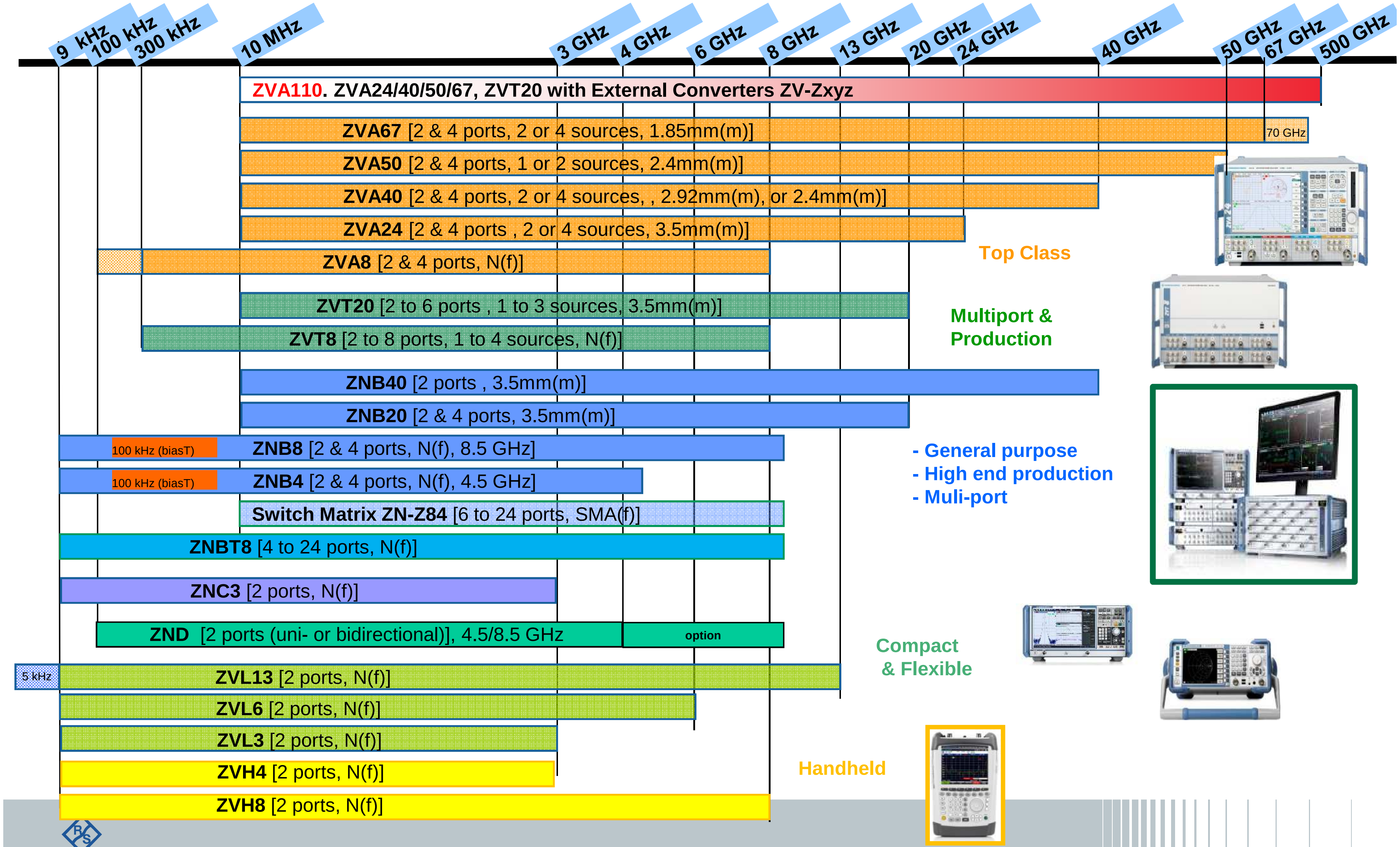
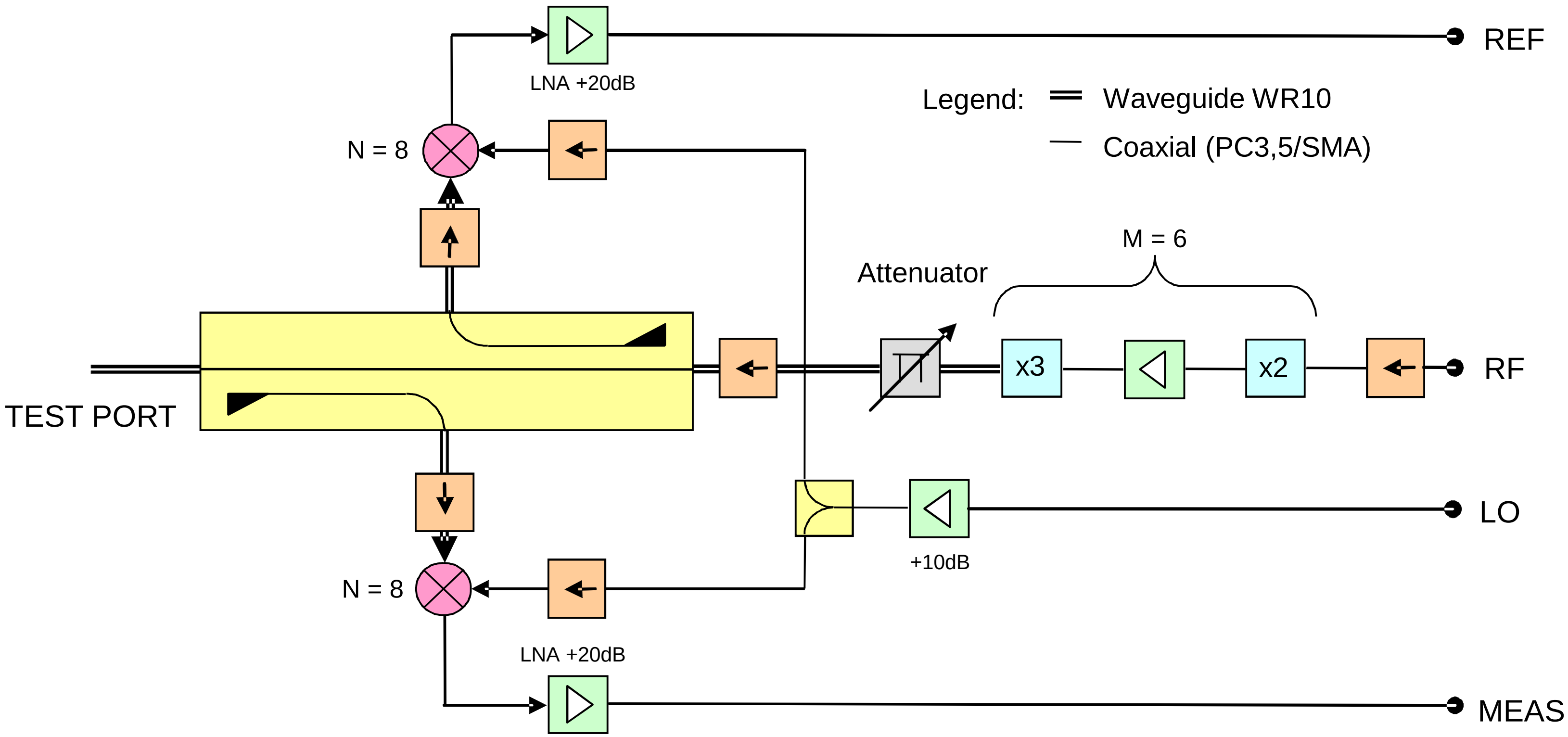
Millimeter Wave Solutions from R&S

ROHDE&SCHWARZ

R&S Portfolio Network Analyzers

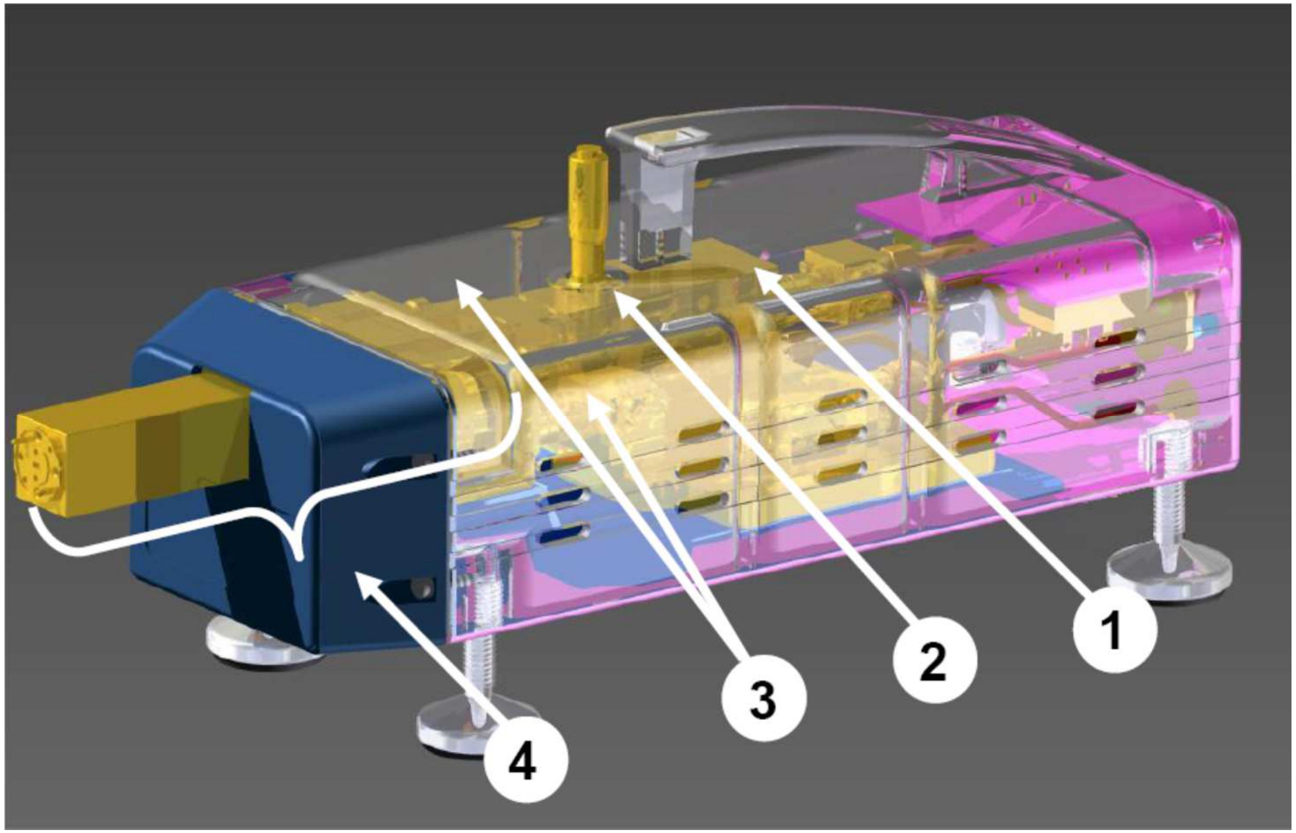


Rohde & Schwarz Converter ZVA-Z110
67 GHz to 110 GHz Reflectometer Module Block Diagram



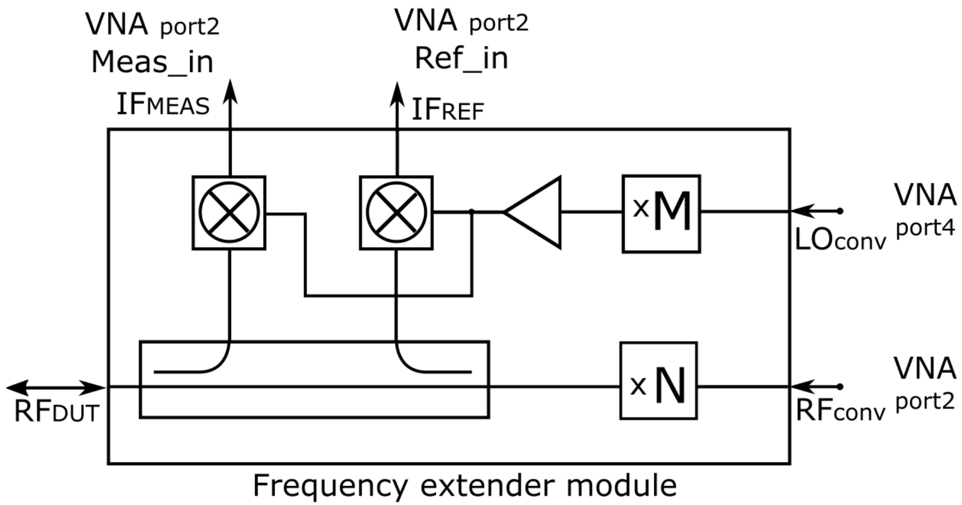
Rohde & Schwarz ZVA-Z110

Single T/R Reflectometer Module – open View



1. **Generator feed path with multiplier stages**
2. **Waveguide variable attenuation adjustment**
3. **Two harmonic mixers for the conversion of the measurement and reference channel to IF**
4. **Bi-directional coupler to separate the transmitted and reflected power**

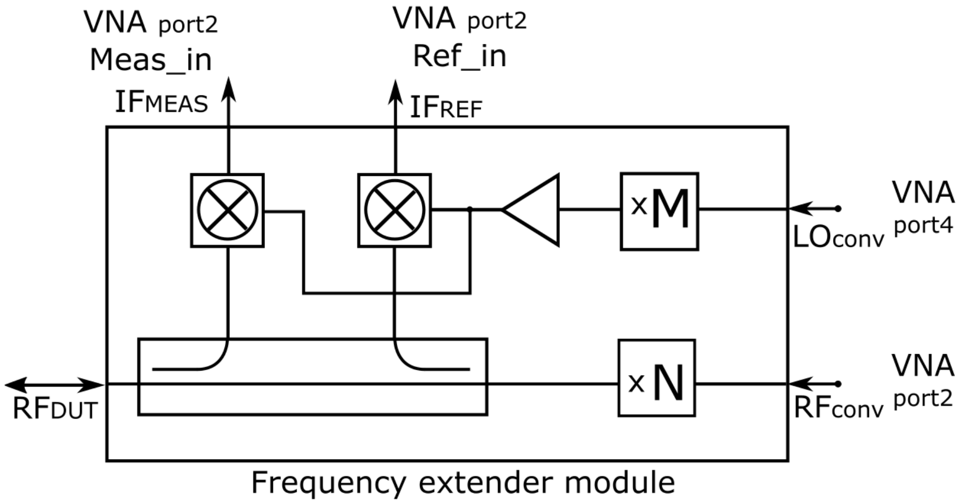
Extending the Frequency into the Tera Hertz Range

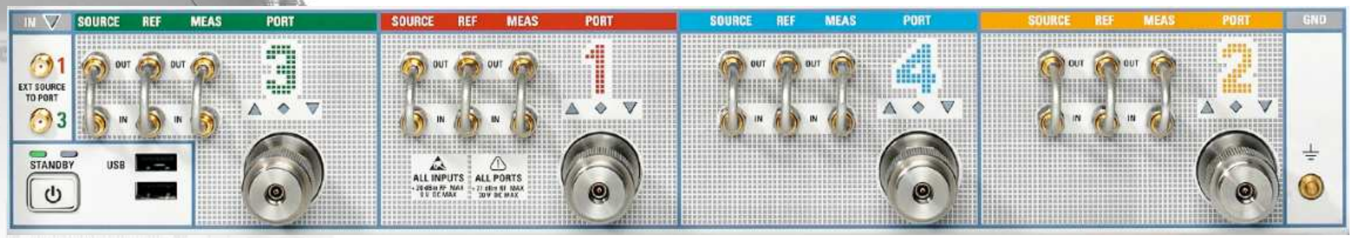


Measurement setup

Block diagram of a frequency extender module

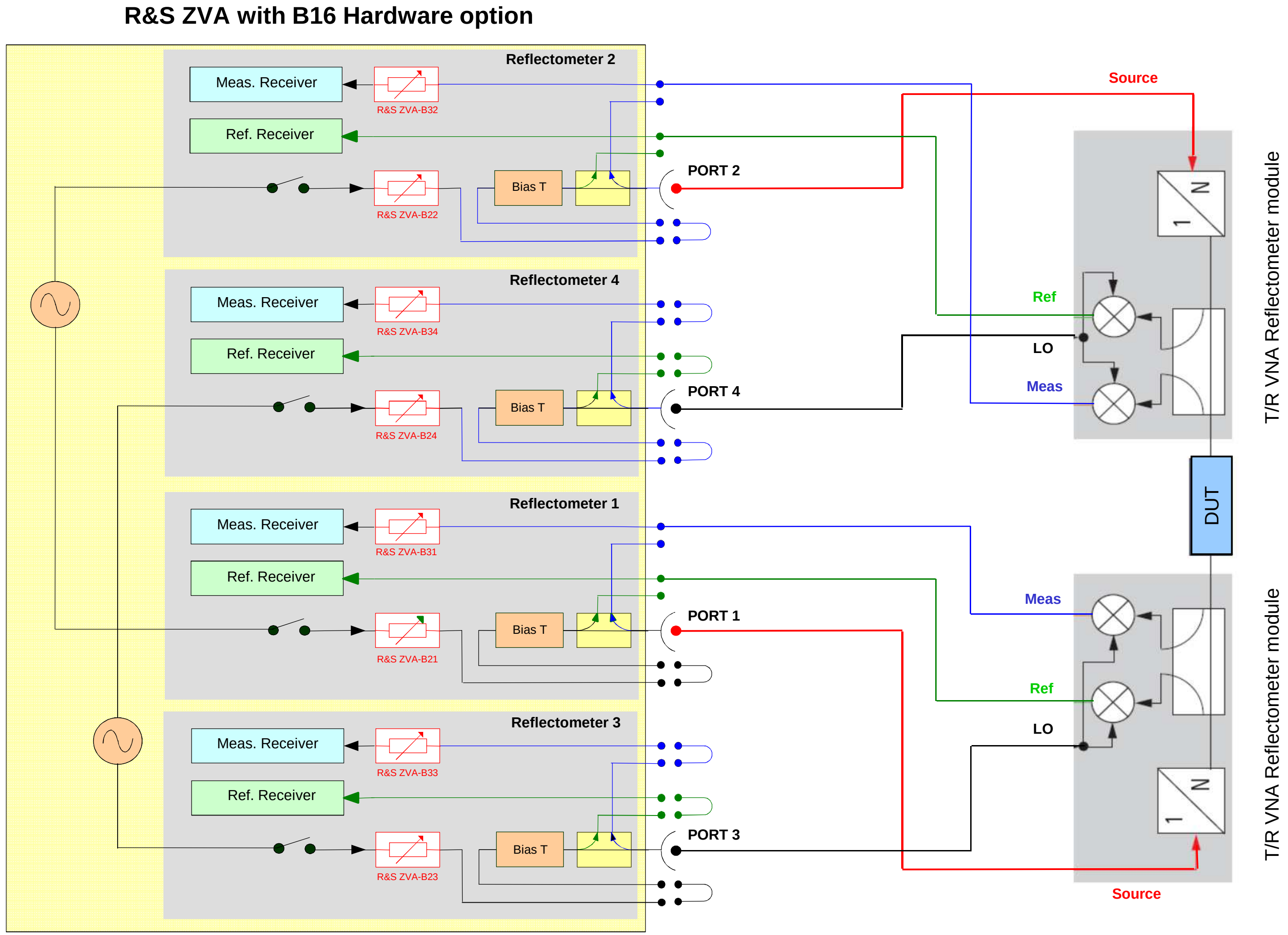
Extending the Frequency into the Tera Hertz Range





Converter Set-Up Schematic Diagram

A&D symposium



RPG, The Rohde&Schwarz Company

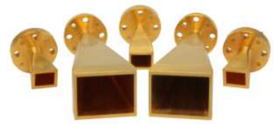
A&D symposium

R&S is the only company in the world offering VNA solutions up to 500GHz without the need to rely on third party companies

MM-wave technology

Microwave sensing

Space technology



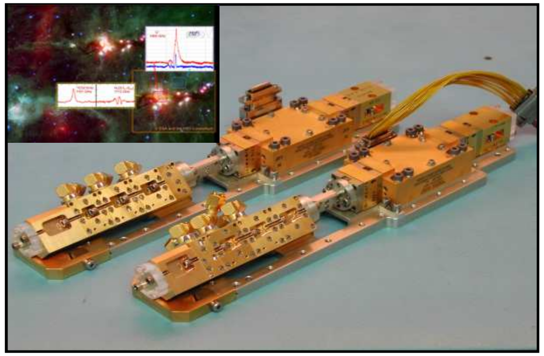




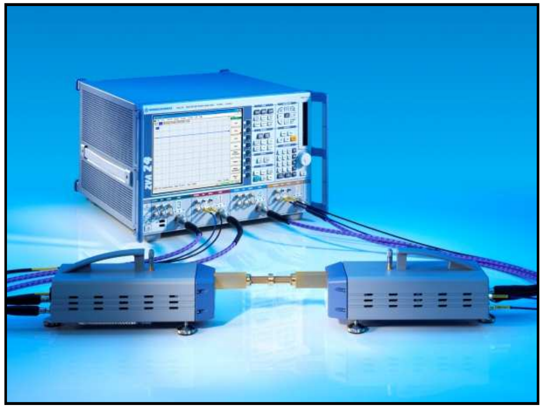


Radiometer Physics GmbH (RPG)
A R&S company

Microwave, sub-mm & THz Turn-key Radiometers,
Space Technology Components,
Design & Scientific Expertise



- Design
- Development
- Manufacturing
- Integration and Test



Product Spectrum

A&D symposium

Mixers

- Broadband Harmonic Mixers
- Fundamental Tunable Mixers
- Sub-harmonic Broadband Mixers
- Spectrum Analyzer Mixers

Multipliers

Our Active Fullband Multiplier (AFM) series cover a full waveguide band without mechanical tuners. With a coaxial input in the 8&ndsh;23 GHz range, this devices are ideally suited for synthesiser-driven sources or heterodyne receiver systems.

Amplifiers

Low-noise from 10 tp 105 GHz, and medium-power amplifiers from 0 to 40 GHz.

Tx/Rx Modules

A variety of full-band Transmit-Receiver systems is available. Frequency ranges from 50 GHz up to 500 GHz. Higher frequencies and customized designs available upon request.

Horn Antennas

- Corrugated Feedhorns
- Conical Horn Antennas
- Dual Mode Horn Antennas

WG Components

- Coax to Rect.
- Waveguide Filters
- Ortho-Mode (OMT)
- E/H Tuners
- Directional Couplers
- Tuneable Attenuators

Circulators

Based on the effect of gyro-magnetic materials in a magnetic field, these devices allow non-symmetric flow of power. Switchable versions available.

Isolators

- Y-juction Full-Band
- Y-juction Narrow-Band
- Faraday Isolator Full Band

Quasi-Optics

RPG has a long experience in the design of uasi optical networks: Frequency-selective surfaces (FSS), polarization splitting, feed-clusters, dichroic plates, wire grids, mirrors...

Zero-Bias Detectors

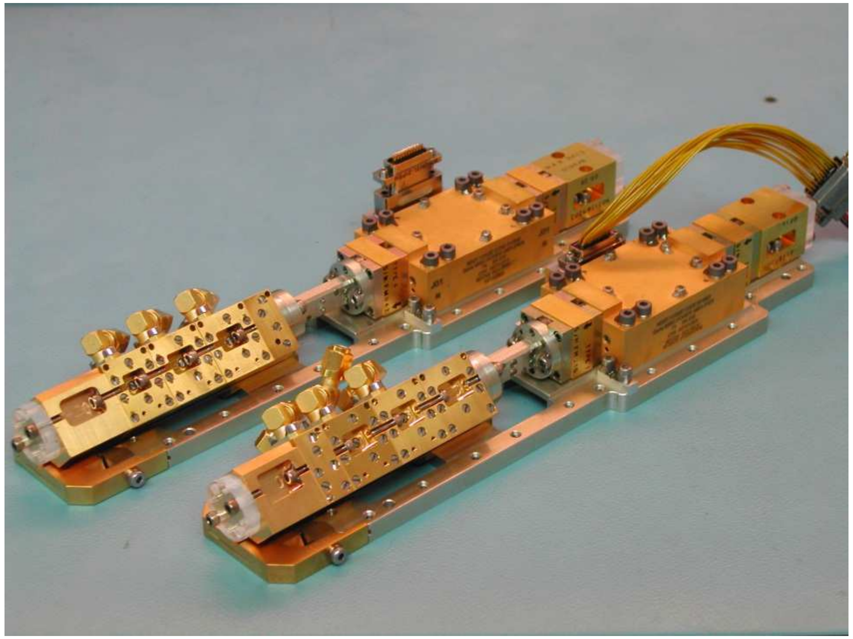
The new series of RPG zero-bias detectors operate up to 900 GHz with Schottky-diode technology.

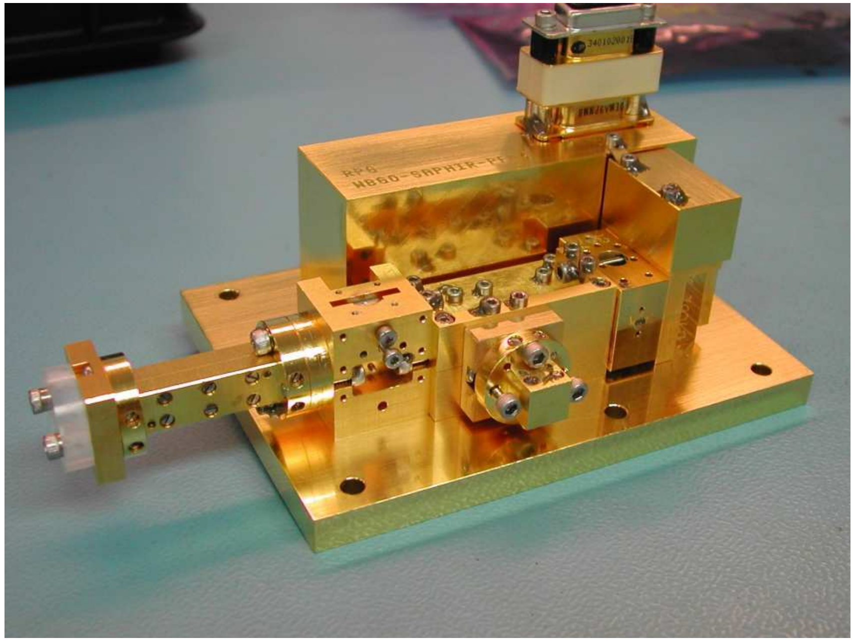
Measurement and Instrumentation

Transmit / Receive Systems, Spectrum Analyser Solution

- Fullband 50-75GHz, 60-90GHz, 75-110GHz, 110-170GHz, 140-220GHz, 170-260GHz, 220-325GHz, 260-400GHz, 325-500GHz
- High Dynamic Receivers for 90 GHz, 183 GHz, 220 GHz, 324 GHz, 502GHz, 640 GHz
- for compact ranges (antenna measurement facilities, phase + amplitude)

Space Components & sub-systems





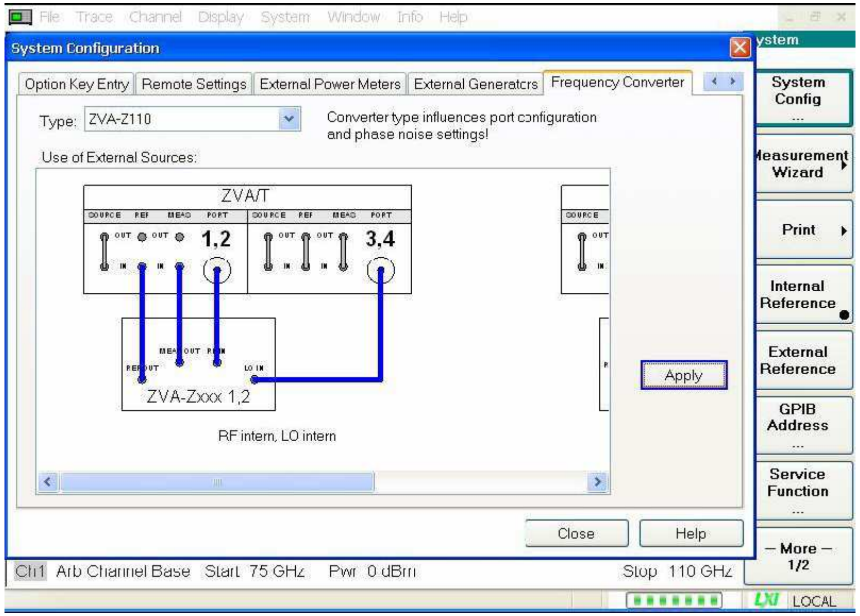
Space qualified local oscillators (Herschel / ESA):
8 local oscillator chains from 480 GHz to 1100 GHz

Other space projects:
EOS (NASA), ODIN (SSA), FIRST/HIFI,
MARFEQ, SAPHIR (CNES), MLS (NASA), FY-3 (China), …

Use of ZVA with Converters up to 0,5 THz

Automatic Configuration with Option ZVA-K8

- SW option ZVA-K8 - Functions:
  - Selection of the measurement setup
  - Automatic configuration of internal sources to provide RF, LO
  - Adoption of the x-axis scaling
  - Installation of the R&D wave guide calibration kit
    (any other can be installed as well)



