Wireless Communications

# 5G MOBILE DEVICE TESTING

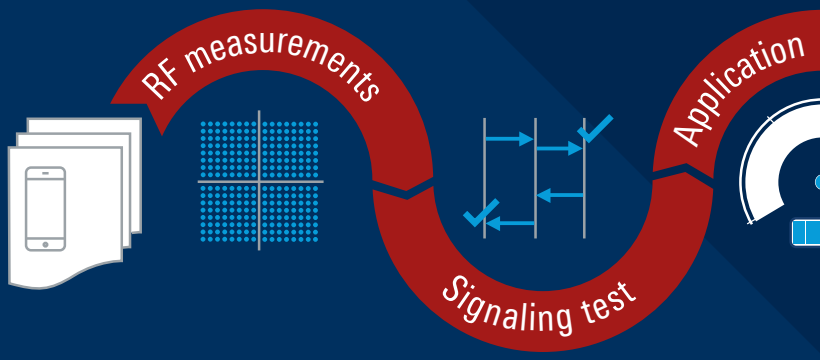
A T&M solution guide for device makers

ROHDE&SCHWARZ

Make ideas real

# 5G NR WAS BORN

Fifth generation mobile communications (5G) is the first communications standard designed to support a wide variety of consumer and industry applications. 3GPP release 15 laid the foundation for 5G NR by introducing new, flexible numerology, advanced channel coding and modulation schemes. Enabling wider channel bandwidths and extended carrier aggregation schemes while also extending frequencies into the millimeterwave range make more radio resources available.

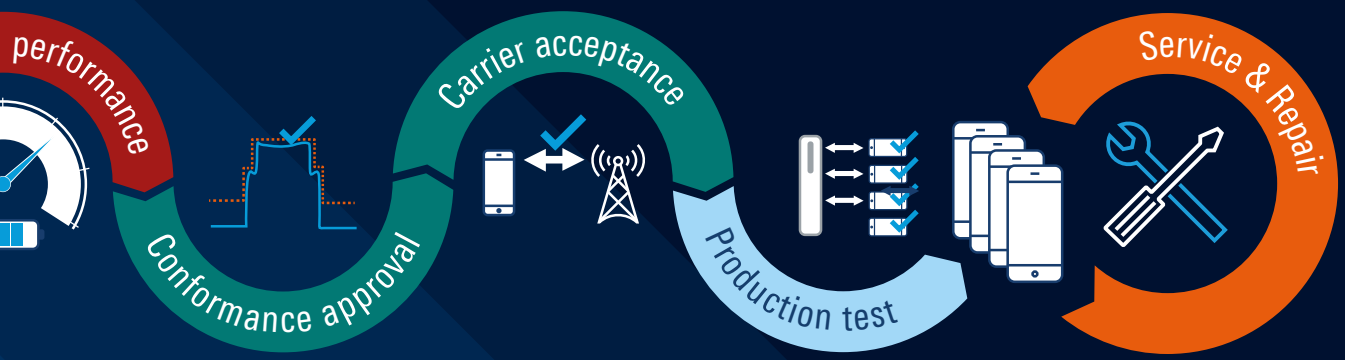



# THE POWER OF R&D TESTING

RF measurements ensure that transmit and receive components such as antennas, filters and transmitters work properly with the expected performance and that all components including power, clock and processing work seamlessly together. Antenna performance is a crucial performance criteria and needs to be evaluated with comprehensive over-the-air (OTA) testing.
The introduction of diverse 5G NR applications such as standalone (SA) and non-standalone (NSA) network architectures, and operational options like carrier aggregation (CA), dual connectivity (DC) or dynamic spectrum sharing (DSS) drive the need for more extensive signaling tests in even more complex test scenarios. Application testing allows a deeper look into the application performance which determines mobile devices and user experience: Basic measurements evaluate data throughput, latency and power consumption, and verify the functionality and performance parameters of specific applications (VoNR, VoLTE, ViNR, ViLTE).

# THE 5G DEVICE MAKER CHALLENGE

More flexibility typically means more variants, more options and higher complexity. This will have high impact on the development process from early design phases to device manufacturing. Especially advanced RF interfaces with antenna arrays operating in the mmWave range will make test setups and procedures even more challenging.




