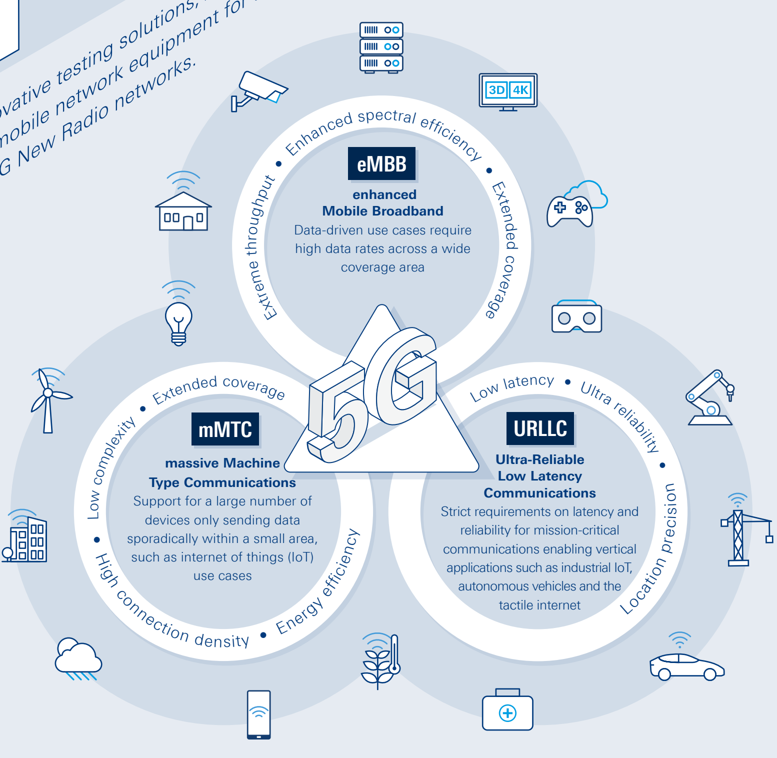
Creating the BASE OF 5G

With its innovative testing solutions, Rohde & Schwarz helps build mobile network equipment for today's and future 5G New Radio networks.



5G NR APPLICATION FIELDS

As the basis for all 5G application fields, high-performance mobile network equipment is critical for success. 5G standardization and applications focused on enhanced mobile broadband (eMBB) as the first main use case to facilitate faster data services for end users. Enabling eMBB required the use of technologies such as massive MIMO and beamforming that entail certain design challenges for mobile network infrastructure equipment. The mMTC use case supports fast and unlimited connection of large numbers of devices such as required for internet of things (IoT) applications. For URLLC, reliable communications and low latency are the key topics which are mandatory for vertical applications such as industrial IoT (IIoT) and autonomous driving. 5G NR exploits new bands in frequency range 1 (FR1) from 410 MHz to 7.125 GHz and introduces higher frequencies in the mmWave range, referred to as frequency range 2 (FR2) from 24.25 GHz to 52.6 GHz. Additional frequency extensions are under consideration.

What is beamforming?

Beamforming is an antenna technology that ensures highly focused antenna directivity and improves overall system efficiency.

Signals are transmitted in the form of targeted beams in order to manage transmission power based on current user demand.

Infrastructure trends

Network densification

Ever increasing demand for higher data rates is driving macro cells to their limits. Network densification makes it possible to cope with the challenging capacity requirements by complementing macro cells. Depending on the available frequency spectrum and implementation regulations, network densification solutions range from low power small cells to distributed antenna systems (DAS) and mmWave solutions. As one of the first use cases for 5G mmWave applications, last mile fixed wireless access (FWA) uses the massively increased capacity to bring broadband to private homes.

Flexibility

The user device evolution from a plain telephone to an application-driven device supporting various use cases necessitates a flexible infrastructure that can cope with 5G service requirements associated with eMBB, URLLC and mMTC. While software defined network methods allow virtualization of functions, the actual functions will be decoupled from a direct hardware binding. Disaggregated networks and open interfaces enable a multi-vendor concept and speed up new service introductions. The objective is to make the network smart, agile and flexible. 5G standalone and non-standalone deployment strategies require flexible hardware to work with the 2G, 3G and 4G legacy technologies. The ever-increasing technical requirements of 5G along with the system complexity make it necessary to rely on future-proof test equipment and dedicated, application-optimized test solutions for the entire lifecycle.

