Satellite Test

ACTIVE PHASED ARRAY ANTENNAS – KEY ENABLERS OF FUTURE SATELLITE COMMUNICATION NETWORKS

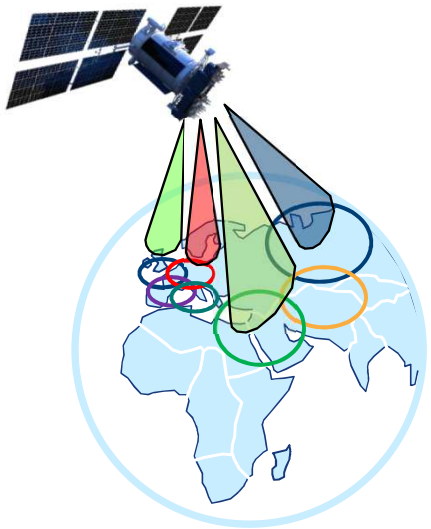
Yvonne Weitsch
Market Segment Manager Satellite Test

ROHDE&SCHWARZ
Make ideas real

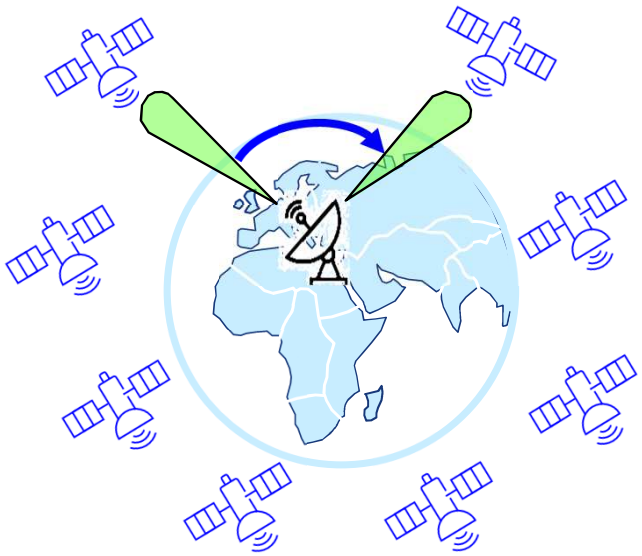
ANTENNA REQUIREMENTS FOR FUTURE SATCOM SYSTEMS

Flexible and reconfigurable beamforming: Active antennas are key to achieve these targets.

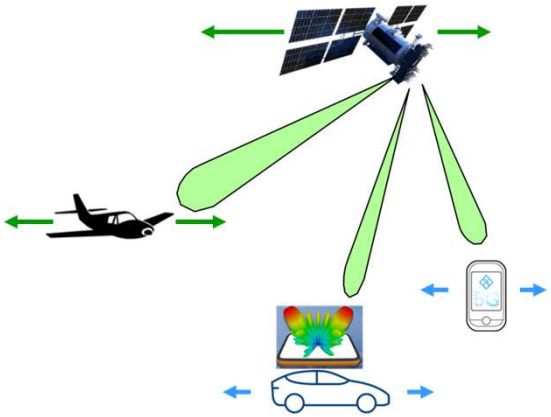
HTS and VHTS



Mega-constellations

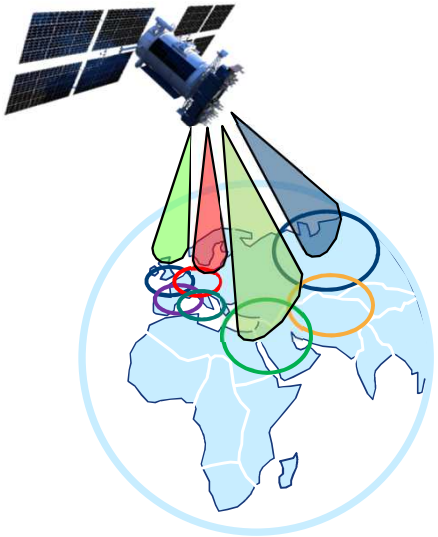


Non-terrestrial NWs in terrestrial mobile NWs

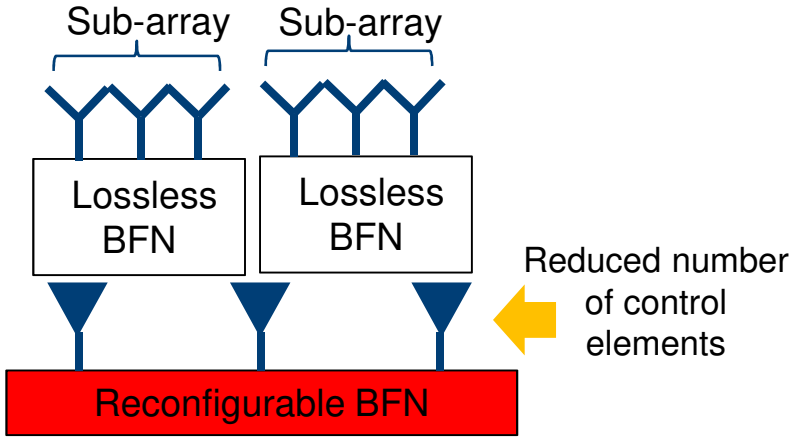


VERY / HIGH-THROUGHPUT SATELLITES

Challenge: Reconfigurability in terms of coverage, large number of activated beams, beam pointing and dimension.



Solution: Advanced smart antenna systems



Key facts

- VHTS: 1000s of beams, up to 1 Tb/s.
- Broad bandwidth, Ka, Q/V band, frequency-re-use, beam-hopping.
- Hybrid beamforming is favored.

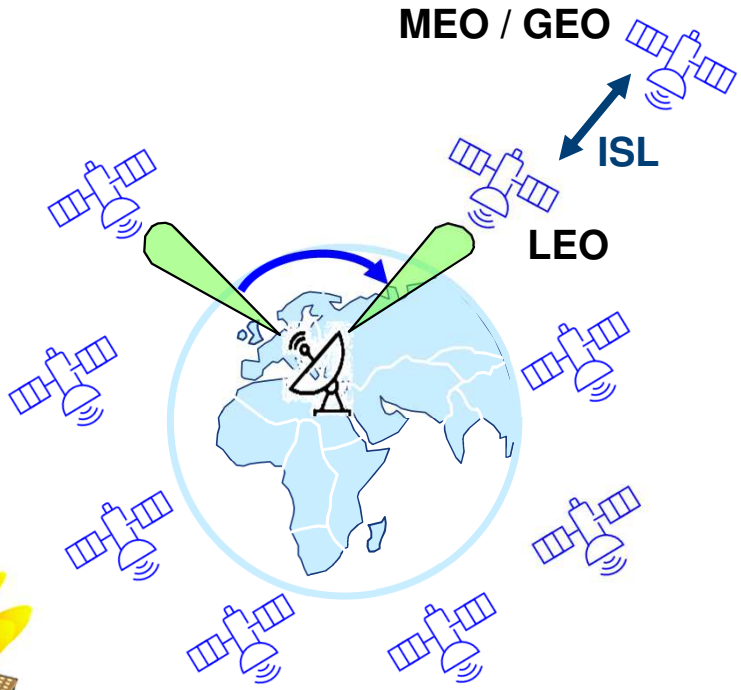
SATELLITE MEGA-CONSTELLATIONS

Challenge: **Compact cost-efficient** antennas, providing high throughput and **multiple beams** with **increased scanning angles**.