## NEED FOR APPROVAL

New product introductions require conformance approval testing from recognized test labs. The devices have to fulfill certification criteria defined by certification bodies such as GCF or PTCRB based on 3GPP specifications. This ensures interoperability and proper functioning in live networks. Some operators have specified supplementary carrier acceptance tests in order to ensure that devices in their network provide the expected functionality and performance.

## FINAL TESTING

Production test solutions help ensure a high device output at reasonable cost while maximizing yield. Besides accurate measurements, test efficiency as seen in test costs, test times, and power consumption are of utmost importance. Easy integration into existing test setups, concepts and manufacturing execution systems (MES) is essential. A small test equipment footprint is also beneficial.

# RF DESIGN VERIFICATION

Component and device developers have to verify transmitter characteristics such as maximum output power, transmit signal quality such as EVM, or frequency emissions (SEM, ACLR) and receiver performance based on receiver sensitivity or blocking performance. A typical standard RF TX/RX test configuration consists of a signal generator for generating the 5G downlink signals and a signal analyzer for verifying the uplink signal transmitted by the device under test (DUT).

## ESSENTIAL INSTRUMENT REQUIREMENTS

Test instruments need to support the required frequency bands and bandwidth. Two frequency ranges are relevant for 5G NR: frequency range 1 (FR1) from 410 MHz to 7.125 GHz and frequency range 2 (FR2) from 24.25 GHz to 52.6 GHz. In the FR2 mmWave range, developers are facing many challenges such as higher path attenuation, higher phase noise and linearity issues. A maximum 5G NR carrier channel bandwidth of 100 MHz for FR1 and 400 MHz for the FR2 mmWave range plus multiple carrier aggregation place high requirements on the bandwidth.

### Expert tip

The most suitable test tool for verifying the performance of 5G antennas and radio components is a vector network analyzer such as the R&S®ZNA covering the complete 5G NR frequency ranges.

## THE EXPERT SOLUTION

For highest performance requirements the R&S®SMW200A wideband signal generator with built-in fading capabilities and the R&S®FSW signal and spectrum analyzer perfectly meet specific 5G NR test requirements with integrated 5G NR software personalities. The R&S®SMM100A mid-range vector signal generator and R&S®FSVA3000 mid-range spectrum analyzer suffice for many 5G NR test applications. They are also ideal for design validation test rack installations (DVT). In addition, the R&S®RTP oscilloscope captures I/Q data and feeds it into the R&S®VSE vector signal explorer software for detailed signal analysis on a PC or in the cloud.

Analyzing 5G NR wideband signals with the R&S®FSW internal analysis bandwidth of up to 8 GHz at FR1/FR2.

The R&S®SMW200A generates FR1/FR2 5G NR signals with an internal modulation bandwidth of up to 2 GHz.

# OVER-THE-AIR TESTING RELOADED

RF testing with legacy device generations supporting only frequencies below 6 GHz were mainly performed in conducted mode, which allows easy-to-use test set-ups. Only few antenna and radio performance measurements were performed over the air, such as for measuring the total radiated power (TRP) and total isotropic sensitivity (TIS). This is still valid for 5G NR FR1 testing. FR2 mmWave testing requires OTA setups as conducted connections are no longer feasible.

## THE mmWAVE CHALLENGE

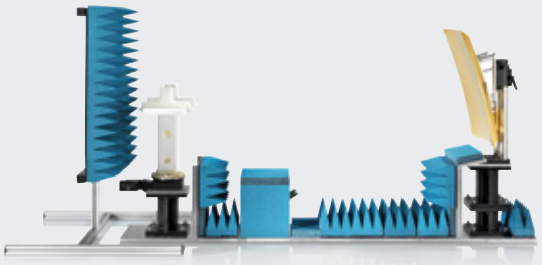
Mobile devices equipped with mmWave antenna arrays, each consisting of transceiver, frontend and phased antenna array, make conducted tests impossible. Moreover, testing of features such as beamforming can only be verified over the air. As a result, 3GPP specifies that all FR2 conformance tests need to be performed over the air under direct or indirect far-field conditions.

## CHAMBERS FOR ALL TEST PURPOSES

Rohde&Schwarz offers a complete solution portfolio for direct (DFF) and indirect far-field (IFF) measurements. This includes the R&S®ATS800R, a rackmounted CATR system, which uses hardware to transform propagating waves into plane waves creating far-field conditions at a considerably shorter than Fraunhofer distance. With a large quiet zone of 20 cm, it is perfect for R&D labs as it enables testing in black-box mode without knowing antenna positions.

