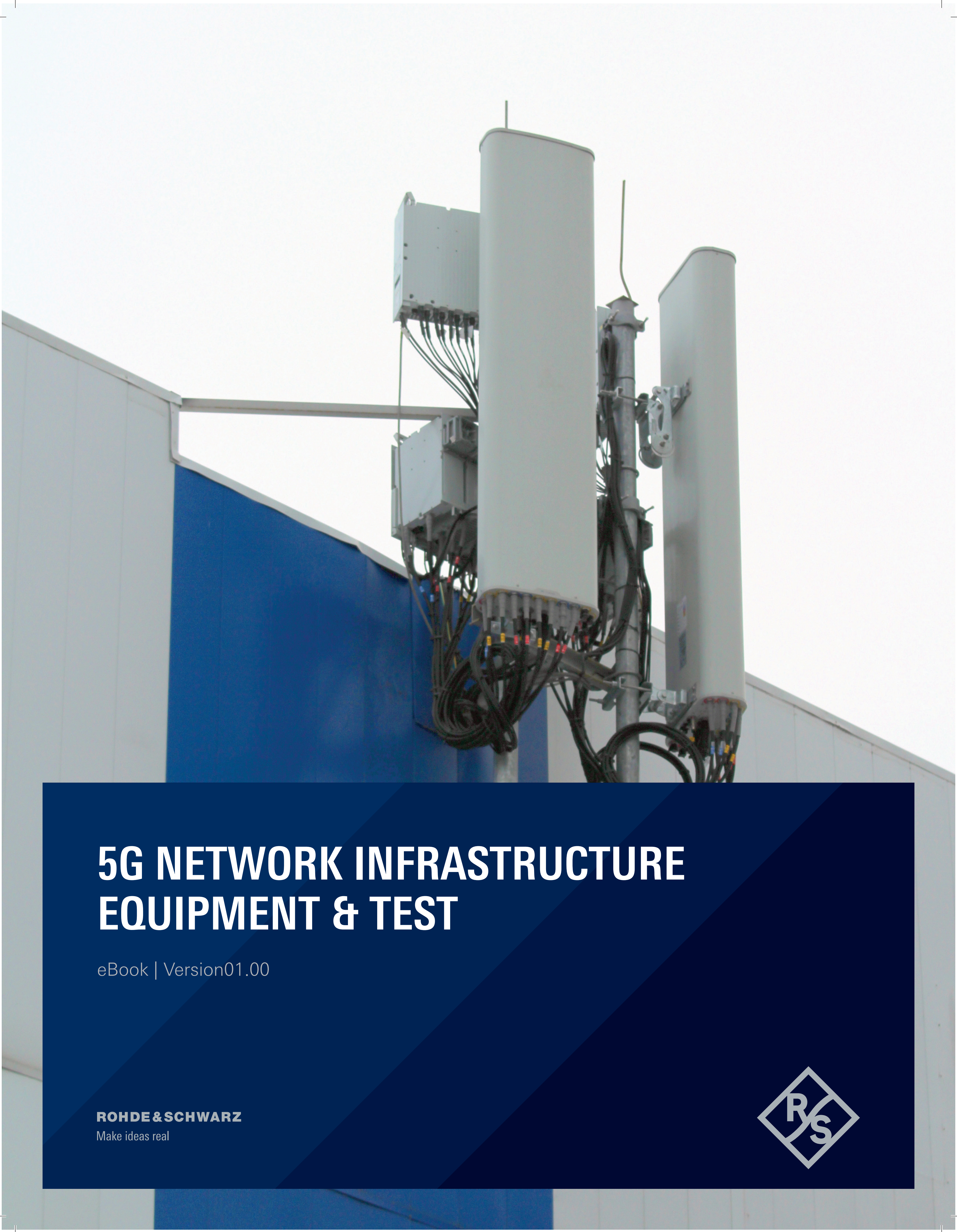

5G NETWORK INFRASTRUCTURE EQUIPMENT & TEST

eBook | Version01.00

ROHDE&SCHWARZ

Make ideas real

