Step attenuator remains unattached after calibration (eg 40 dB)
  - Select power for calibration and measurement using 100 dB electronic power range

LOW POWER STIMULATION & S11
OPTION ZNAXX-B501 (→ ISOLATION AMPLIFIER)

- Switchable amplifier in the Port 1 measurement path

- Application #1: suppression of LO leakage
  - Crosstalk of the LO from the measurement receiver IF mixer to the test port
  - LO leakage may reach up to -70 dBm
  - Unnoticed DUT compression

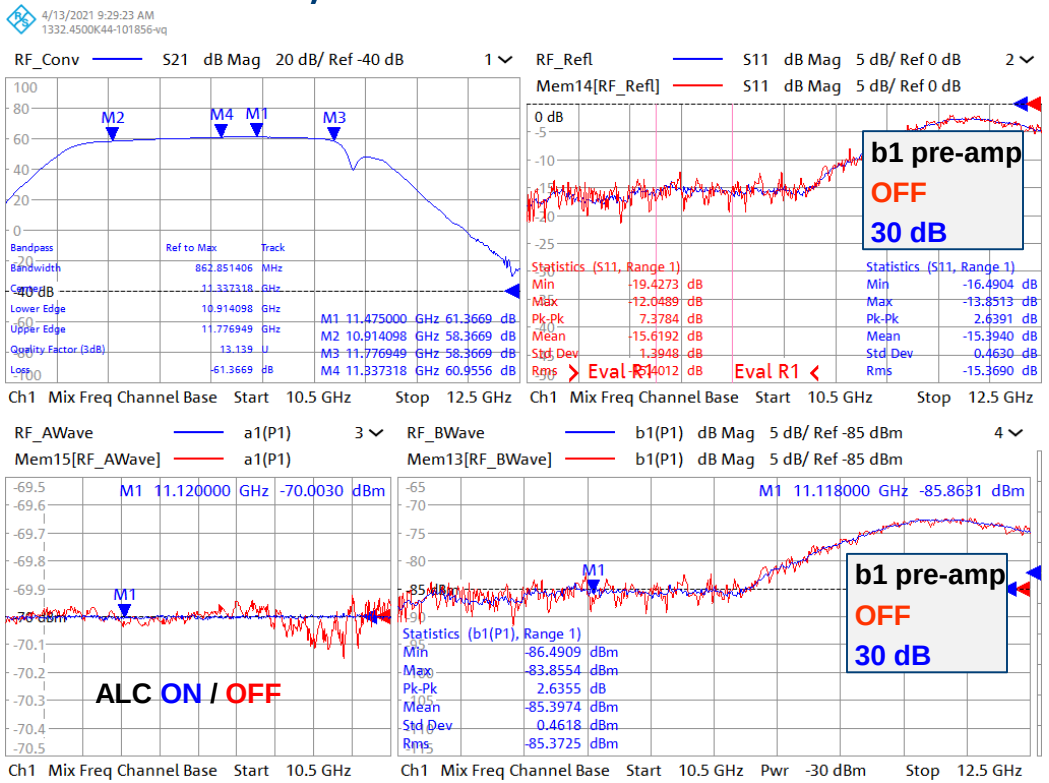
- Solution
  - Isolation amplifier (0 dB, 30 dB)
  - Port 1 only
  - Spur level < 110 dBm



LOW POWER STIMULATION & S11
OPTION ZNAXX-B501 (→ FOR B1 AMPLIFICATION)

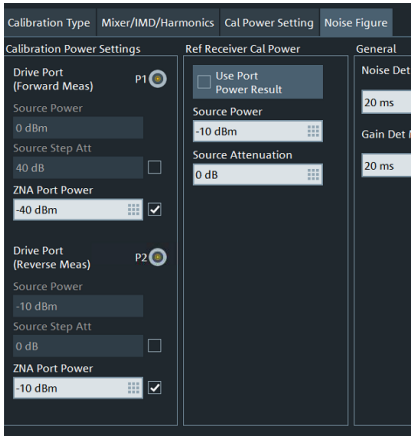
- Application #2:
  Improvement with S11 measurement