### Expert tip

Using a compact desktop CATR setup such as the R&S®ATS800B for far-field OTA measurements to optimize the RF performance in the early product development phase at reasonable costs.



The R&S®DST200 RF diagnostic chamber is ideal for FR1 analysis in R&D.

CATR based R&S®ATS800R antenna test system for black-box testing in R&D.


R&S®ATS1800C CATR mmWave chamber for conformance testing and R&D

# ONE SIGNALING PLATFORM SERVES IT ALL

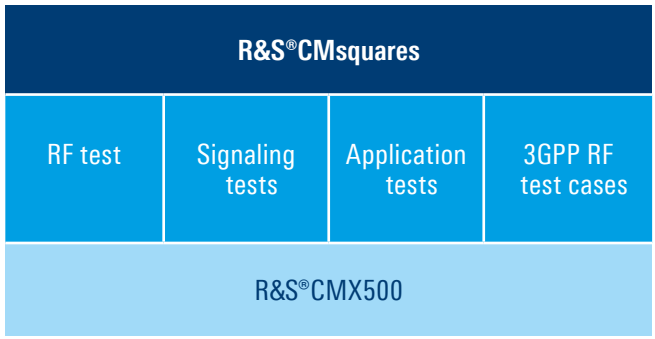
5G NR flexibility based on enhanced numerology, a variety of bands and deployment options as well as application-optimized feature sets make testing in signaling mode by emulating a mobile network environment more important than ever. Testing in signaling mode is required for verifying protocol implementations but it is also necessary for RF parameter and application testing. It allows an easy connection establishment and opens a wealth of possibilities to verify performance parameters with varying network parameters and scenarios.

## DESIGNED FOR THE FUTURE

The R&S®CMX500 radio communication tester is designed to meet the diverse 5G NR testing needs. As a single solution, it provides extensive device testing capability including support for all 5G NR variants: FR1 and FR2, non-standalone (NSA) and standalone (SA), for both FDD and TDD. The R&S®CMX500 works seamlessly with the R&S®CMW500 wideband radio communication tester, the industry standard for cellular (LTE, NB-IoT, LTE-M, 3G, 2G) and wireless (Wi-Fi, Bluetooth®) connectivity testing. Combining the R&S®CMX500 and the R&S®CMW500 covers all major wireless technologies relevant to mobile device makers.

## A UNIQUE PLACE OF MEASUREMENTS

The R&S®CMX500 has a modular hardware and software design. The R&S®CMsquares state-of-the-art web based graphical user interface makes it easy to configure the tester according to specific test requirements. All tools are in one place. The unified user interface is ideal for all test applications from protocol testing, RF parameter testing and application testing, and opens the way for a unique user experience and a "DUT-centric" test approach. An interactive mode allows manual tests, that can be easily automated with a graphical test script suite or a script-based sequencer (SCPI, XLAPI, Python), making it ideal for use in R&D, 3GPP preconformance testing and repair. The powerful R&S®CMXmars message analyzer completes the test application set.






5G NR test setup consisting of the R&S®CMX500 and the R&S®CMW500 for FR1 and LTE testing. The setup is easily upgradeable to cover FR1 and FR2 testing.

# TESTING OF mmWAVE FUNCTIONS

5G NR expanding into the mmWave range will have a huge impact on reliable, accurate device testing in signaling mode. Small, fully integrated mmWave antenna arrays on mobile devices make conducted tests impossible. Consequently, RF parameter, protocol and end-to-end application tests need to be performed over the air under MIMO conditions, demanding a practical shielding solution that meet the requirements (shielding, quiet zone, size, cost) of device makers.

## ONE-STOP TEST SOLUTION

The R&S®CMX500 is easily upgradeable. A tester for FR1 can also perform FR2 testing by adding dedicated interface boards. Remote radio heads used for upconversion/downconversion and path switching together with a shielding cube and integrated wideband test antennas complete the one-stop solution for FR1 and FR2 signaling testing. This makes it also to the perfect solution for service and repair of mobile devices.