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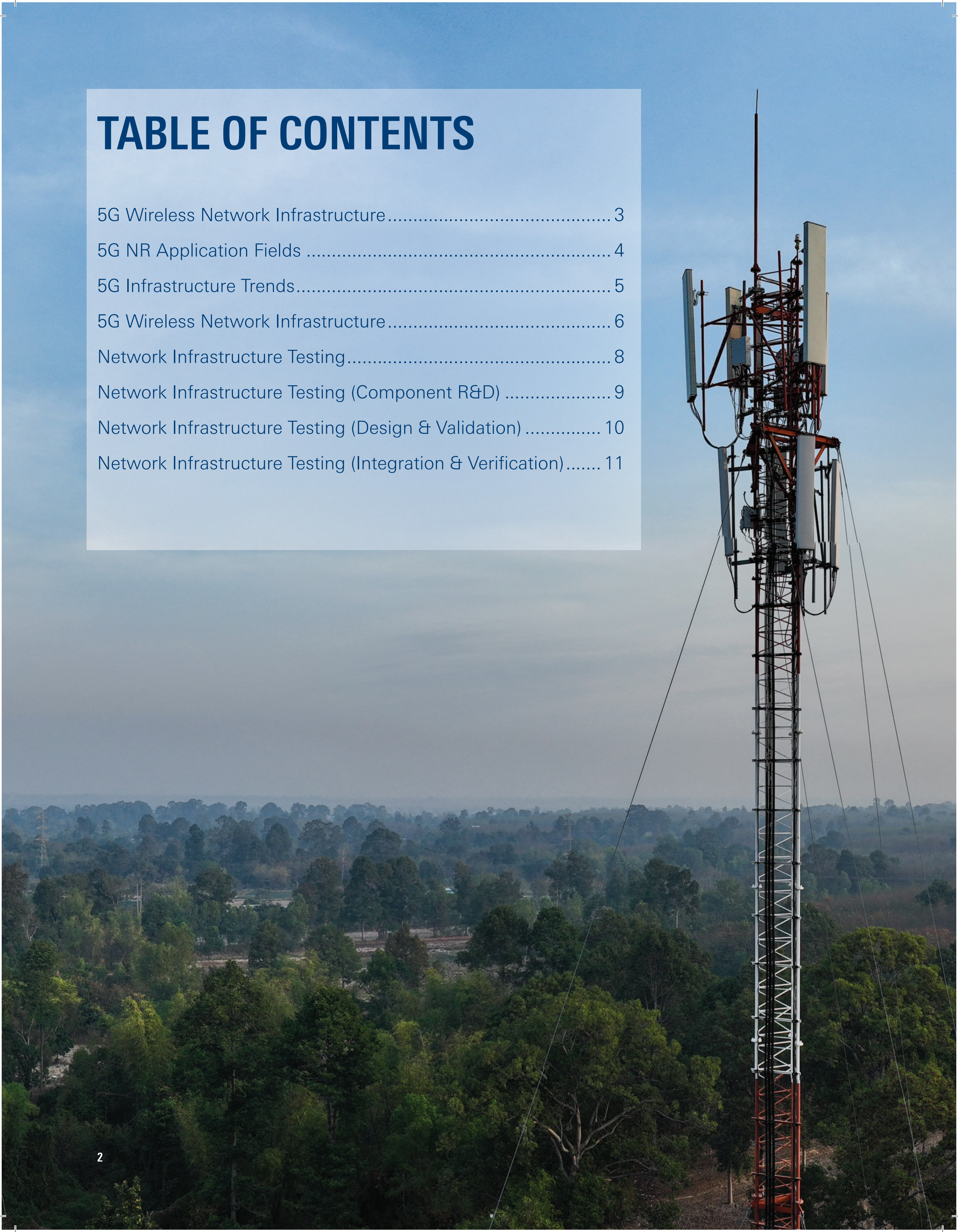
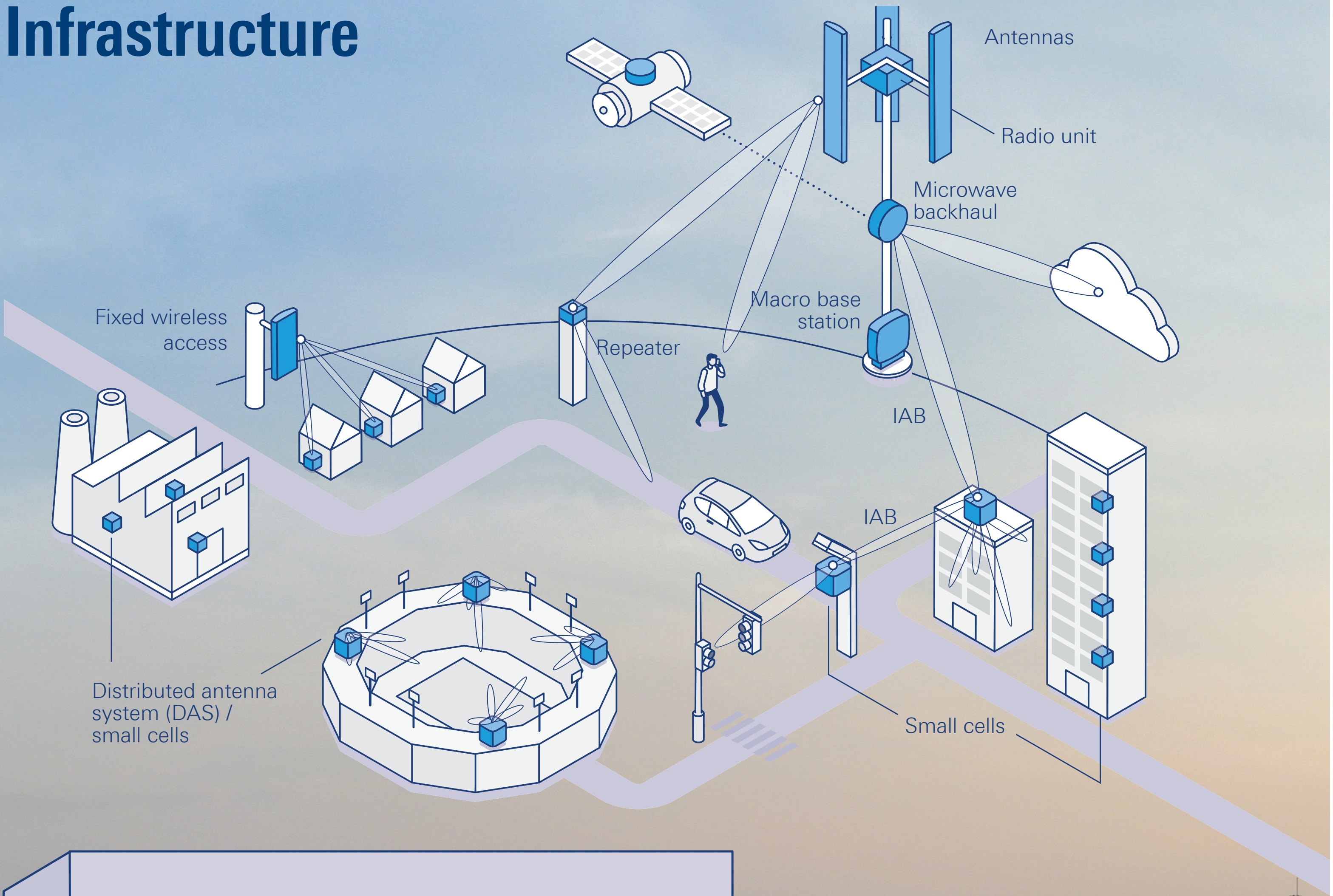
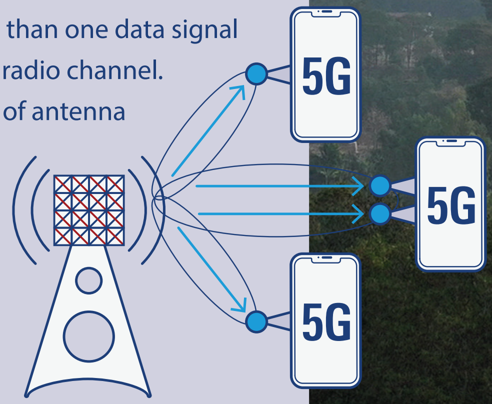