Evolving mobile network architecture

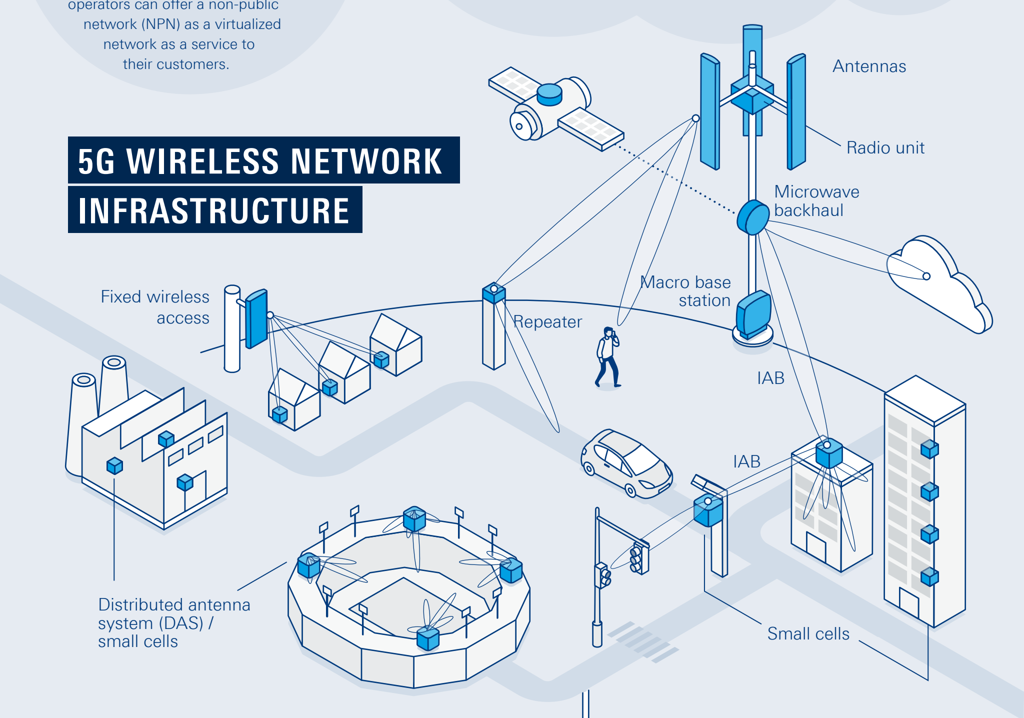
The importance of 5G mobile network infrastructure is growing along with the need for reliable network performance in various use cases, ranging from sporadic data bursts to fast and reliable low latency transmission. Trends like cloudification, disaggregation and multi-access edge computing (MEC) are targeting smart, agile and flexible networks. The challenge is to bridge the gap between centralization, lower energy consumption and lower complexity vs. hierarchical disaggregated network deployment fostering low latency, intelligent RAN control and QoS optimized scheduling aspects.

The 3GPP's integrated access and backhaul (IAB) feature enables access and backhaul via the same 5G air interface technology, leveraging fast deployment of infrastructure components. Ubiquitous connection is an important goal to bring connectivity to rural areas and IoT networks in remote locations, fostering non-terrestrial networks (NTN).

Private/local networks

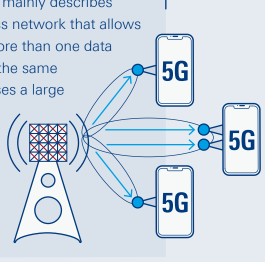
Industries, such as production facilities, can use 5G technology to create a local or private network within a dedicated area. Based on network slicing or individual industry-owned networks, private networks feature unified connectivity, use-case optimized services and a secure environment. Governments have begun to provide specific spectrum allocations for private networks. Network operators can offer a non-public network (NPN) as a virtualized network as a service to their customers.

5G WIRELESS NETWORK INFRASTRUCTURE

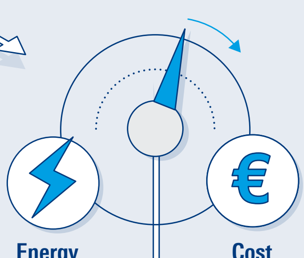


What is massive MIMO?

MIMO stands for multiple-input multiple-output. Involving several technologies, it mainly describes spatial multiplexing; i.e. a wireless network that allows transmission and reception of more than one data signal layer simultaneously over the same radio channel. Massive MIMO uses a large number of antenna elements and combines MIMO with beamforming, supporting single-user MIMO (SU-MIMO) and multi-user MIMO (MU-MIMO).



