

Optimize beamforming From bits to RF beams

Improve components for
advanced antenna systems (AAS):

- ▮ Digital circuitry
- ▮ RF beamforming frontend
- ▮ Phased array antennas



ROHDE & SCHWARZ

Your challenge

Radar, satellite communications and 5G NR use AAS with phased array antennas for beamforming. Hybrid beamforming combines the flexibility of digital beamforming with the efficiency of analog beamforming.

Increasing integration enables compact and cost-efficient AAS. To achieve accurate, reliable and efficient beamforming, it is necessary to understand and compensate for the nonlinear behavior of RF components.

While discrete components such as phase shifters, switches and amplifiers are tested conducted, highly integrated frontends with antenna-in-package (AiP) and system level tests require over-the-air (OTA) testing.

Rohde & Schwarz gives you the benefit of a well-coordinated portfolio of conducted and OTA test solutions.

More information at
www.rohde-schwarz.com/antennas

Filtering

Filters need to be sharp edged with a large attenuation to clean up the signal effectively.

Rohde & Schwarz network analyzers offer:

- ▀ Fast sweep times for quasi-realtime filter measurements
- ▀ Large dynamic range to see the full stop-band suppression

Digital section

Power and signal integrity, clock tree and SerDes PLLs:
www.rohde-schwarz.com/signal-power-integrity

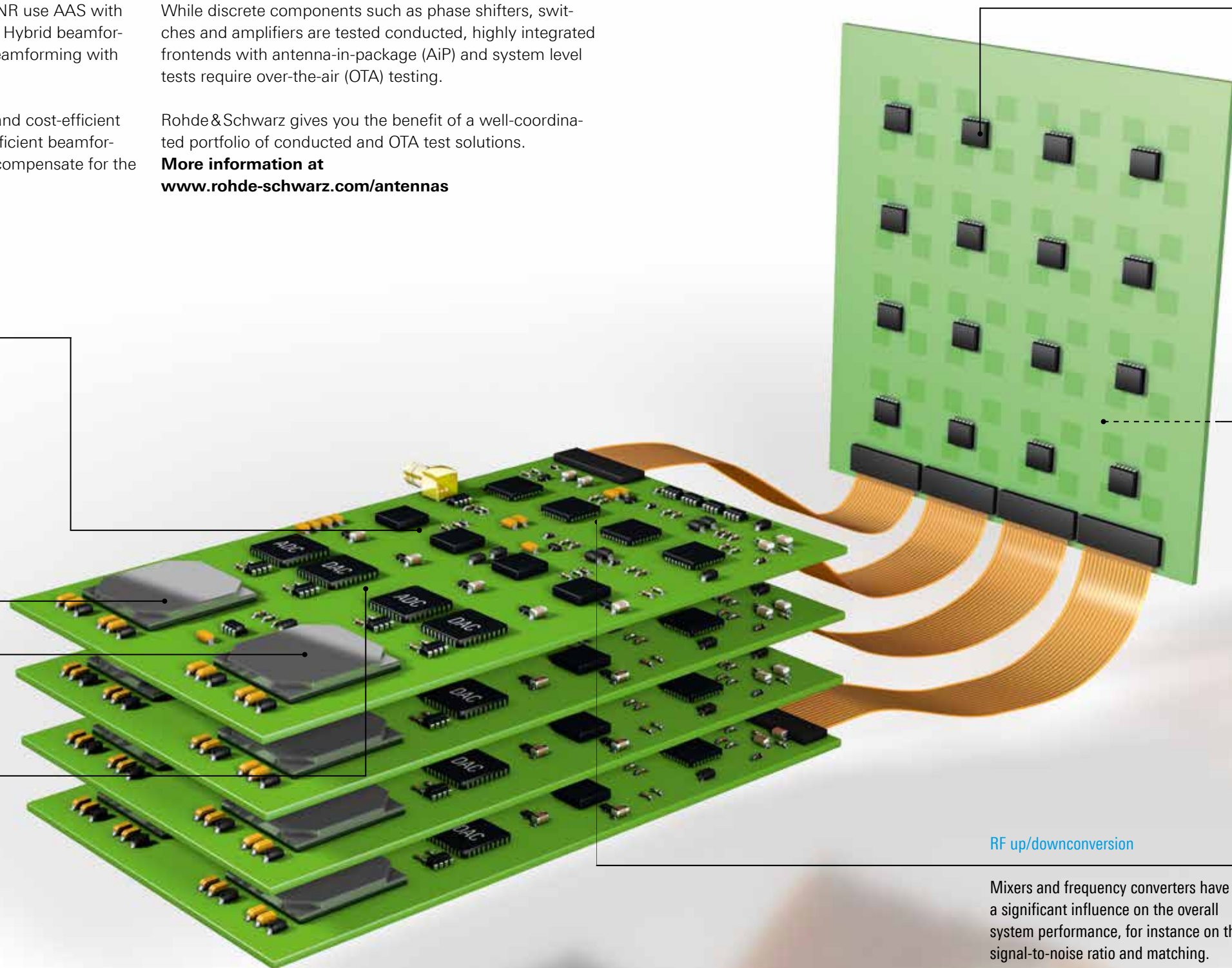
Transceivers

Data converter design:

www.rohde-schwarz.com/data-converter
Beamforming needs aligned signals to feed the antennas. Accurate timing between the channels is essential; clock timing and signal flow need to be in sync.

Rohde & Schwarz oscilloscopes offer:

- ▀ Advanced trigger capabilities at full oscilloscope sampling speed to enable accurate timing measurements
- ▀ Statistics that provide insight into distribution of variance
- ▀ 4 phase coherent receivers to provide relative phase and amplitude differences between antenna signals



Analog beamforming / RF conditioning

Analog beamforming uses discrete phase shifters, gain control components or highly integrated beamforming ICs. The resolution in the phase shifter and the stability of the RF system define the beamforming capabilities.

Rohde & Schwarz multiport network analyzers offer:

- ▀ Parallel measurements on up to 24 ports and 40GHz to increase test speed and uncover any correlation between the various antenna links
- ▀ Two sources to support intermodulation measurements to characterize nonlinear components with just one test instrument
- ▀ Fast parallel testing in production on multiple DUTs
- ▀ For more information on RF amplifier testing, see: www.rohde-schwarz.com/power-amplifier

Antenna

Phased array antennas consist of many antenna elements to create the pointed RF beam. Rohde & Schwarz offers:

- ▀ Fast 3D antenna measurement solutions for near-field and far-field applications, including test software and various test chamber sizes with positioners to adapt to the test frequency and device size
- ▀ OTA power measurement setup for accurate power calibration at the system level
- ▀ Complementing OTA and modulated test solutions to support calibrated performance measurements such as EVM and ACLR

RF up/downconversion

Mixers and frequency converters have a significant influence on the overall system performance, for instance on the signal-to-noise ratio and matching.

Rohde & Schwarz network analyzers offer:

- ▀ Up to 4 built-in sources to simplify and speed up mixer tests
- ▀ Easy-to-use wizard for mixer measurements
- ▀ Dedicated calibration routine to achieve accurate power measurements for frequency-converting test devices

From bits to RF signals

Digital beamforming with appropriate phase and level weighting takes place in the baseband to generate individual streams. Many beams can be overlaid to enable multiple links via one RF system.

Complex digital chips such as FPGAs and ASICs have strict timings between the different sections of their booting sequences. To ensure the time sequence is in proper order, the R&S®RT-ZVC offers up to 8 channels to monitor the power consumption of the different sections over time. Other oscilloscope channels can simultaneously show e.g. SPI control commands.

Digital beamforming requires separate paths per stream with individual data converters. Time alignment between the different channels is essential since jitter and time variances between channels degrade beamforming accuracy.

Digital-to-RF simplifies the design with highly integrated SoCs and transceivers. The R&S®RTP oscilloscope offers:

- ▀ Time resolution down to 25 ps; statistic functions such as the histogram provide deep insight into variation and jitter trends
- ▀ 4 phase-coherent receivers for beamforming testing on RF signals to ensure proper phase and level per antenna signal
- ▀ Signal evaluation using R&S®VSE software
- ▀ Triggering on digital serial buses to evaluate timing between control signal and RF output

The combination of R&S®RTP oscilloscope and R&S®ZVC multi-channel power probe enables synchronized measurement of analog, digital and RF signals.



Beamforming leads to high signal path density on PCBs. This density and the high signal data rates means special attention must be given to board layout to ensure proper signal integrity (SI). Reflections and crosstalk are the main challenges when designing PCB signal paths, including vias and connectors. Together with our partner PacketMicro, we offer rugged probes for direct measurements on the PCB.

Vector network analyzers such as the R&S®ZNA offer advanced signal integrity (SI) features:

- ▀ Advanced time domain and eye diagram analysis
- ▀ Fast embedding/deembedding for impedance matching

The R&S®ZNA vector network analyzer makes mixer measurements easier than ever thanks to the following features:

- ▀ The R&S®ZNA four-port model offers up to four internal sources. Swept LO measurements and intermodulation measurements versus frequency on mixers are performed up to ten times faster compared with setups that use external generators.
- ▀ The R&S®ZNA determines the return loss and scalar conversion loss of mixers and converters with high precision using R&S®SMARTerCal.
- ▀ The analyzer performs relative phase measurements on frequency converters using vector error correction, a feature that is essential for digital beamforming, where the RF phase is controlled from the digital baseband through the complete RF chain.
- ▀ The R&S®ZNA offers a unique approach for phase and group delay measurements on converters without LO access.