5G Wireless Network Infrastructure



What is massive MIMO?

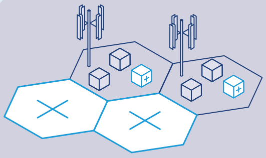
MIMO stands for multiple-input multiple-output. Involving several technologies, it mainly describes spatial multiplexing; i.e. a wireless network that allows transmission and reception of more than one data signal layer simultaneously over the same radio channel. Massive MIMO uses a large number of antenna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



5G NR APPLICATION FIELDS

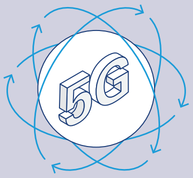
As the basis for all 5G application fields, high-performance mobile network equipment is critical for success. 5G standardization and applications focused on enhanced mobile broadband (eMBB) as the first main use case to facilitate faster data services for end users. Enabling eMBB required the use of 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.

5G 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.



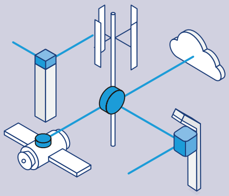
Flexibility

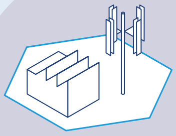
The user device evolution from a plain telephone to an application-driven device supporting various use cases necessitates a flexible infrastructure that can cope with 5G service requirements associated with eMBB, URLLC and mMTC. While software defined network methods allow virtualization of functions, 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).