- Test case example
  - Stimulus power -70 dBm
  - DUT matching ~ 15 dB
  - → b1 ~ -85 dBm
  - → S/N ~ 15 dB
  - Peak-Peak: about ±2 dB
- Improvement
  - B501 pre-amp set to 30 dB
  - trace noise ~tenth dB
  - @ -85 dB measured power



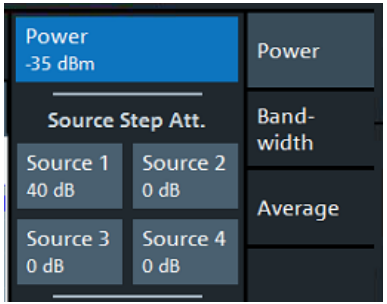
CALIBRATION
SMARTERCAL

- **SmarterCal:**
  - Combines power calibration and system error correction (SEC)
  - PCal of one port is „copied“ to all ports involved
  - Comprehensive menus give control on cal power, meas power etc



- **Benefit**

1. Calibration of the reference receiver with power test head
   ✓ at „high“ level, high accuracy with test head
2. Calibration of the source level using the reference receiver
   ✓ at „low“ measurement level, using receiver linearity

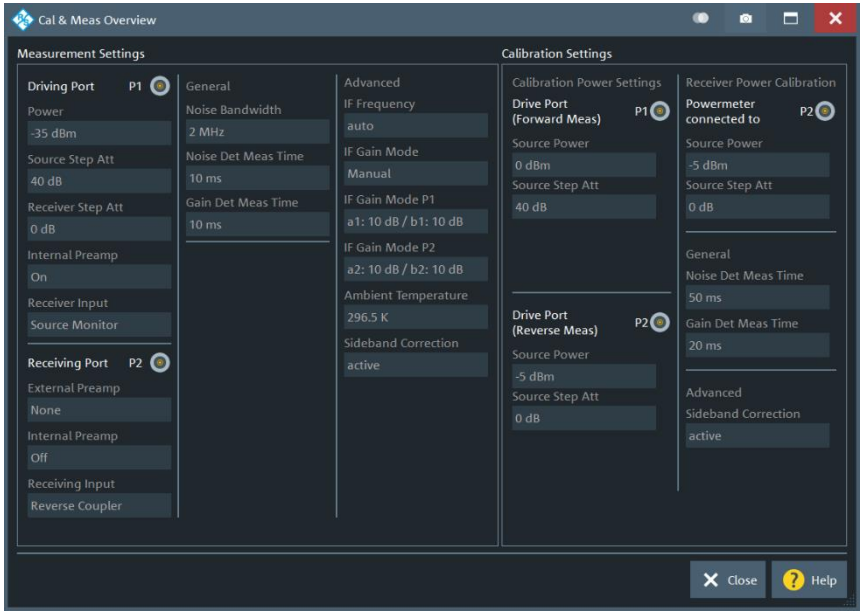


CALIBRATION
POWER SCHEME

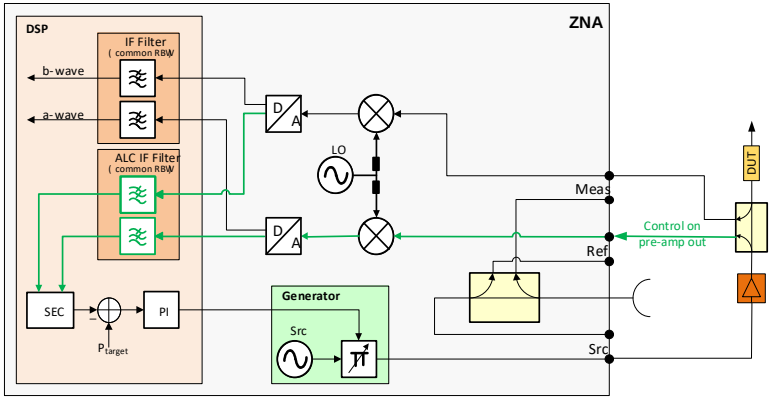
- Example: NF „Cal & Settings Overview“

- Calibration
  - SEK (forward/reverse): -40 dBm / -5 dBm
  - Power meter ref-rec cal: -5 dBm
  - Source level cal: -75 dBm
    (electronic: -35 dBm, src step att: 40 dB)