The R&S®ZNA vector network analyzer simplifies phase measurements on frequency-converting components such as mixers since no reference mixer is required.



Improve RF frontend

In a hybrid beamforming architecture, analog beam-forming is added to address a higher number of antenna elements. This narrows the beamwidth in a cost-efficient way and enables the RF signal to achieve a longer range. Modern highly integrated ICs offer digitally controlled beamforming. They help overcome the space limitations at higher frequencies where the antenna elements become rather small.

Important characteristics include:

- Phase and level control, resolution accuracy and stability per transmit and receive path
- Supported bandwidth in the forward and reverse link
- Maximum power level capability and linearity of the input and output – P1dB or P3dB – for the low noise amplifier (LNA) in the RX path and the output amplifier in the TX section.

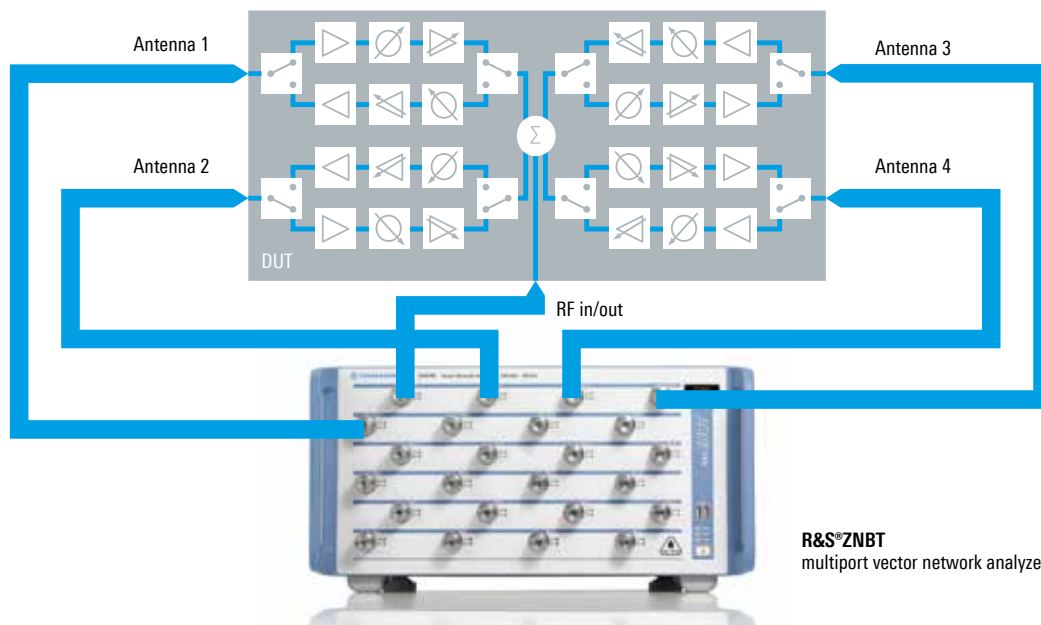
Vector network analyzers (VNA) support all measurements on one platform. The fastest way to characterize beam-forming ICs is to connect to all ports on the device and run the measurements in one sequence without recabling. A true multiport VNA like the R&S®ZNBT offers many advantages:



Comprehensive beamforming testing with the R&S®ZNBT

- Parallel measurements on all ports of the DUT offer fastest test results and provide insight into cross-correlation between ports
- Up to 24 ports on a scalable platform enable direct connection to all DUT ports of single-ended or differential devices
- Large dynamic range to see the full DUT performance
- Two sources inside the R&S®ZNBT support inter-modulation testing on nonlinear components
- First-to-market, true multiport VNA up to 40 GHz supports all major radar, satellite communications and 5G mmWave bands

Testing the beamformer IC using the multiport vector network analyzer R&S®ZNBT



Designers have a large degree of freedom in the structure of the beamforming network. Design decisions are made based on design goals such as the number of simultaneous beams (links), targeted beam width and range. Separate power amplifiers boost the output signal for radar or compensate for losses from power splitters integrated into the signal chain.