Key fact: Mobility market is increasing.

Solution:

- Phased array antennas based on **new technologies**.
- **Integrated antennas** for small terminals ready for mass market.



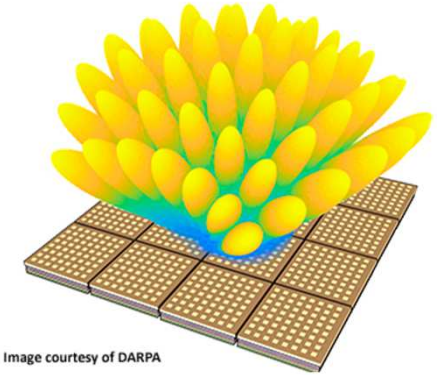


Image courtesy of DARPA

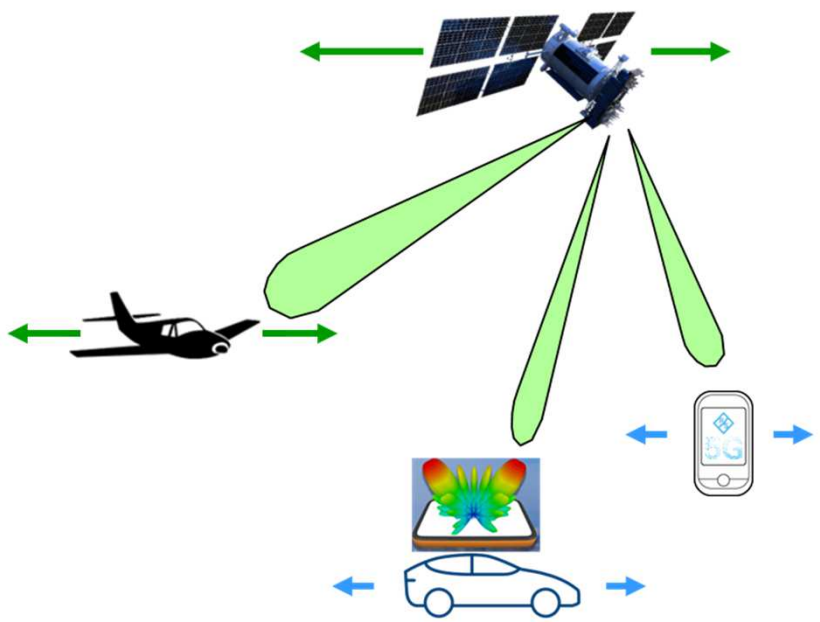
Source:Microwavejournal, https://www.microwavejournal.com/articles/33357-comprehensive-survey-of-commercial-mmwave-phased-array-companies

NTN IN MOBILE COMMUNICATION NETWORKS

Challenges: Path loss, non-linear channels, delay, mobility of satellites and users, standardized interfaces,...

Solutions:

- **High-power amplifiers** together with **beamforming** techniques.
- **VHTS on LEOs** for short latency communication.
- **Ephemeris data** of satellite and **GNSS** functionality of user receiver.



ANTENNA REQUIREMENTS FOR FUTURE SATCOM SYSTEMS

- Increased number of beams
- Large angular field of view: up to 60% scanning
- Possibility of digital and optical beamforming
- **Reconfigurability**: Coverage, number of activated beams, beam pointing and dimension
- Increased frequency BW, i.e. 10% as compared to central frequency
- Compact: Integration of dual polarizations and T/R functionality
- Smaller & cheaper antennas for constellations

Active phased array antennas are key to achieve these targets.

Source: ESA: https://youtu.be/nKeBvQRIvts

ACTIVE ANTENNAS: TEST REQUIREMENTS

- **OTA:** Over-The-Air: Whenever a system needs to be measured under operation-like conditions and the passive antenna RF I/O cannot be accessed.
- Active antennas include active components (SSPA's, LNA's) and narrow band components (filters), which affect the end-to-end performance of the payload.
- If active elements are involved: The transmit and receive case are to be considered separately, since the system is non-reciprocal.
- The test parameters change from classical radiation characteristics to end-to-end characteristics.

ANTENNA PARAMETERS

Passive antenna systems

Conducted

- Input impedance
- S-parameters (reflection, transmission)
- Bandwidth

Radiated

- Radiation characteristics
  - Direction, HBPW, side lobe level
- Co-/ cross-polarization
- Radiated power, directivity, gain

Active antenna systems (SSPAs, LNAs, filters)

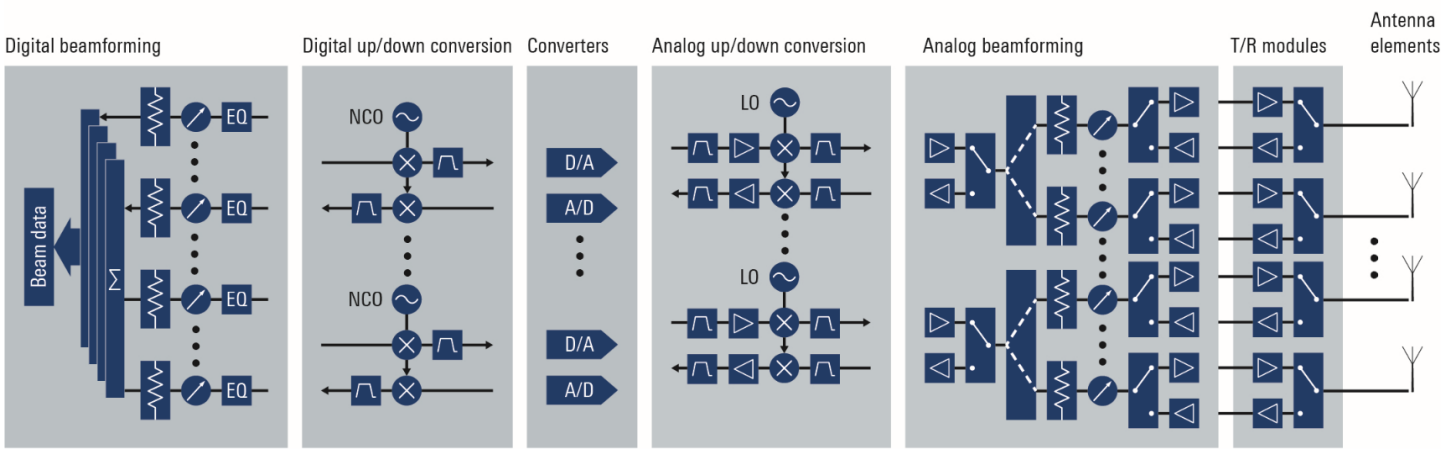
Conducted / OTA measurements of each active signal chain

- S-parameters over frequency range and dynamic range
- In-band parameters: gain flatness, group delay variation,…
- Spurious out-of-band
- Noise Power Ratio
- Antenna noise figure
- Input saturation level
- 1-dB compression level (at antenna output)
- Third-order intermodulation distortion
- **E**quivalent **I**sotropically **R**adiated **P**ower
- **G**ain-to-Noise-**T**emperature ratio G/T

HIGH NUMBER OF SIGNAL PATHS

VHTS: >1000 active beams plus high level of flexibility.