Challenges for manufacturers



TEST CHALLENGES

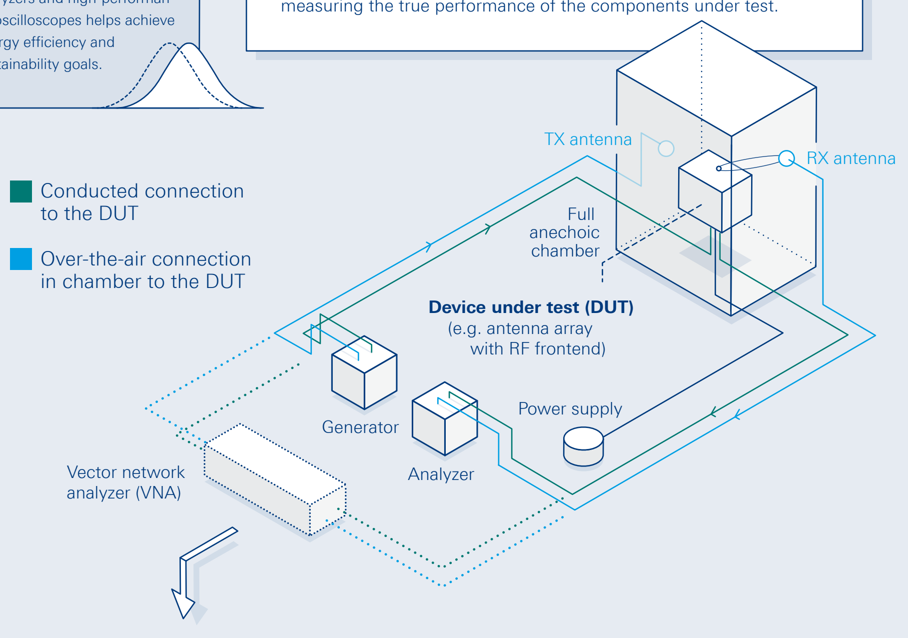
TESTING

Energy efficiency

Base station equipment with its various components offers significant energy savings potential. Advanced power analysis, gathering of real-time power statistics over time, and debugging of device activity vs. power consumption are important R&D tasks. Using dedicated T&M equipment such as power supplies, power analyzers and high-performance oscilloscopes helps achieve energy efficiency and sustainability goals.

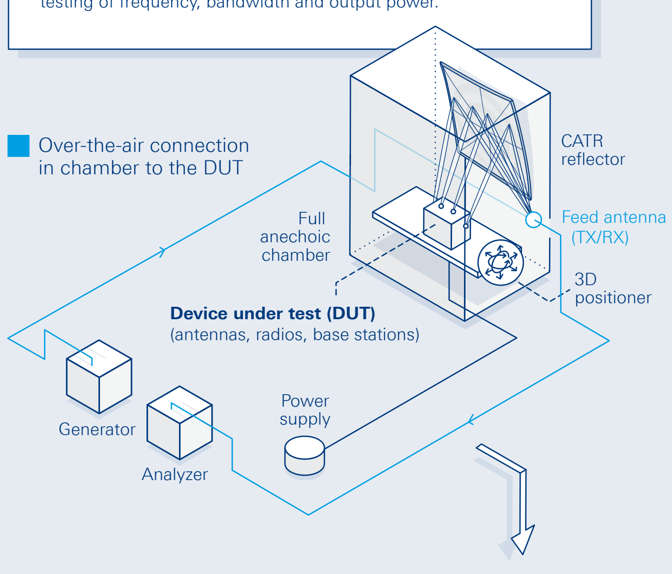
1. Component R&D

Developing wireless network equipment starts with testing RF components (power amplifier, RF frontend, D/A converter, filter, antenna arrays) and verifying the digital signal processing and power modules. Typically, continuous wave (CW) signals are used to characterize RF performance metrics such as S-parameters. More sophisticated methods are increasingly applied to perform testing with modulated signals. Advanced techniques, such as digital predistortion (DPD), help achieve optimal performance. High-end test equipment is critical for measuring the true performance of the components under test.



2. Design and validation

Design and validation testing helps ensure the functional performance of components, subsystems and systems over a wide range of conditions. Test sequences can have a large scope and cover multiple parameters such as frequency, power, beams and temperature. This includes the power and modulation performance of components and transmitters, beamforming accuracy, e.g. beam direction and power, and signal integrity over high speed digital interfaces. High-end test equipment ensures accurate testing of frequency, bandwidth and output power.