R&S ZVA-Z110 Millimeter-Wave Converter

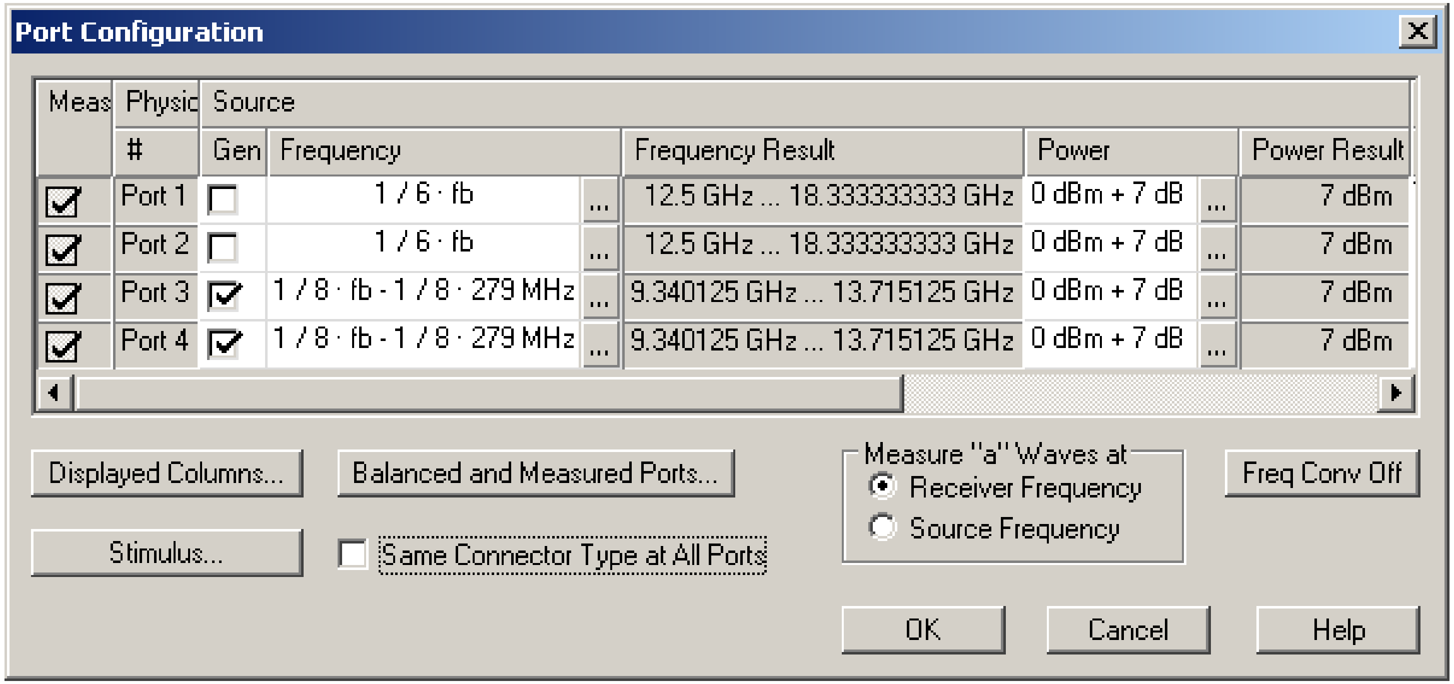
- **Source Input (from NWA):**
  - Frequency Range: 12.5 GHz (11,1 GHz for ZVA110) to 18.333334 GHz (x6)
  - Input power range: +4 dBm to +10 dBm

- **Local Oscillator Input (from NWA / ext SRC)**
  - Frequency Range: 9.3375 GHz (8,375 GHz for ZVA110) to 13.74875 GHz (x8)
  - Input power Range: +5 dBm to +10dBm

- **Measurement/Reference Output (to NWA)**
  - Frequency Range: 10 MHz to 300 MHz here 279 MHz

Port Config Setup Table

Multiplication Factors 6 and 8

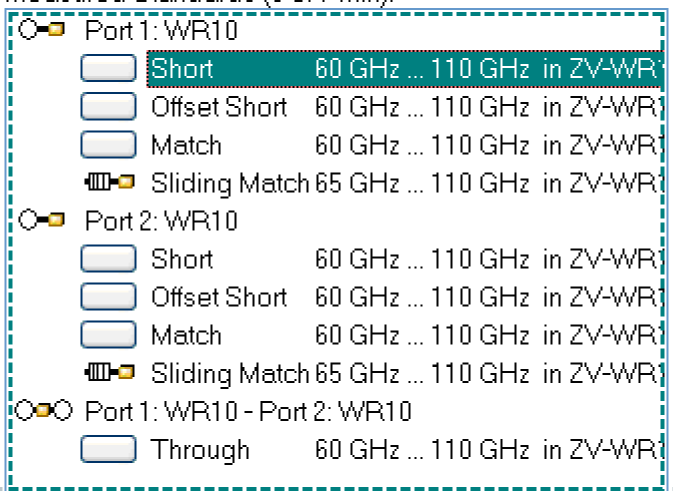


The R&S Waveguide Calibration Kits

- A high quality calibration kit is an important condition to achieve a good measurement accuracy.
- In case of WR08 and smaller waveguide dimensions, the calibration standards ‘through’, ‘reflect’, and ‘line’ are verified by their mechanic tolerances. The match standard is verified based on a TRL calibration.

Calibration

Level adjustment



Connect calibration standards to both converters and press ok

Fixed match

Short

Offset short

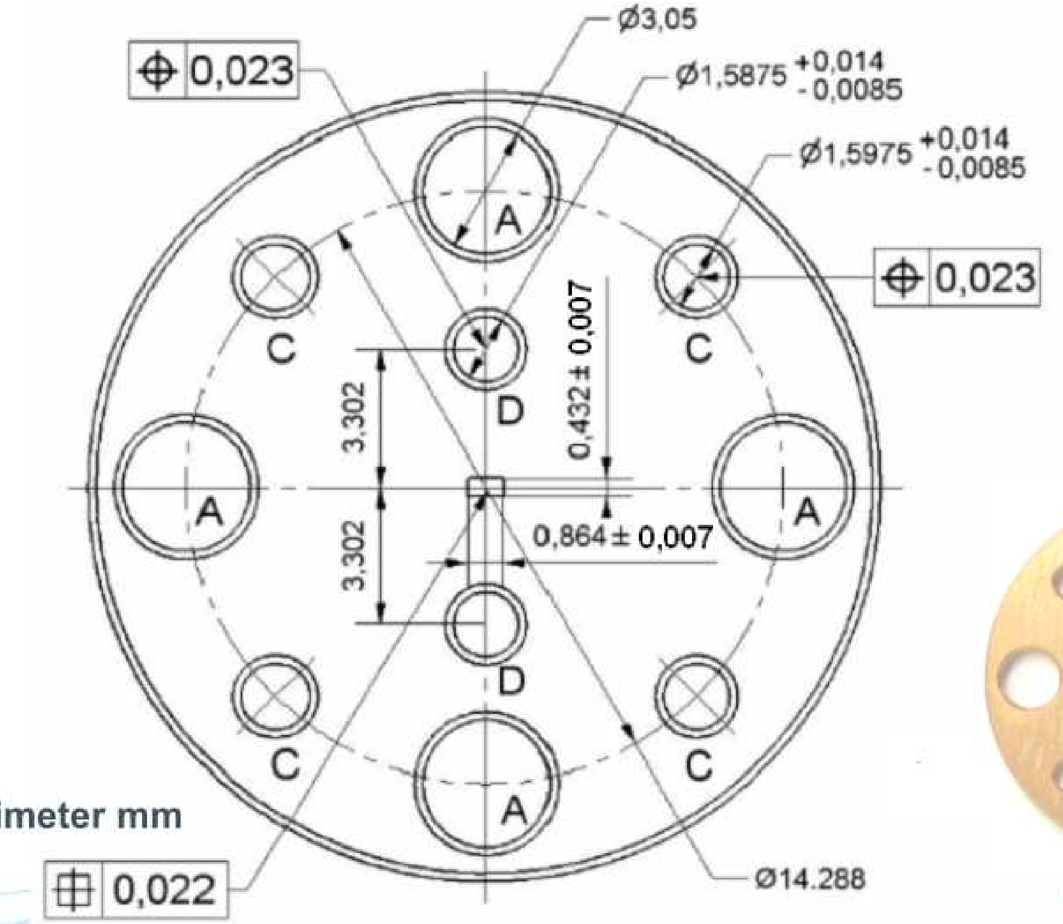
+

Shim

Through

Direct connection of both test ports

Mechanical Tolerances



All values in Millimeter mm

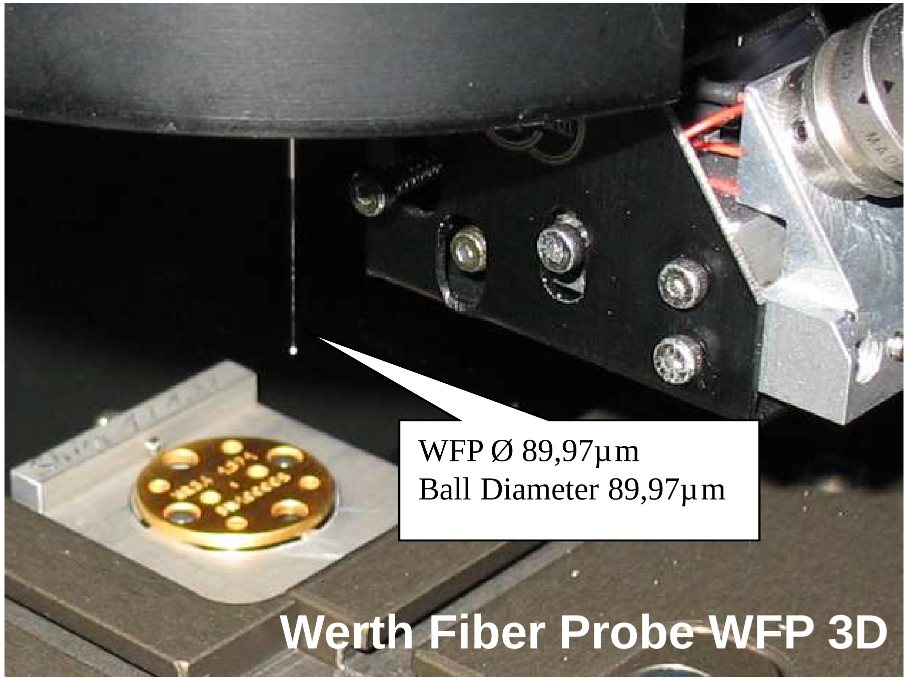
The R&S Waveguide Calibration Kits

A fly sitting next to a 500 GHz shim

The R&S Waveguide Calibration Kits

Verification of a WR03 shim at R&S fab in Teisnach

Ultra accuracy coordinate measuring machine in a „fixed bridge“ design



Smallest and most accurate fiber probe in the world allows measurement of smallest details, such as holes, radii, …

Tactile measurement without the typical problems of optical probes

The R&S Waveguide Calibration Kits

Mechanical measurement accuracy

Resolution: 0,001 µm

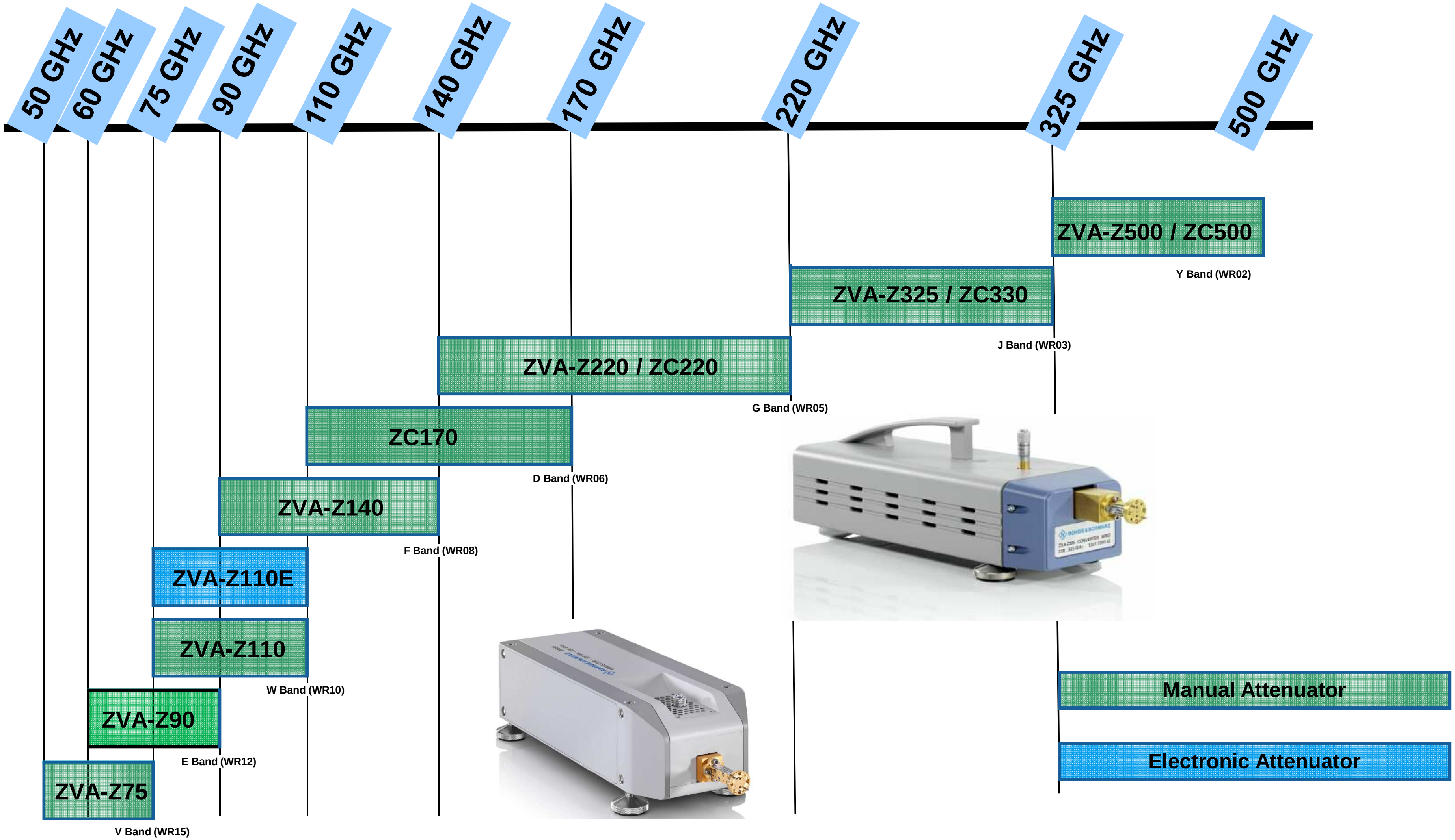
Maximum permissible error (MPE):
Fundamental MPE of machine
+ Sensor-related MPE
= worst case MPE of measurement

Maximum permissible error for this application

Task	**Drill position**	**Drill diameter**
Combined MPE worst case:	1.0126 µm	1.0040 µm

Millimeter Converter Family

A&D symposium



Power Calibration and Power Sweep

Precise power calibration up to 110GHz

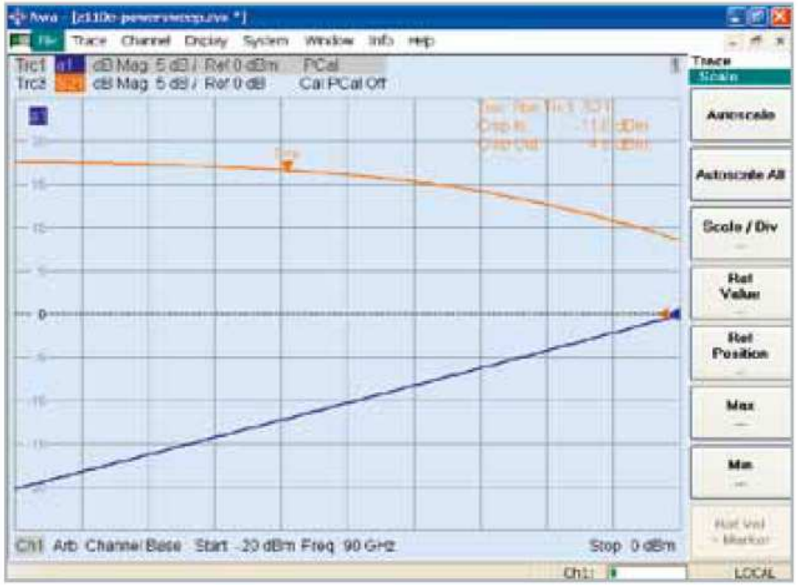
- **Unique power measurements from DC up to 110GHz with 1.0mm connector**
- **First millimeter power sensor that is traceable to a national metrology institute (NMI)**
- **S-Parameters of waveguide transition can be loaded directly into sensor for accurate power measurements**
- **USB interface means the power sensor can be used directly with the ZVA or PC running the free NRP analysis software.**
- **Lowest uncertainty 0.040 to 0.318dB**
  Highest Linearity 0.010dB @110GHz
  30% faster than competition

ZVA-Z110E to 110 GHz with electronic Power Control using variable Attenuation

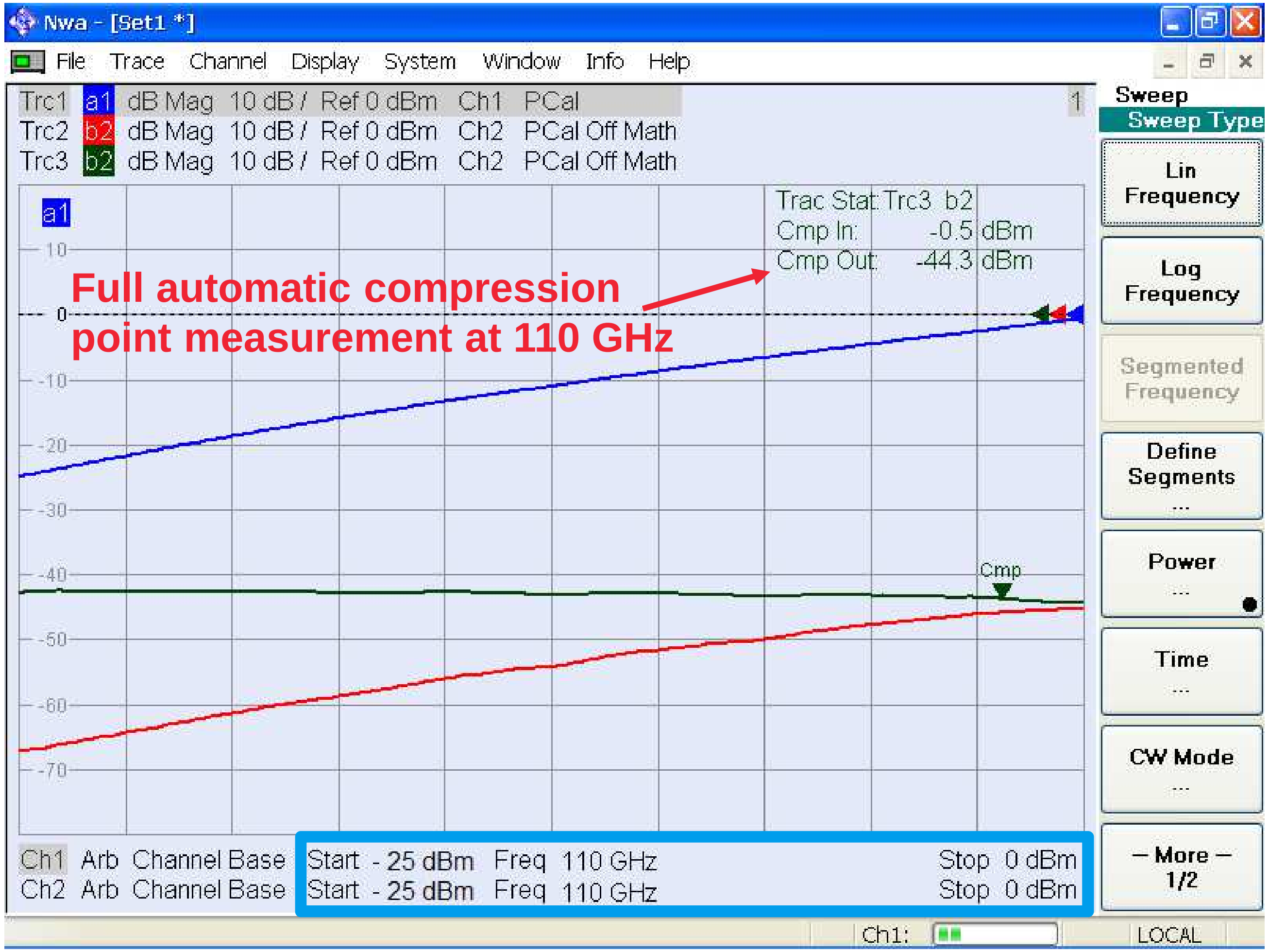
- 67 GHz to 110 GHz with electronic power control
- 0 to 25 dB (35 dB typ.) attenuation
- Allows power sweep and compression point measurement on amplifiers

Electronic Power Control with ZVA-B8

A&D symposium



Electronic power control



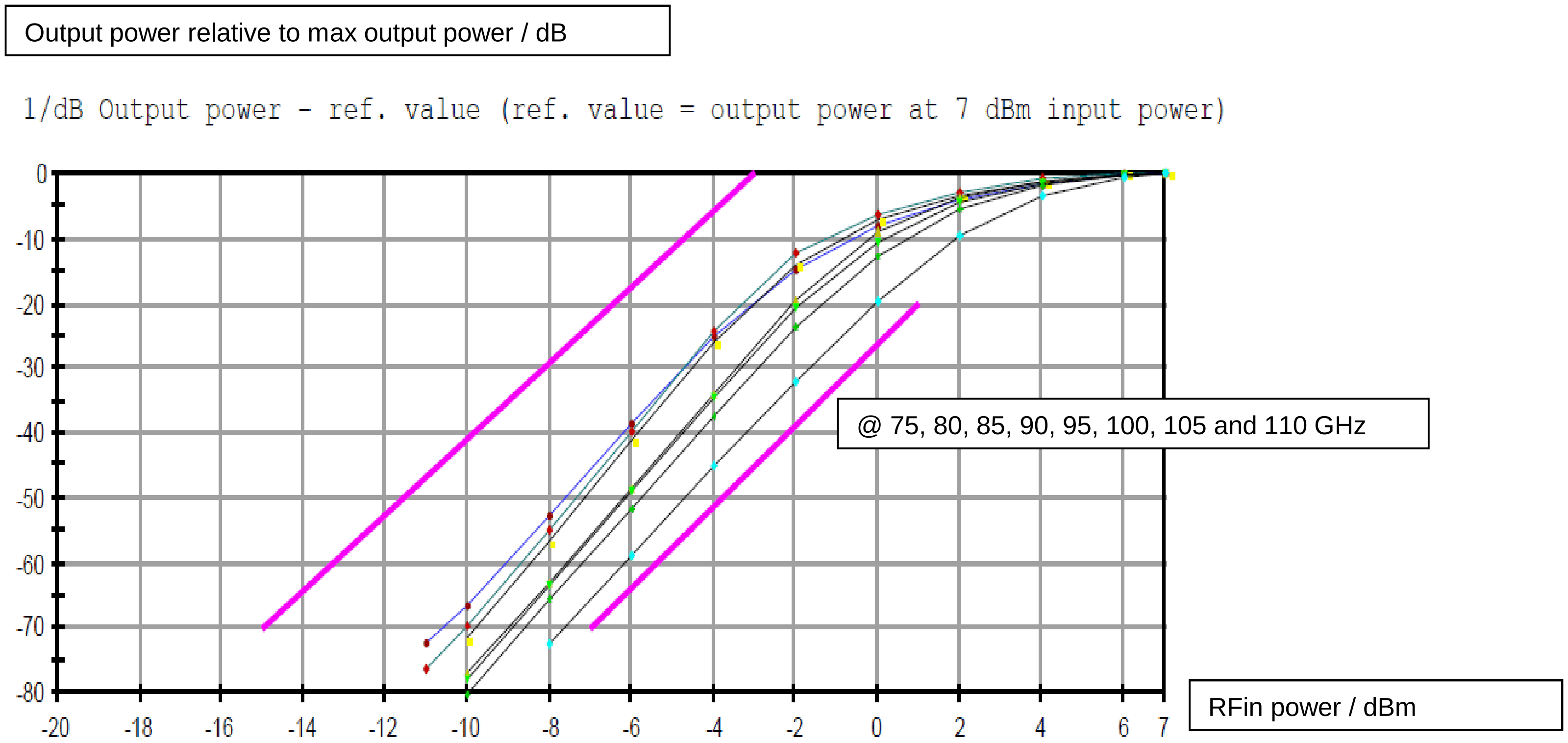
Only possible with R&S®ZVA-B8 option and R&S®ZVA-Z110E frequency converter with elec. attenuator

Option R&S®ZVA-B8

25dB Electronic Power Sweep Range (typ. 40dB)

Power Control by RF-Input Power Variation

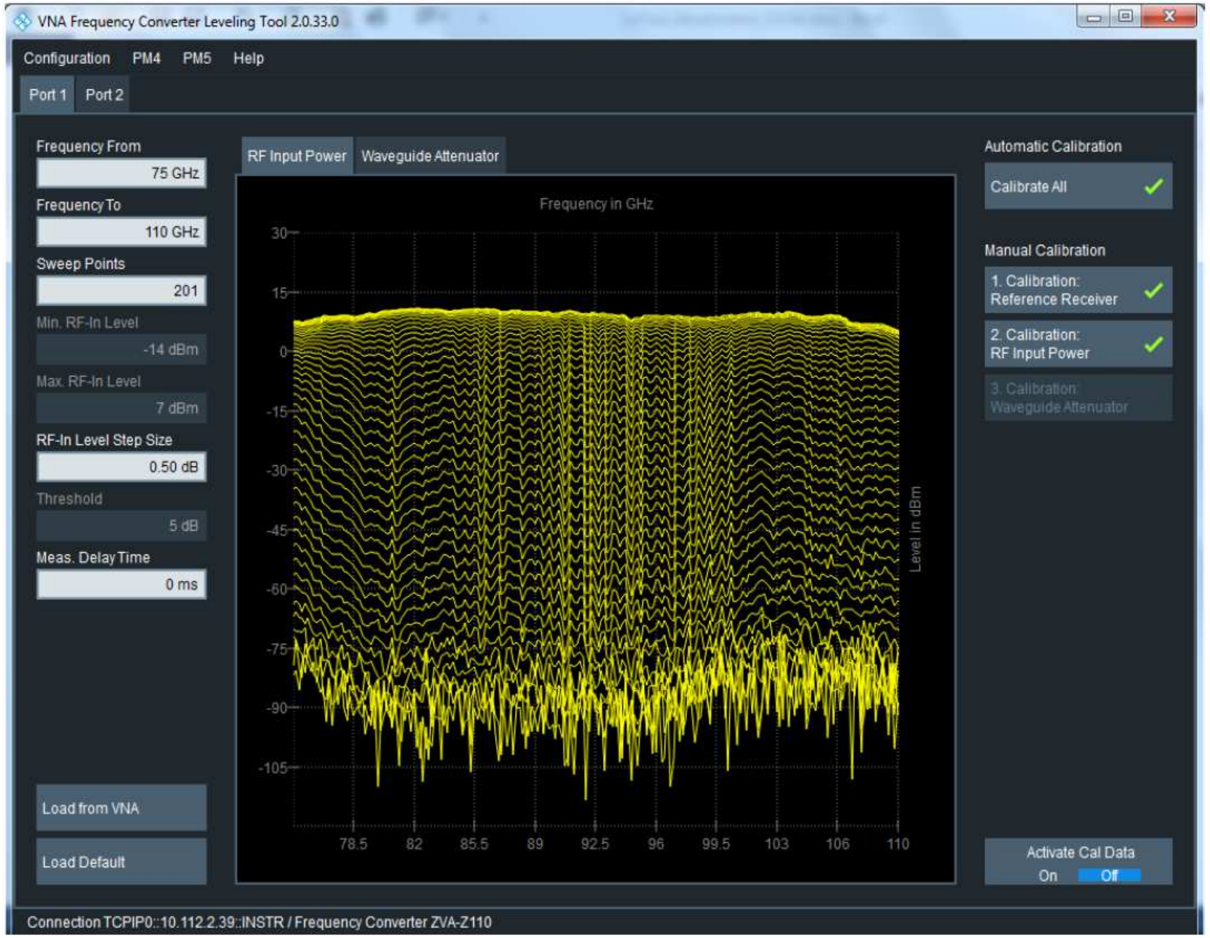
- Power sweep range of 70dB by RF input power variation
- Frequency dependency can be calibrated out by software tool