► Many signal states and signal paths are to be measured.

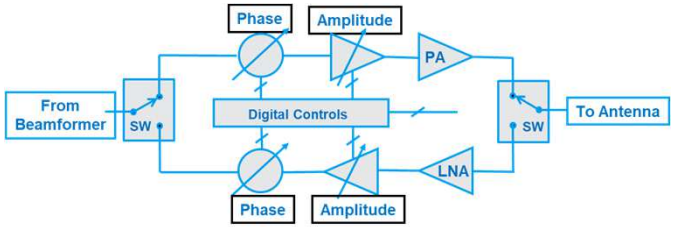


MULTIPORT VNAS SPEED UP THE MEASUREMENT

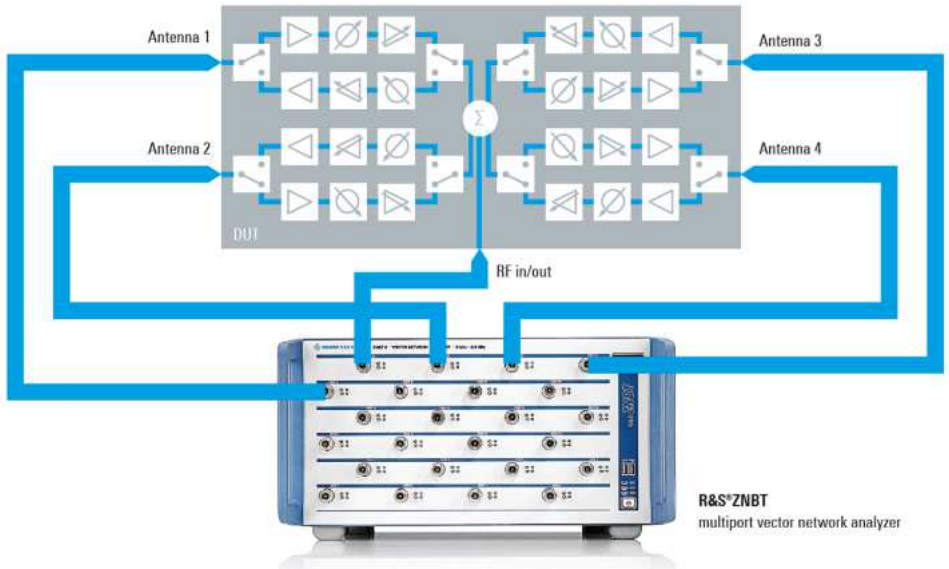
Many T/R modules need reliable reproducible and fast test cycles.

► 24 ports with identical RF performance from 100 kHz up to 40 GHz.

TR module



Integrated antennas for compact user terminals

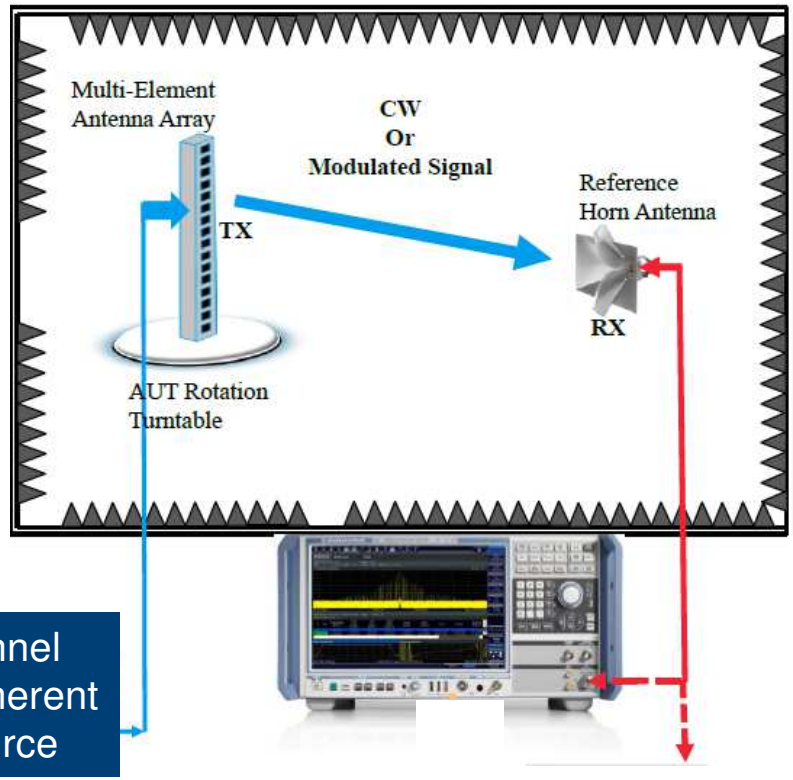


MULTI-CHANNEL PHASE COHERENT SOURCES

- R&S®ZNA: Four phase coherent sources, eight phase coherent receivers.
- R&S®SMW200A: Several signal generators can be coupled.