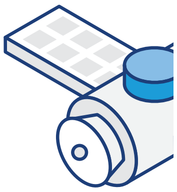


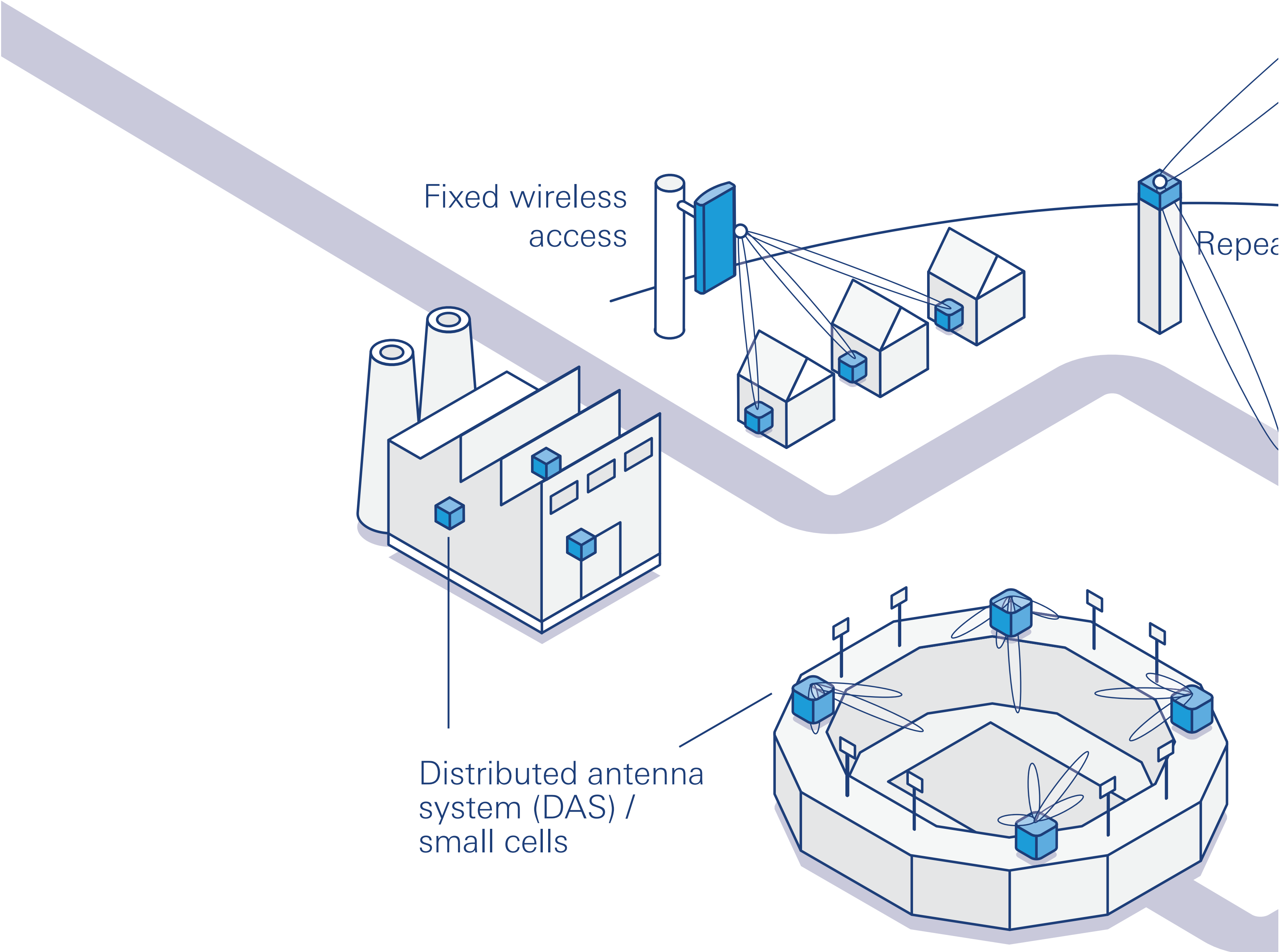


Private/local networks

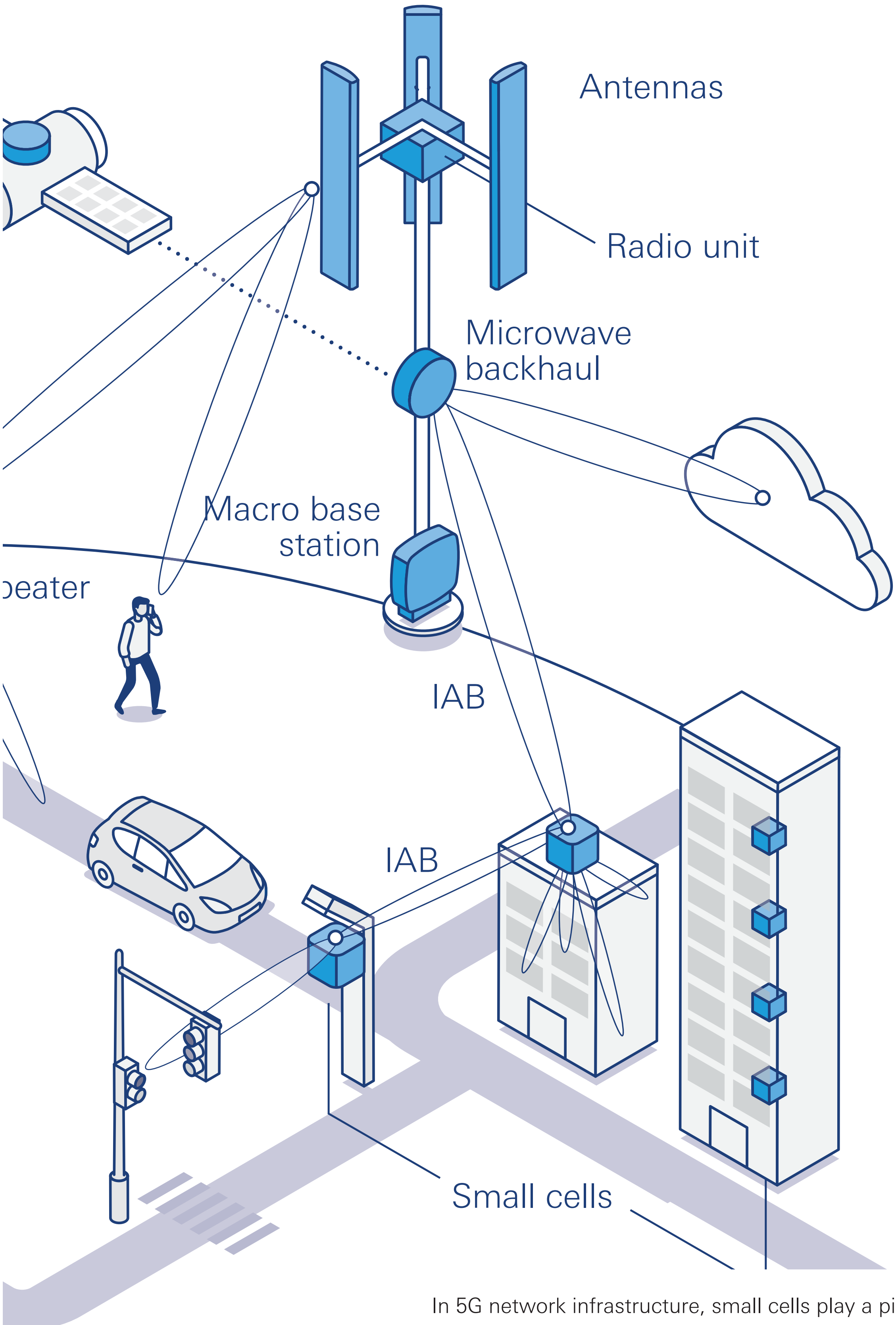
Industries, such as production facilities, can use 5G technology to create a local or private network within a dedicated area. Based on network slicing or individual industry-owned networks, private networks feature unified connectivity, use-case optimized services and a secure environment. Governments 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





5G network infrastructure employs key principles of ultra-high frequency bands, massive MIMO (Multiple-Input Multiple-Output) technology, low-latency communication, network slicing, and edge computing. These principles collectively enable faster data speeds, lower latency, increased capacity, and support for diverse applications in the next-generation wireless communication systems.