Leveling Tool RF-Input Power Variation

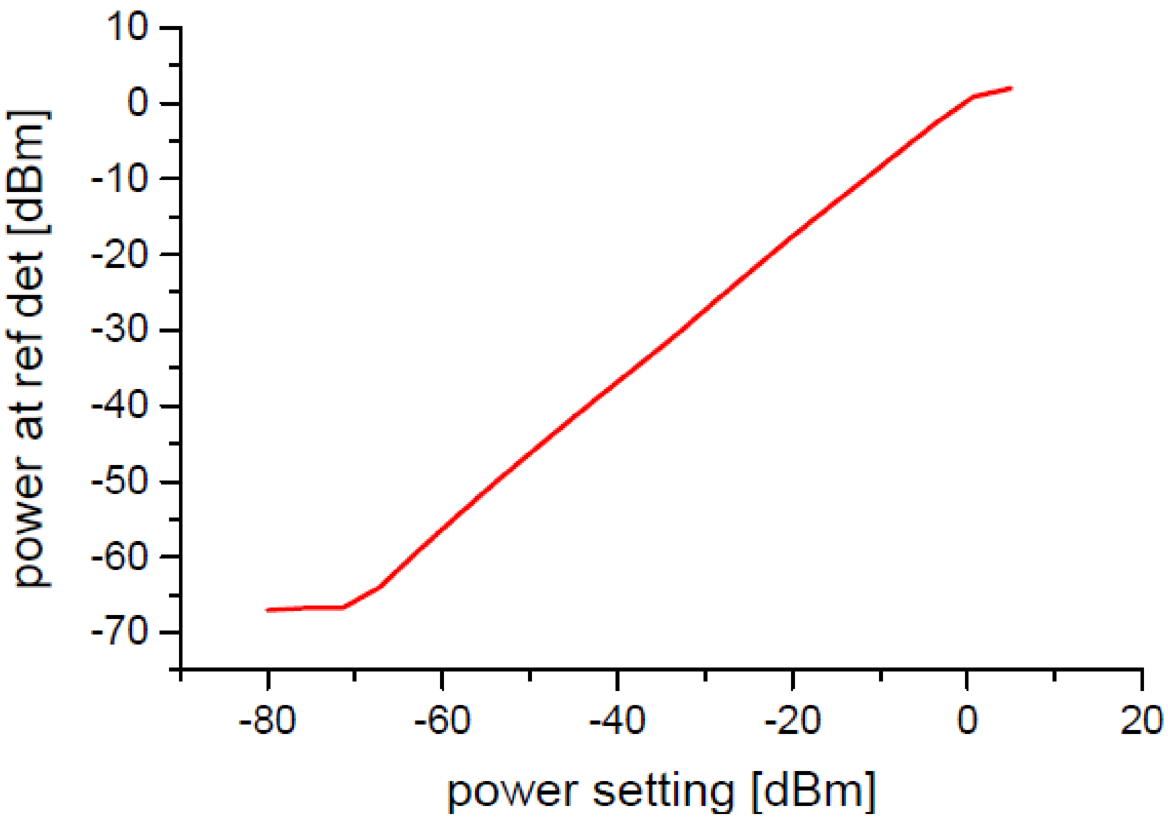
RF-Input

mm-wave output



Power Sweep (e.g. ZC220 Converter)

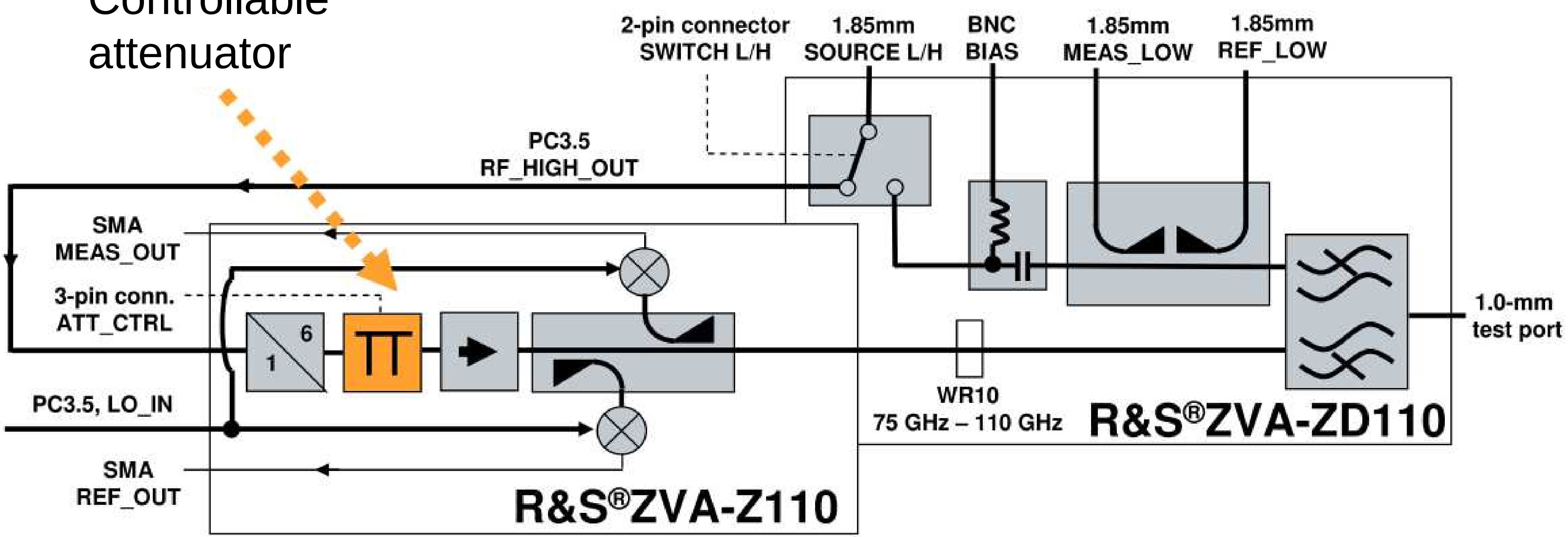
70dB power sweep range



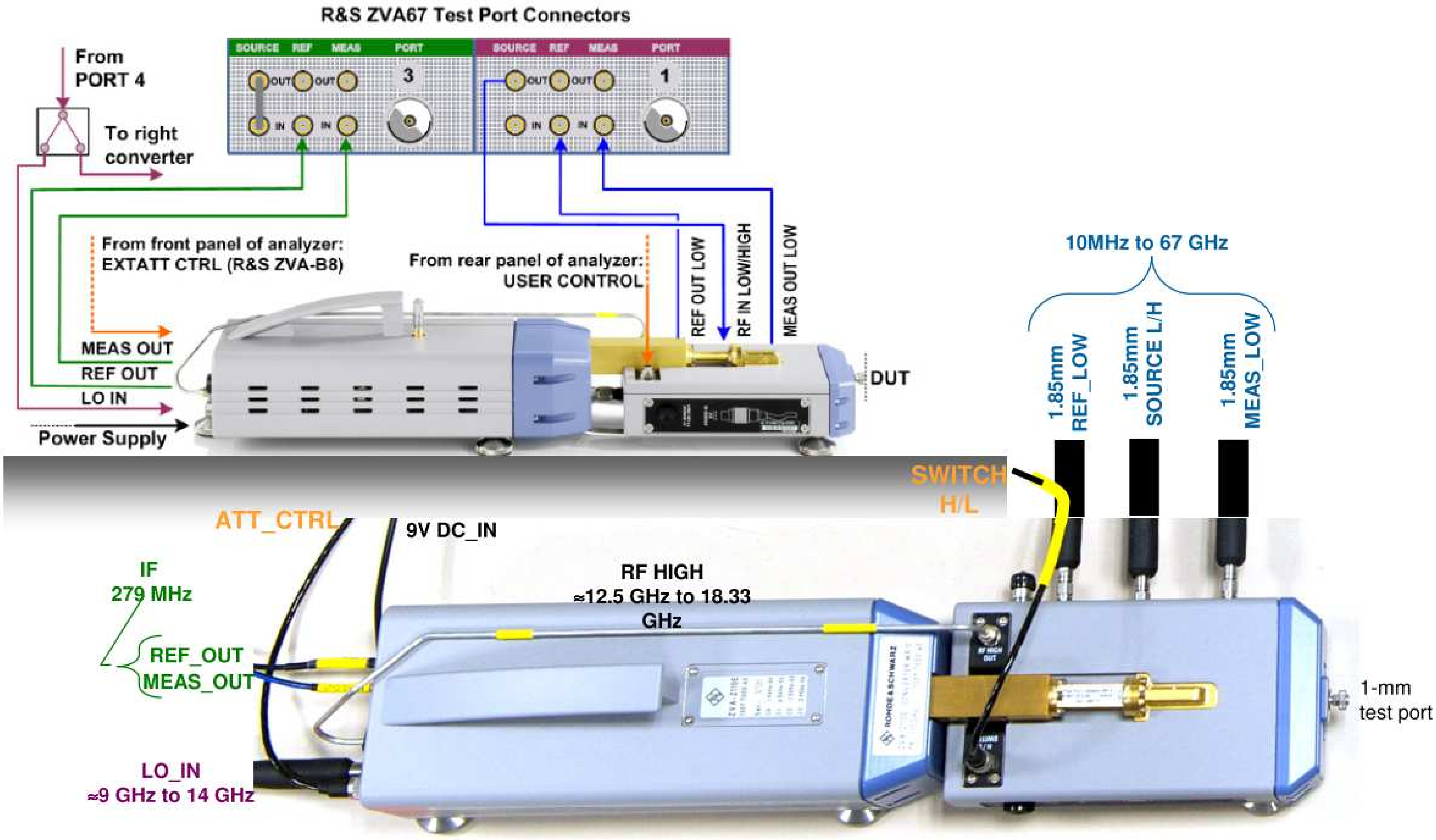
ZVA110 - 110 GHz in one Sweep

The Diplexer combines the ZVA67 with the Converter

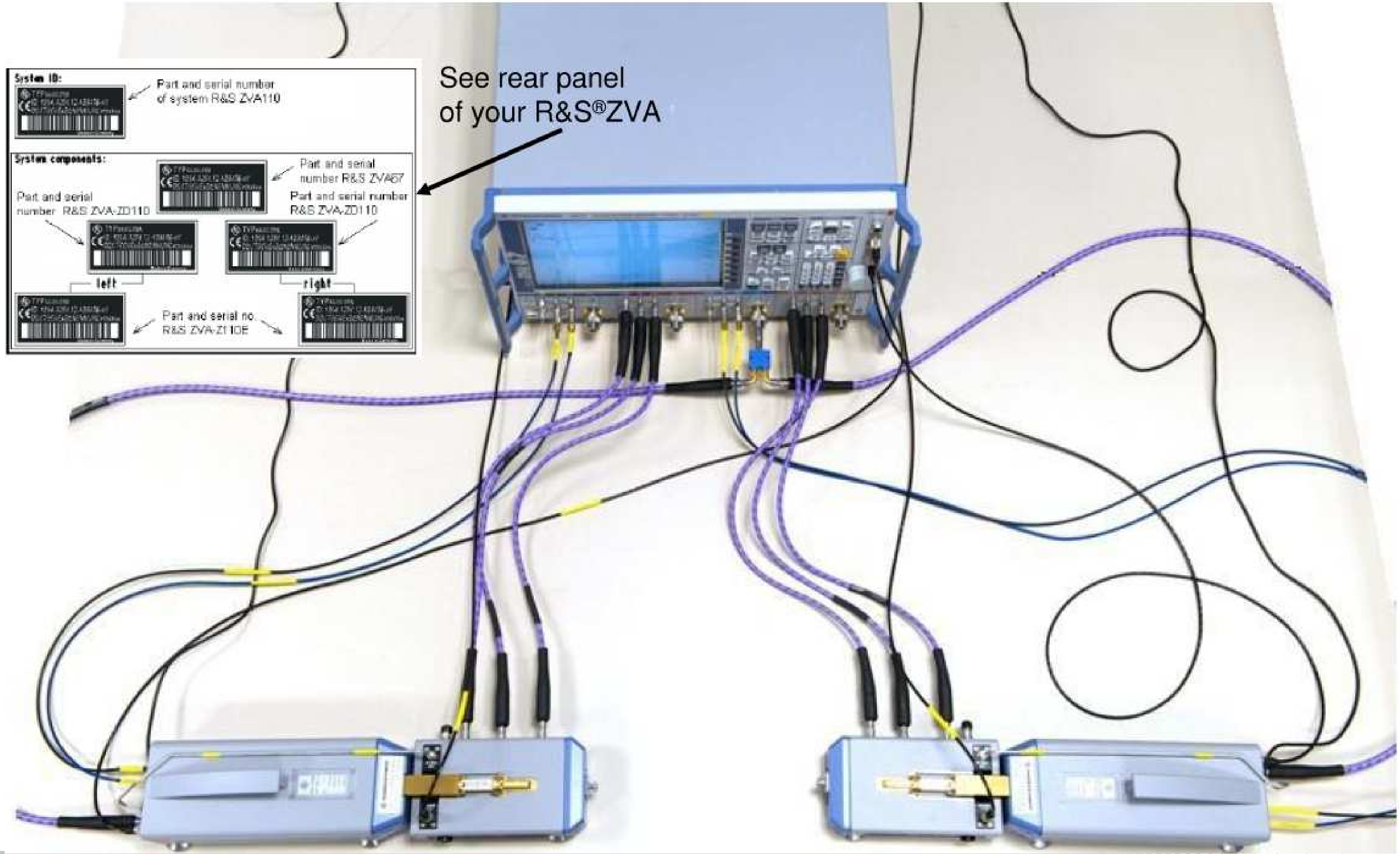
Controllable attenuator



Configuring the ZVA110

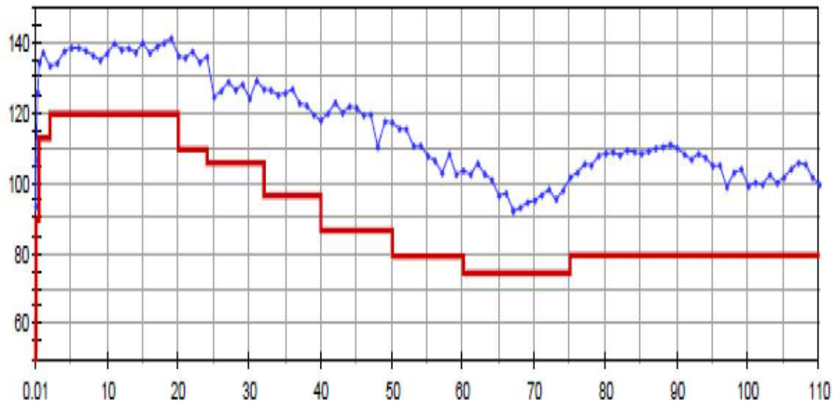


Configuring the ZVA110

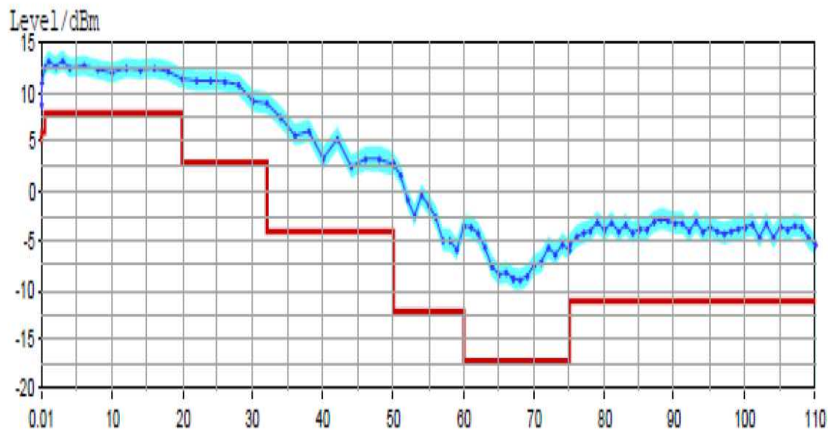


ZVA 110 Key Data

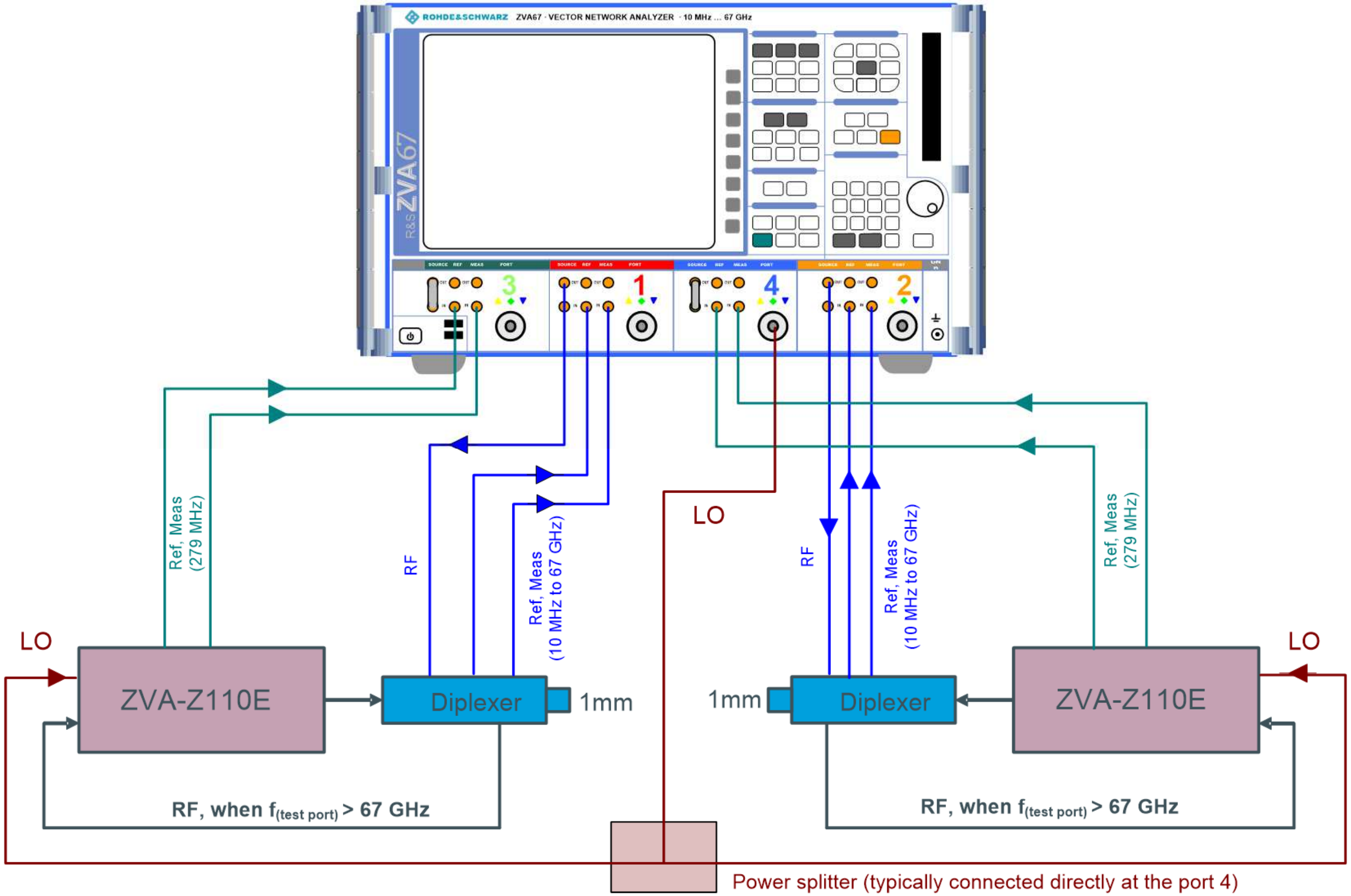
- Dynamic range
  80 dB…120 dB
- Max output power
  -10 dBm….10 dBm
- 1…60001 Points
- 1 Hz..30 MHz IFBw
- Effective directivity and load port match
  > 32 dB (typ.)



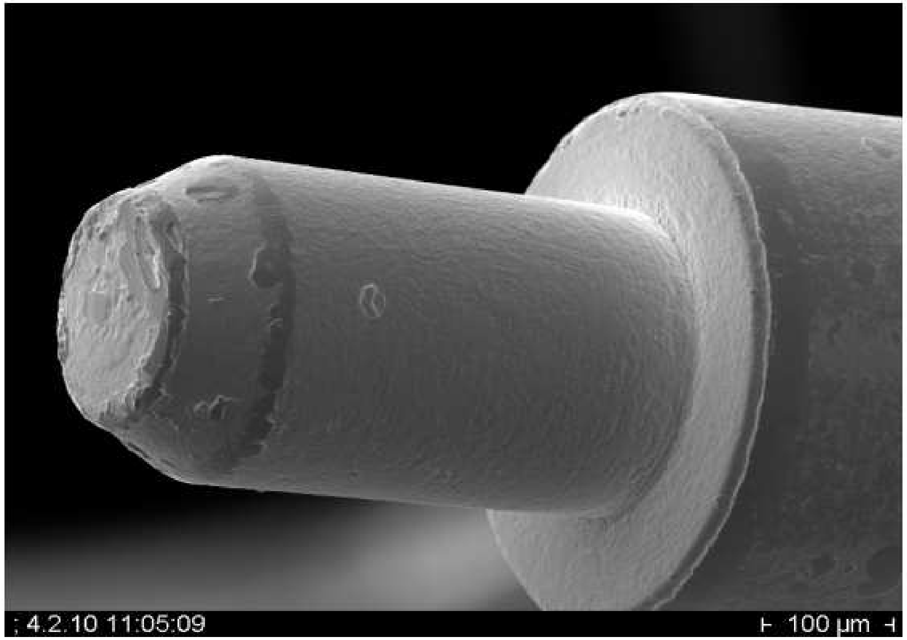
Dynamic range in dB versus frequency in GHz of the R&S®ZVA110.



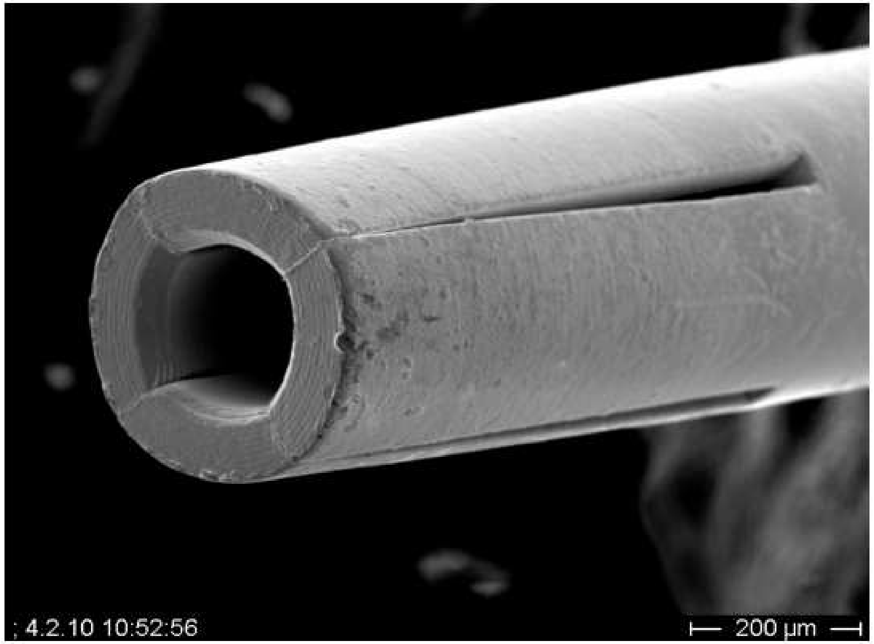
ZVA110 - Principle



1 mm Connector System



REM picture from an inner conductor
of a 1.0-mm male connector



REM picture from an inner conductor
of a 1.0-mm female connector

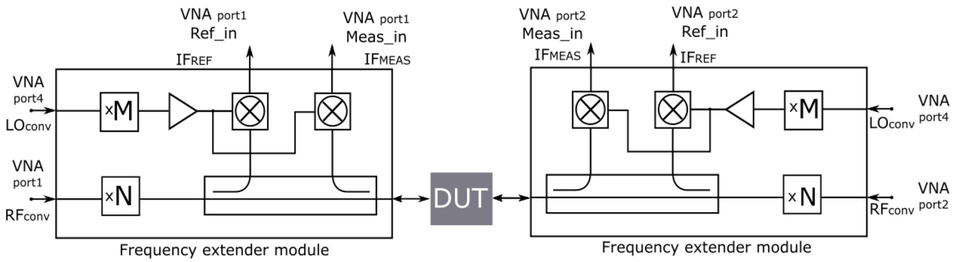
Accurate S-Parameter Measurements

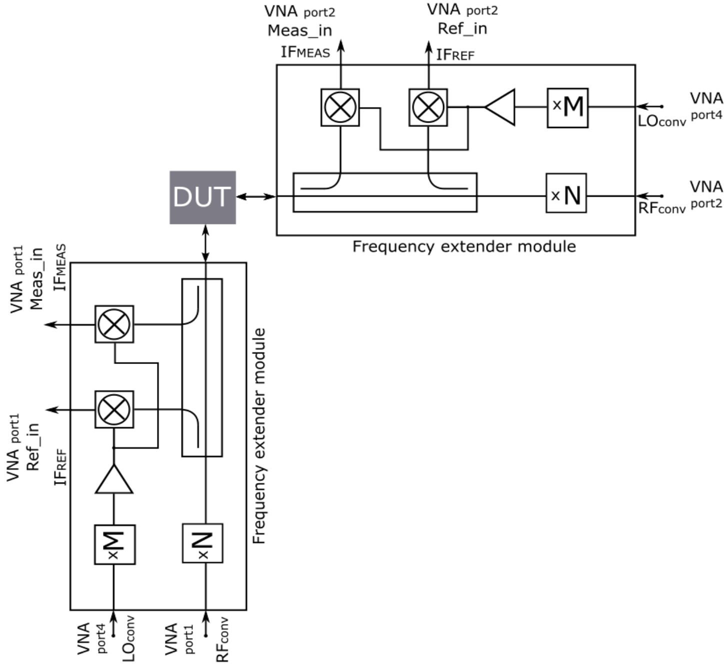
Measurements with different orientations of the modules

- Two measurements of the phase with different orientations of the frequency extender modules