All amplification stages need to support the wideband signals used in radar, satellite communications or 5G NR. This can easily be verified with the powerful wideband signal generation and analysis solution offered with the R&S®SMW200A and the R&S®FSW. They offer:

- Wide frequency range coverage up to 43 GHz for all important 5G applications
- Wide internal signal bandwidth of 2 GHz that simplifies test setup
- Built-in signal creation and analysis for all signal types from radar to 5G NR

The R&S®SMW200A vector signal generator together with the R&S®FSW signal and spectrum analyzer form a powerful test setup for RF amplifiers.



Antenna and system level

Integration is an important enabler for compact, cost-efficient beamforming systems. Antenna-in-package (AiP) is a logical next step in integration. It is not possible to verify antenna modules or AiP devices such as fully integrated 5G mmWave RFICs with a conducted test. A controlled OTA (over the air) link is the only way to get reliable performance information.

Rohde & Schwarz benefits from a long history in antenna measurements with near-field (NF) and far-field (FF) solutions. The R&S®AMS32 antenna measurement software supports fast and easy characterization of single antenna elements or complete phased arrays using amplitude and phase information measured by a vector network analyzer. The integrated algorithms for NF-FF transformation make it possible to perform antenna characterization of arrays that exceed the maximum size for FF conditions in a smaller chamber.

R&S®ATS1000: one compact OTA chamber for antenna and RF performance measurements



Based on the size and frequency range of the DUT, chambers with different form factors are required. Large walk-in chambers to small benchtop solutions are available to meet different requirements. 5G NR includes mmWave frequencies to support the maximum data rates enabled by high integration in infrastructures and handset frontends.

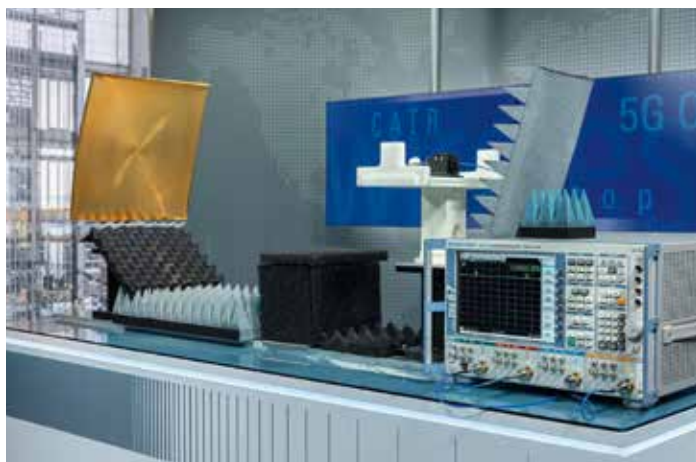
The R&S®ATS1000 antenna test system family is mmWave optimized for 5G applications. It offers:

- Far-field conditions in a compact and mobile form factor for flexible use in lab environments without the need for a fixed installation
- Multiuse for antenna characterization and modulation performance tests like EVM and ACLR when used together with appropriate RF instruments
- Precision positioner for accurate 3D antenna patterns allow exact evaluation of beamforming capabilities
- Device characterization under extreme temperature ranges using an integrated quasi-transparent temperature bubble, an especially important feature for highly integrated devices with active RF functions and AiP
- Integrated compact antenna test range (CATR) to increase the maximum test size for far-field conditions

For generic lab setups, the CATR system is available as an open benchtop solution. This is more cost-efficient and provides easy access to the test object between measurements. It is ideal for tuning the design while maintaining a large quiet zone with a homogeneous far field. Calibrating the output power of a device requires the highest accuracy offered by power meters, no matter if conducted or OTA. The R&S®NRPM OTA power measurement solution is a unique integration of antenna and power meter, offering easy power measurements at any position.

Functional beamforming tests are as simple as measuring signal strength at different positions. Using multiple antenna modules, the R&S®NRPM provides direct information on the direction of the beam and the signal strength of the main lobe and side lobes in a fast and cost-efficient way.

Cost-efficient OTA solution: R&S®ATS800B benchtop version with feeder antenna, reflector and positioner to create uniform planar waves paired with an R&S®ZVA vector network analyzer for antenna characterization



OTA power calibration and functional beamforming tests made easy with the R&S®NRPM OTA power measurement solution



Service that adds value

- | Worldwide
- | Local und personalized
- | Customized and flexibel
- | Uncompromising quality
- | Long-term dependability

Rohde & Schwarz

The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, monitoring and network testing. Founded more than 80 years ago, the independent company which is headquartered in Munich, Germany, has an extensive sales and service network with locations in more than 70 countries.

www.rohde-schwarz.com

Sustainable product design

- | Environmental compatibility and eco-footprint
- | Energy efficiency and low emissions
- | Longevity and optimized total cost of ownership

Certified Quality Management

ISO 9001

Certified Environmental Management

ISO 14001

Rohde & Schwarz training

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