## TRUSTABLE mmWAVE SETUP

The R&S®CMXHEAD30 remote radio heads can be mounted directly on an anechoic chamber such as the R&S®ATS800R, R&S®ATS1800C and R&S®CMQ500 to minimize the cable distance between the radio head and the test antennas. For example, the R&S®CMQ500 shielding cube allows 3GPP RF performance measurements with beam peak under direct far-field (DFF) conditions. For mmWave precompliance and conformance measurements, the R&S®CMX500 works seamlessly with the R&S®ATS800R or R&S®ATS1800C test chamber. The integrated 3D positioner allows measurements of TRP or cumulated distribution function (CDF) of EIRP as defined by 3GPP.

### Expert tip

The field-to-lab engine CM360° of the R&S®CMX500 allows testing of devices in the lab with field data representing real-world network scenarios from network scanners or device log data.

5G NR test setup consisting of the R&S®CMX500 and the R&S®RRH, combined with the R&S®CMW500 and the R&S®CMQ500 shielding cube – the optimal solution for 5G FR1 and FR2 signaling tests.

# COVERING A LARGE VARIETY OF APPLICATIONS

5G devices are designed to meet certain application requirements ranging from low-cost tracking services (mMTC) to mission-critical industry applications (URLLC) or augmented reality games (eMBB) on a phone or wearable. Testing against the specific application requirements includes testing of basic parameters such as data throughput and latency. Even more important is the testing of the specific functions and quality performance parameters, such as mobile network services including voice/video services (VoNR, ViNR), SMS, or location based services (LBS), but also typical IP/web services such as messaging or video streaming services.

### Expert tip

Simply use the web server running on the R&S®CMX500 to have quick access to a couple of performance analyzer tools from a browser running on the device under test.

## COMPREHENSIVE APPLICATION TESTING

The R&S®CMX was designed to provide extreme high data throughput in the 20 Gbps range to test the most demanding applications. The built-in application test enabler comes with ready-to-use servers for testing web, FTP, DNS or IMS services allowing easy setup for various end-to-end test scenarios in a well-defined network environment. Alternatively, the R&S®CMX can be connected to an external data server. Benchmarking makes it possible to compare the application performance under different network setups or on different devices. User-configurable impairments and RF fading can be activated for performance tests under non-ideal conditions.

## DEEP TRAFFIC INSPECTION

The R&S®CMX allows detailed analysis of the application traffic on several layers and testing by applying specific network impairments. Dedicated test setups enable analysis of an application's video and audio quality. Besides the built-in servers and applications, it is also possible to connect directly to specific applications running on the local lab network or public internet. An IP traffic analysis option adds monitoring capabilities for investigating the secure communications behavior of an application running on the device.

The R&S®CMX application test enabler allows comprehensive testing of the key performance indicators of applications running on built-in or connected external servers.

# CONFORMANCE APPROVAL

Conformance approval is one of the most important steps to bringing mobile devices to the market. This process can be quite difficult and costly if not well prepared in advance. With the introduction of 5G NR, the sheer number of test cases grows exponentially due the huge number of supported band combinations, deployment options and evolving standards. The certification criteria defined by certification bodies such as GCF, PTCRB and CTIA based on the 3GPP technical specification (TS 38.521) comprise four test areas: radio frequency conformance (RF), radio resource management conformance (RRM), protocol conformance (PC) and performance quality analysis (PQA).

## EFFICIENCY AND ACCURACY COUNT

Dedicated test setups ensure reproducibility and comparability of test results, and allow a high level of test automation. For example, the popular R&S®TS8980 RF test system covers mobile technologies all the way from 2G to 5G on one platform. Together with the R&S®CONTEST software, the highly efficient test system offers precise, reproducible results with easy-to-use test case parameterization and debugging capabilities.

## OPERATOR-SPECIFIC ACCEPTANCE TESTING

Major 5G operators ask for additional carrier acceptance testing of devices in order to ensure that they properly work in the networks and meet quality, performance and functionality expectations. Tests include enhanced RF, RRM, data throughput (PQA), protocol and performance tests for verifying IMS applications, emergency call systems, location based services, power consumption and security. The one-platform concept of the R&S®CMX makes it the first choice for operator-specific test cases among network operators around the globe.