90° orientation

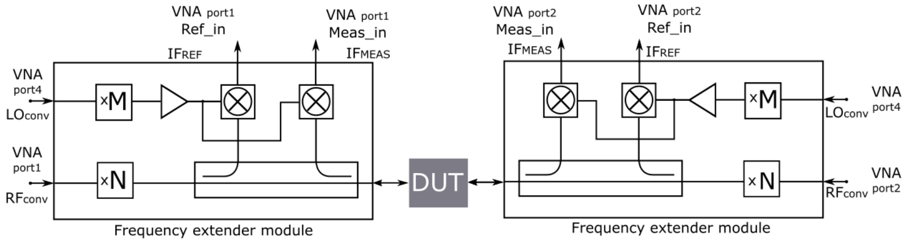
0° orientation

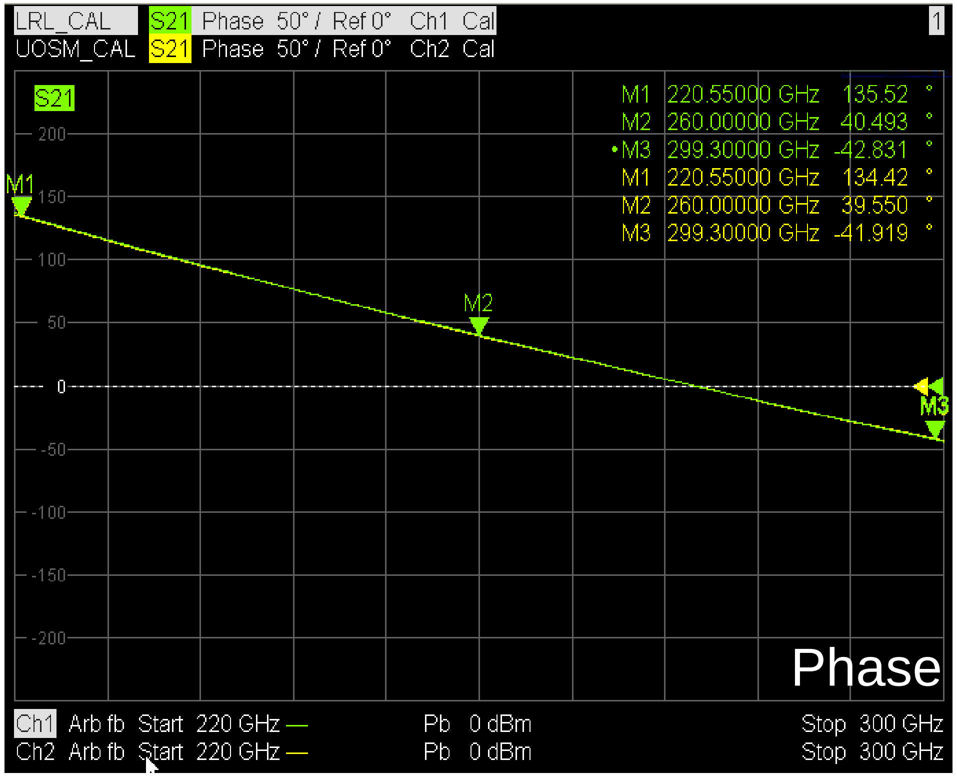




Measurement results at 0 deg. orientation
LRL Calibration

0° orientation

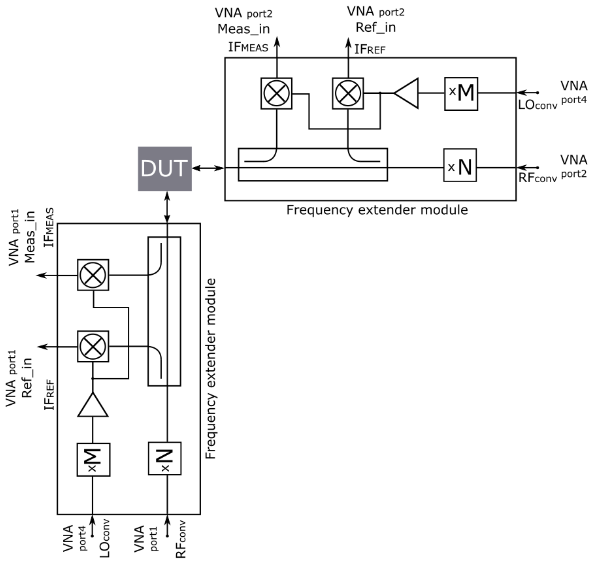


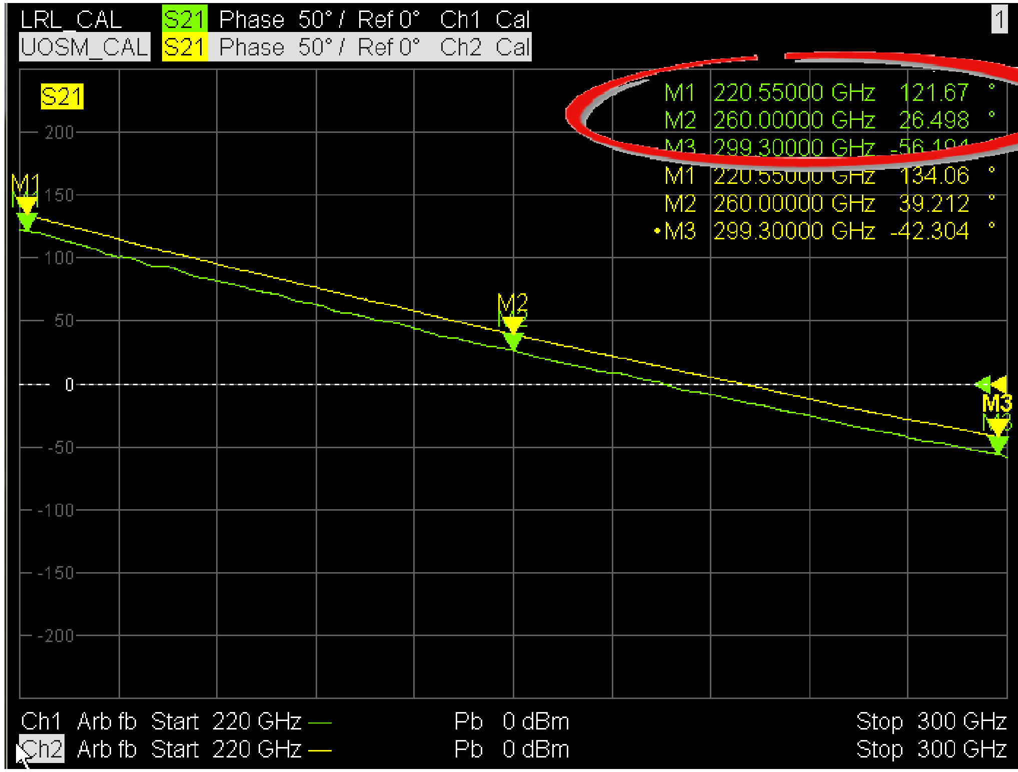


Measurement results at 90 deg. orientation

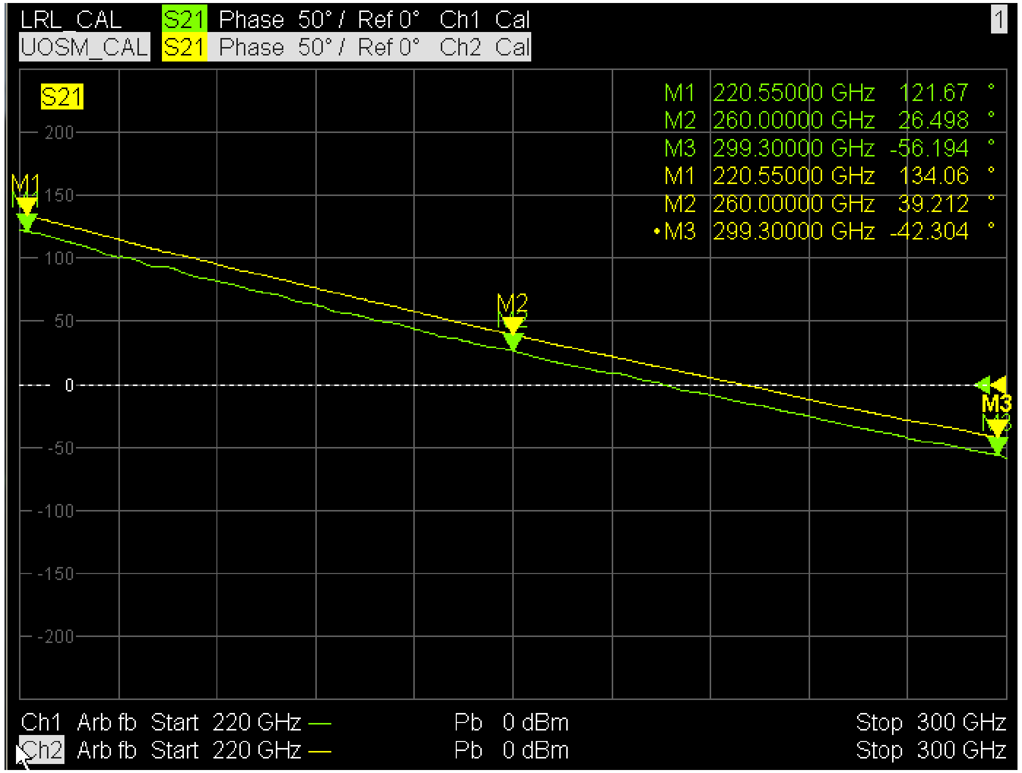
A&D symposium

90° orientation





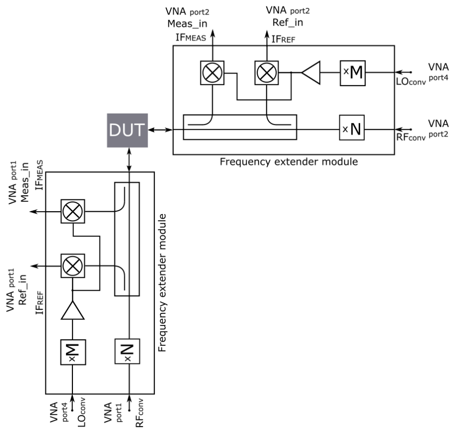
Measurement results at 90 deg. orientation LRL Calibration vs. UOSM

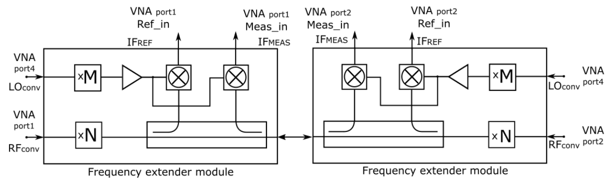


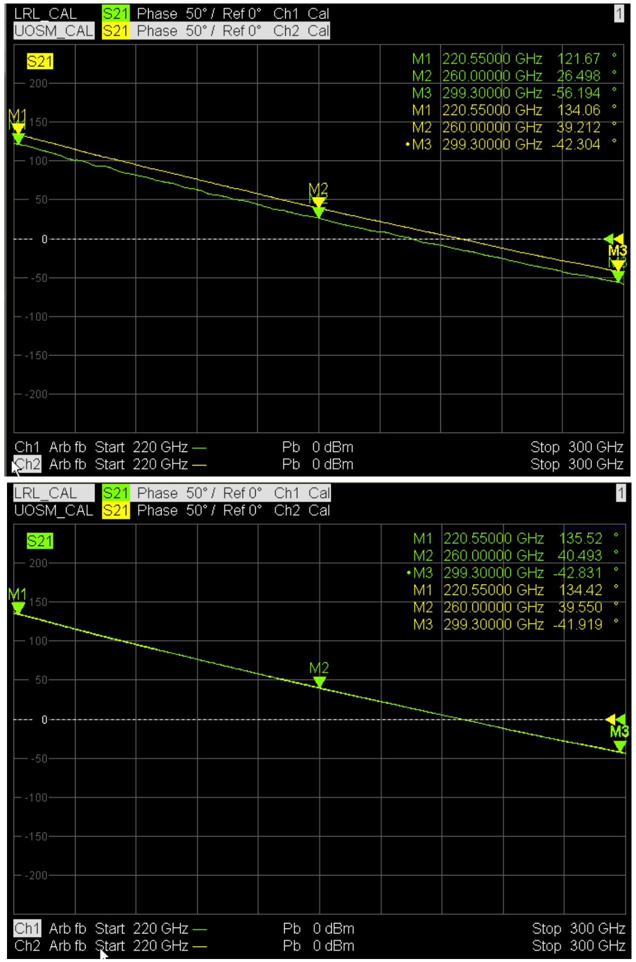
Data at 0° orientation

- Phase of the measurement data based on LRL changed by 14°
- Phase of the measurement data based on UOSM calibration maintains stable

Measurement results
LRL Calibration vs. UOSM





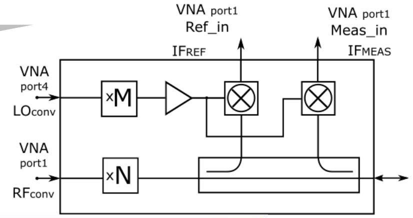


What is the reason for this effect and why does UOSM provide a better result than LRL calibration technique?

Multiplication of VNA signal

Frequency range and multiplication factor **Source input (RF IN)**			
	R&S®ZC170	9.167 GHz to 14.167 GHz,	× 12
	R&S®ZC220	11.667 GHz to 18.333 GHz	× 12
	R&S®ZC330	12.222 GHz to 18.333 GHz	× 18

Frequency range and multiplication factor **Local oscillator input (LO IN)**			
	R&S®ZC170	10.972 GHz to 16.972 GHz	× 10
	R&S®ZC220	11.643 GHz to 18.310 GHz	× 12
	R&S®ZC330	9.155 GHz to 13.738 GHz	× 24

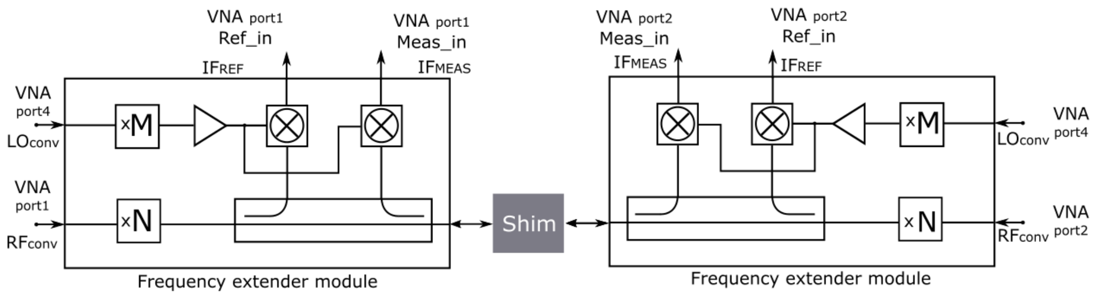


Port Configuration

Meas	Physical Port #	Source Frequency	Frequency Result	Power Result	Receiver Frequency	Frequ
☑	Port 1	1 / 18 · fb	12.222222222 GHz ... 18.333333333 GHz	7 dBm	279 MHz	
	Converter Port 1	fb	220 GHz ... 330 GHz	0 dBm		
☑	Port 2	1 / 18 · fb	12.222222222 GHz ... 18.333333333 GHz	7 dBm		
	Converter Port 2	fb	220 GHz ... 330 GHz	0 dBm		
☑	Port 3	1 / 18 · fb	12.222222222 GHz ... 18.333333333 GHz	7 dBm		
☑	Port 4	1 / 24 · fb - 1 / 24 · 279 MHz	9.155041667 GHz ... 13.738375 GHz	7 dBm		

Impact of the cable movement

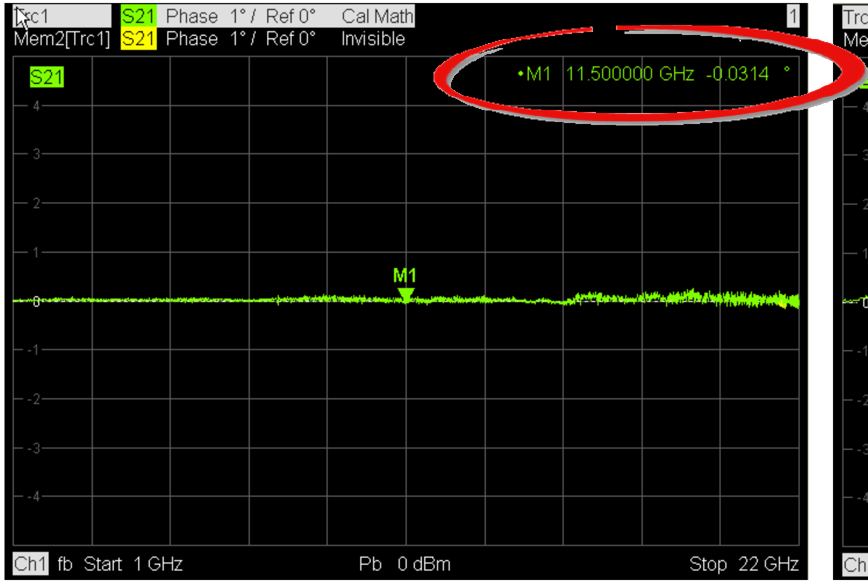
- The LRL calibration on wave guide is done with 2 or more shims, with different length



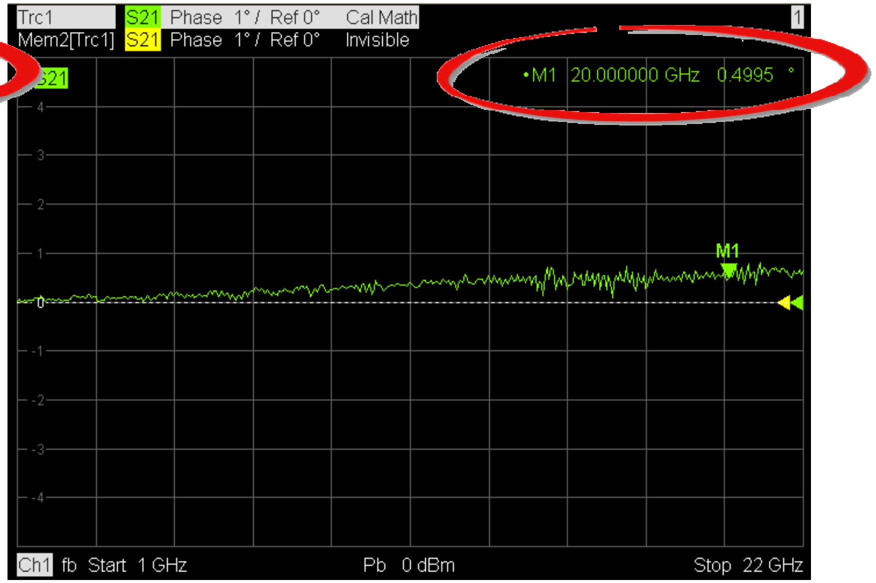
- This requires, that the calibration has to be done by a horizontal alignment of the two frequency extender modules

Impact of the Cable Movement

- For the LRL: the frequency converter gets moved in 90° to each other after the calibration
- Depending of the quality of the LO-cables, this leads to a small, constant phase error:



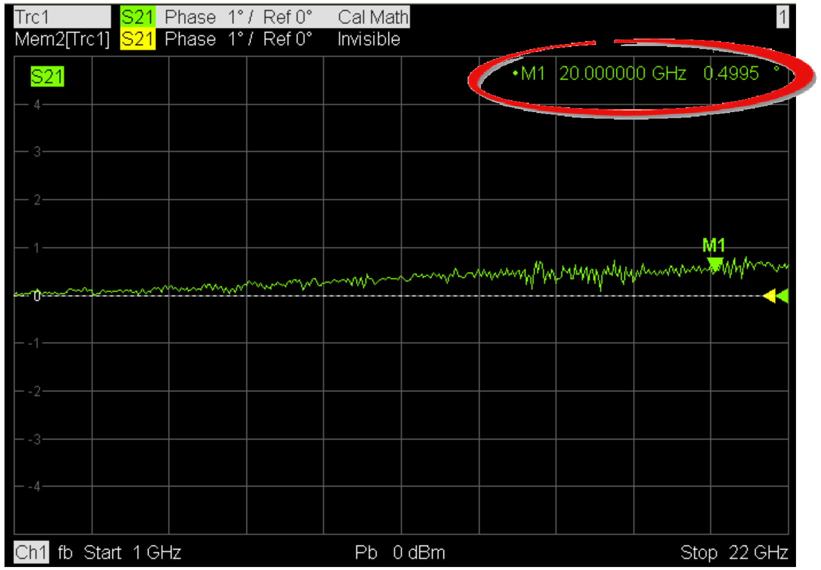
Cable bending at 0 deg orientation

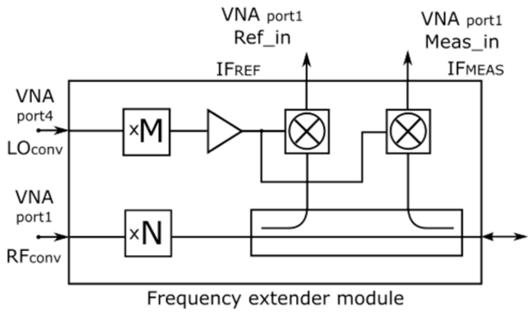


Cable bending at 90 deg orientation

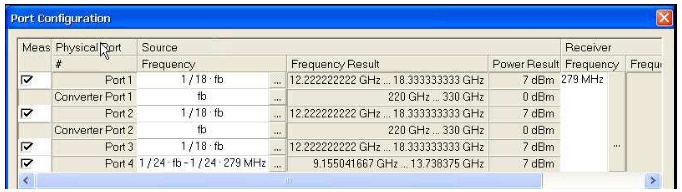
Impact of the cable movement

- The phase error due to the cable movement gets multiplied by the factor M of the frequency extender modules





M: 24



Port Configuration

Meas	Physical Port #	Source Frequency		Frequency Result	Power Result	Receiver Frequency
☑	Port 1	1 / 18 · fb	...	12.222222222 GHz ... 18.333333333 GHz	7 dBm	279 MHz
	Converter Port 1	fb	...	220 GHz ... 330 GHz	0 dBm	
☑	Port 2	1 / 18 · fb	...	12.222222222 GHz ... 18.333333333 GHz	7 dBm	
	Converter Port 2	fb	...	220 GHz ... 330 GHz	0 dBm	
☑	Port 3	1 / 18 · fb	...	12.222222222 GHz ... 18.333333333 GHz	7 dBm	
☑	Port 4	1 / 24 · fb - 1 / 24 · 279 MHz	...	9.155041667 GHz ... 13.738375 GHz	7 dBm	

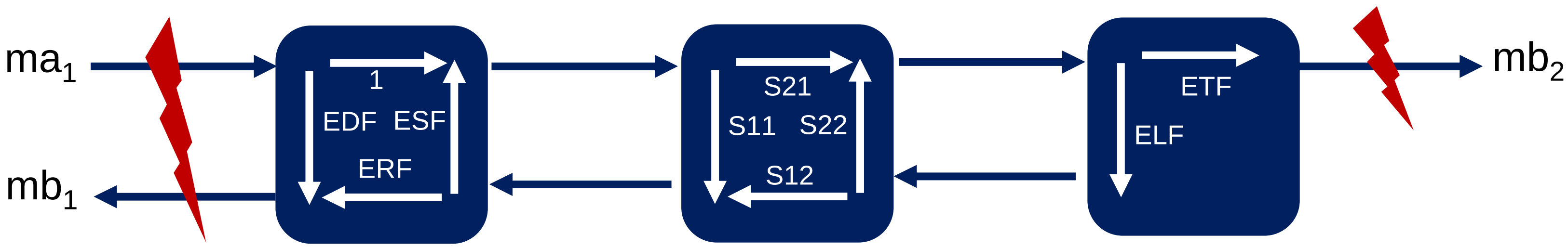
24 * 0.5°

Calculated phase error: 12°

Impact of the cable movement

- Due to the 90° alignment of the frequency extender modules, the RF and LO cables are bent

- As shown in the measurement results, a phase error of up to 14° due to the LO cable movement can be seen



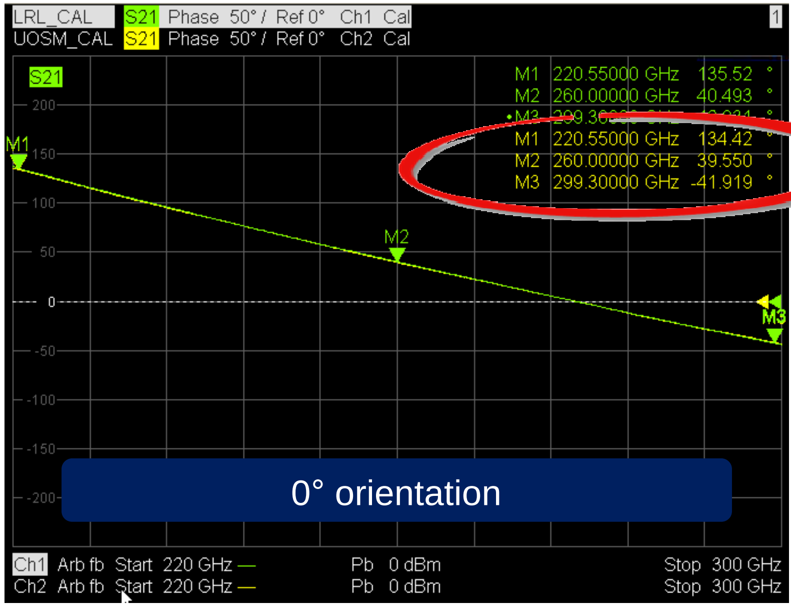
Calibration &Technique: UOSM

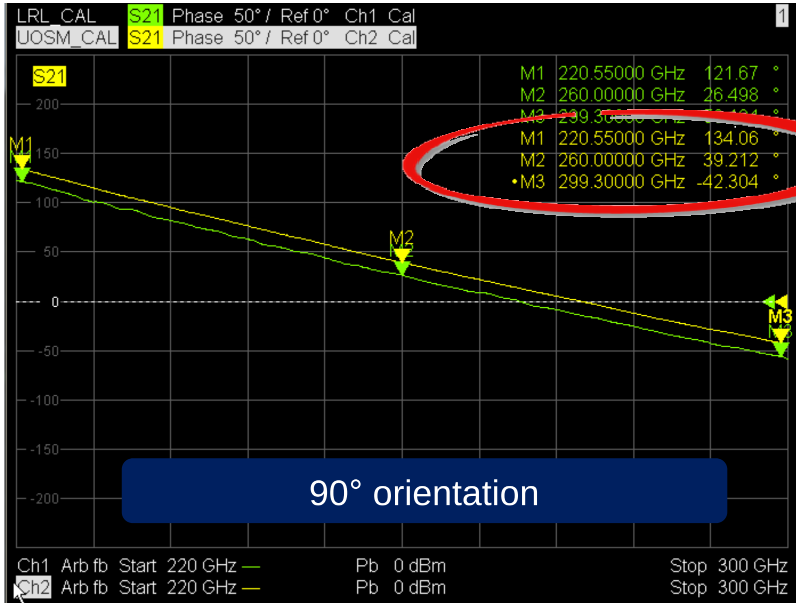
- UnknownThru-Open-Short-Match
- The calibration technique UOSM (for waveguide, the open gets replaced by an Offset Short) allows to have a thru, which has been not specified in the calkit data
- UOSM: 7 Term calibration technique
- Thru can be also lossy, 10 dB or more attn. are OK
- Requirement: Thru has to be reciprocal, it can be also the DUT itself

UOSM calibration technique allows to perform the calibration in the final position

No cable bending required after calibration

Summary



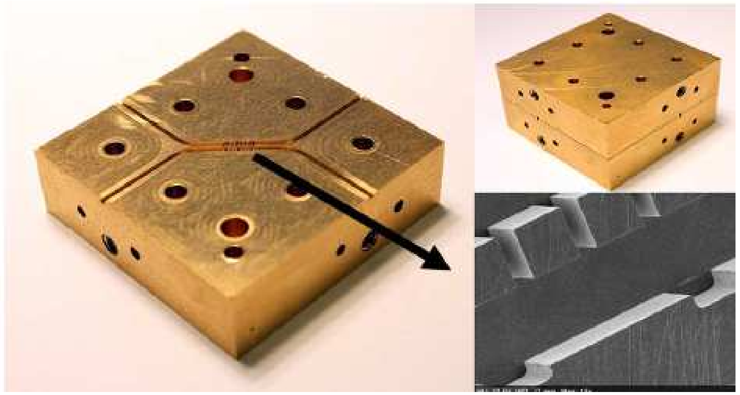


- For the UOSM calibration the DUT can be used as the Thru standard. (→ Reciprocal)

Example

H. Rashid, V. Desmaris, V. Belitsky, M. Ruf, T. Bednorz and A. Henkel, "Design of Wideband Waveguide Hybrid With Ultra-Low Amplitude Imbalance," in *IEEE Transactions on Terahertz Science and Technology*, vol. 6, no. 1, pp. 83-90, Jan. 2016.
doi: 10.1109/TTHZ.2015.2502070

- DUT is 90° waveguide hybrid with ultra-low amplitude imbalance
- Designed for 159–216 GHz band
- Multiple branch waveguide design



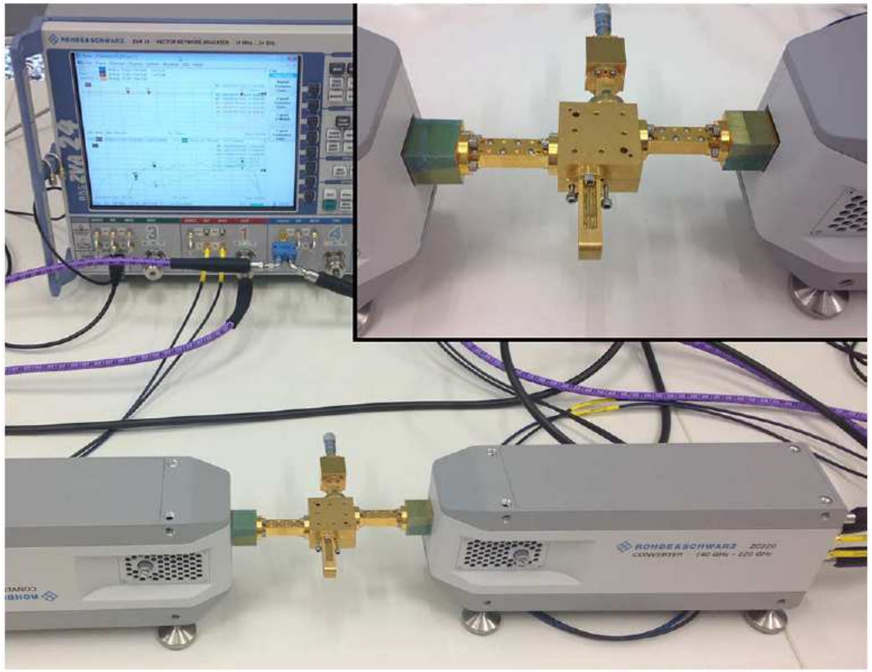
Amplitude and phase imbalance are simulated and compared to measurement.

Example

H. Rashid, V. Desmaris, V. Belitsky, M. Ruf, T. Bednorz and A. Henkel, "Design of Wideband Waveguide Hybrid With Ultra-Low Amplitude Imbalance," in *IEEE Transactions on Terahertz Science and Technology*, vol. 6, no. 1, pp. 83-90, Jan. 2016.
doi: 10.1109/TTHZ.2015.2502070

- Converters are rotated between measurements
- Errors in phase measurements occur

Solution:
- Calibrate UOSM before rotation
- Recall O, S, M data after 90° rotation, re-measure U.