3GPP: definitions of three different base station types

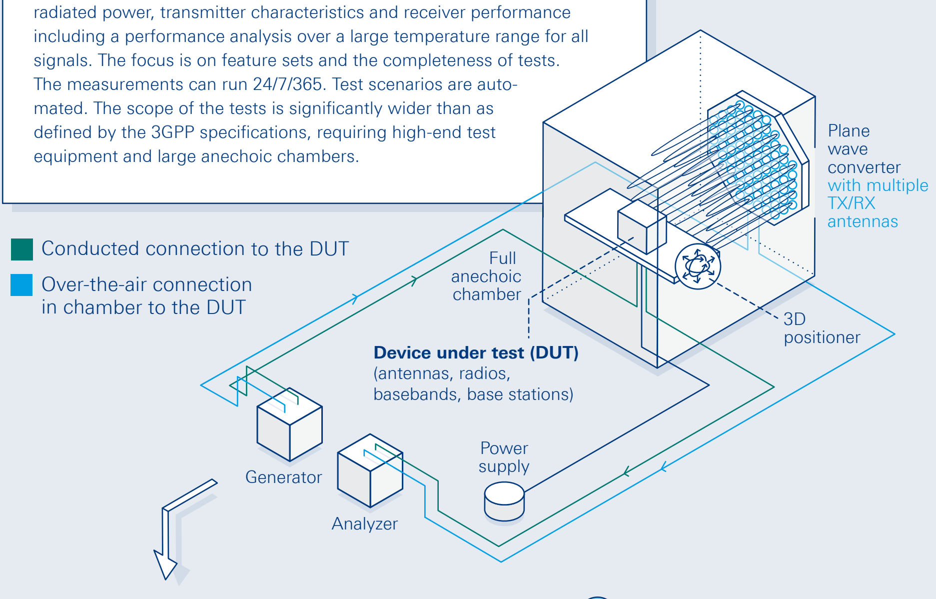
Conducted (BS type 1-C): 5G NR base station operating at FR1 with conducted requirements defined at individual transceiver array boundary (TAB) antenna connectors.

Hybrid (BS type 1-H): 5G NR base station operating at FR1 with conducted requirements defined at individual TAB connectors and OTA requirements defined at radiated interface boundaries (RIB).

OTA/radiated (BS type 1/2-O): 5G NR base station operating at FR1/FR2 with OTA requirements defined at the radiated interface boundary.

3. Integration and verification (preconformance tests)

Integration and verification tests cover the complete base station as well as its subsystems. Testing includes spherical radiation patterns, total radiated power, transmitter characteristics and receiver performance including a performance analysis over a large temperature range for all signals. The focus is on feature sets and the completeness of tests. The measurements can run 24/7/365. Test scenarios are automated. The scope of the tests is significantly wider than as defined by the 3GPP specifications, requiring high-end test equipment and large anechoic chambers.



BRINGING 5G NETWORK EQUIPMENT TO THE MARKET

OTA methods

The 3GPP accepts three OTA methods for RF conformance testing. The applicable setup depends on various parameters such as the frequency range, device aperture size and OTA application.

Direct far-field (DFF)
The chamber size satisfies the Fraunhofer distance ($2D^2 / \lambda$).

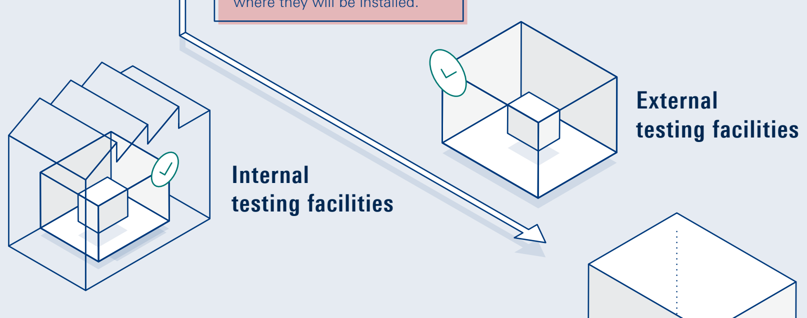
Near-field to far-field transformation (NFTF)
A compact chamber size is combined with software based postprocessing to yield far-field results.