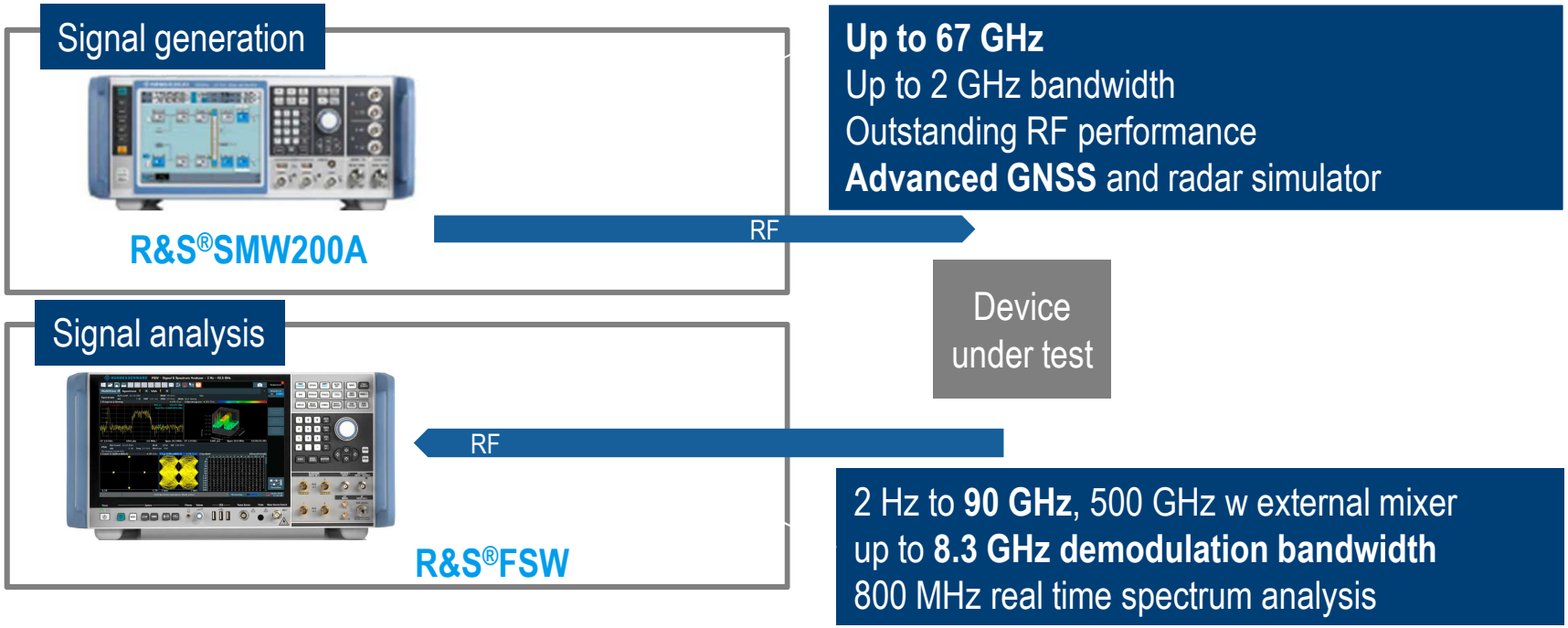
R&S®ZNA

R&S®SMW200A



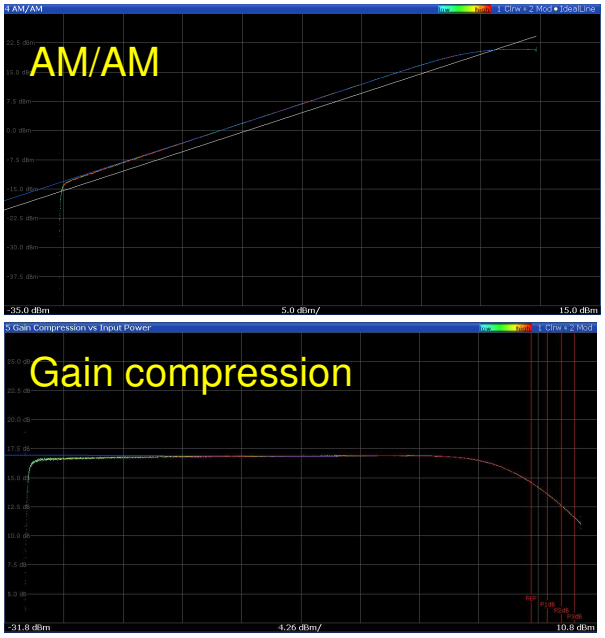
Multi-channel phase coherent signal source

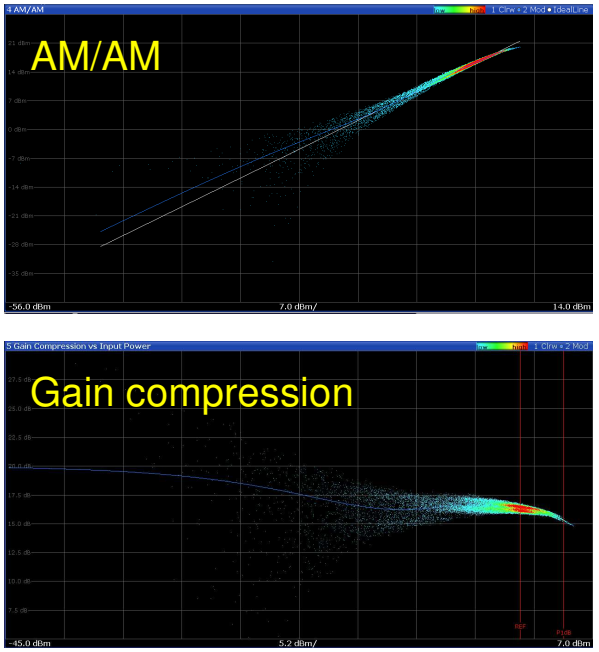
SIGNAL GENERATION AND ANALYSIS



CW VS. DIGITALLY MODULATED SIGNALS AS STIMULUS

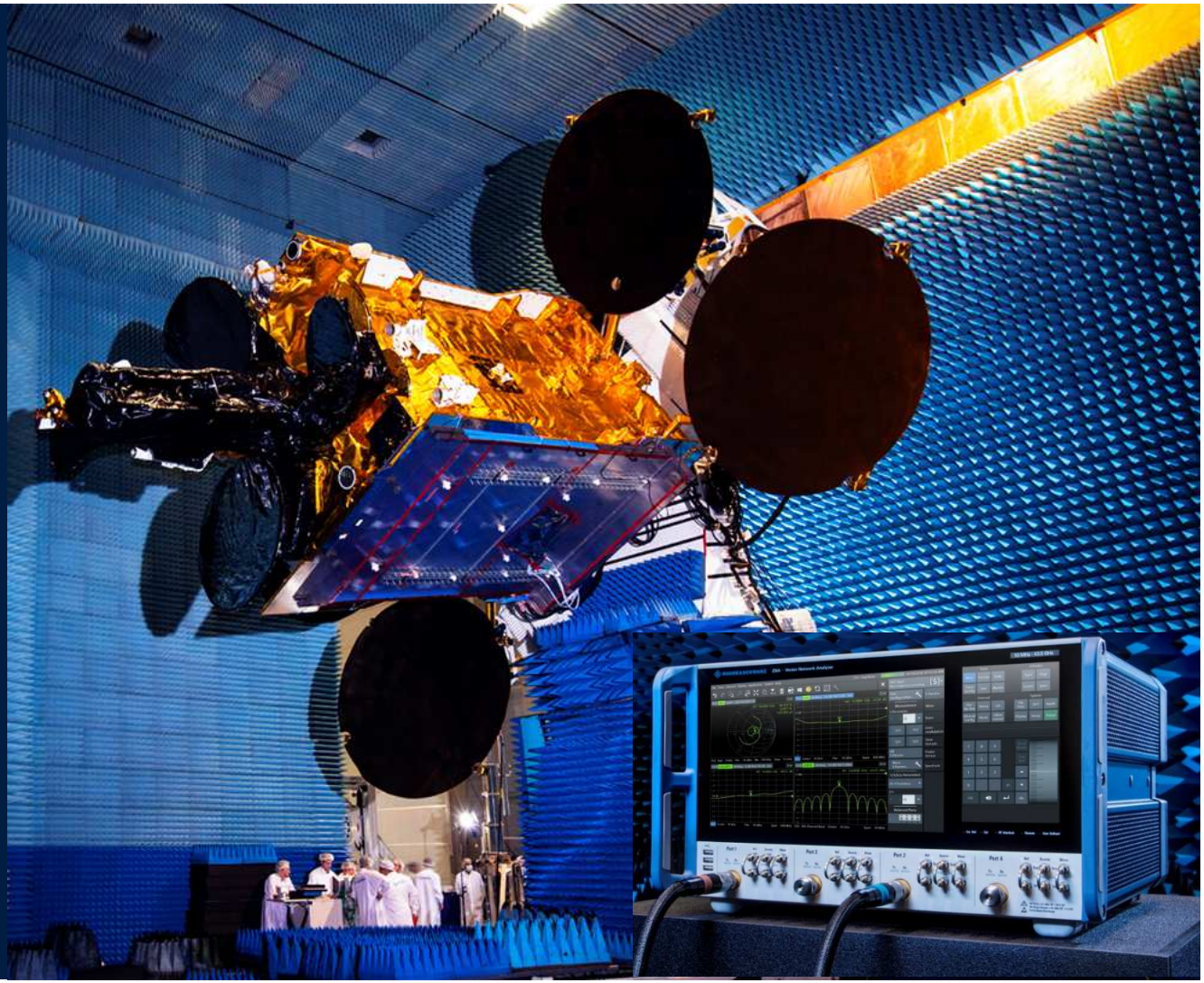
NTN in 5G NR will use OFDM signals. **Test as you fly!**