| Relevant specifications |
|---|
| 3GPP TS 38.521-1 Radio transmission and reception Part 1: Range 1 (FR1) standalone – conducted only |
| 3GPP TS 38.521-2 Radio transmission and reception Part 2: Range 2 (FR2) standalone – radiated only |
| 3GPP TS 38.521-3 Radio transmission and reception Part 3: Range 1 and range 2 interworking operation with other radios |
| 3GPP TS 38.521-4 Radio transmission and reception Part 4: Performance |
| 3GPP TS 38.533 Radio Resource Management (RRM) |
| ETSI EN 301 908-25 Harmonized standard for access to radio spectrum; Part 25: New Radio (NR) User Equipment (UE) |
| CTIA Test Plan for Millimeterwave Wireless Device Over-the-Air Performance |

| R&S®CONTEST software | | | | | |
|---|---|---|---|---|---|
| Conformance | | | Operator acceptance | | |
| RF | RRM LBS | PCT | ATE | NPT | PQA |
| R&S®CMX500 based test system | | | | | |


The R&S®TS8980 RF test system solution includes the R&S®ATS1800C CATR chamber and the R&S®CMX500 radio communication tester for 5G NR FR1/FR2 signaling tests.

# 5G NR EXTENSION

With the R&S®CONTEST software and the R&S®CMX500 platform, Rohde&Schwarz supports the testing needs of major 5G network operators. The compact R&S®CMX500 covers protocol and RF tests for LTE and 5G NR FR1 and can be extended to provide FR2 frequencies and test cases.

## 3GPP PRECOMPLIANCE TESTING

In order to be well prepared for the approval process, it is highly recommended to perform precompliance protocol and RF performance tests in the R&D lab, saving time and money. The tests can be performed with conformance test systems or by using the automated test cases provided by the R&S®CMX500 and sequencer software.

## KEEP YOUR SYSTEM UP TO DATE

As 3GPP standards are constantly evolving, new test cases will be created and operators are adapting their test strategies. Rohde&Schwarz covers actual test requirements by offering dedicated service packages to ensure up-to-date test system hardware and software. These packages include hotline support, continuous updating of system software and test cases, calibration and various maintenance services.

Operator acceptance test setup consisting of two R&S®CMW500, an R&S®CMWC controller, an R&S®CMX500 and the R&S®CMW-RF88 switching matrix.

# ACCURATE LOCATION DETERMINATION

Location based services (LBS) play a critical role in today's commercial mobile devices and it is expected to play an even bigger role in 5G. Given this importance, along with the introduction of new satellite location technologies in mobile phones such as modernized GPS (L5) and GALILEO, it is critical that the LBS performance of mobile devices is verified in the lab before commercial launch. Moreover, with the rollout of 5G NR in the millimeterwave range, it is critical to ensure continued reliability of emergency calls such as 911, and location determination of mobile devices.

## COMPREHENSIVE LBS TEST SOLUTION

The R&S®TS-LBS test system, which consists of the R&S®CMX500 and R&S®CMW500 radio communication testers is a seamless and comprehensive test platform for LTE, 5G NR FR1 and FR2 tests. The R&S®SMBV100B vector signal generator simulates the GPS L1 & L5, Galileo, GLONASS and BeiDou satellite constellations for A-GNSS. The solution also provides other positioning technologies such as barometric pressure sensors, Wi-Fi and Bluetooth®. Legacy technologies like GSM, WCDMA and LTE are all supported using the same hardware.

## TEST CAPABILITIES ON DEMAND

4 cloud testing

With the R&S®Cloud4Testing, you can enjoy a quick and easy access to Rohde&Schwarz testing essentials without having to make a big investment. Simply measure, analyze and process your individual RF data, on demand and on the go.

The R&S®TS-LBS comprehensive test platform for testing LTE, 5G NR FR1 and FR2, and simulating GPS L1 & L5, Galileo, GLONASS and BeiDou satellite constellations for A-GNSS.

# FINAL CALIBRATION AND VERIFICATION

Manufacturing floor test processes consist of various stages. At the board/panel level, system level and final device testing which typically include calibration are followed by RF verification tests in non-signaling mode using chipset-specific test control interfaces. Since test time is a significant factor, manufacturers are constantly looking for ways to minimize both the test time and the associated costs. For example, parallel testing of multiple devices enables efficient instrument-use and production line throughput.

### Expert tip

Powering devices for testing in the factory and use the power consumption measurement feature on the R&S®NGL200 power supply series for a fast indication of device performance issues.