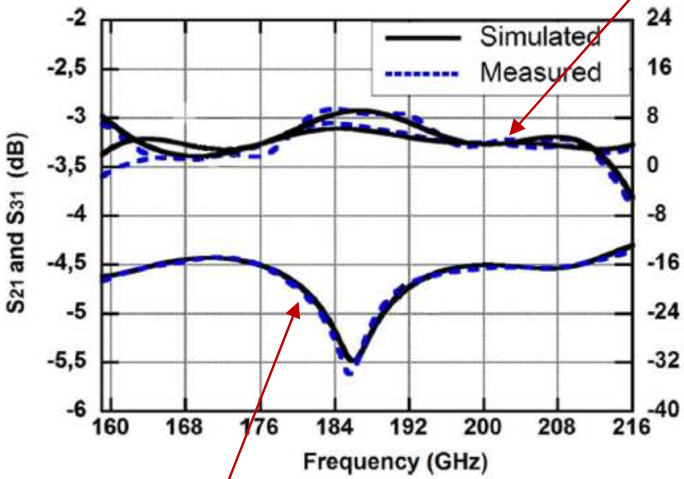


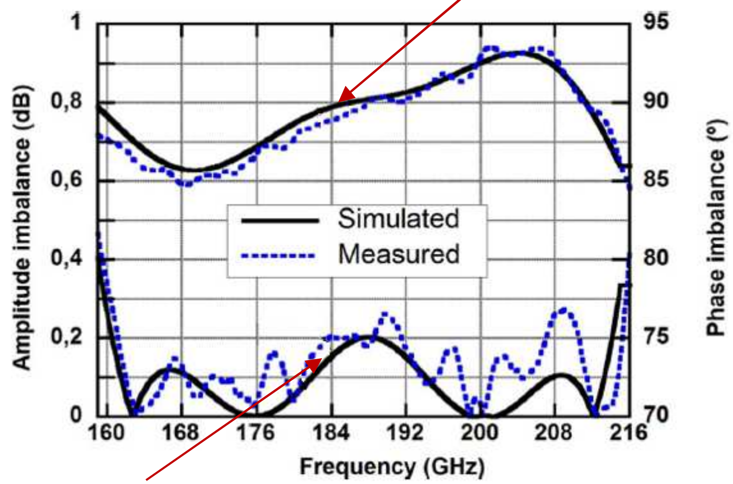
Example

H. Rashid, V. Desmaris, V. Belitsky, M. Ruf, T. Bednorz and A. Henkel, "Design of Wideband Waveguide Hybrid With Ultra-Low Amplitude Imbalance," in *IEEE Transactions on Terahertz Science and Technology*, vol. 6, no. 1, pp. 83-90, Jan. 2016.
doi: 10.1109/TTHZ.2015.2502070

Through,
Coupled

Phase





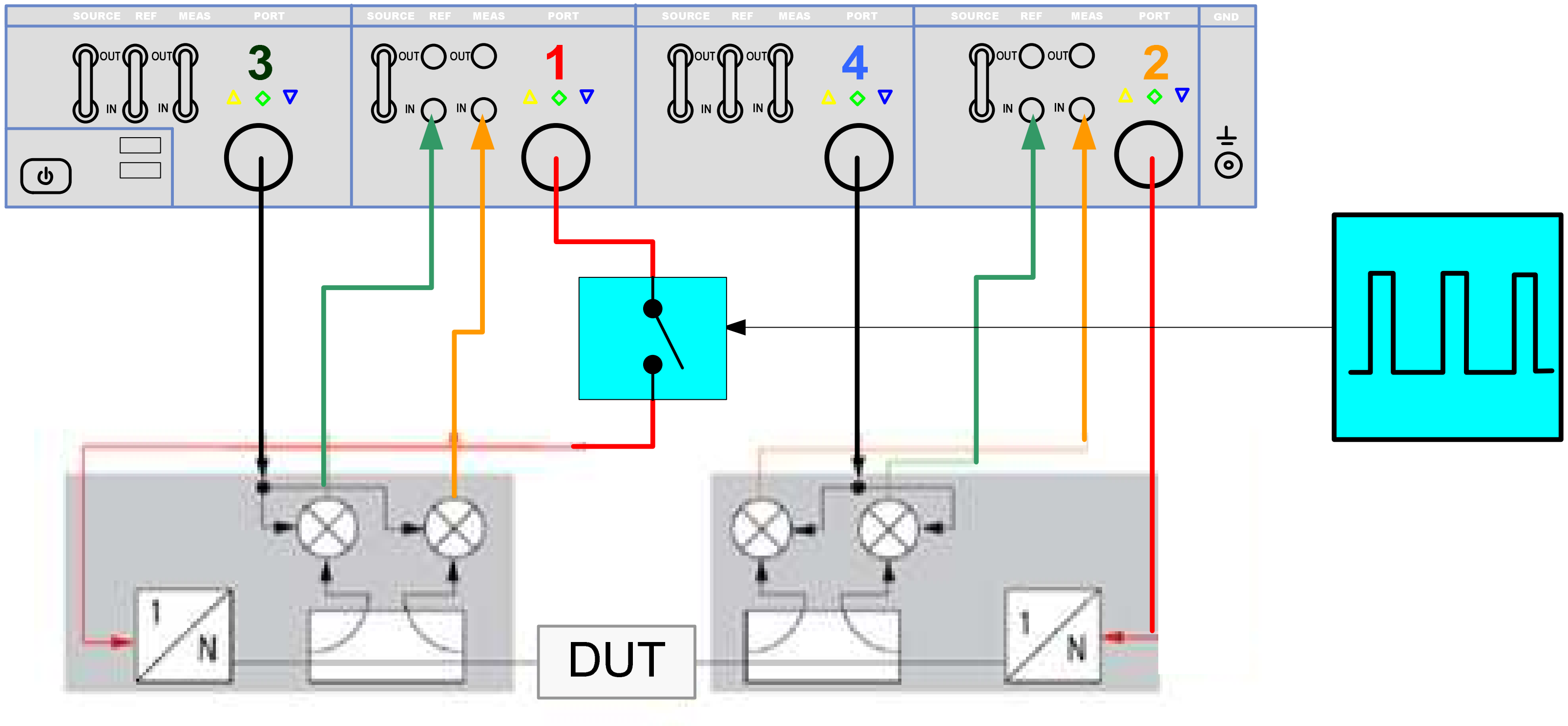
Reflection
Isolation

Amplitude

Very small deviation between simulated and measured phase

Amplifier & Mixer Measurements

Pulsed Measurements at 110 GHz



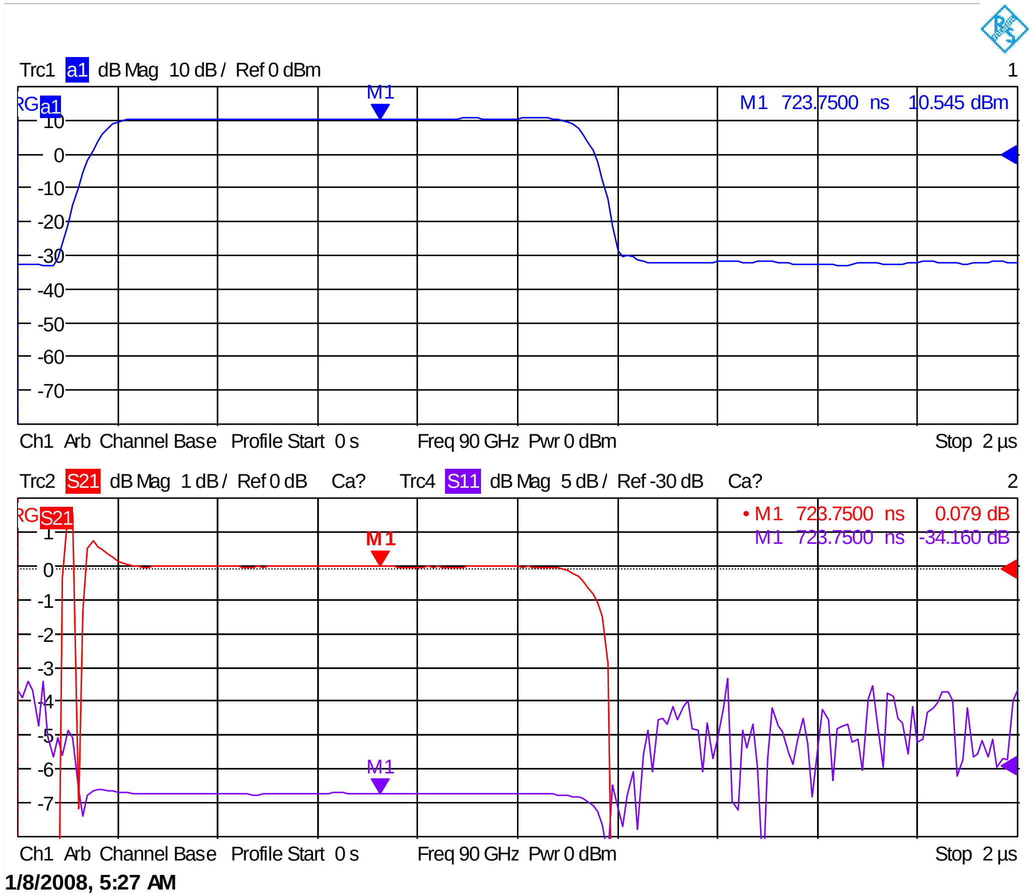
Pulsed Measurements at 110 GHz

- Modulator in source path of freq. converter
  - Frequency range 12 GHz ….20 GHz
- Modulator in source path of VNA part
  - Frequency range 10..70 GHz

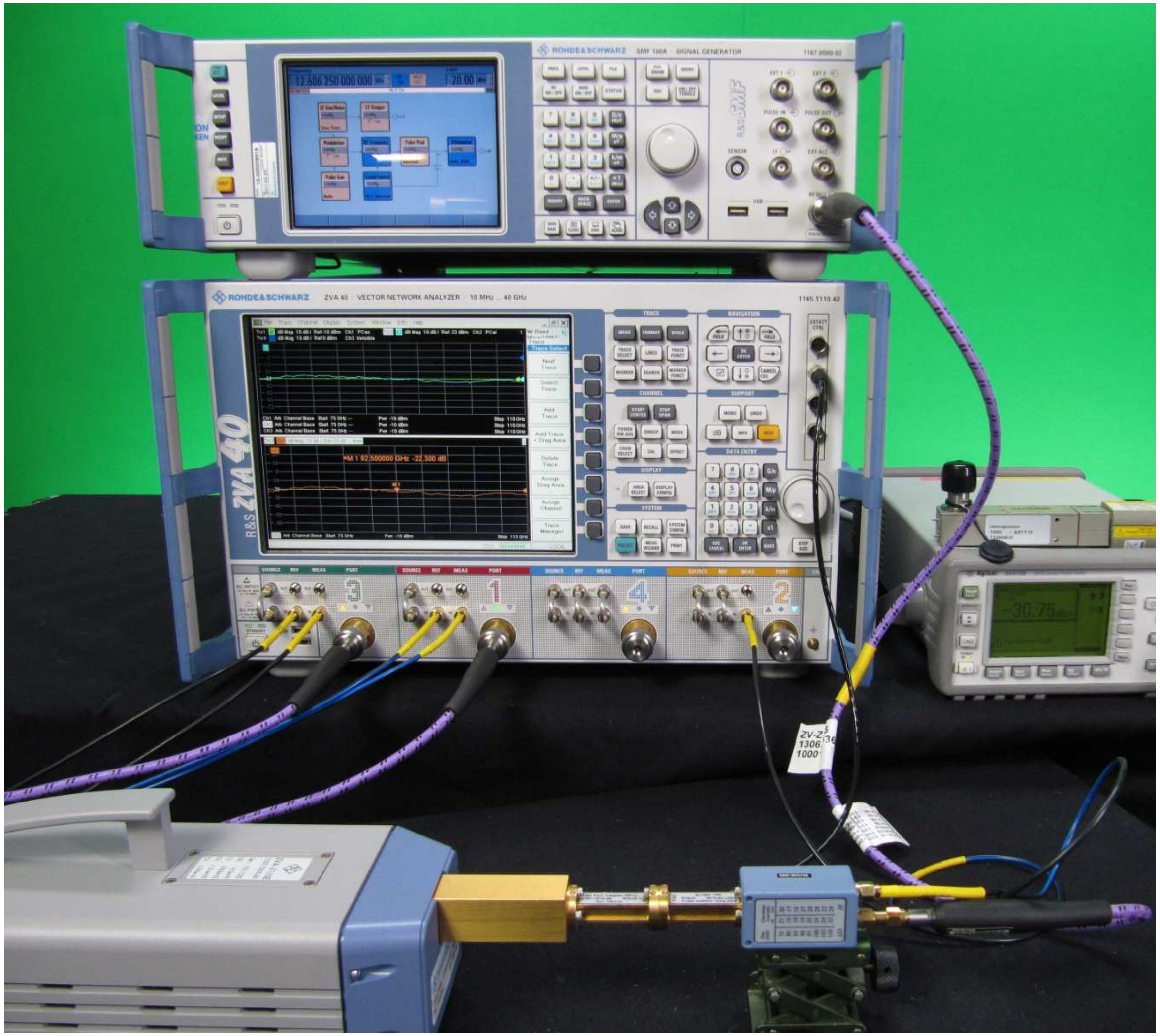
- Pulsing the supply voltage

- Low loss (no retuning of RF power level necessary)
- For average pulse, point in pulse and pulse profile test

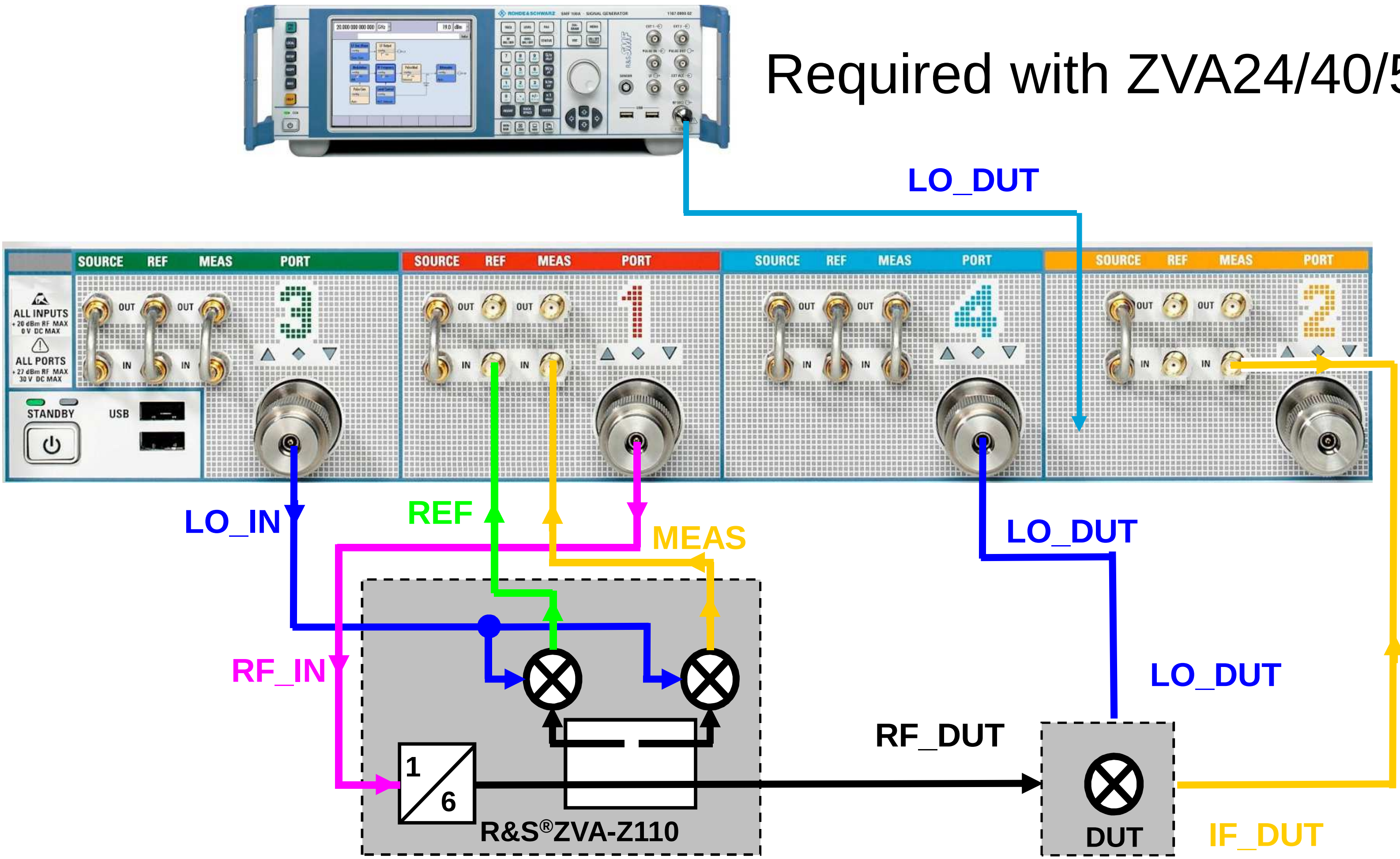
Pulsed Measurements at 110 GHz



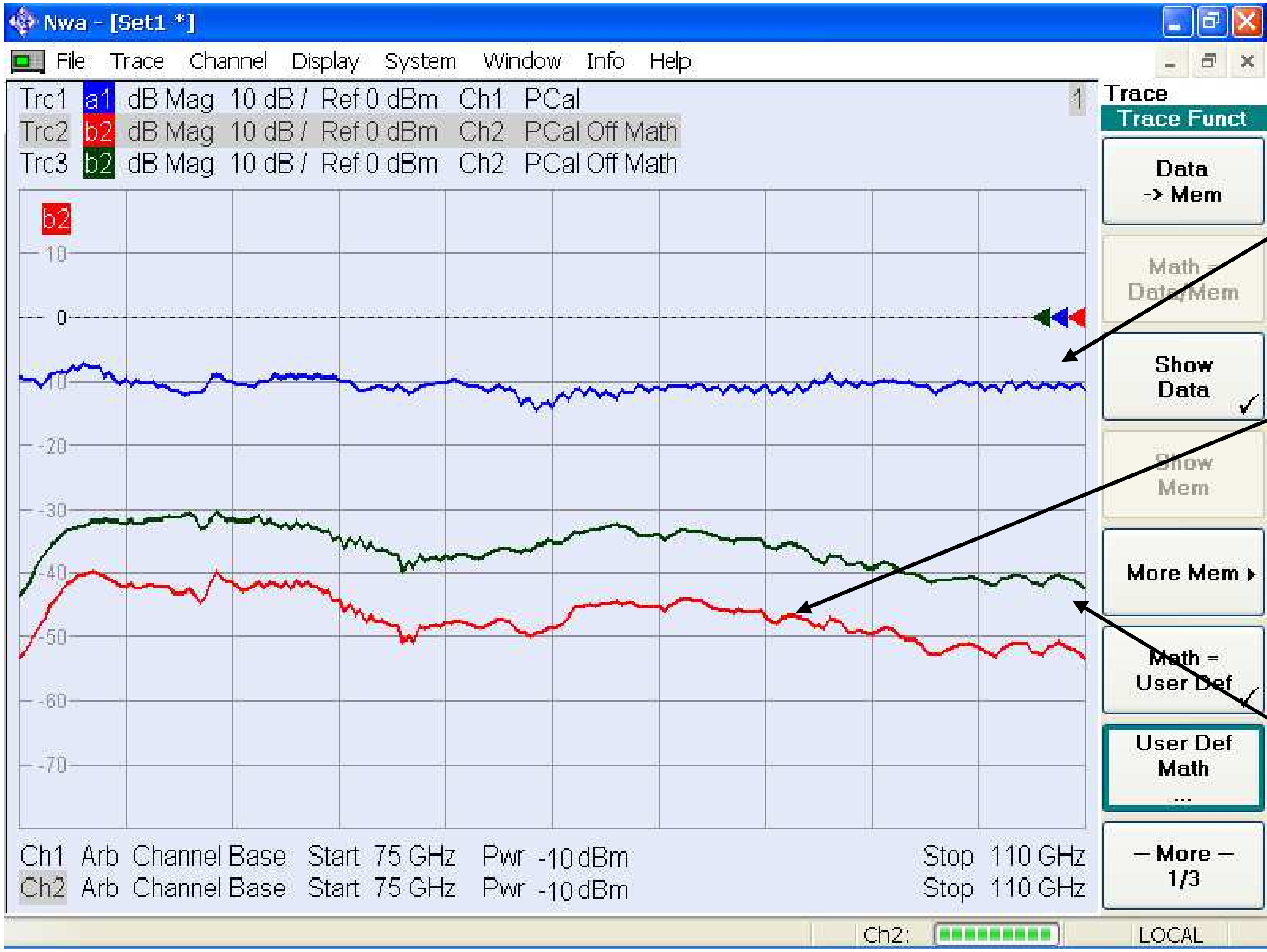
Set-up for Mixer Measurements



Mixer Measurement Set-up Cabling



Mixer Measurement Results



RF_DUT power at waveguide test port (receiver level calibrated)

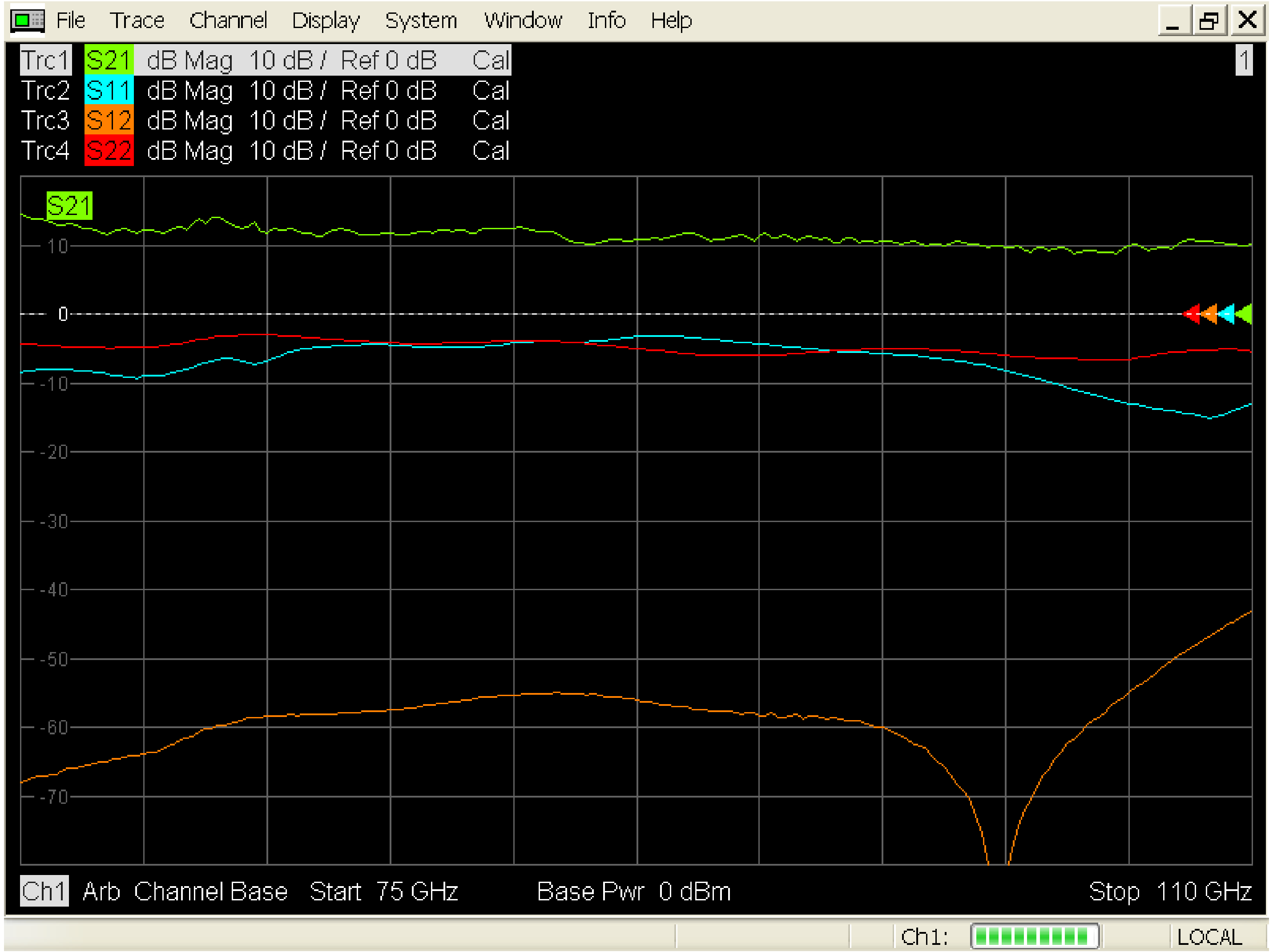
IF_DUT power at mixer IF/LO port (corrected by value of step 1)

Conversion loss calculated from RF_DUT and IF_DUT

Mixer Measurement Results

Set-up for Amplifier Measurements

Amplifier Measurement Results (Sweep Mode)



Amplifier Measurement Results (Pwr Sweep Mode)

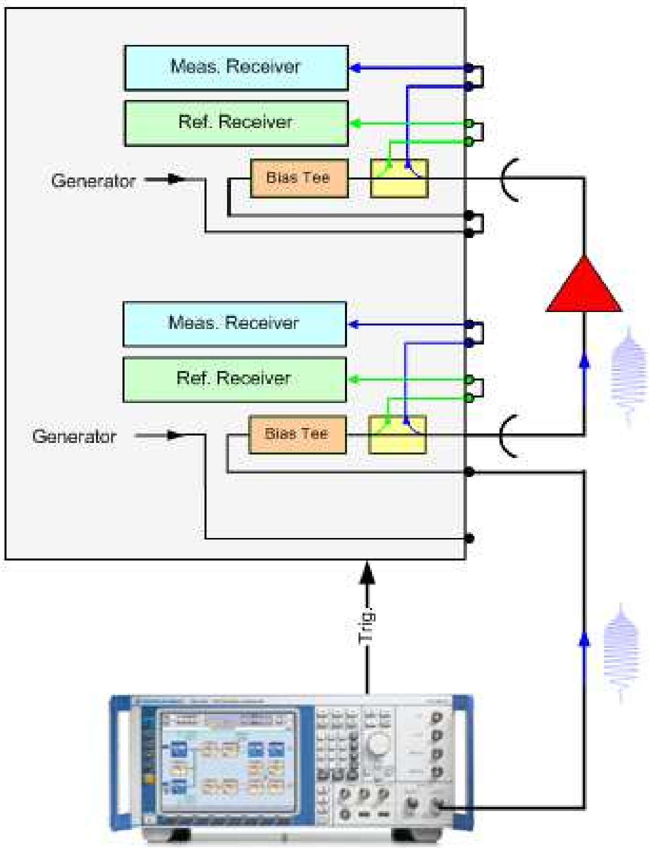
Amplifier Measurements Results (Intermodulation)

Measurements with wideband modulated Signals

Measurement with modulated Signals
Typical Applications

- Multicarrier systems
  - Used for wideband communication application as 4G
  - OFDM signals with multiple carriers generate nonlinear effects different to single carrier stimulation
- Radar systems
  - Use of pulsed chirp signals
  - Resolution is dependent on the bandwith of the freq. chirp
    - Range resolution = (c_0) / (bandwidth x 2)

Setup for Analysis with modulated Signals



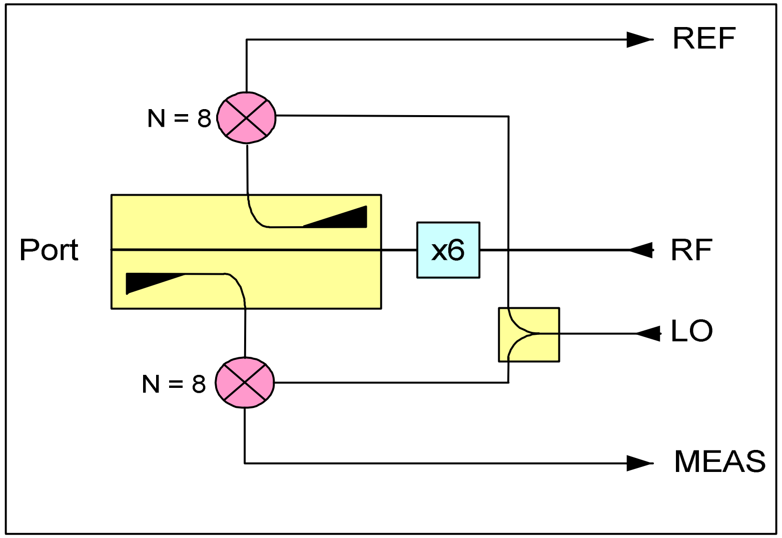
- Modulated signal injected into generator path of VNA
- Measurement and reference signal are modulated
- Power-, ratio- and S-parameter measurements in forward direction possible
- Trigger signal from sig.-gen.