In 5G network infrastructure, small cells play a pivotal role by enhancing network coverage and capacity in dense urban areas. Microwave backhaul facilitates high-speed data transport between cell sites and core networks. Macro base stations remain crucial for broader coverage, while Distributed Antenna Systems (DAS) improve indoor connectivity. Fixed wireless access extends broadband services to homes and businesses, diversifying the 5G ecosystem.

NETWORK INFRASTRUCTURE TESTING

Network equipment manufacturers in the 5G domain grapple with a range of technical challenges, including optimizing spectrum efficiency, implementing massive MIMO technology, achieving low-latency communication, enabling network slicing, and enhancing security measures. Overcoming these hurdles demands continuous innovation and technological advancements to meet the evolving demands of the 5G ecosystem. These challenges can be addressed by the four areas below:

Antenna complexity MIMO & beam forming

Testing 5G networks presents formidable challenges, particularly in the realm of antenna complexity and beamforming. The deployment of massive MIMO systems and phased-array antennas demands rigorous evaluation of beamforming algorithms, spatial coverage, and beam alignment accuracy. Ensuring optimal performance and mitigating interference issues in dynamic, multi-user environments is a critical testing focus, necessitating advanced test equipment and methodologies to validate the reliability and efficiency of 5G networks.

Over the air (OTA)

Over-the-air (OTA) testing in 5G networks poses unique challenges. Ensuring precise and reliable OTA measurements for beamforming, signal quality, and throughput requires careful consideration of test environments, such as anechoic chambers or outdoor scenarios. Managing radio wave reflections, multipath effects, and interference sources becomes essential. OTA testing methodologies need to adapt to dynamic network conditions, and advanced test setups are essential for accurately assessing the performance and quality of 5G OTA communications, making it a complex and crucial aspect of 5G network testing.