- Measurement
  - DUT stimulus: -75 dBm
  - B163: a1 reference: -55 dBm

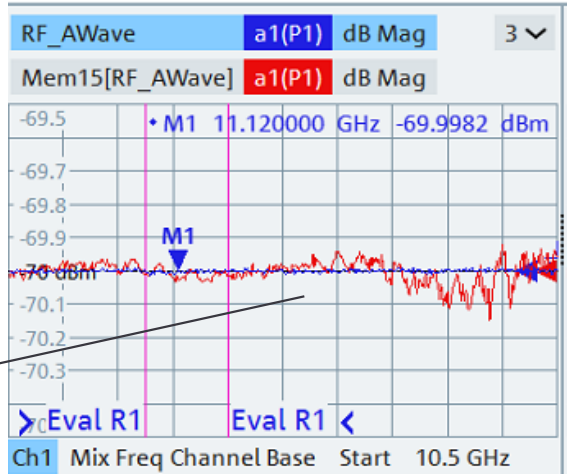


LONG TERM POWER ACCURACY
AUTOMATIC LEVEL CONTROL FUNCTION (ALC)



- Automatic Level Control:
  - Online adjustment of the source power
  - Control loop: ref-signal -> ref-receiver -> source
  - Reference signal picked up internally or from any access point in the external setup
  - Overcoming drift, varying matching conditions
  - All a- and b-waves can be used as reference

- Accuracy consideration using ALC
  - P_{out} in the reference plane referenced to the reference receiver
  - Accuracy given by reference receiver calibration accuracy



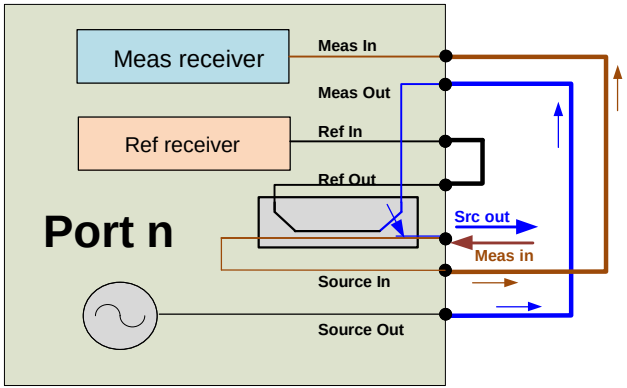
red trace: a1 w/o ALC
blue trace: a1 with ALC active

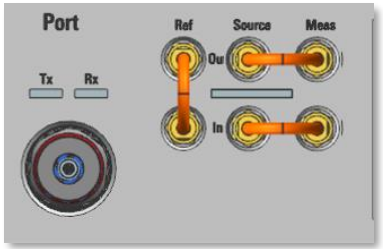
OPTIMIZE RECEIVER SENSITIVITY
OPTION ZNAXX-B16 (DIRECT CHANNEL ACCESS)

- **Options ZNA26/43-B16**

- Application
  - Direct access to the source and receivers, bypassing the coupler
  - Insertion of auxiliary devices
  - Rerouting of signal paths

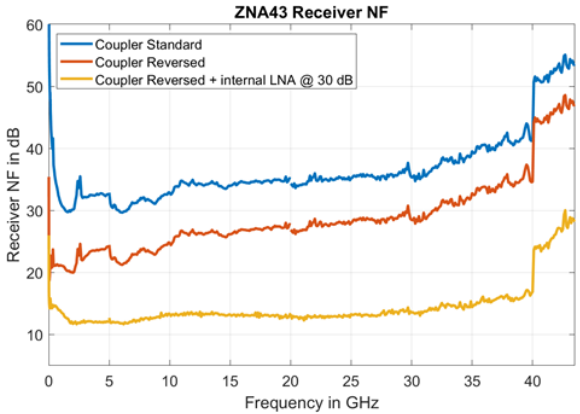
- Especially for NF test
  - Inverse coupler operation: No coupler loss with the mesurement signal
  - Receiver sensitivity increased by ~>10 dB