## OPTIMIZED FOR MANUFACTURING NEEDS

The R&S®CMW100 is part of the successful radiocommunications tester family. With its flexibility and high measurement speed, the R&S®CMW100 is the ideal solution for high-volume manufacturing environments. Designed for testing and verifying wireless devices in production, the R&S®CMW100 supports a wide range of methods for reducing test time and maximizing capacity utilization. It has a dustproof housing for high reliability and its fanless design ensures silent and clean operation. In line with high throughput expectations, the R&S®CMW100 can test up to eight antennas and/or devices in parallel and is ideal for use in fully automated production lines.

## 5G NR FR1 TESTING IN MANUFACTURING

The R&S®CMW100 offers high measurement accuracy and performance for carrier frequencies up to 6 GHz and RF bandwidths up to 160 MHz. In addition to sub 6 GHz 5G NR devices, the flexible testing solution is suitable for other wireless standards supporting legacy radio access technologies such as GSM, WCDMA or LTE as well as Wi-Fi and Bluetooth®. This makes the R&S®CMW100 a cost-effective solution for mass production of both cellular and non-cellular wireless connectivity devices calibrated and verified in non-signaling mode.

R&S®CMW100 manufacturing test setup together with the R&S®TS7124 – a perfect 5G NR FR1 solution for fully automated production environments.

# mmWAVE TESTING ON THE FACTORY FLOOR

Since it is not possible to use RF connectors, validating 5G devices operating in the mmWave range (FR2) requires over-the-air testing approaches on the factory floor. All system components have to be matched exactly to get reliable and accurate results.

## A FULLY INTEGRATED SOLUTION

The system concept of the R&S®CMPQ is completely flexible. The user can configure the individual components and the system constellation independently of each other to create customized solutions. The R&S®CMPQ consists of the R&S®CMP200 radio communication tester, the R&S®CMPHEAD30 mmWave remote radio head and the R&S®CMQ200 shielding cube. It integrates all system components, including the antennas, cables, feedthroughs and power sensors to ensure optimal and stable system parameters. The R&S®CMPQ manufacturing test solution is a fully integrated mmWave (FR2) solution from a single supplier.

## A COMMON PLATFORM STRATEGY

Following the proven platform strategy of the R&S®CMW family, both the R&S®CMP200 and the R&S®CMX500 use the same technology, comparable hardware and common software architecture across all test solutions. The R&S®CMP200 combines vector signal analyzer and ARB based generator functionality in a single box. The compact integrated solution can be customized with up to three R&S®CMPHEAD30 remote radio heads (RRH), for upconverting/downconverting signals to 5G FR2 frequencies. The R&S®CMP200 is also controlled via the R&S®CMsquares standardized graphical user interface. Integrated sequencer applications simplify automated production test setups.

### Expert tip

Intelligent, LAN enabled power measurements using power sensors such as the R&S®NRP18/33SN are ideal for remote monitoring applications.