Frequency Extension to 500 GHz and above with Frequency Converters

- RF signal of VNA source is multiplied e.g. with factor 6
  - 15 GHz -> 90 GHz
  - Modulation bandwidth
  - 160 MHz -> 960 MHz

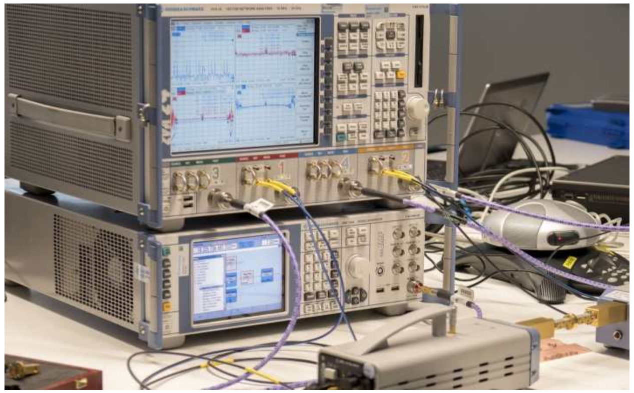
- Reference and measurement signal is down converted by using a harmonic mixer e.g. using the 8th Lo harmonic

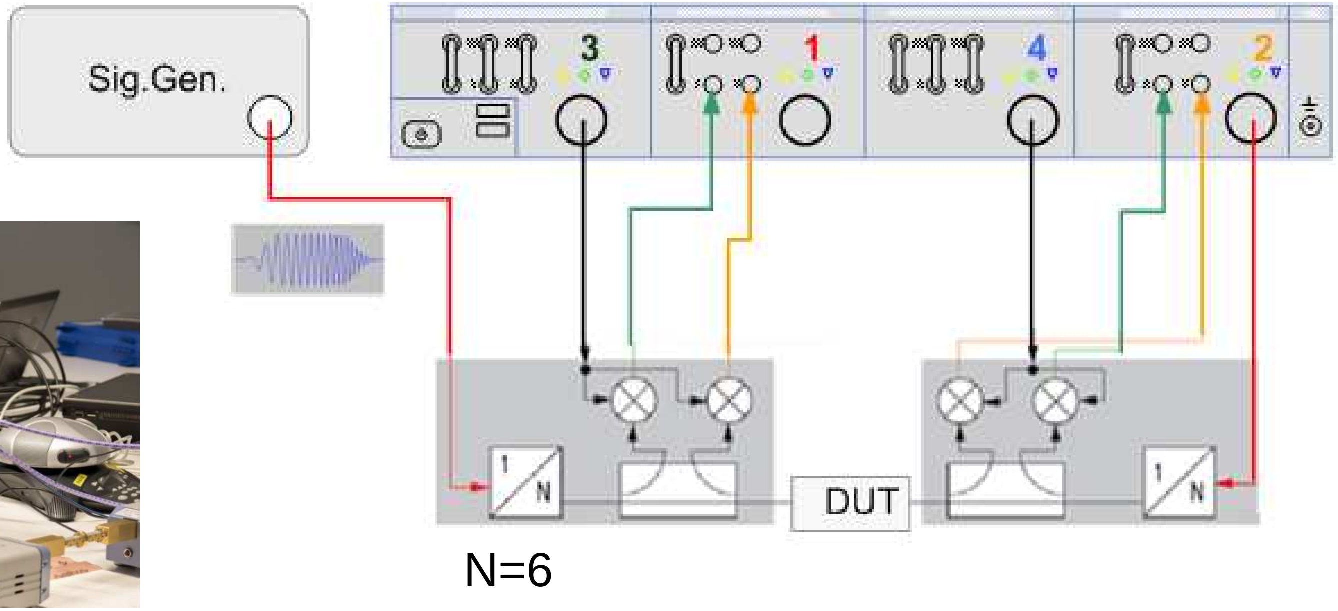
- Ref & Meas out
  - Down converted to 500 MHz ± 480 MHz



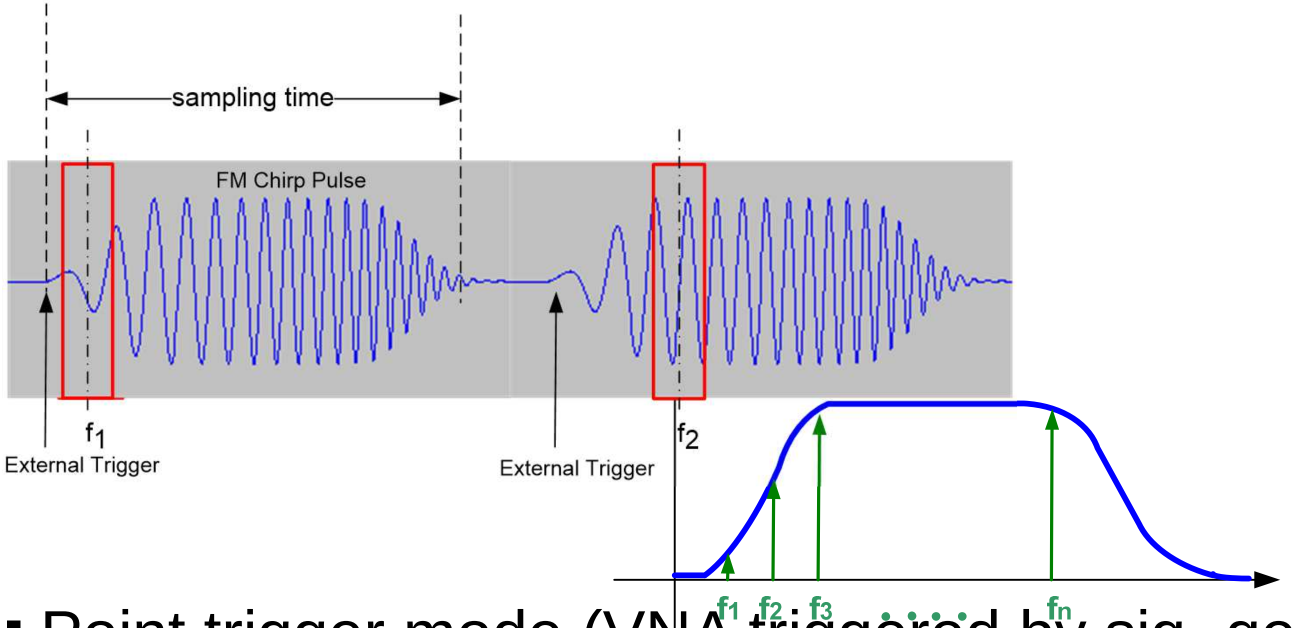
S-Parameter Measurements with Chirp Signals in the mm-Wave Range

- Generation of chirp signals with 960 MHz bandwidth
- 160 MHz bandwidth @ 15 GHz
- 960 MHz bandwidth @ 90 GHz (multiplied with 6)





Measurement with Chirp Signals versus Frequency

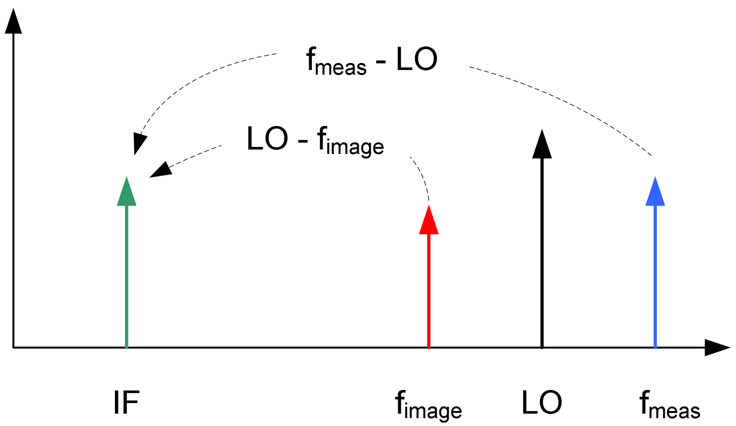


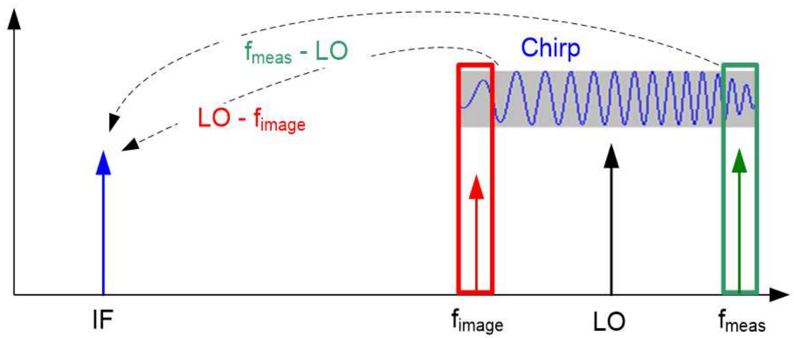
- Point trigger mode (VNA triggered by sig.-gen)
- Sampling time ≥ pulse width
  - Set by appropriate measurement bandwidth
  - Sampling mainly during the on-time of the pulse

Sampling Times of the IF Filters

Filter	Sampling Time us	Filter	Sampling Time in us
Normal 5 MHz	0,41	High 5 MHz	0,41
Normal 3 MHz	0,68	High 3 MHz	0,83
Normal 2 MHz	1,01	High 2 MHz	1,24
Normal 1 MHz	1,81	High 1 MHz	2,44
Normal 500 kHz	2,93	High 500 kHz	4,80
Normal 300 kHz	4,54	High 300 kHz	8,13
Normal 200 kHz	6,13	High 200 kHz	12,38
Normal 100 kHz	11,96	High 100 kHz	24,75
Normal 50 kHz	22,33	High 50 kHz	49,88
Normal 30 kHz	34,13	High 30 kHz	84,81
Normal 20 kHz	51,19	High 20 kHz	126,85
Normal 10 kHz	94,50	High 10 kHz	258,13
Normal 5 kHz	185,25	High 5 kHz	525,00
Normal 3 kHz	309,56	High 3 kHz	883,50
Normal 2 kHz	464,75	High 2 kHz	1325,25
Normal 1 kHz	923,31	High 1 kHz	2697,00
Normal 500 Hz	1857,38	High 500 Hz	5425,00
Normal 300 Hz	3095,63	High 300 Hz	9120,00
Normal 200 Hz	4541,23	High 200 Hz	13893,75
Normal 100 Hz	8888,00	High 100 Hz	27812,50

Usable Bandwidth of Chirp Signal





- Direct down conversion of VNA receiver to IF frequency
- Second receiver window
  - So-called image frequency window
  - Distance = 2*IF frequency

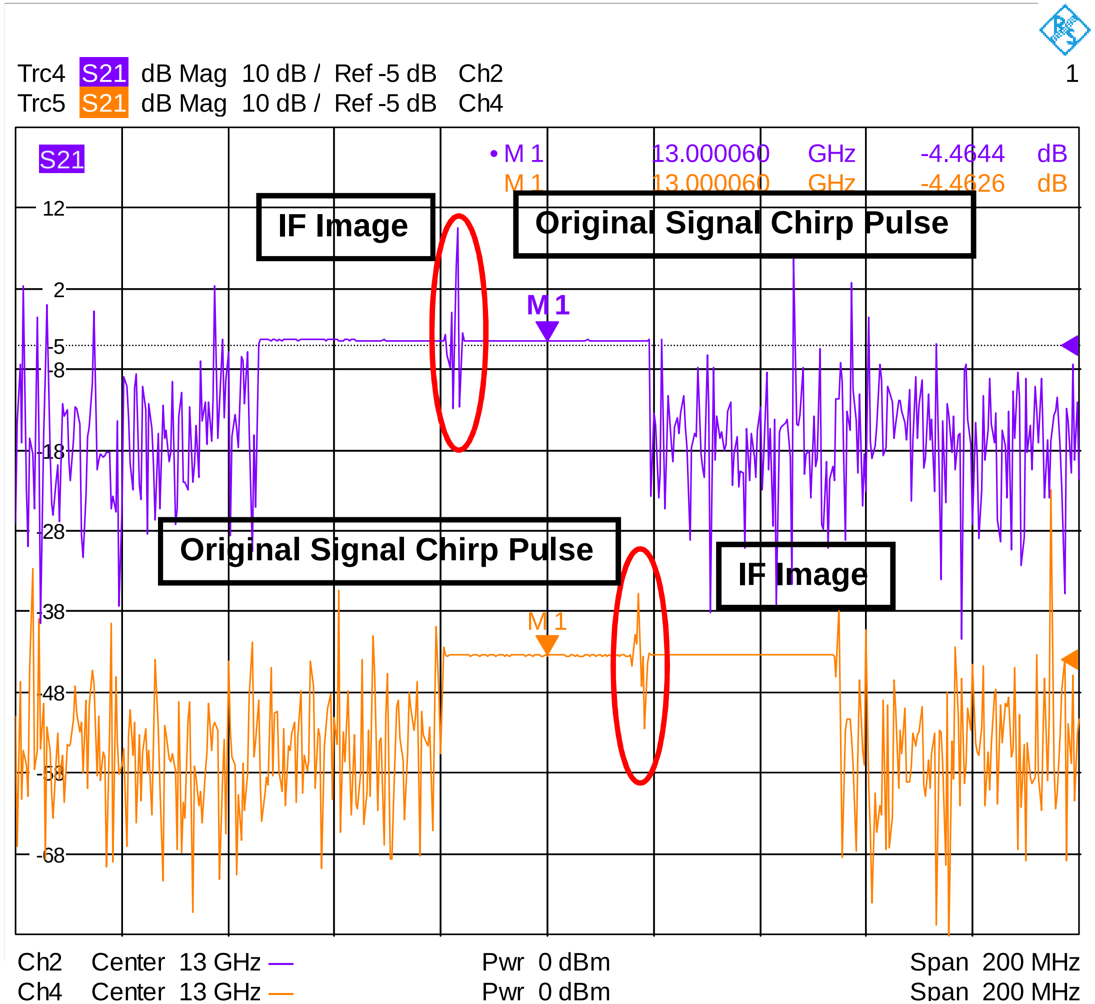
- IF frequency of ZVA 17 MHz

=> Image window 34 MHz apart

- For wide Chirp frequency span simultaneous detection at measurement and image receiver window possible

=> 34 MHz of usable chirp bandwidth

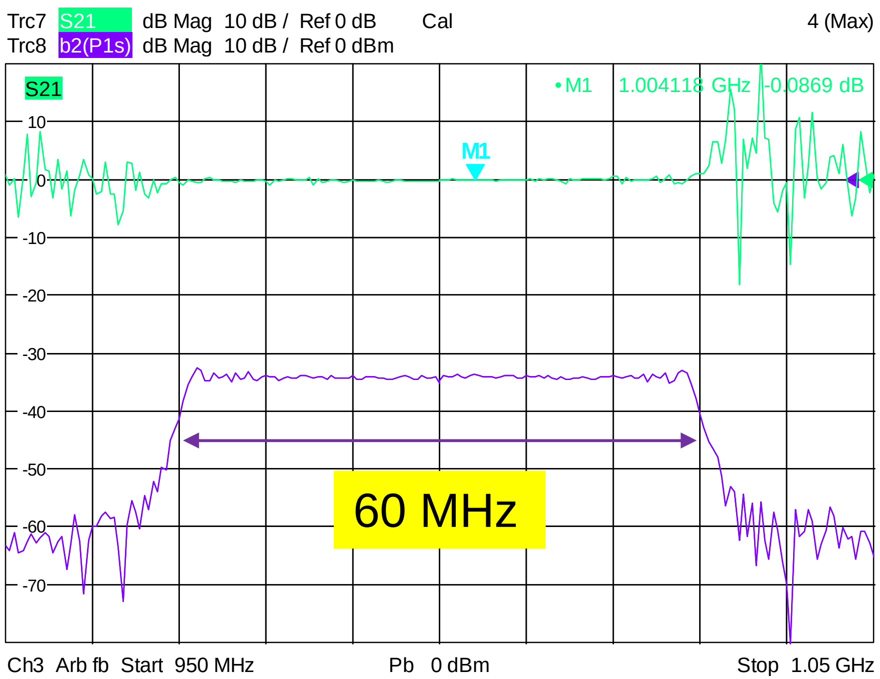
Influence of the Image Receiver Window

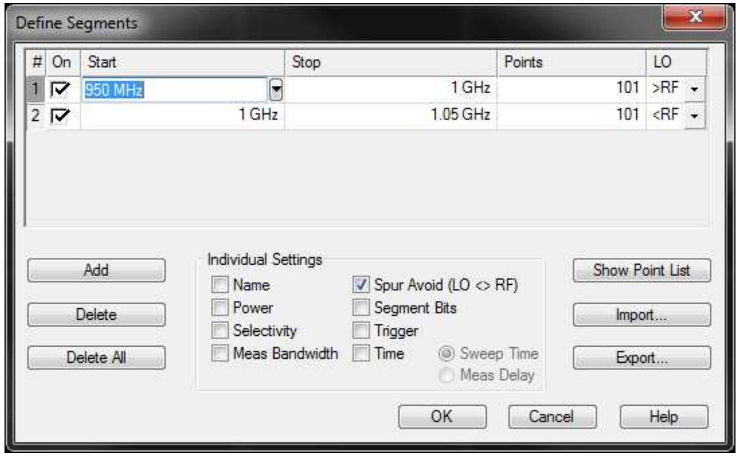


IF Image above measurement frequency

IF image below measurement frequency

S-Parameter Measurements using a 60 MHz Chirp



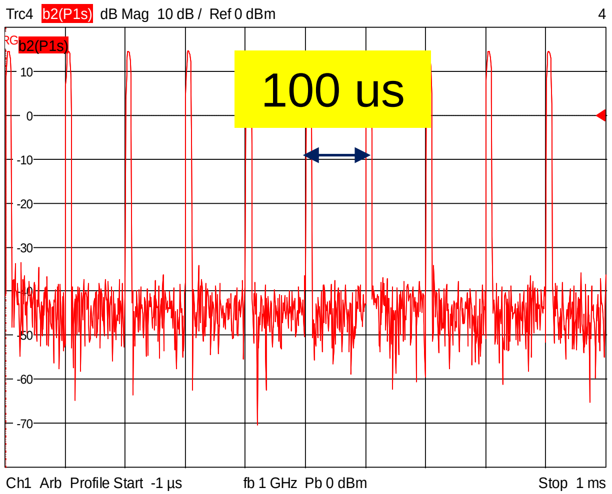


How to avoid Problems due to Image Frequency

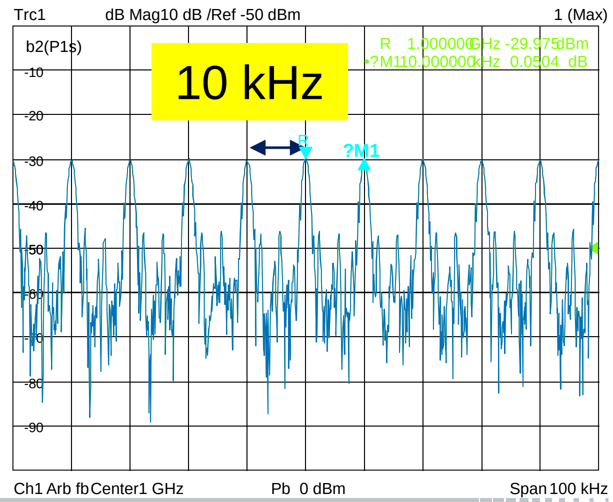
- Pulsed Chirp will provide discrete spectrum as soon as sampling time >> chirp repetition rate

- 100 us pulse frequency -> 10 kHz tone spacing

time domain



frequeny domain



ROHDE&SCHWARZ

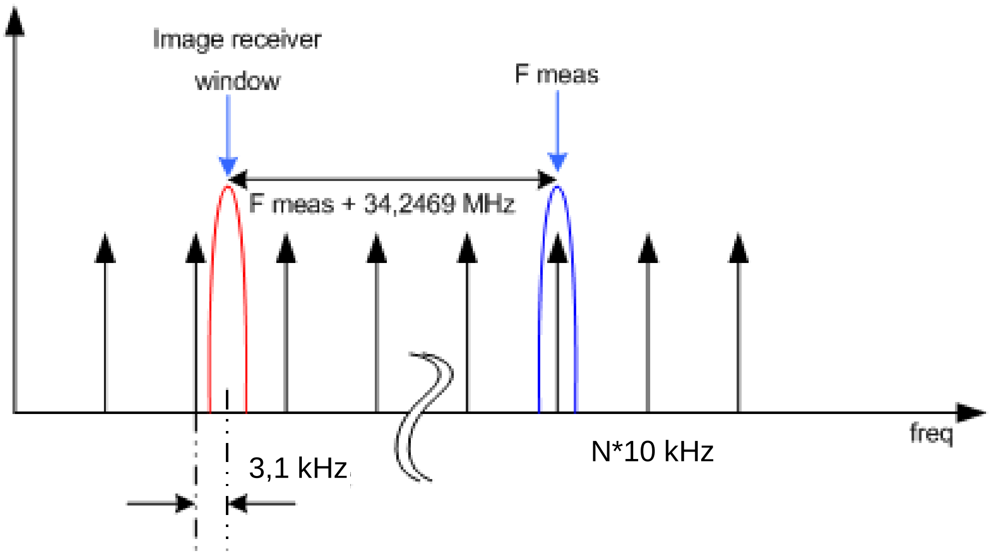
Shifting Image Frequency Window between the Carriers

- Multi-carrier signals have less problems with image frequency

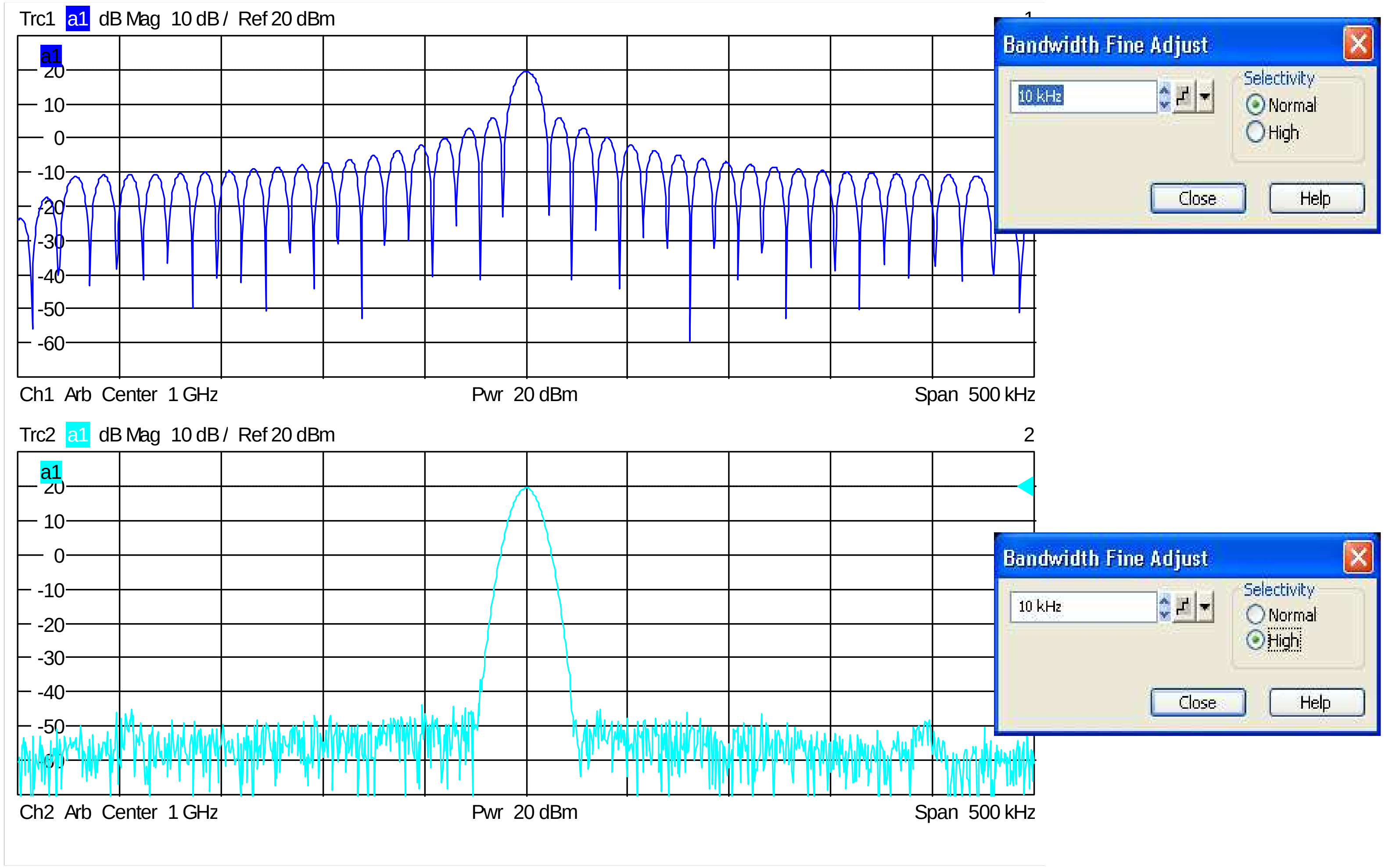
- Reason: „Odd“ value for the ZVA - IF frequency
  - 17,12345 MHz

- Image receiver window :
  - f meas ± 34,2469 MHz

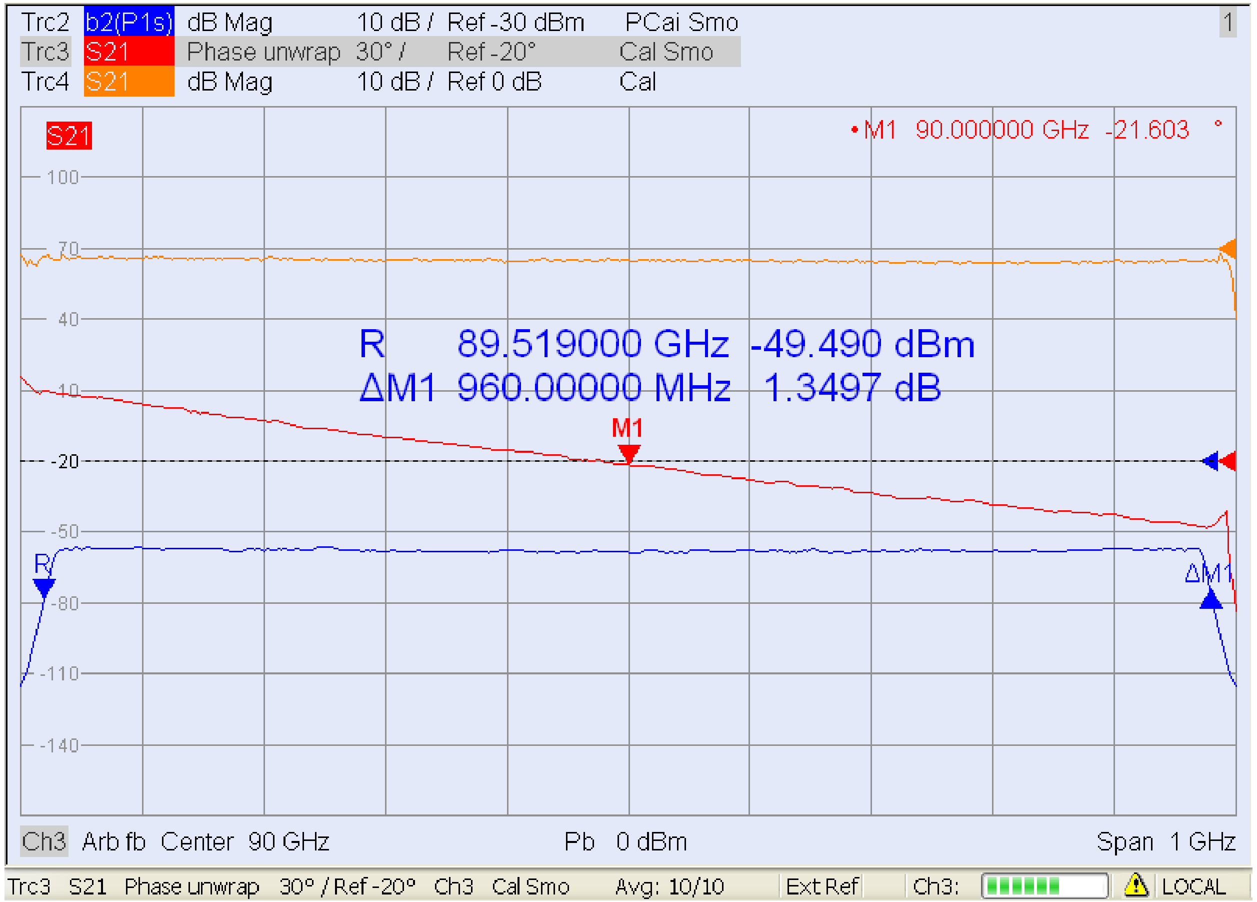
- Example:
  - Freq. carriers on 10 kHz grid
  - Image always 3,1 kHz apart
  - IF filter < 1 kHz recommended



High selective IF Filters to suppress adjacent Carriers



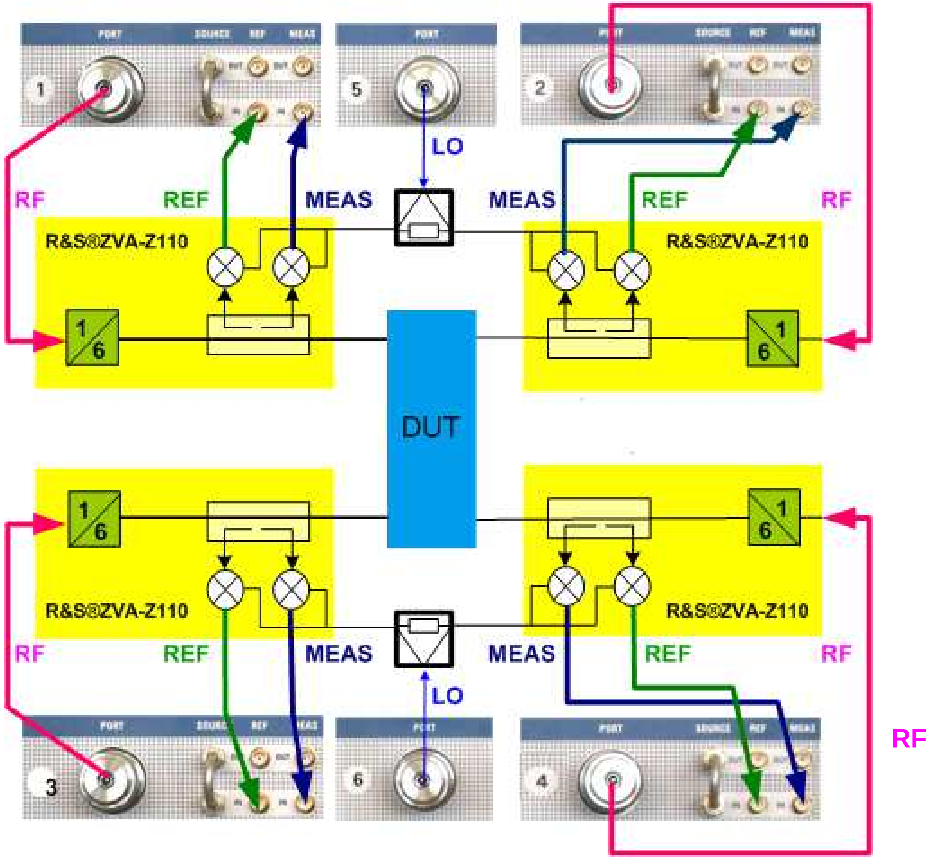
Measurement of a Waveguide Adapter with a 960 MHz Chirp