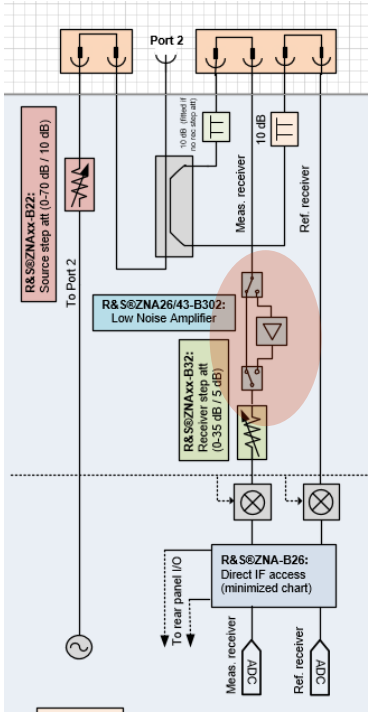


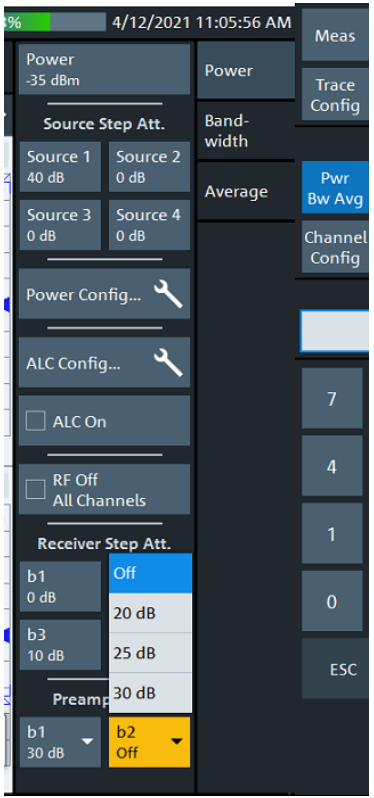


OPTIMIZE RECEIVER SENSITIVITY
RECEIVER SETTING: ZNAXX-B302 NF PRE-AMP

- Measurement receiver pre-amplifier Port 2
- Amplifier can be switched to:
  - Off (bypassed)
  - 30 dB gain
  - Gain stages from combination with receiver attenuator
- Decreases receiver noise figure:

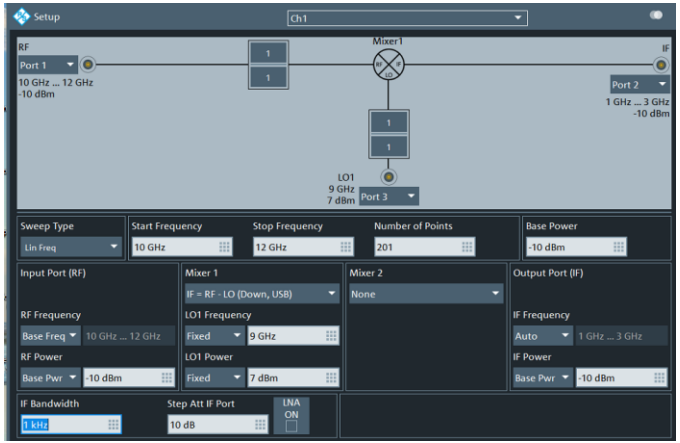


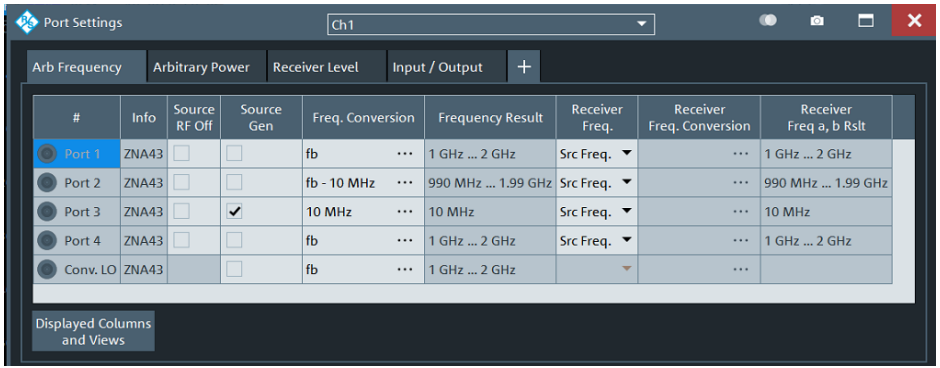




MEASUREMENT SW OPTIONS & FUNCTIONS ZNA-K4

- **Option ZNA-K4: Mixer and arbitrary frequency conversion measurements**
- Dedicated Menu for mixer test configuration
- Dedicated Menu for intermodulation test configuration
- Arbitrary configuration of frequency and power of all 4 sources(*), all 8 receivers

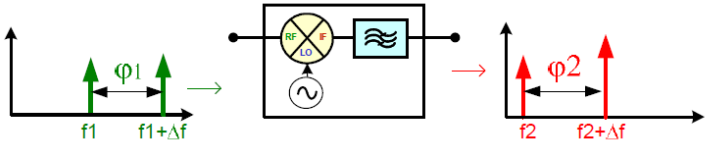




(*) 4-port ZNA: standard 2 src, 4 src with option B3

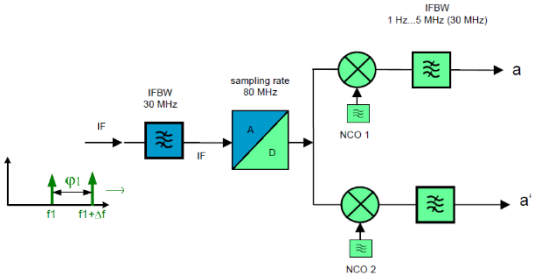
MEASUREMENT SW OPTIONS & FUNCTIONS ZNA-K9

- **Option ZNA-K9**
- Embedded LO converter group delay test
- using a two-tone signal, the phase difference between both tones is measured at the input and at the output of the DUT (a, a`, b, b`)
- ZNA unique „dual digital down conversion“
- Includes **Embedded LO tracking** function



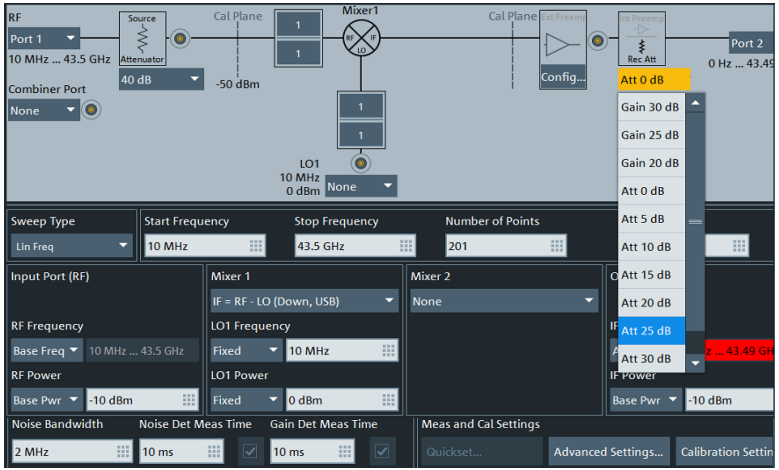
$$\tau = \frac{-1}{360°} \bullet \frac{\Delta\varphi}{\Delta f} \qquad with \quad \Delta\varphi = \varphi 2 - \varphi 1;$$