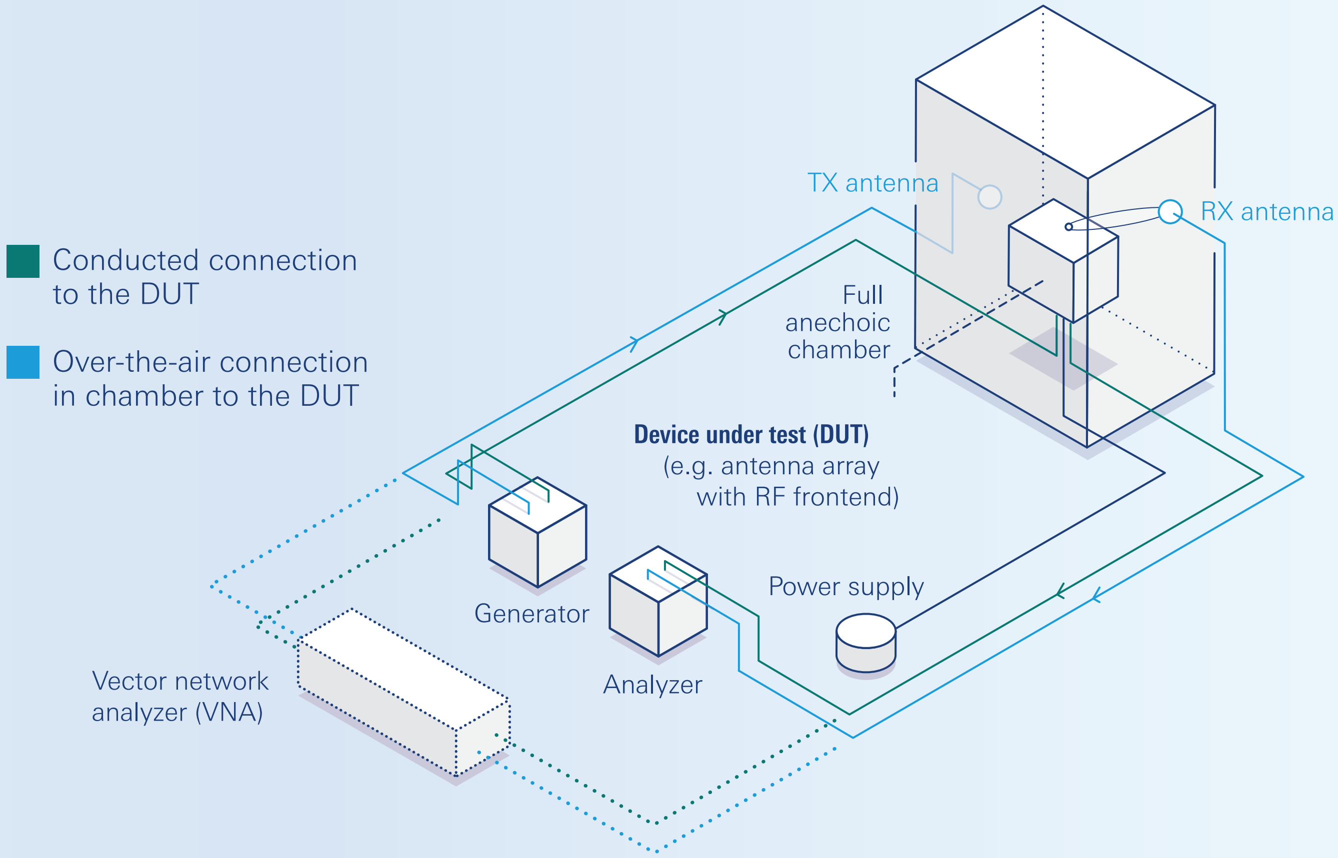
Expanding bandwidth

Expanding bandwidths in 5G networks introduces significant testing challenges. The transition to higher frequency bands, such as millimeter-wave (mmWave) spectrum, requires specialized testing equipment to assess signal propagation characteristics and ensure robust connectivity. Moreover, wider bandwidths demand increased testing complexity, as they necessitate meticulous verification of data rates, modulation schemes, and spectral efficiency. Ensuring seamless coexistence with existing frequency bands and minimizing interference while harnessing the potential of expanded bandwidths requires sophisticated testing methodologies and equipment, making it a pivotal testing frontier in 5G network development.

Higher frequencies, more band combinations

Testing 5G networks at higher frequencies and with more band combinations presents formidable challenges. The propagation characteristics at higher frequencies, such as millimeter-wave (mmWave) spectrum, require precise evaluation to ensure adequate coverage and reliability. Additionally, as the number of available bands and combinations increases, testing becomes more intricate. Verifying interoperability across diverse frequency bands, managing potential interference issues, and assessing the impact on network performance demand advanced testing tools and methodologies, making it imperative for the successful deployment and optimization of 5G networks.

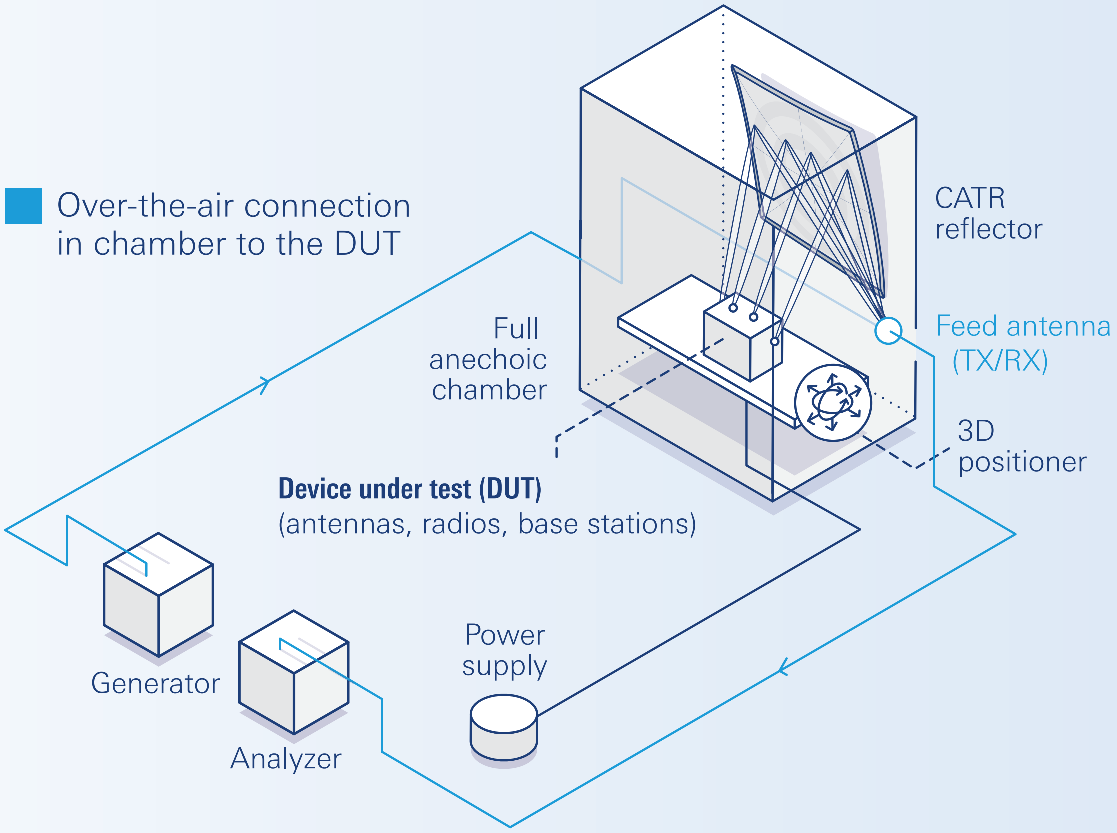
NETWORK INFRASTRUCTURE TESTING



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.