Antenna Measurements

1. Unparalleled measurement speed by extremely high sensitivity up to 67 GHz
2. Up to 8 truly parallel receivers
3. Up to 4 phase controllable / phase coherent sources + 2 internal LOs.
4. 4 pulse generators + 4 pulse modulators
5. Direct IF access with 1 GHz bandwidth
6. Trigger + synchronization: board with 12 sockets



R&S®ZNA mmW Solution

- Microwave & mmW range from 10 MHz to 500 GHz
- R&S®ZCxxx frequency converters: Simple and convenient extension.
- Multiport measurements with up to four converters
- High output powers
- Easy configuration GUI

ANTENNA FIELD ZONES

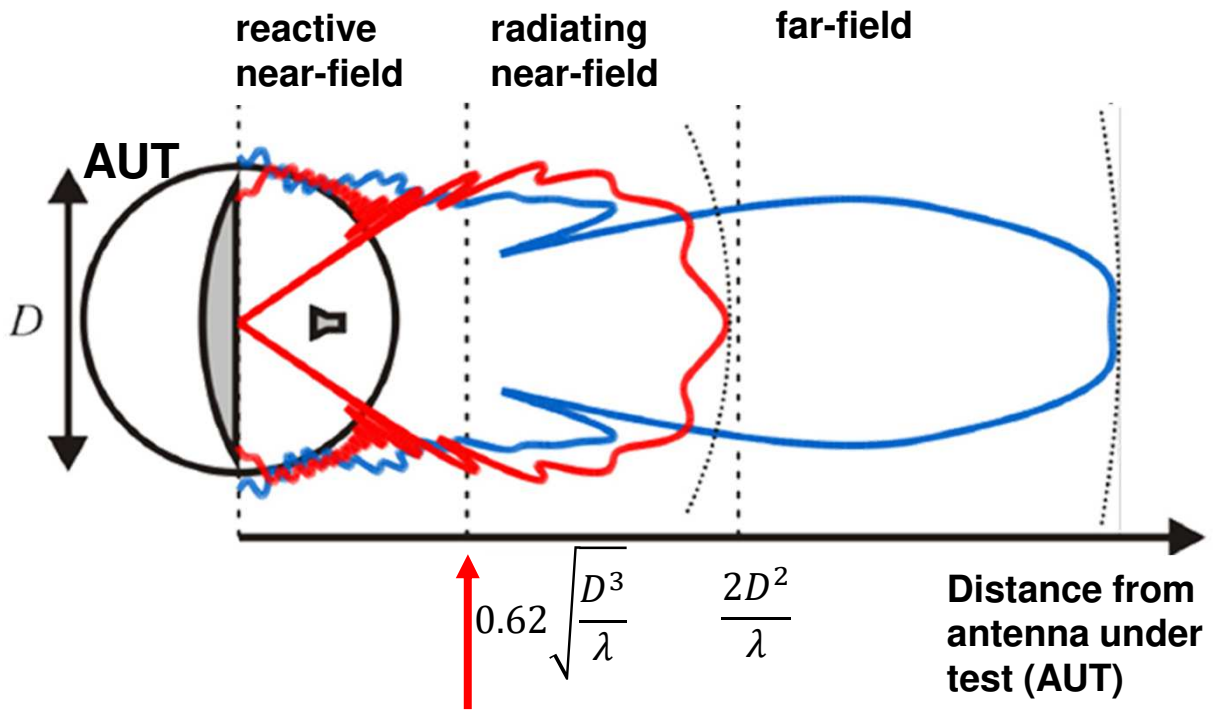
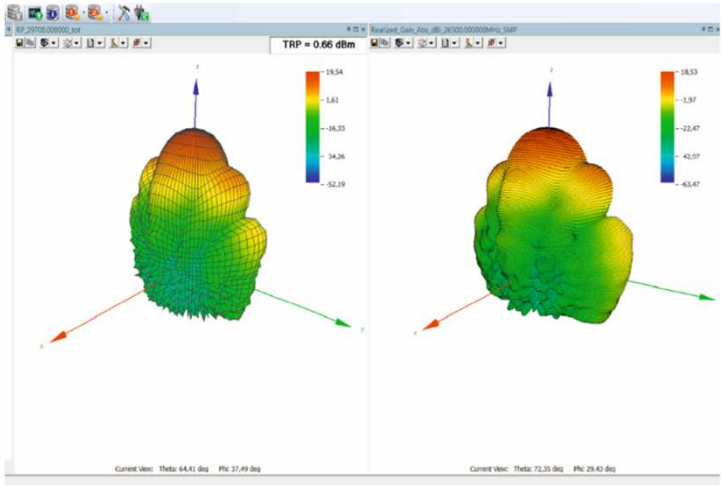


Image source: TU Munich

THE R&S®AMS32 SOFTWARE

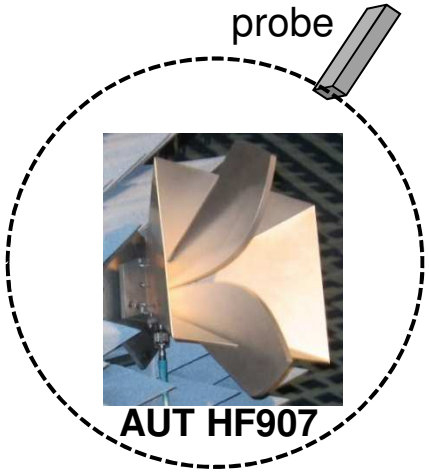
- Broadband measurement probe by integrated full probe correction within NFFF transformation.
- NFFF algorithm based on equivalent current principle.