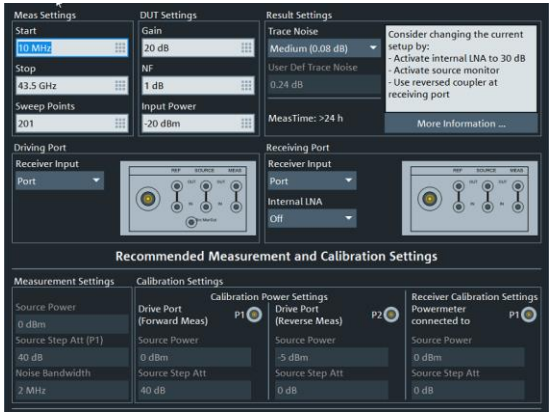
- ✓ Compensates even for fast embedded LO drift
- ✓ Easy configuration
- ✓ No auxiliary components with internal combiner



MEASUREMENT SW OPTIONS ZNA-K30

- **Option ZNA-K30**
- Noise figure measurements
  - Frequency conversion capability with ZNA-K4 installed
  - Supports internal pre-amp (up to 30 dB gain)
- Quickset
  - Auto-setting of test parameters on basis of the DUT characteristics





SATELLITE RECEIVER & CONVERTER TESTING S-PARAMETER RESULTS

- Measurement results & details

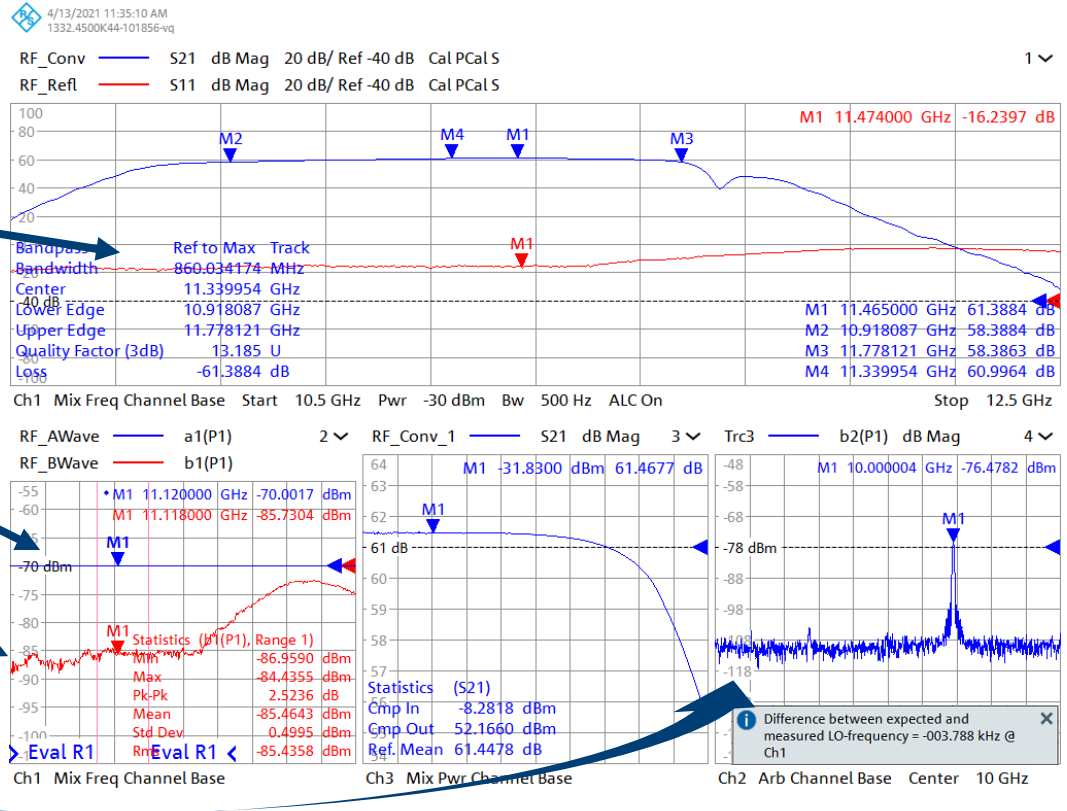
  - S11 with b1 preamplifier
    (taken with -70 dBm input power)