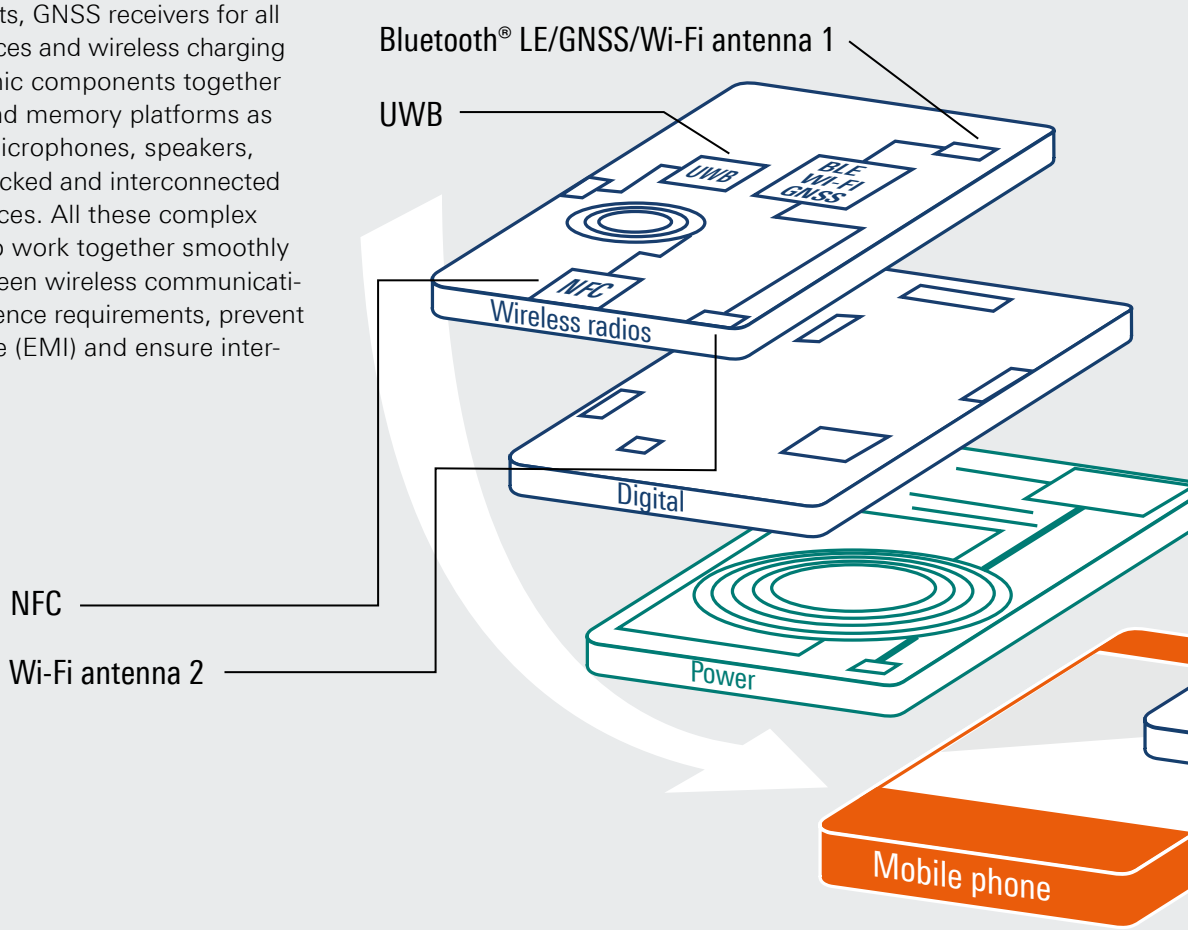
R&S®CMPQ test setup for mmWave (FR2) testing in the production line based on the R&S®CMP200 and the R&S®CMQ200 shielding cube.

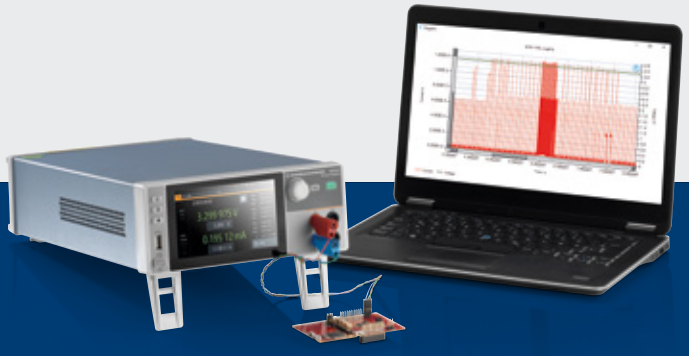
# MUCH MORE THAN 5G

Mobile devices are fully packed with powerful hardware. For example, modern smartphones are powered by a couple of wireless technologies to meet customer demands: Wi-Fi for the broadband experience at home and offices, Bluetooth® to connect with accessories and wearables, UWB for secure ranging applications, NFC for secure payments, GNSS receivers for all types of location based services and wireless charging interfaces. All these electronic components together with powerful processing and memory platforms as well as screens, cameras, microphones, speakers, etc. need to be powered, clocked and interconnected by analog and digital interfaces. All these complex system components need to work together smoothly to prevent interference between wireless communications interfaces, meet coexistence requirements, prevent electromagnetic interference (EMI) and ensure interface conformance.

## LONG BATTERY LIFE

The battery life of mobile devices is a key performance criterion and can become a great competitive advantage. Therefore, verifying and optimizing the power consumption and battery behavior is important. To get the full picture, it is recommended to combine it with application testing e.g. applying power saving features of wireless technologies like DRX in 5G or LTE and verifying the impact on the application performance and power consumption.



R&S®NGM power supply with comprehensive power analysis functions.