Measurement Antenna
Patented dual-polarized Vivaldi probe
Minimal radar cross section
Broadband frequency range: 4 – 85 GHz

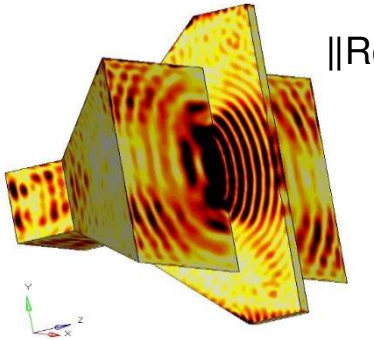
ANTENNA DIAGNOSTICS

► By the inverse equivalent current principle:

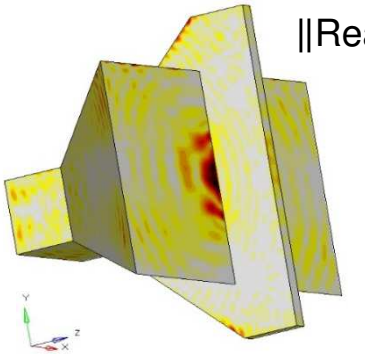


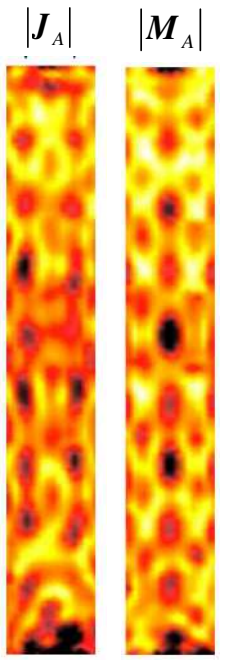
1. Spherical near-field measurement

2. Choice of representing surface



3. Reconstructed equivalent surface current densities

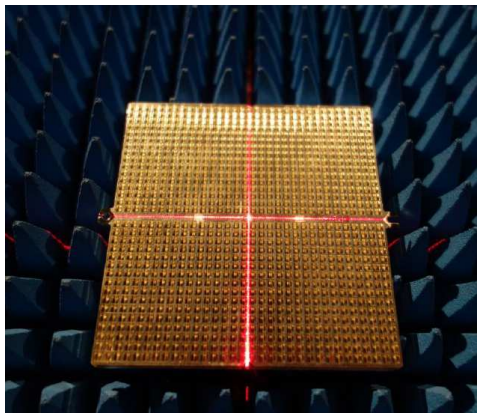


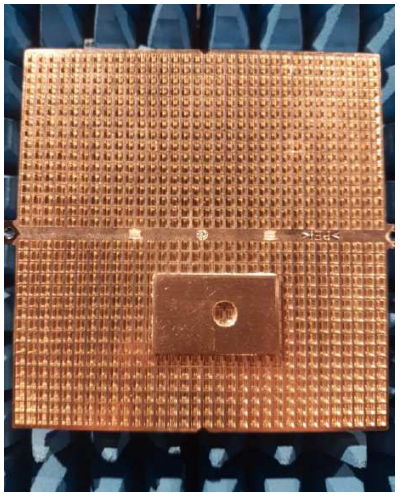


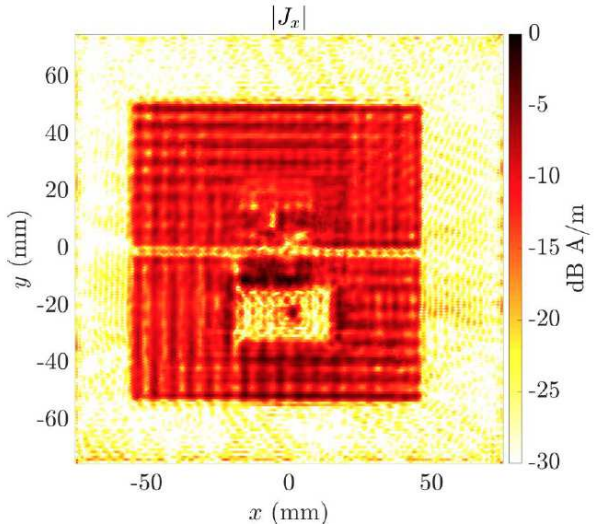
Array antennas

ANTENNA DIAGNOSTICS

- Ideal for the identification of erroneous elements in antenna arrays by the equivalent current principle



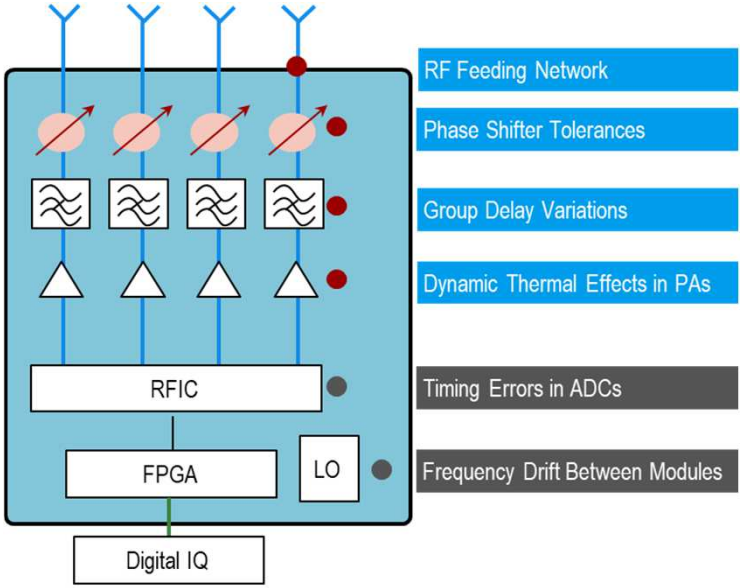


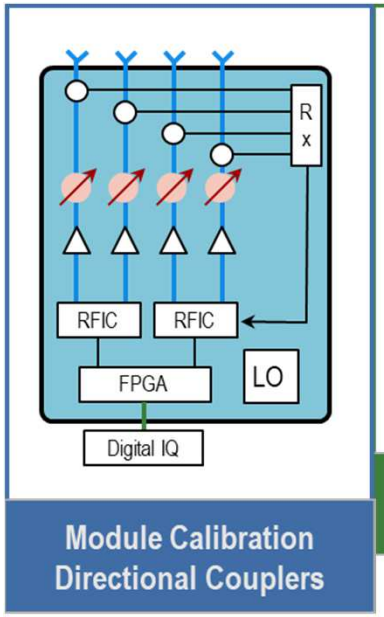


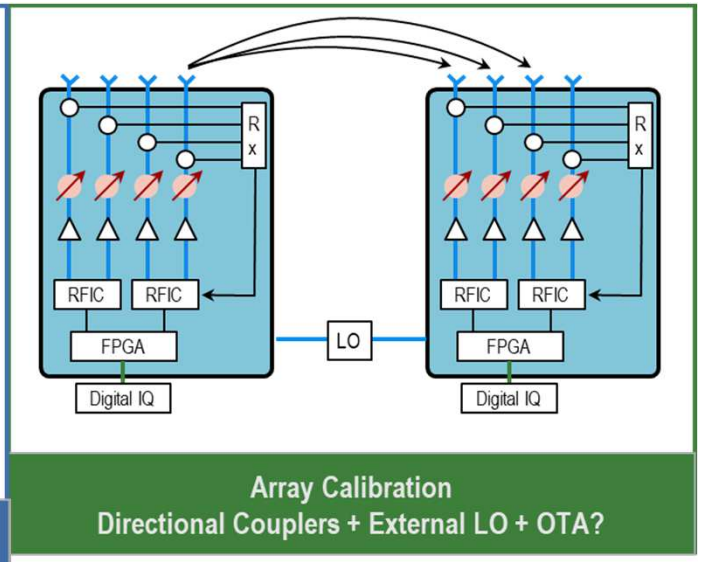
 G. F. Hamberger et al., „Near-field techniques for millimeter-wave antenna array calibration," AMTA, Oct. 2019.