  - Stimulation power for S-parameters:
    -70 dBm → a1 with ALC

  - b1 ~-85 dBm
    with pre-amplifier

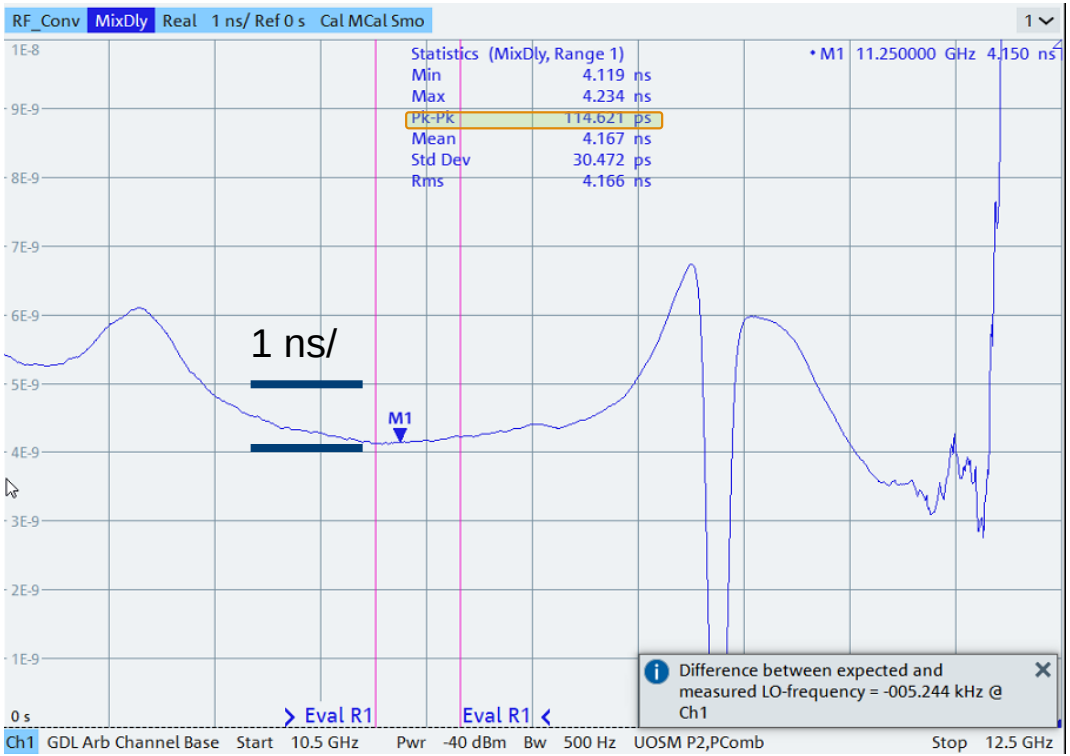
  - Compression

  - LO crosstalk with b2
    (shows LO tracking value)