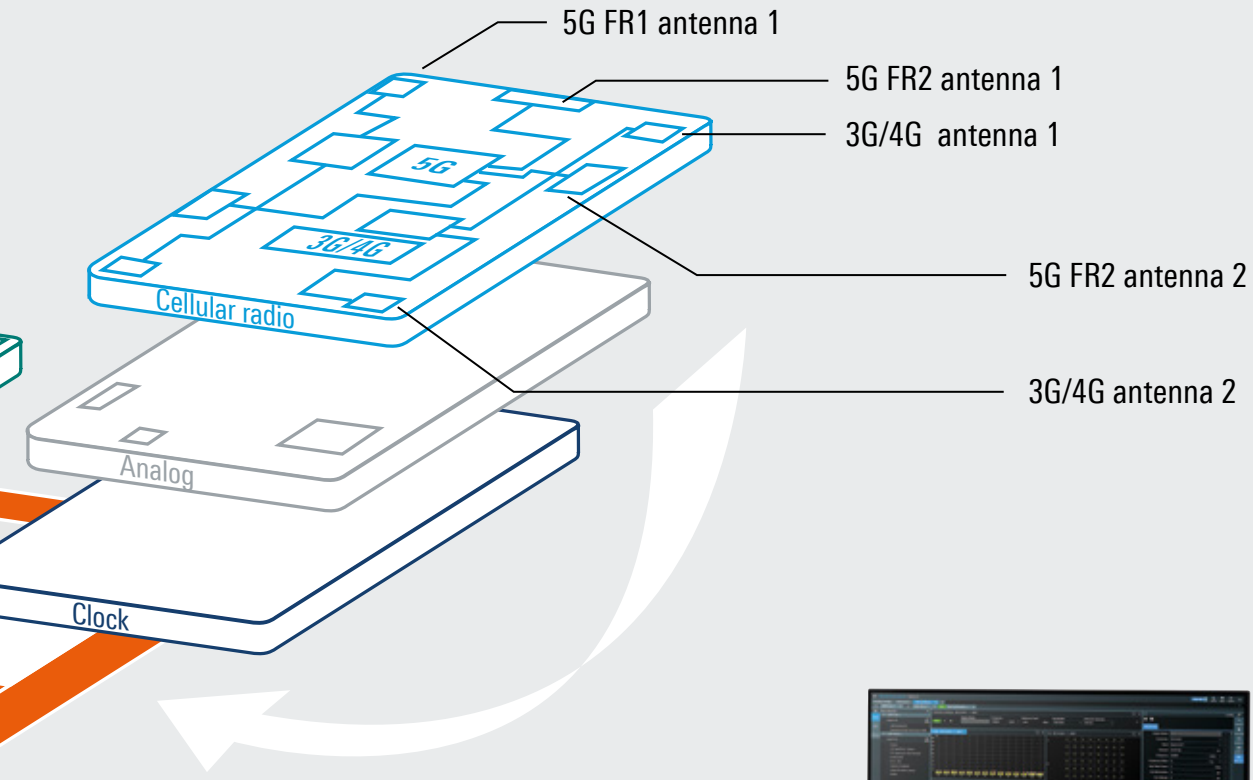
R&S®RTP high-performance oscilloscope for highly accurate measurements on multiple domains.

## DIGITAL INTERCONNECTIVITY PLANE

All internal (MIPI, I²C, UART, JTAG, PCIe) and external (USB, HDMI™, SD card, etc.) digital interfaces need to comply with relevant standards and sometimes need to be investigated for debugging and optimization purposes. Often, multi-domain analysis of several digital and analog interfaces is required at the same time. An oscilloscope is ideal for this, providing the necessary channels, bandwidth, resolutions and system analysis tools.

## WIRELESS CONNECTIVITY BESIDE 5G

Similar to cellular technologies, Wi-Fi, Bluetooth® and UWB also need to be tested in line with relevant standards and regulatory requirements. In addition to standalone testing of these technologies, the interworking e.g. switching from cellular to Wi-Fi and the coexistence (parallel operation) needs to be verified to ensure the expected quality and performance. Rohde&Schwarz offers the R&S®CMW mobile radio tester platform, the R&S®SMW200A signal generator and the R&S®FSW signal and spectrum analyzer for testing all cellular and non-cellular technologies, eliminating the need for additional test equipment.




R&S®CMW270/500 for testing Wi-Fi or Bluetooth® in signaling or non-signaling mode.

R&S®CMP200 applicable for UWB non-signaling testing based on IEEE802.15.4z.

## Service that adds value

- Worldwide
- Local and personalized
- Customized and flexible
- 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.

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