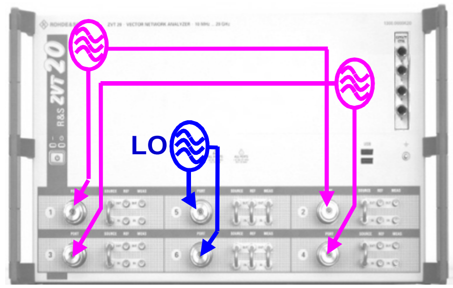
ROHDE&SCHWARZ

True Differential Measurements

The Setup with Converters in the mm-Wave Range

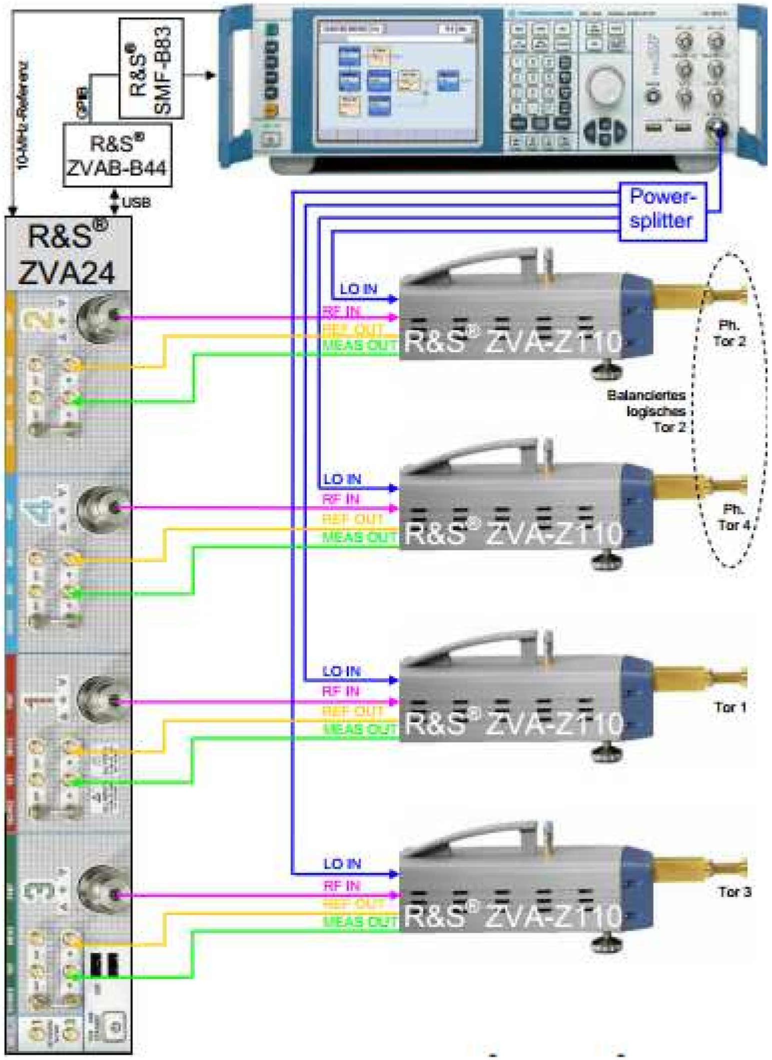


Base unit ZVT20

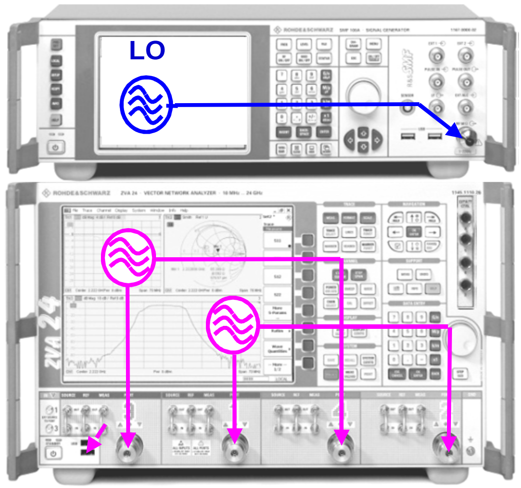


ZVT20 with 6 Ports and 3 sources

Setup with Converters in the mm-Wave Range

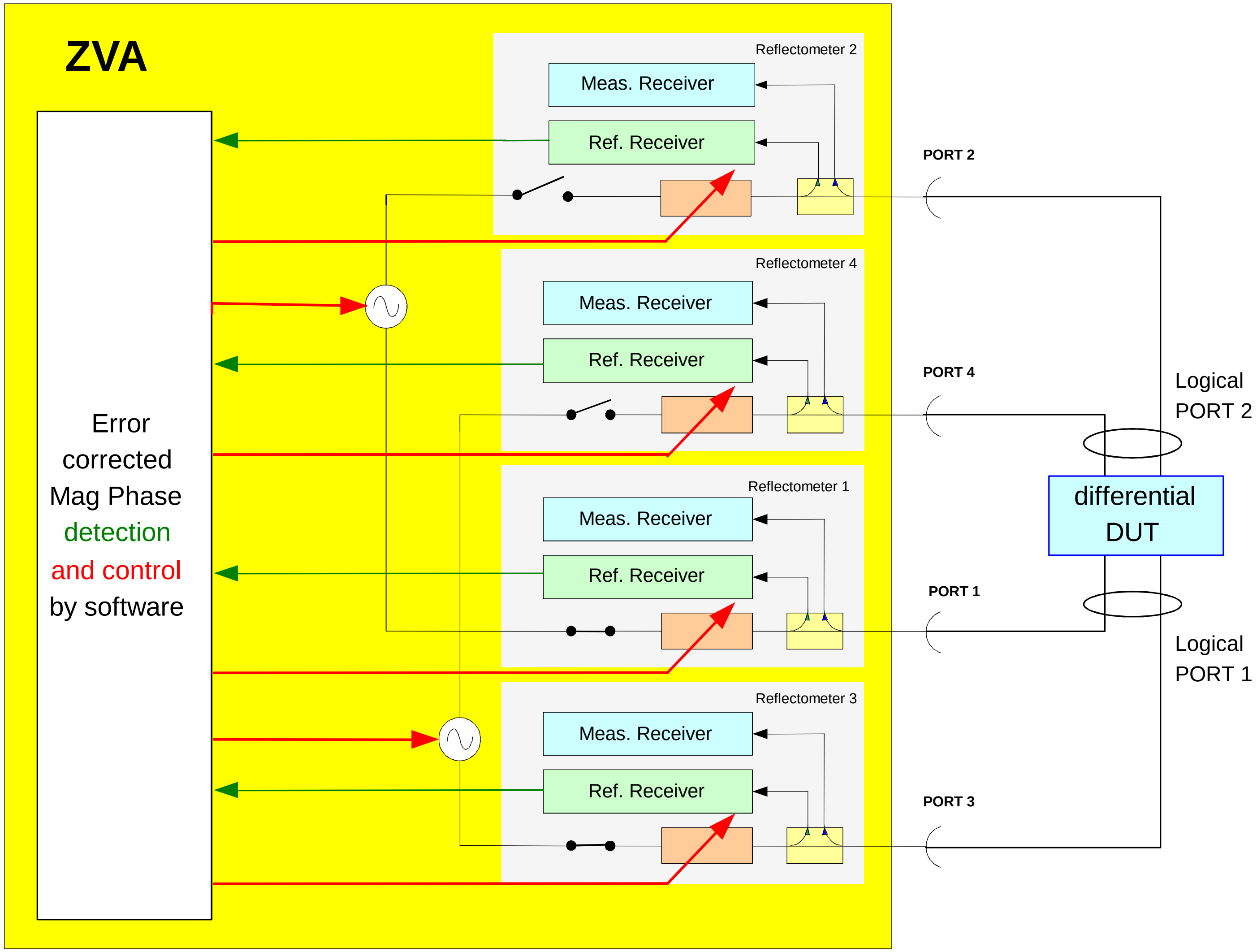


Base Unit ZVA



- External generator as LO source
- Controlled by ZVA via GPIB or LAN

Test Setup for TruDi up to 70 GHz



Generating True Differential and Common Mode Stimulus Signals

- Phase detection of the sources is done by the reference (a-) receivers
- Phase setting is accomplished by increasing the frequency of one source by a small amount for a defined time interval:

$$\Delta f = \frac{\Delta\varphi_w - \Delta\varphi_a}{360° \cdot \tau}$$

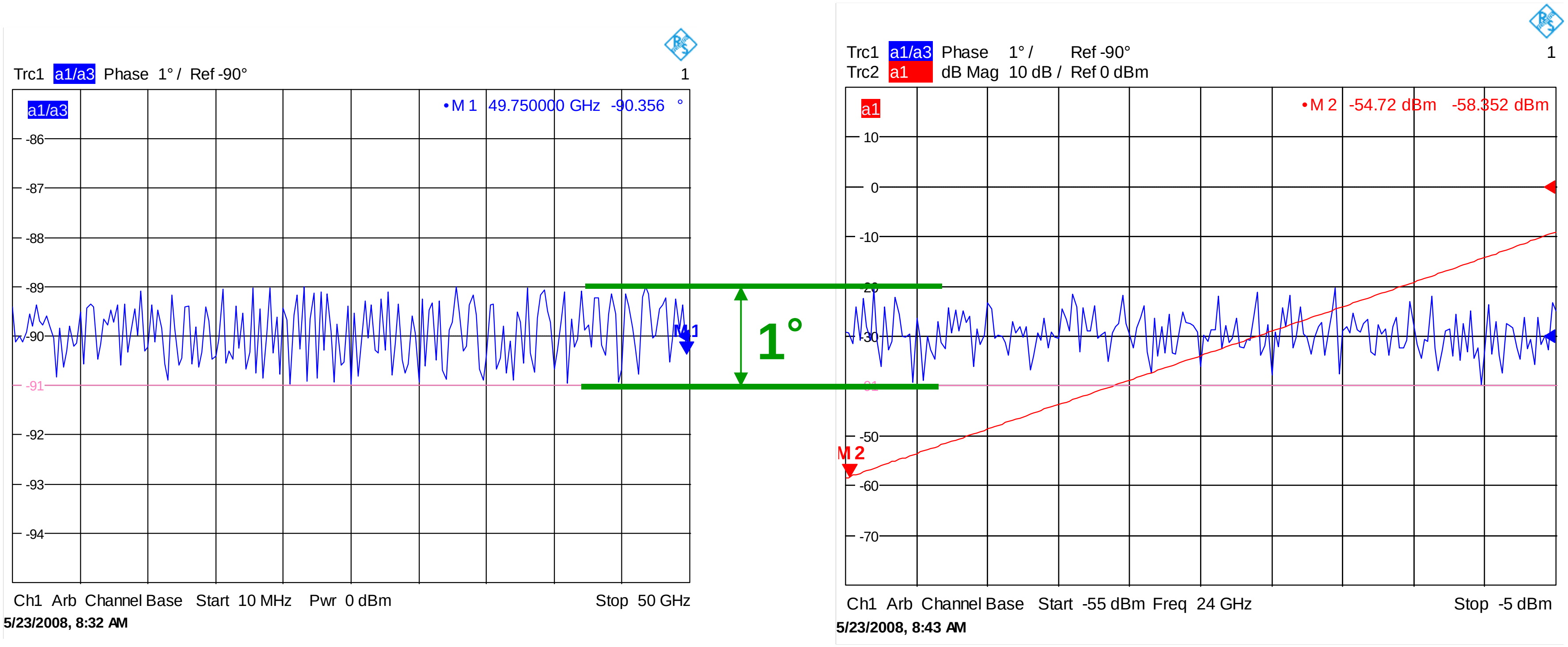
  - Δ**f:** **Frequency increment** (adjustable)
  - $\Delta\varphi_w$**:** **Wanted phase difference**
  - $\Delta\varphi_a$**:** **Actual phase difference**
  - τ**:** **Time interval (fixed)**

Stability of the Phase

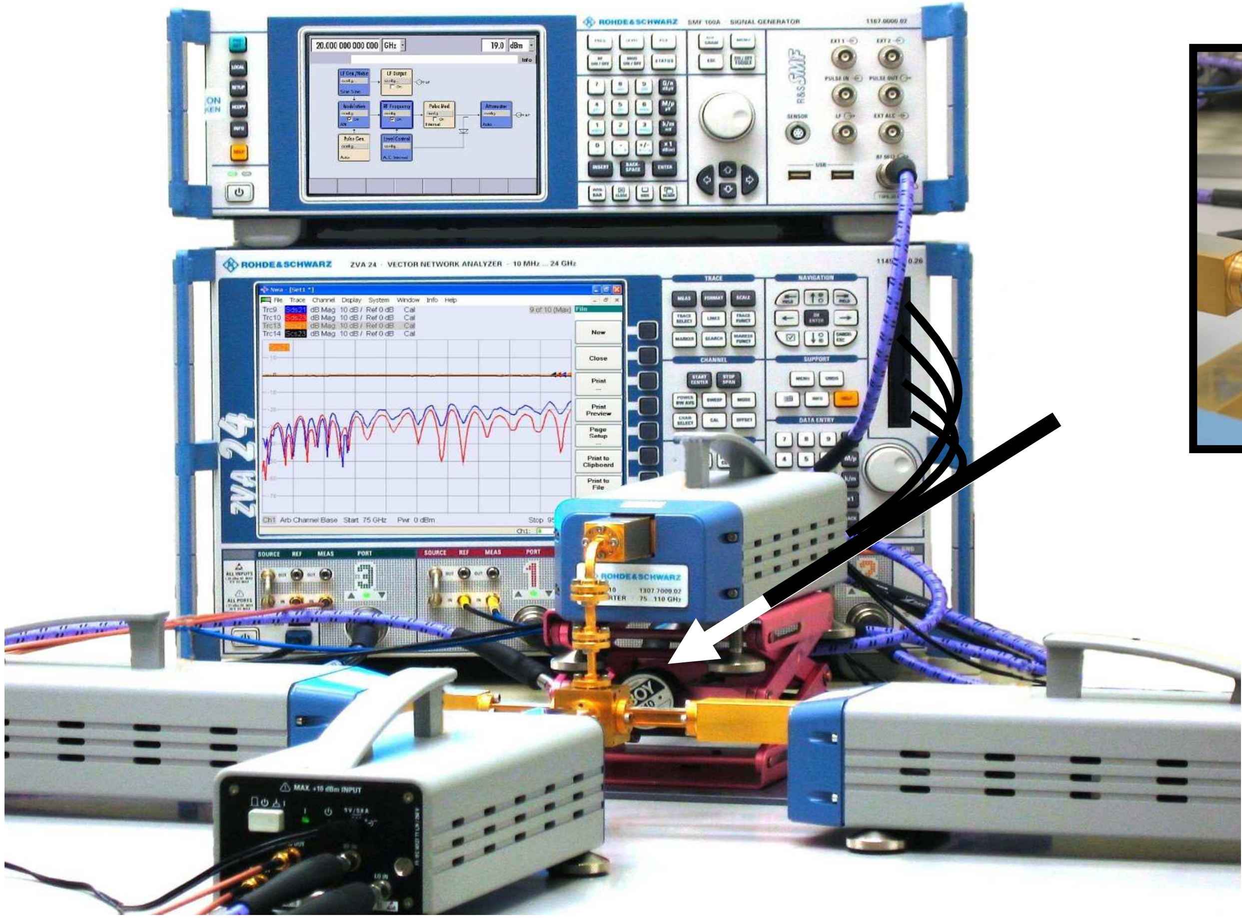
Phase accuracy depends on:

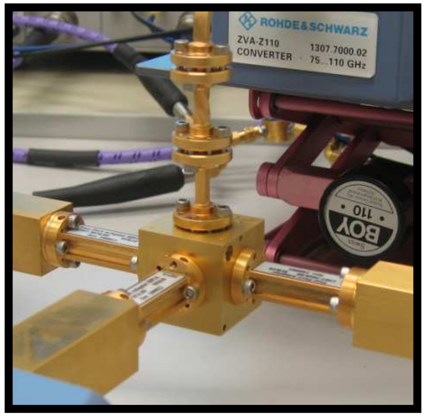
- Accuracy of system error correction
- S/N for phase measurement in the reference receiver
- System clock and IF frequency
- Used frequency offset for phase adjustment of the synthesizers
- Desired measurement time
- Current settings for 1° of phase stability

Phase Stability vs. Frequency and Power



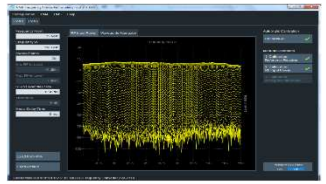
A linear Waveguide DUT Example (Magic Tee)





A linear Waveguide DUT Example (Magic Tee)

A&D symposium



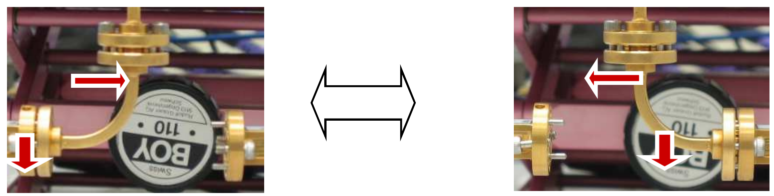
__1st Step:__

Power calibration of all reference receivers and generators using converter leveling tool and a power meter (waveguide sensor)

__2nd Step:__

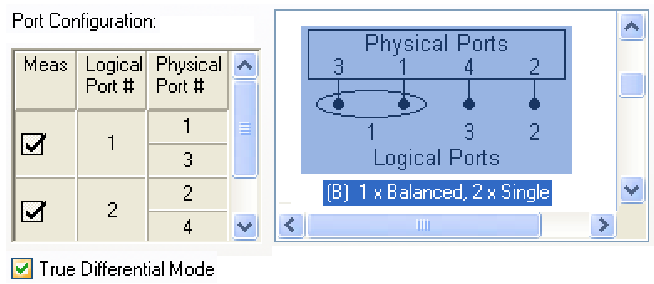
System error correction (waveguide cal. kit + bends as unknown Throughs

Note: Different polarization with E bends (compare “➡”)



__3rd Step:__

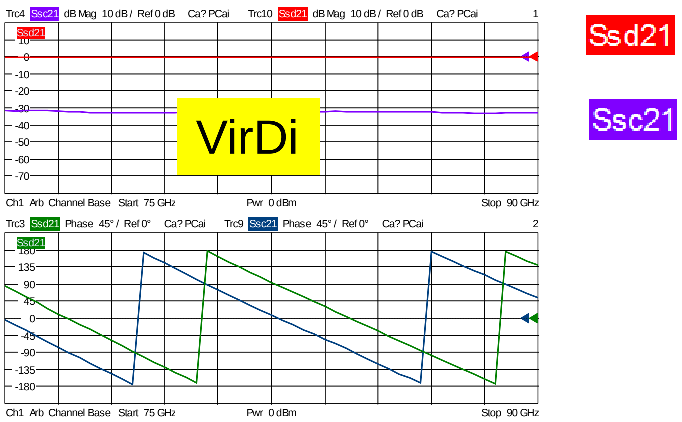
Balanced port assignment and activation of true differential mode (without check mark VirDi is used)

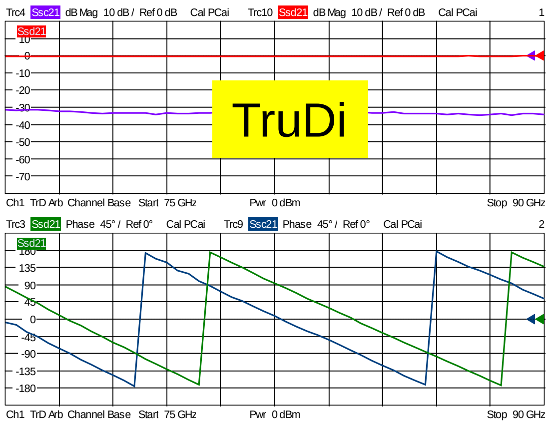


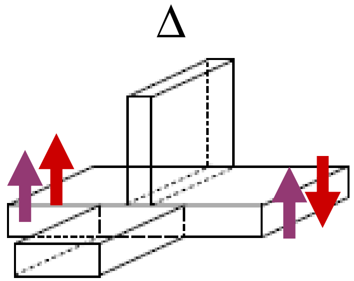
A linear Waveguide DUT Example (Magic Tee)

A&D symposium

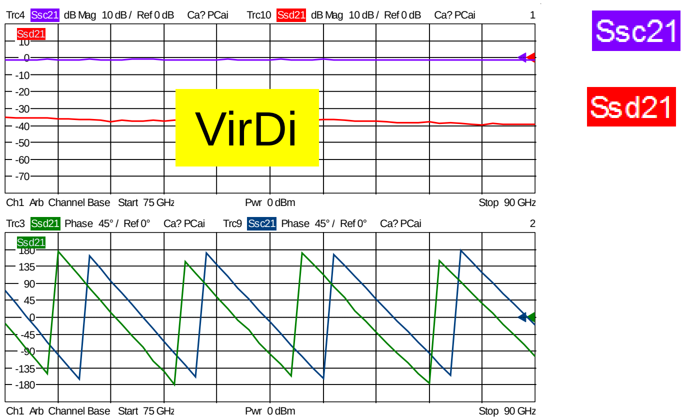
Result: Collinear ports to Δ port

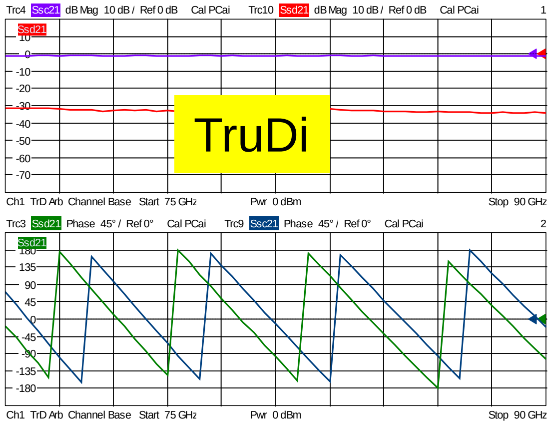


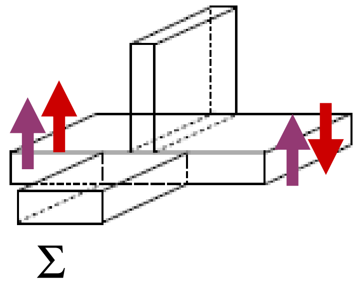




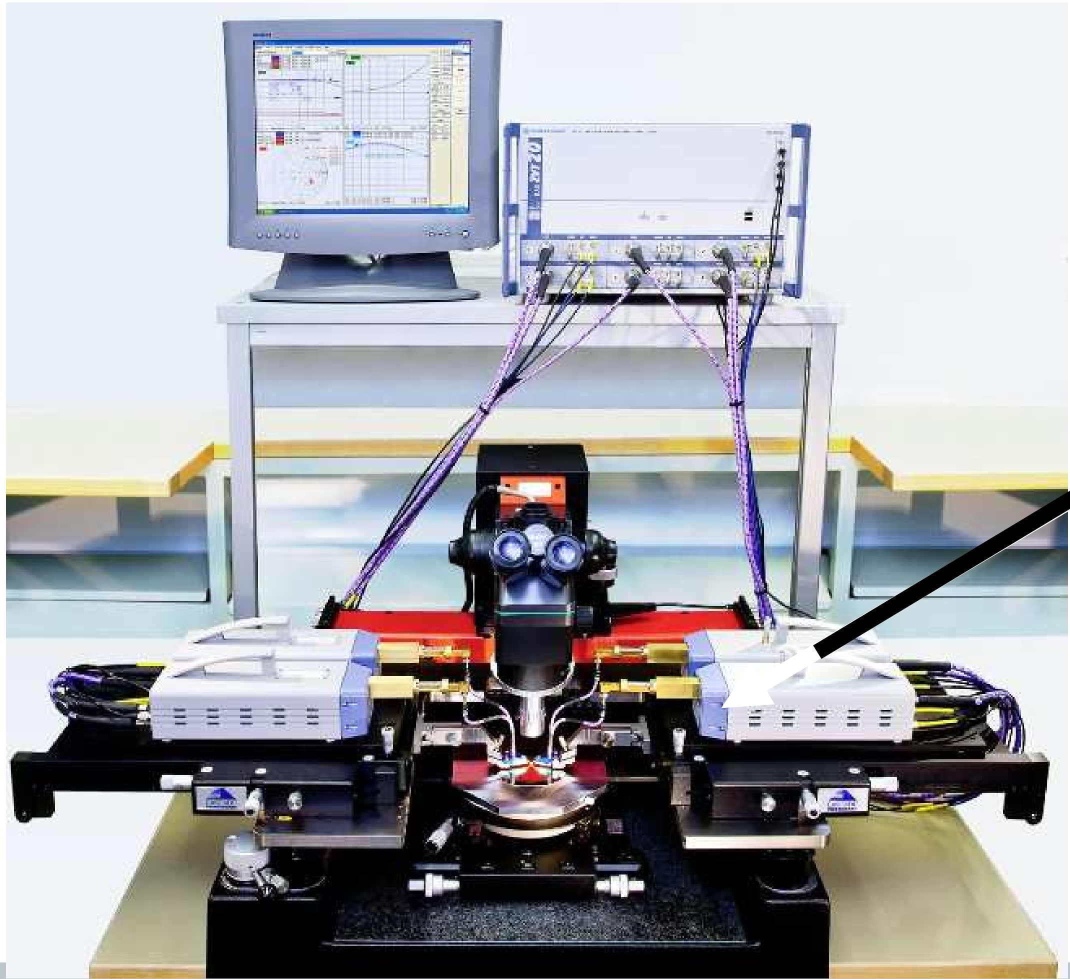
Result: Colinear ports to Σ port

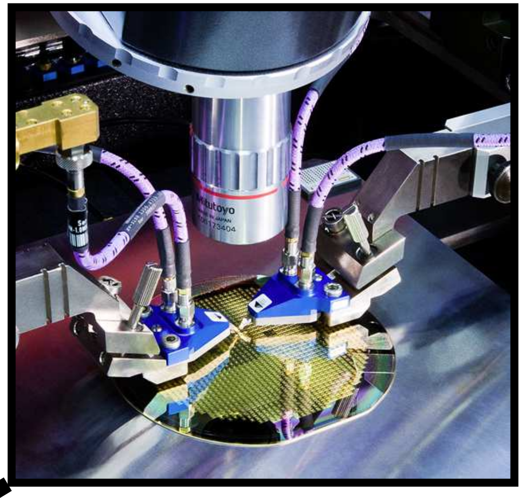


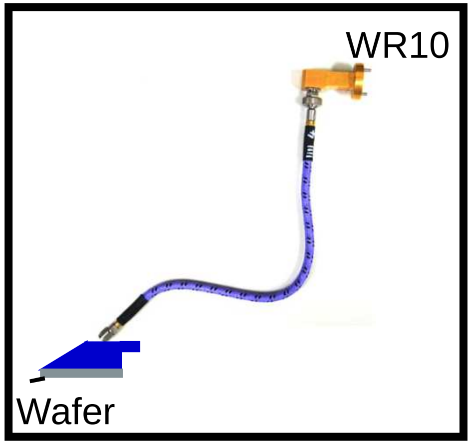




A nonlinear on-Wafer DUT Example (Amplifier)







A nonlinear on-Wafer DUT Example (Amplifier)

symposium

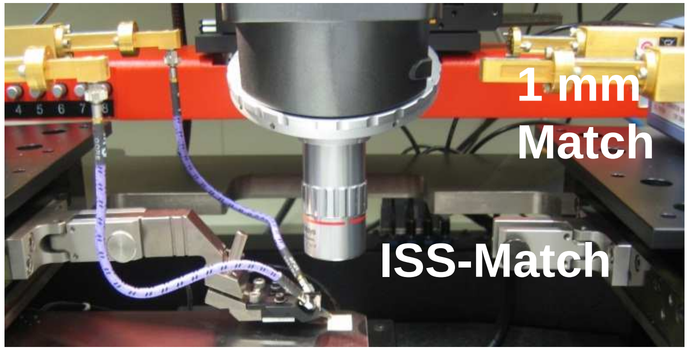
1st Step: UOSM cal. to characterize the connection between coaxial interface and on-wafer reference plane

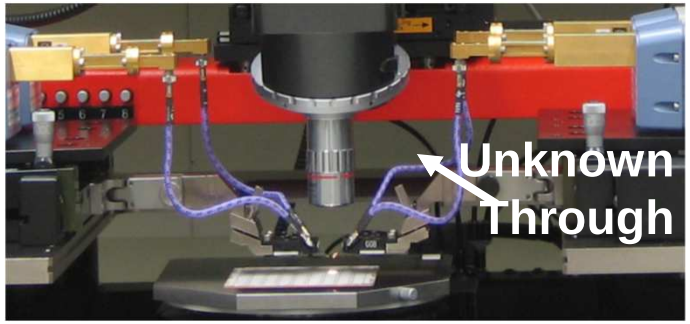
⇒ Power loss list for each port

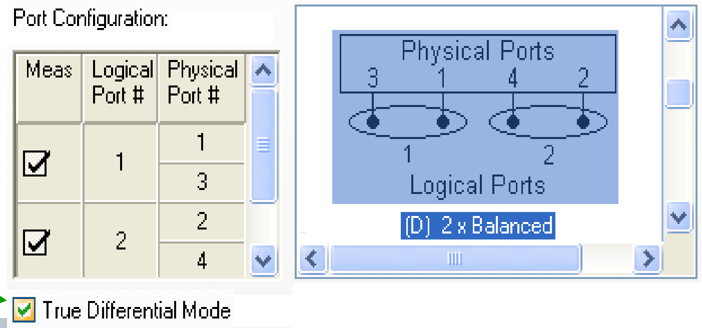
2nd Step: Power cal. At the coaxial interfaces using the power loss list from 1st step.