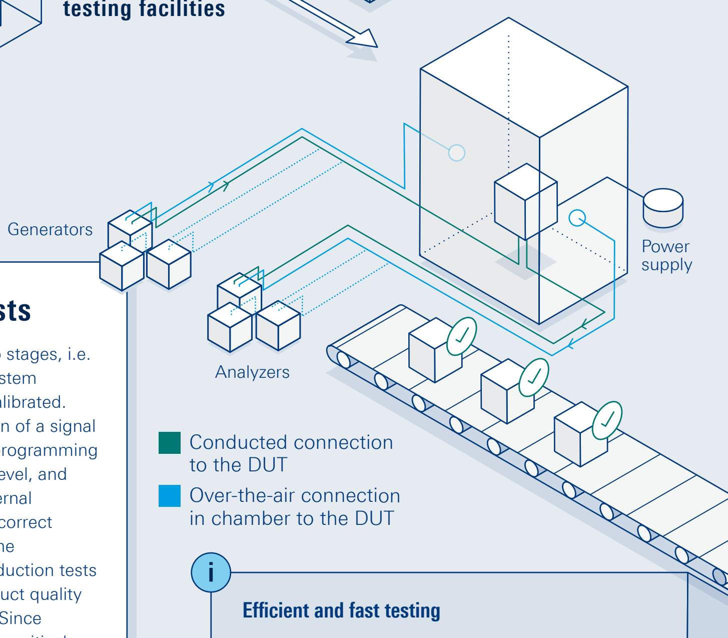
Indirect far-field (IFF)
There are two major setups for hardware based transformation: compact antenna test range (CATR) and plane wave synthesis (PWS).

1. Conformance approval

Standardization bodies, such as 3GPP, specify conformance tests to ensure that base stations operate within well-defined RF and performance constraints. The conformance tests specified by 3GPP cover transmitter and receiver characteristics as well as receiver performance under noise and fading conditions. Regulatory authorities, such as the FCC, OFCOM and BNetzA, typically set the limits for these tests. Base stations need to pass conformance tests in the region where they will be installed before they can start operation in the field. High-end test equipment is required for conformance testing.

Every region has its own regulatory authority, i.e. base stations have to fulfill the test approval criteria in the region where they will be installed.



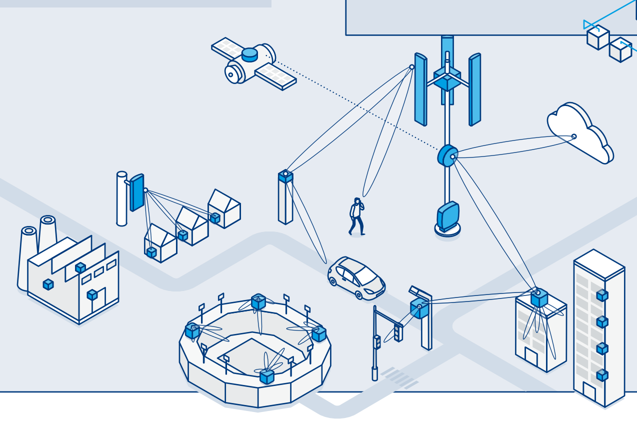


2. Production tests

Production tests involve two stages, i.e. subsystem and complete system testing. First, systems are calibrated. This includes, e.g. application of a signal with a known level, device programming to report the correct signal level, and filter tuning or setting of internal attenuation to generate the correct output power. Afterwards, the performance is verified. Production tests are designed to ensure product quality independent of 3GPP tests. Since throughput and efficiency are critical, high-speed instruments with top performance and compact footprints are essential. Production tests are also increasingly parallelized and automated.

Efficient and fast testing

The separation of RF data capturing, performed by the test equipment, and data processing, performed by the server, allows much shorter characterization times and faster production testing e.g. through parallel execution of test jobs. Server based testing (SBT) helps to actively reduce test time and costs while maintaining quality.



3. Network installation and mobile network testing

Each new cell site needs to be verified to ensure correct network performance and quality of service (QoS). A typical site acceptance procedure involves spectrum measurements conducted over the air (OTA) in order to analyze the transmitter in the frequency and time domains and troubleshoot issues. 5G has a new requirement for functional tests which verify the connection to the network and gather performance KPIs such as latency, download speed and upload speed using a smartphone. Finally, signal decoding is used to verify network information and synchronization signals for the 5G and LTE anchor signals. Once the network is operational, any technical issues can be diagnosed and resolved using functional, spectral and signal decoding procedures.