DIGITAL BEAMFORMING CIRCUITS: CHALLENGES

Any phase difference has a significant influence on the beamforming accuracy.





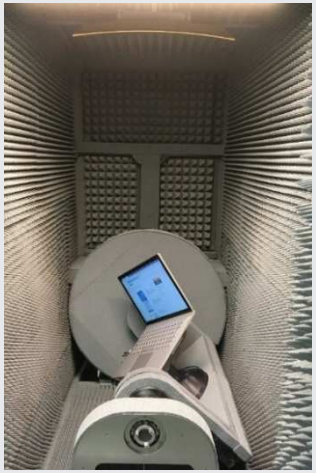
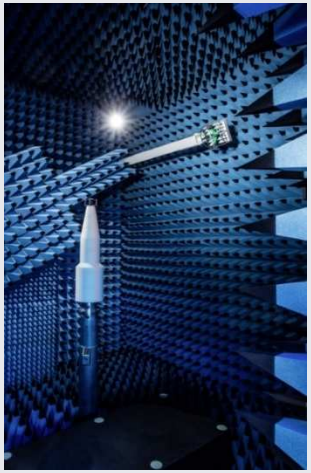


EXTREME TEMPERATURE TESTING

Key Features & Benefits

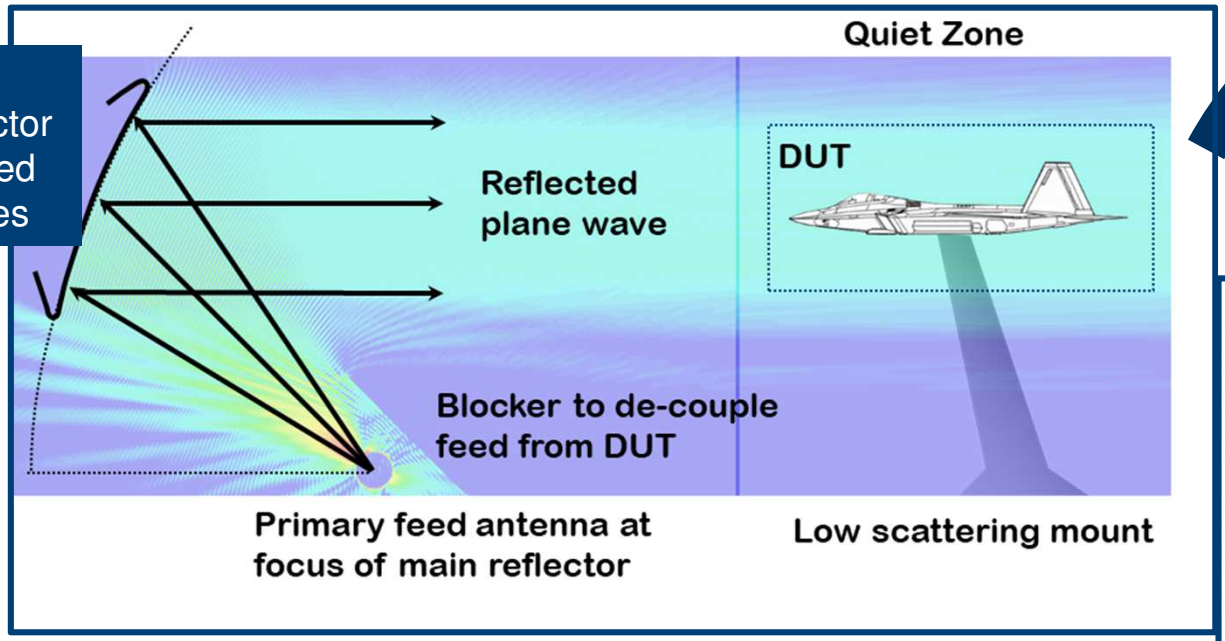
- Full spherical measurement under controlled temperature condition from -40°C to 85°C within a Rohacell® dome.
- RF performance and thermal testing all in one test setup.

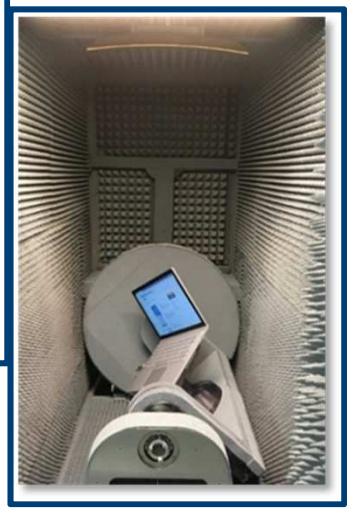
OTA RANGES – mmWAVE CAPABLE SOLUTIONS

R&S®ATS1000	R&S®ATS800B/R	R&S®ATS1800C	R&S®WPTC	1. CMQ200 RF test 2. CMQ500 signaling
				 
UE Early stage Antenna + chip tests -40°C to +85°C	R&D Cost efficient	R&D	R&D RF performance	UE FR2 High Quantity
DFF / NF	CATR	CATR	DFF / NF	
18 - 87 GHz	20 - 50 GHz	23.5 GHz – 90 GHz	0.4 - 90 GHz	1. 20 GHz – 77 GHz 2. 0.7 GHz – 77 GHz
3D conical cut		3D great circle	3D conical cut	