3rd Step: System error correction with on-wafer using ZVA firmware or WinCal™ with downloading error terms to ZVA

4th Step: Balanced port assignment and activation of TruDi (without check mark VirDi is used)

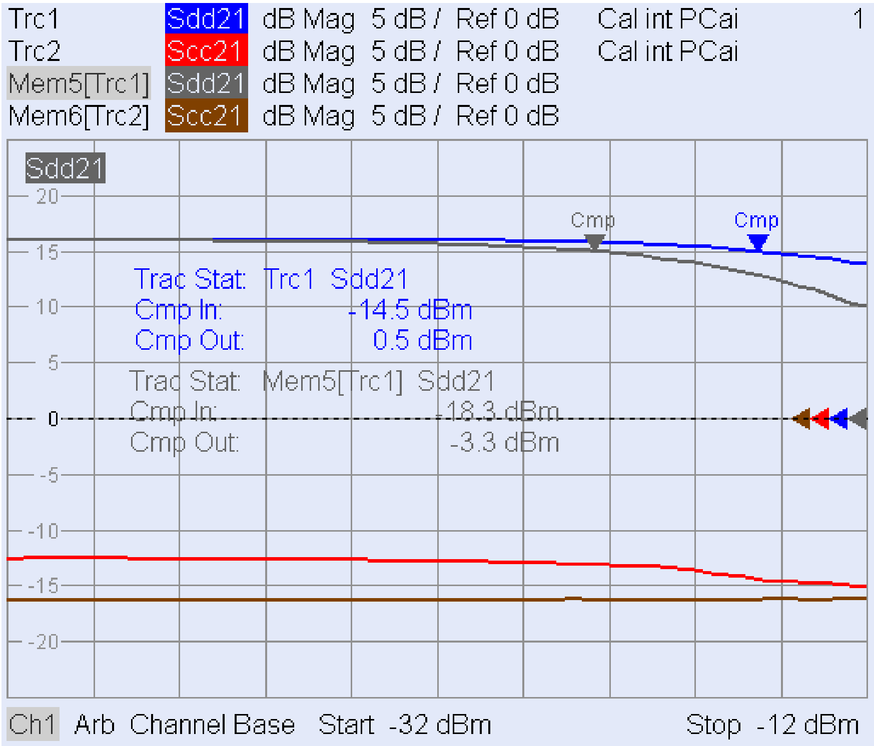


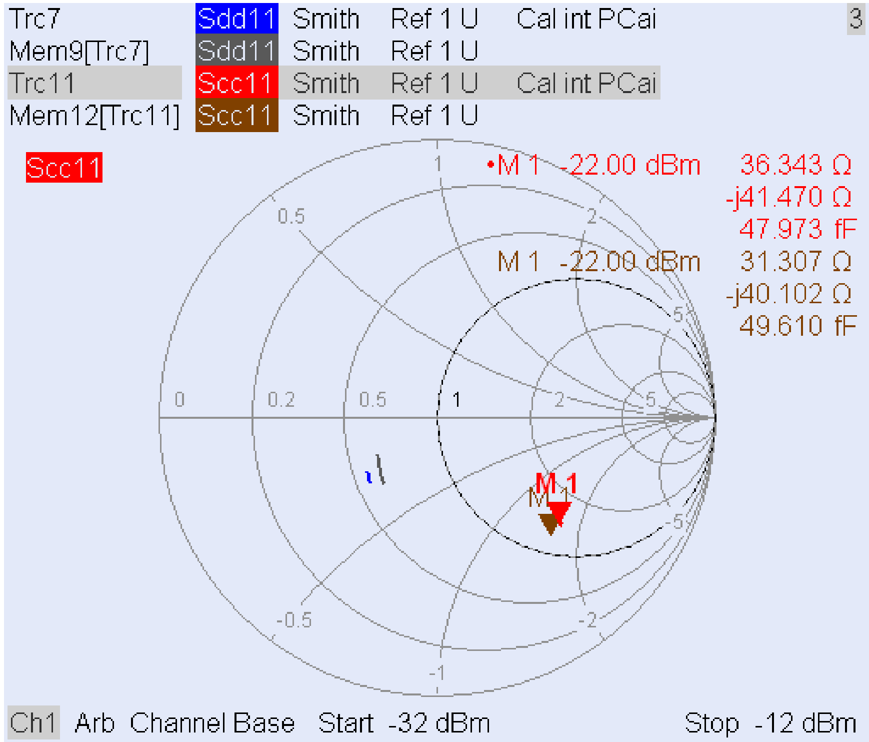




Nonlinear on-Wafer DUT Example (Amplifier)

Results: Power sweep at 80 GHz

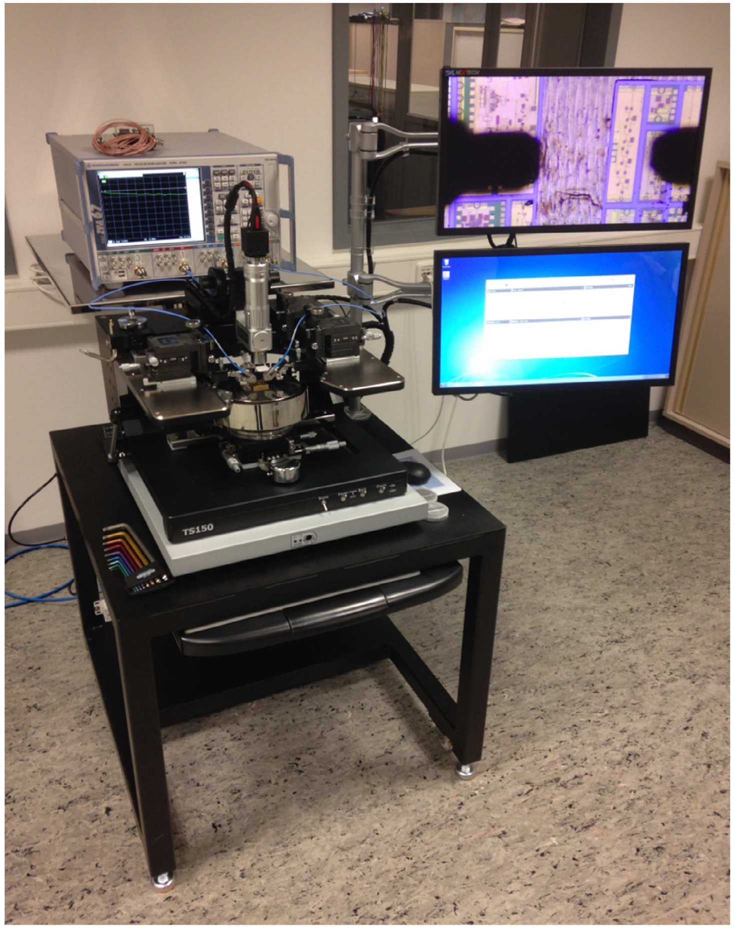




Memory traces	= TruDi results
Active traces	= VirDi results

Wafer Prober Measurements

OnWafer System Providers



Cascade
- WinCal support of ZVA, ZVT
- Mechanical adaption of mm-wave converters, ZVA110

Semiprobe
- Support of ZVA

MPI
- Support of ZVA, ZNB, ZVT in QAlibria software
- Mechanical adaption of mm-wave converters, ZVA110

Signatone (local cooperation)

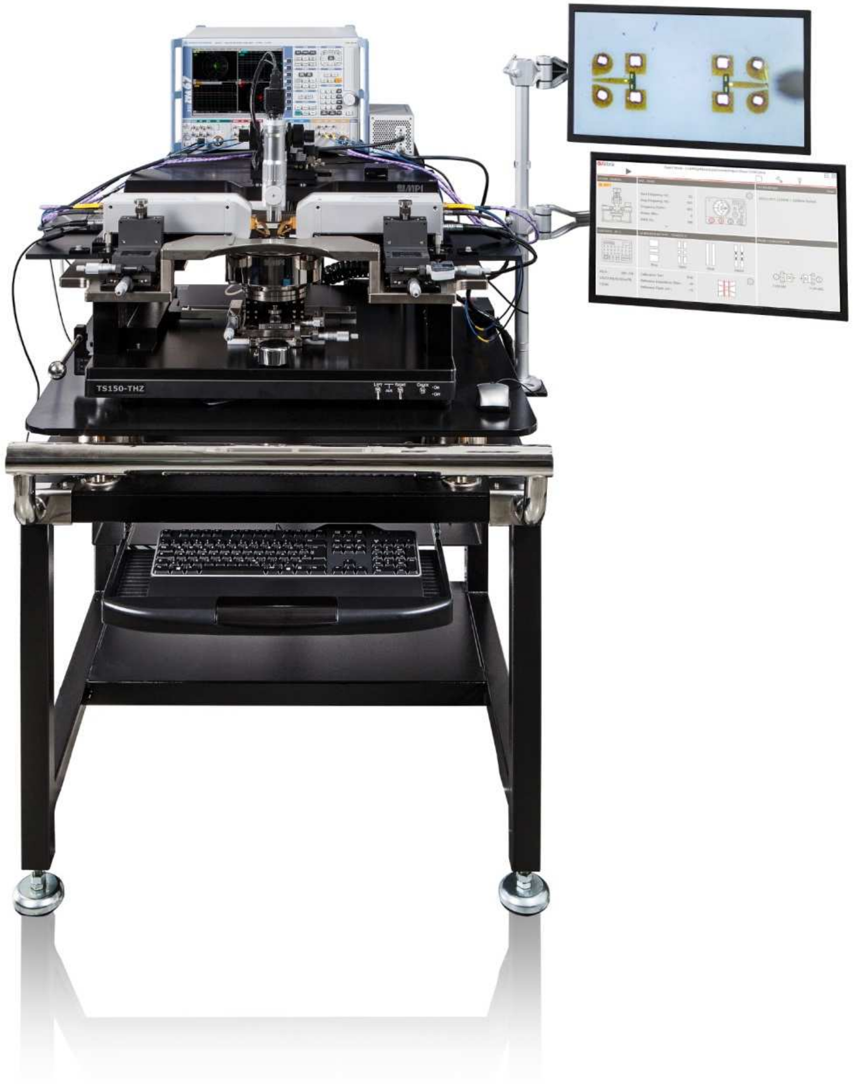
Millimeter On Wafer setups

Rohde & Schwarz converters have been developed to work in conjunction with many manufactures of wafer probers

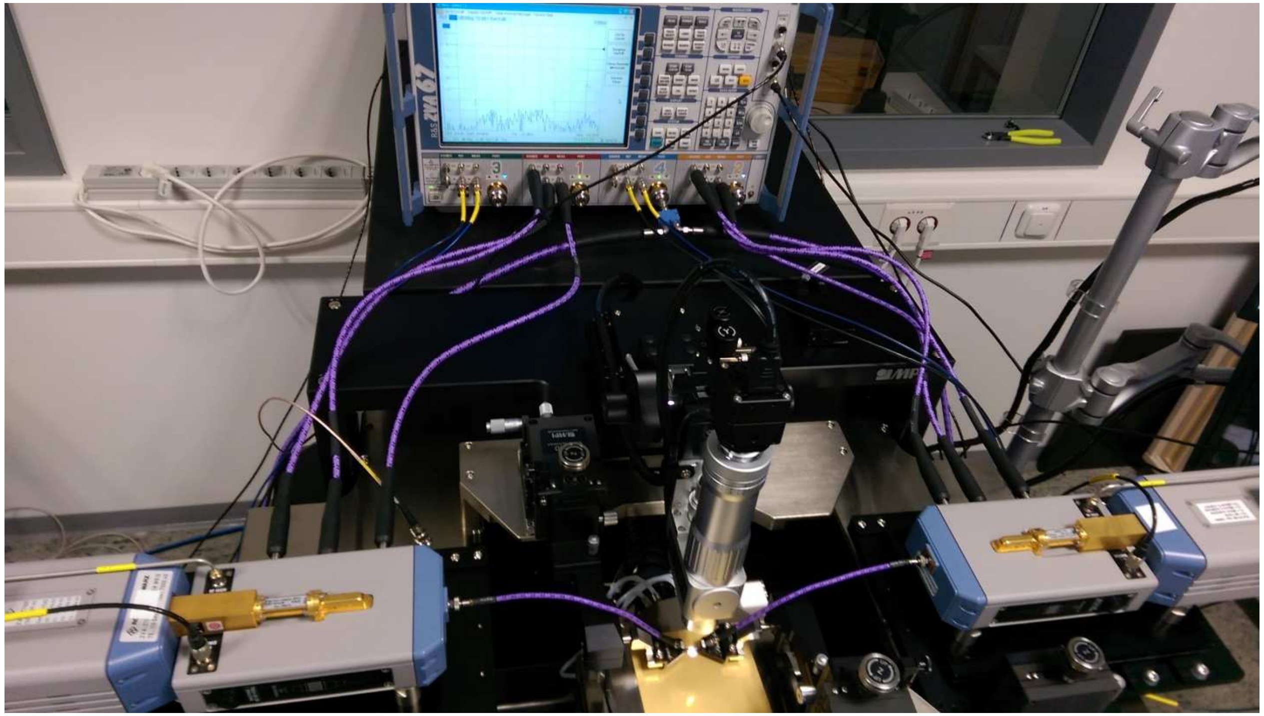
Probe stations already prepared for mounting of Rohde & Schwarz converters

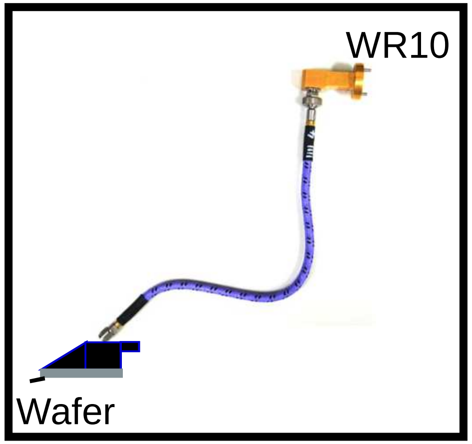
The ZVA network analyser is fully integrated into the software packages

TS150-THZ
Millimeter Wave System



Power Calibration on the Wafer





Challenges for accurate Power Levels

Goal : Power calibration in the reference plane of the DUT (amplifier)

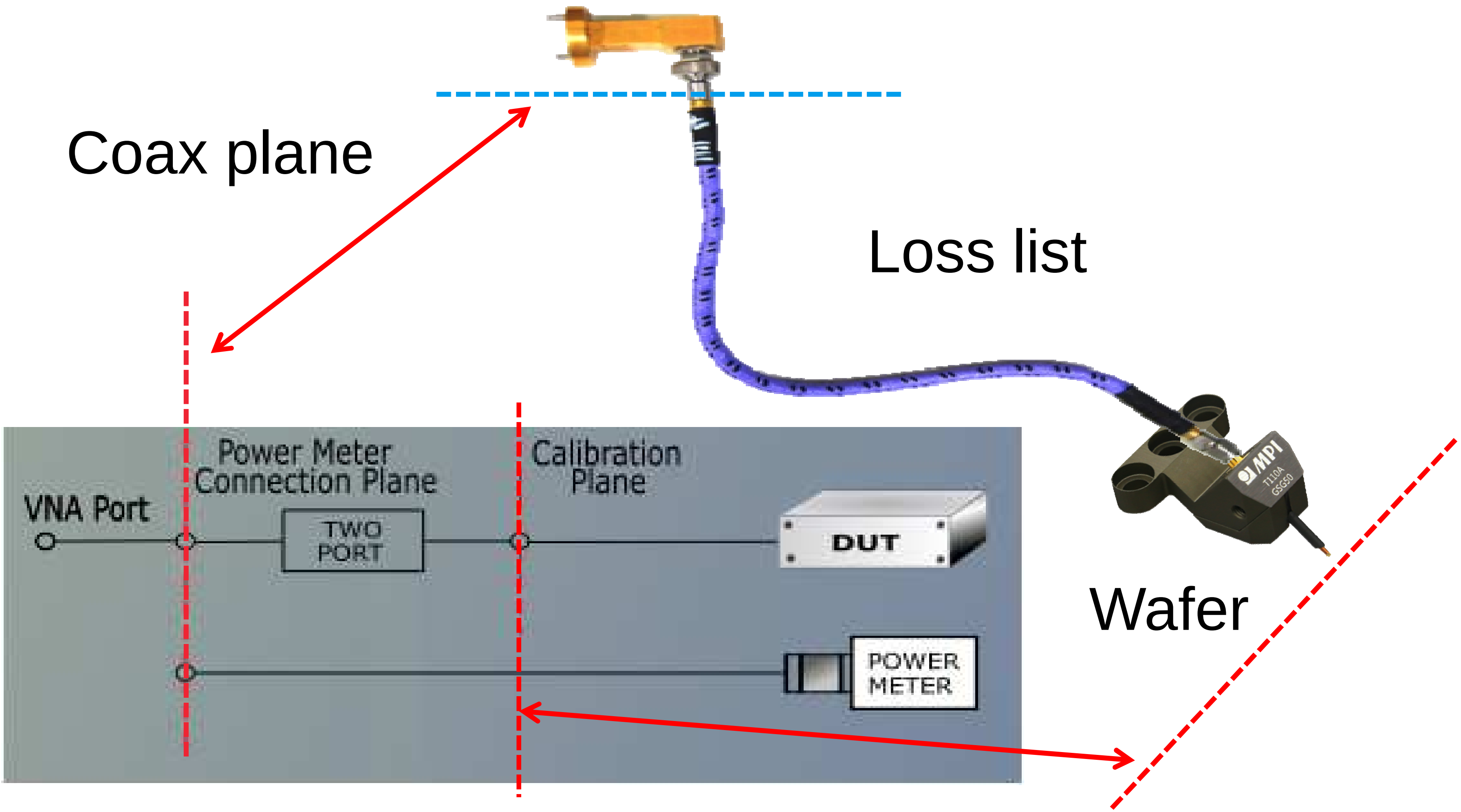
Problem : No access with coaxial power meter possible

Solution:

- Characterization of the S-parameter between coaxial interface and the wafer prober tip

- Correction of the coaxial power calibration with this loss list

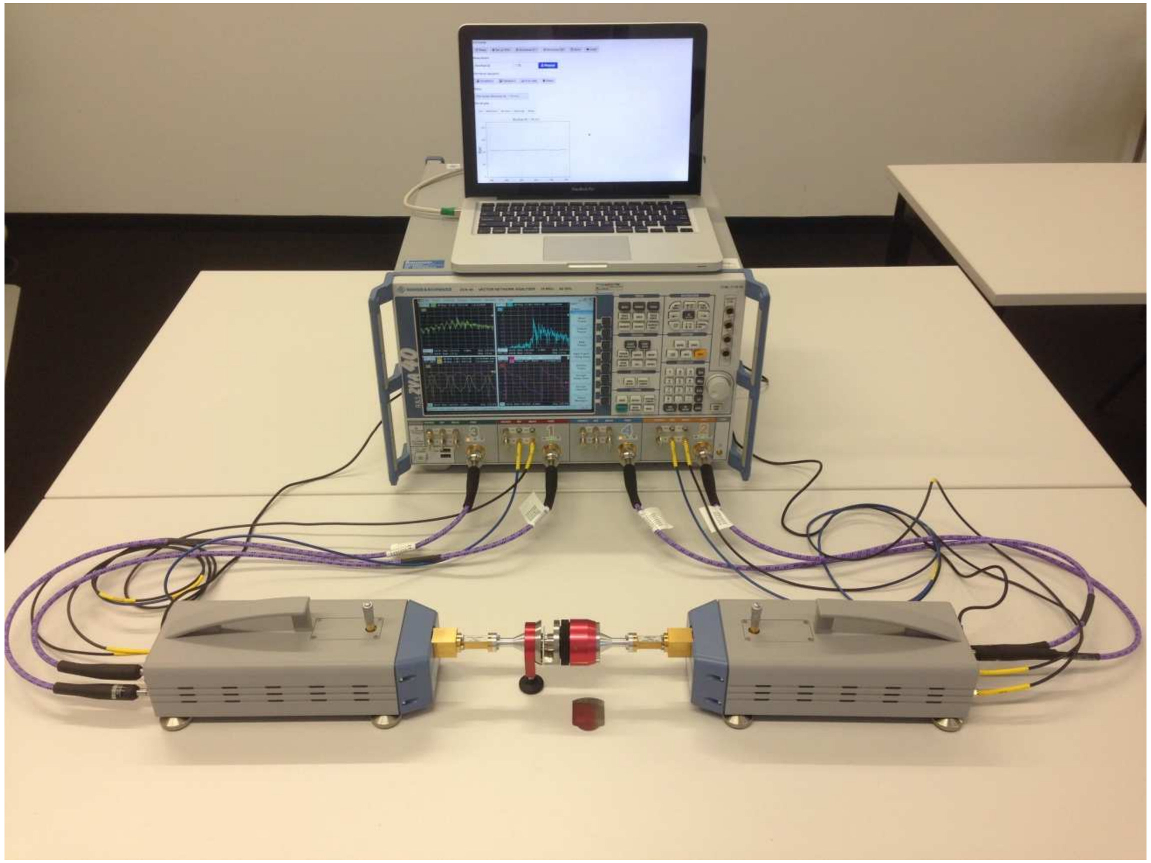
Power Correction with Loss List



Material Measurements

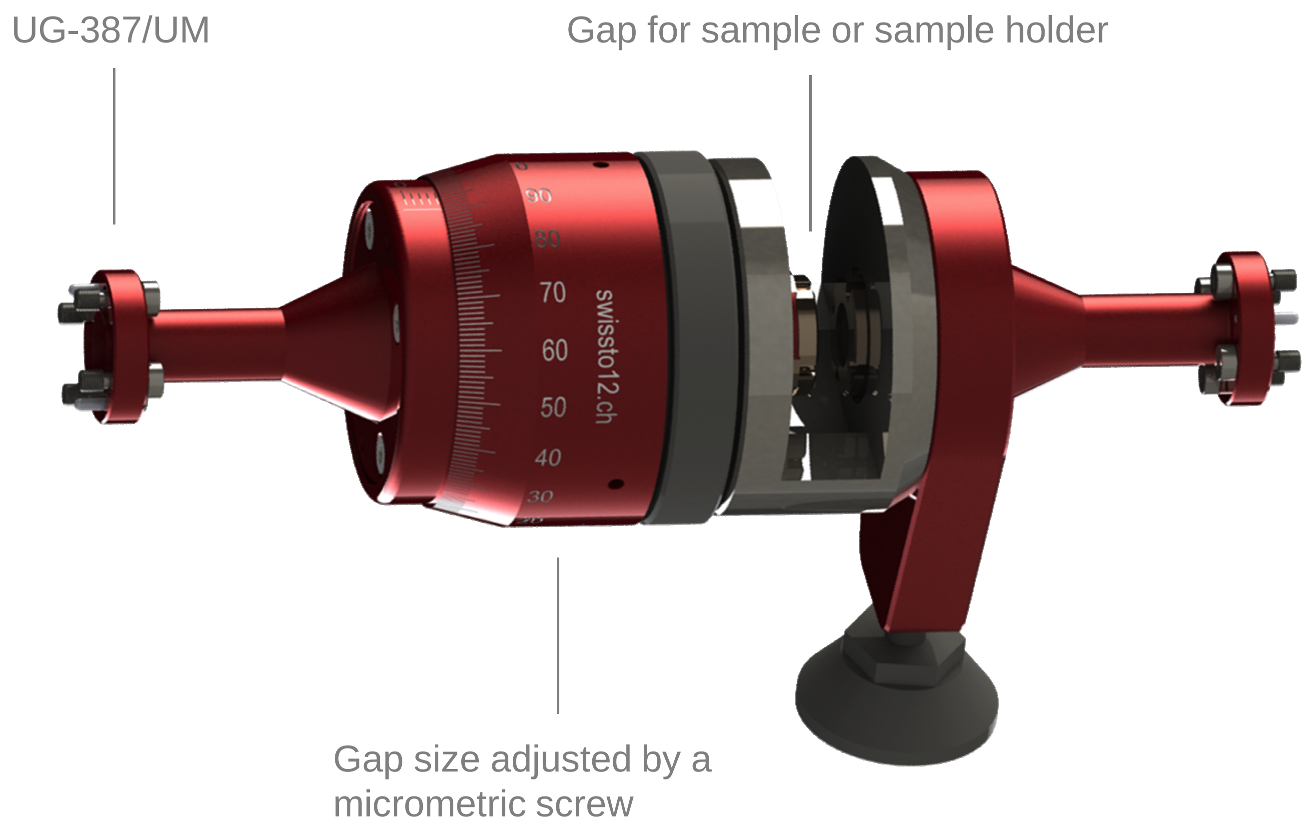
Swissto12
terahertz applications

A&D symposium

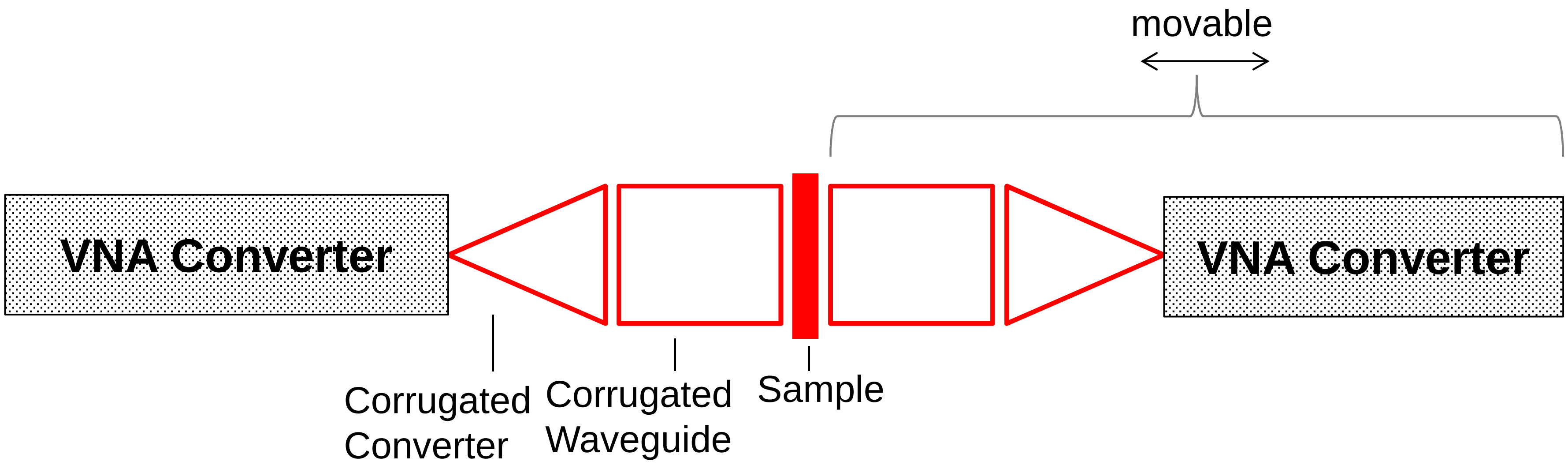


ROHDE&SCHWARZ

Material Characterization Kit
Image of WR 5.1 band (140-220 GHz)



Material Characterization Kit (MCK) Concept: 2-Port configuration (S11, S21)



- The sample is clamped into a gap between two Corrugated waveguides
- “guided free-space” approach
- Samples are exposed to a beam with a plane phase front
- Minimum measurement configuration, needs only S21 and S11 data

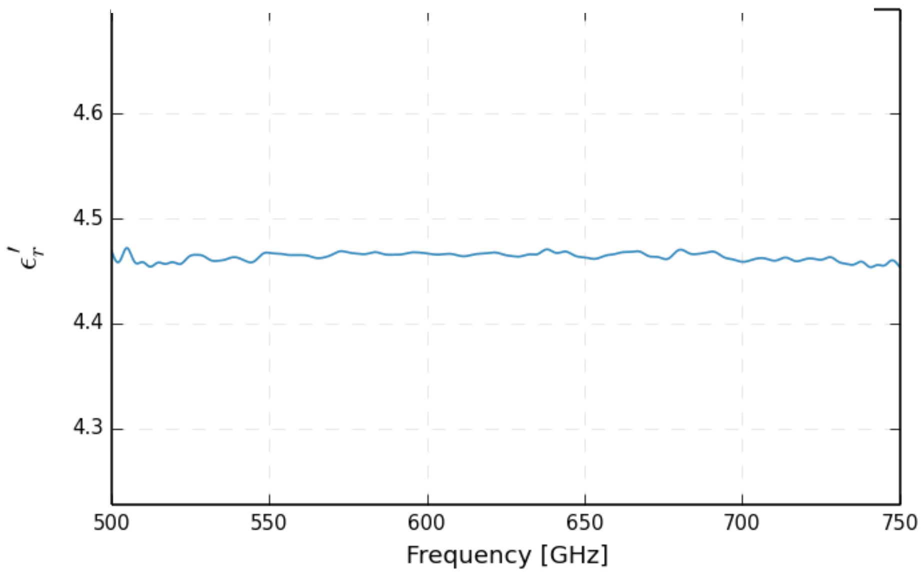
Material Characterization Kit (MCK)
Fast Measurement Sequence

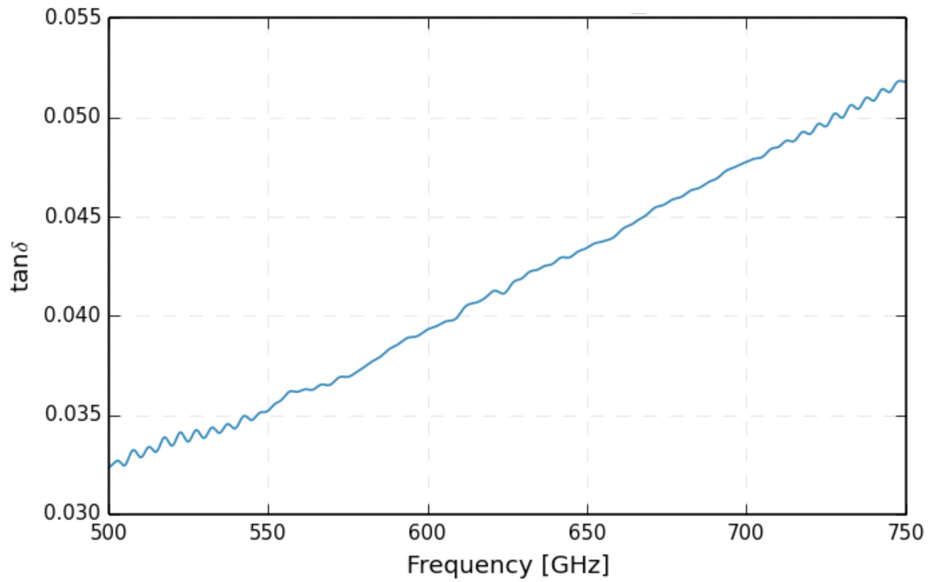
A&D symposium

- Re-normalize the S21 raw data: “through” configuration
- Re-normalize the S11 raw data : “short” configuration
- Clamp the sample, Acquire S21 and S11
- Post-process the S parameter data with a dedicated software to extract material properties (Epsilon and Tan(delta))
- µ currently not possible to extract

Material Measurement

Example : Schott Borofloat 33





Rohde & Schwarz – The Partner for mm-Wave Applications

We design, produce and service the complete portfolio in house

- Components
- Frequency multipliers
- Harmonic mixers
- Modules for generators, spectrum analyzers and network analyzers
- Power meters up to 110 GHz

We don‘t have to rely on or wait for third party companies