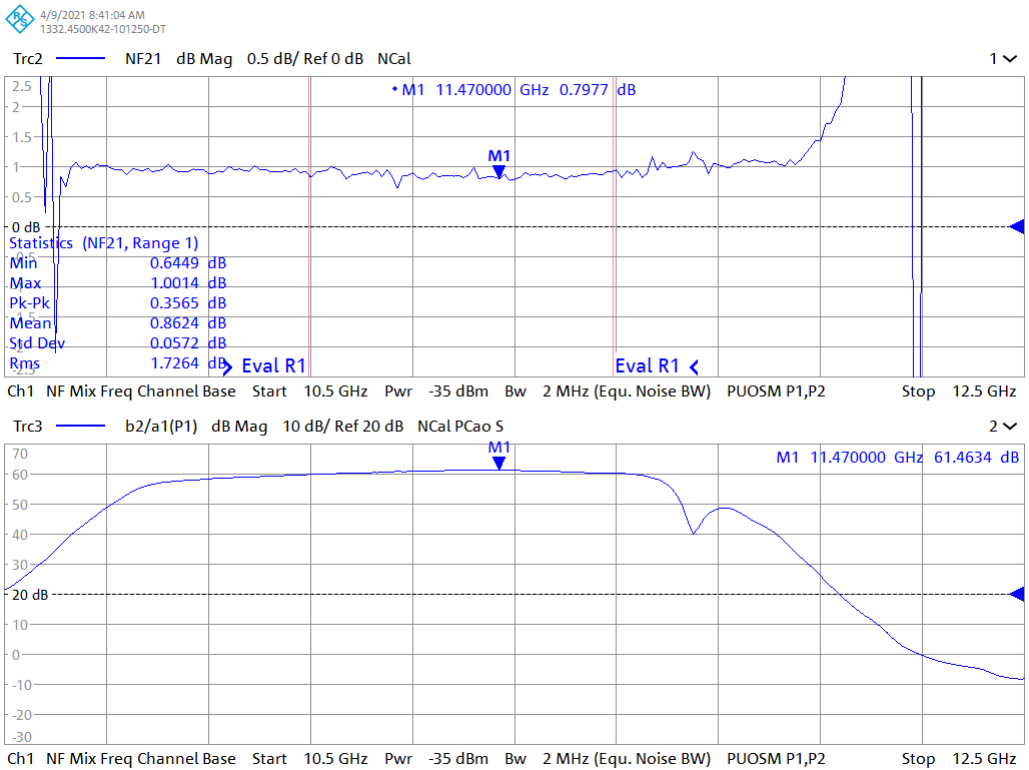
SATELLITE RECEIVER & CONVERTER TESTING GROUP DELAY RESULTS

- Embedded LO converter group delay
  - Measured: 4 ns
  - **peak-peak ~0.1 ns**
  - (in middle range of transmission path)



SATELLITE RECEIVER & CONVERTER TESTING
NF RESULTS

- Expected value
  - 0.8 dB
- Measured mean value
  - 0.86 dB
  - incl test head uncertainty (0.1 dB)
  - Loss of f-f power meter adapter is de-embedded
- Details
  - Stimulation power: -75 dBm
    (30 dB att - 35 dBm electronic)
  - Gain: 61 dB



HIGH-GAIN CONVERTERS SUMMARY

Option	Function	Benefit
Source port / low signal stimulus / S11		
ZNAxx-B163:	Selectable reference signal access	Low trace noise of **a1** & **a3** even with at very low output power
ZNAxx-B501:	b1 amplification	Low trace noise of **b1** / S11 measurement with low power
ZNAxx-B2n	Source step attenuators	Optimize the power level plan
ZNAxx-B213	Internal combiner	Two-tone signal for ZNA-K9 embedded LO group delay and intermodulation test
Receive port		
ZNAxx-B3n	Receiver step attenuators	Compression free measurements
ZNAxx-B302	Receiver pre-amplifer	Improve the ZNA receiver sensitivity for NF measurements
ZNAxx-B16	Direct source/receiver access	Increased receiver sensitivity, reversed coupler operation

HIGH-GAIN CONVERTERS SUMMARY

Option/Feature	Function	Benefit
Calibration & Accuracy & Specifications		
SmarterCal	System error correction and source/receiver power calibration	Easy calibration of comprehensive setups, very low levels, power calibration
ALC	Automatic realtime source level control	High long-term power accuracy
Power sweep range	Electronic power sweep range of up to 100 dB	Get the optimum excitation power for calibration and measurements
Receiver quality	Sensitivity up to -151 dBm	High S/N ratio for high accuarcy / low trace noise
Software & features		
ZNA-K4 ZNA-K9 (incl LO tracking) ZNA-K30	Frequency conversion measurements Embedded LO group delay measurements Compensates DUT embedded LO drift Noise figure measurements	Comprehensive converter characterization (gain, matching, crosstalk, compression, intermodulation, group delay, noise figure,…)

ZNA - THE BEST SOLUTION FOR YOUR MOST DEMANDING NEEDS!

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Make ideas real