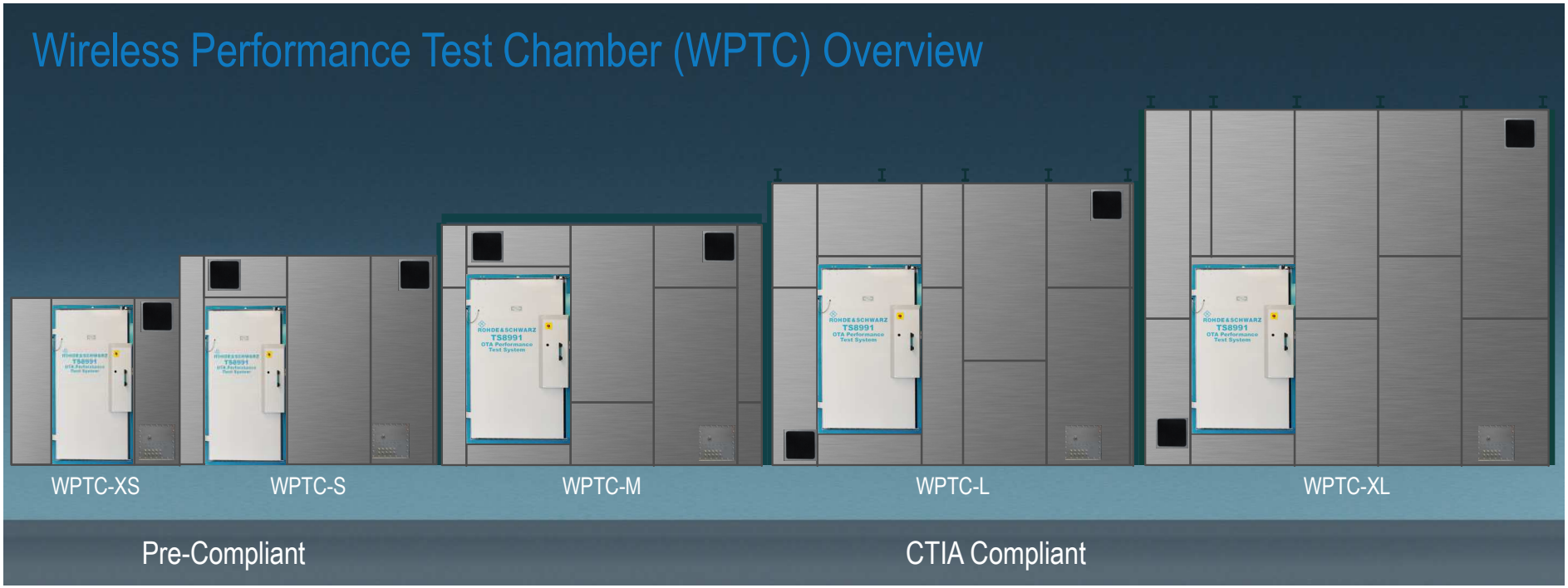
CATR: COMPACT ANTENNA TEST RANGE

Parabolic main reflector with blended rolled edges

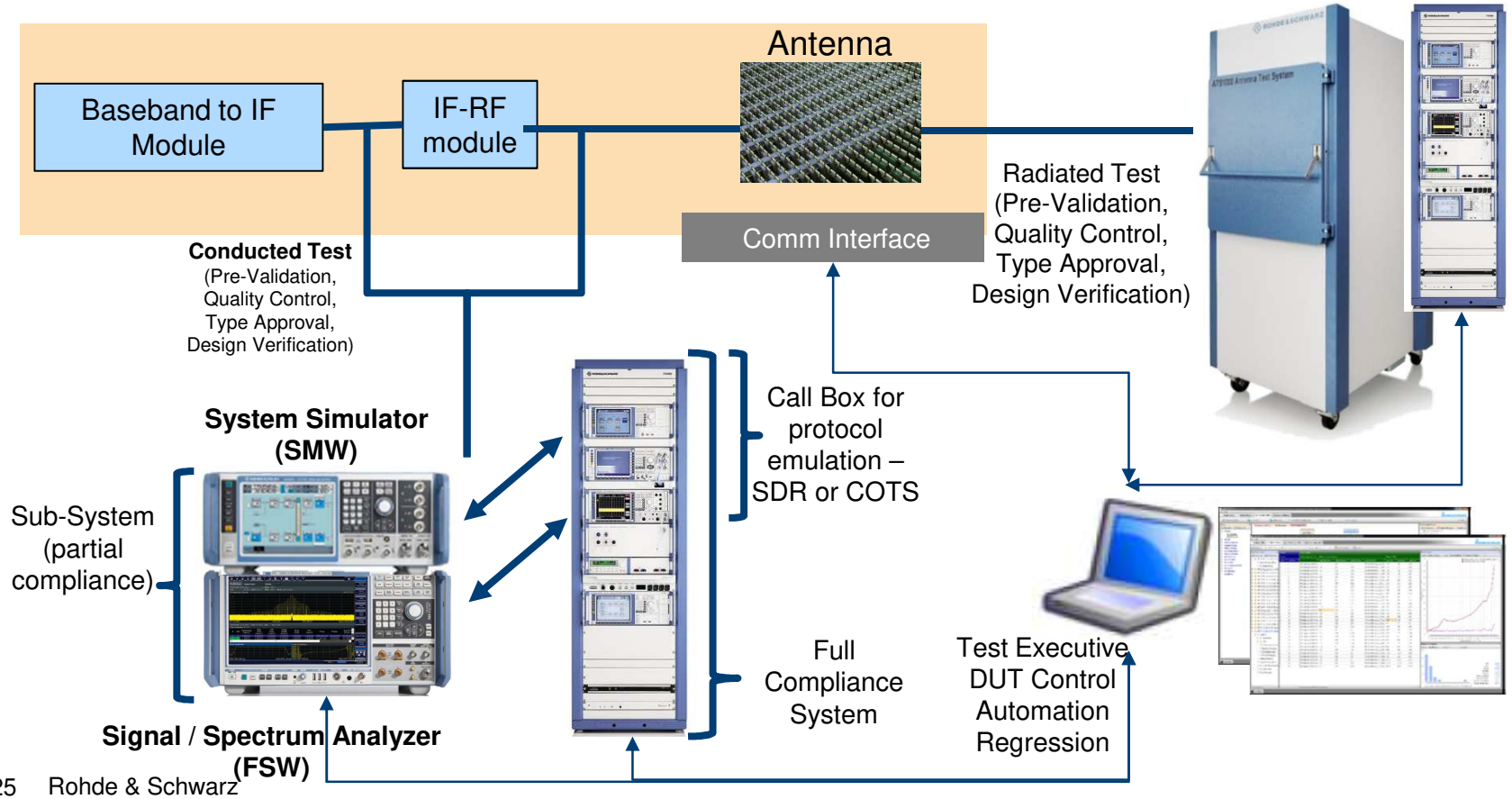




CHAMBER PORTFOLIO



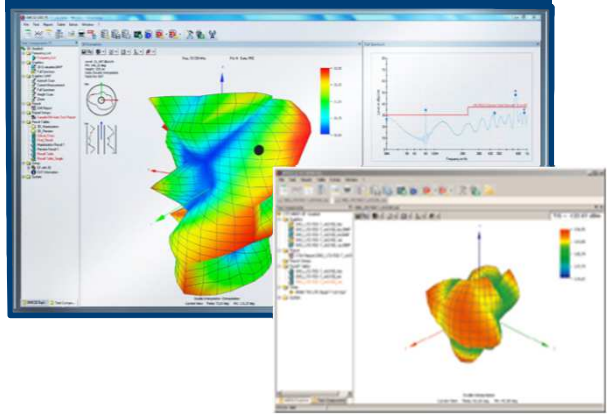
TERMINAL TEST (GROUND STATION, UT, SATELLITE)



ONE-STOP SHOP FOR OTA

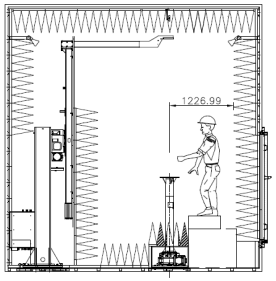
Completely integrated and customized OTA solution (no 3rd party)

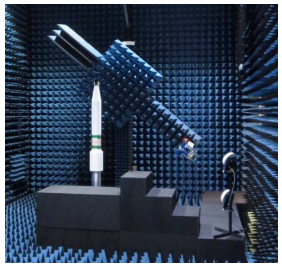
The R&S®AMS/EMS32 software



Measurement equipment

Wide range of chambers





Customized EMC and OTA chambers

Turn-key desktop systems

Single point of contact and complete integration for greater efficiency