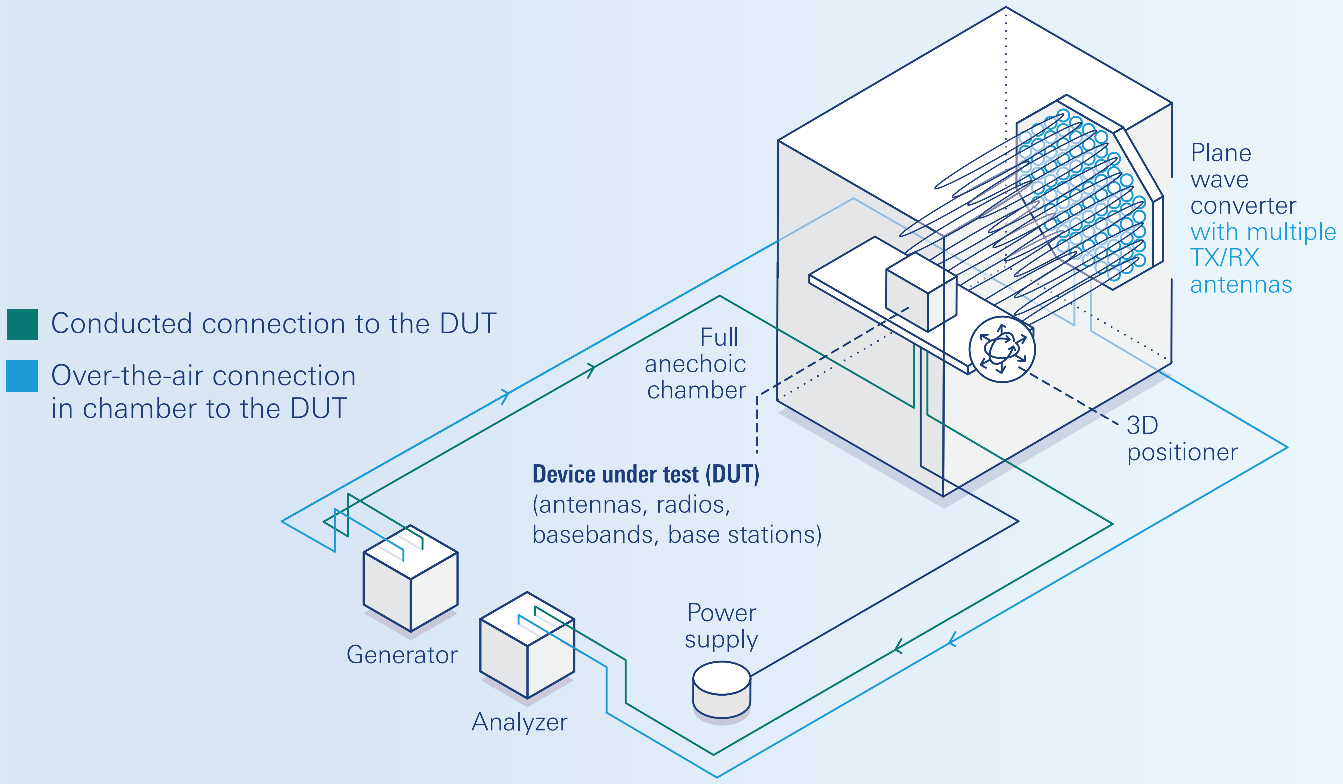
NETWORK INFRASTRUCTURE TESTING



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.

NETWORK INFRASTRUCTURE TESTING



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.

About Rohde & Schwarz

The Rohde & Schwarz technology group is among the trailblazers when it comes to paving the way for a safer and connected world with its leading solutions in test & measurement, technology systems and networks & cybersecurity. Founded more than 85 years ago, the group is a reliable partner for industry and government customers around the globe. The independent company is headquartered in Munich, Germany and has an extensive sales and service network with locations in more than 70 countries.

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Ten key enablers for 6G wireless communications