BE AHEAD IN 5G.
TRUST THE PIONEERS IN 5G NETWORK TESTING.

What do you really need to know?
The most important facts and solutions.

eBook | Version 02.00

ROHDE&SCHWARZ
Make ideas real

MAXIMIZE NETWORK QUALITY AND PERFORMANCE

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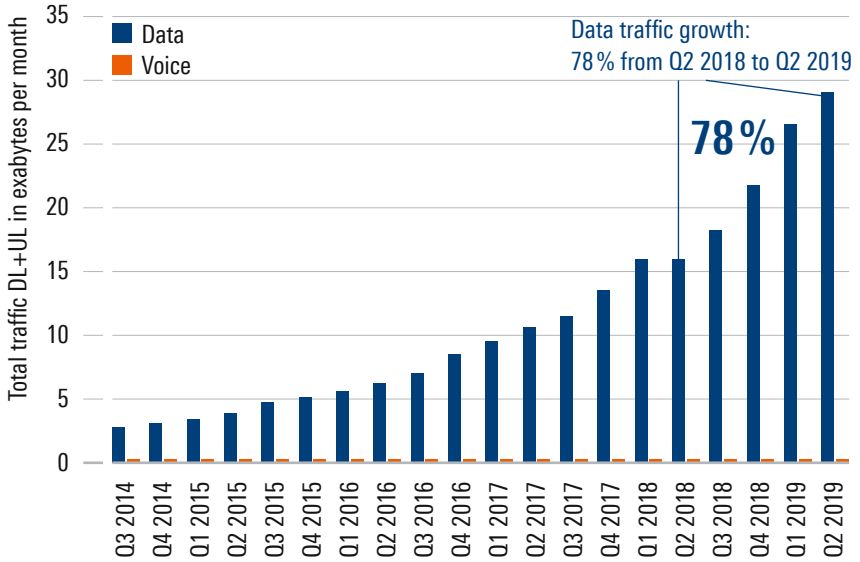
5G NR MARKET AND DRIVERS

Data consumption in mobile networks is still growing enormously. To meet this high traffic demand, new spectrum was allocated (e.g. in the 3.5 GHz range) and 5G NR commercial rollouts started in 2019.

"In Q2 2019, mobile data traffic grew 78 percent year-on-year. The high growth rate was mainly influenced by the increased number of smartphone subscriptions in India and increased data traffic per smartphone per month in China."

Ericsson Mobility Report June 2019

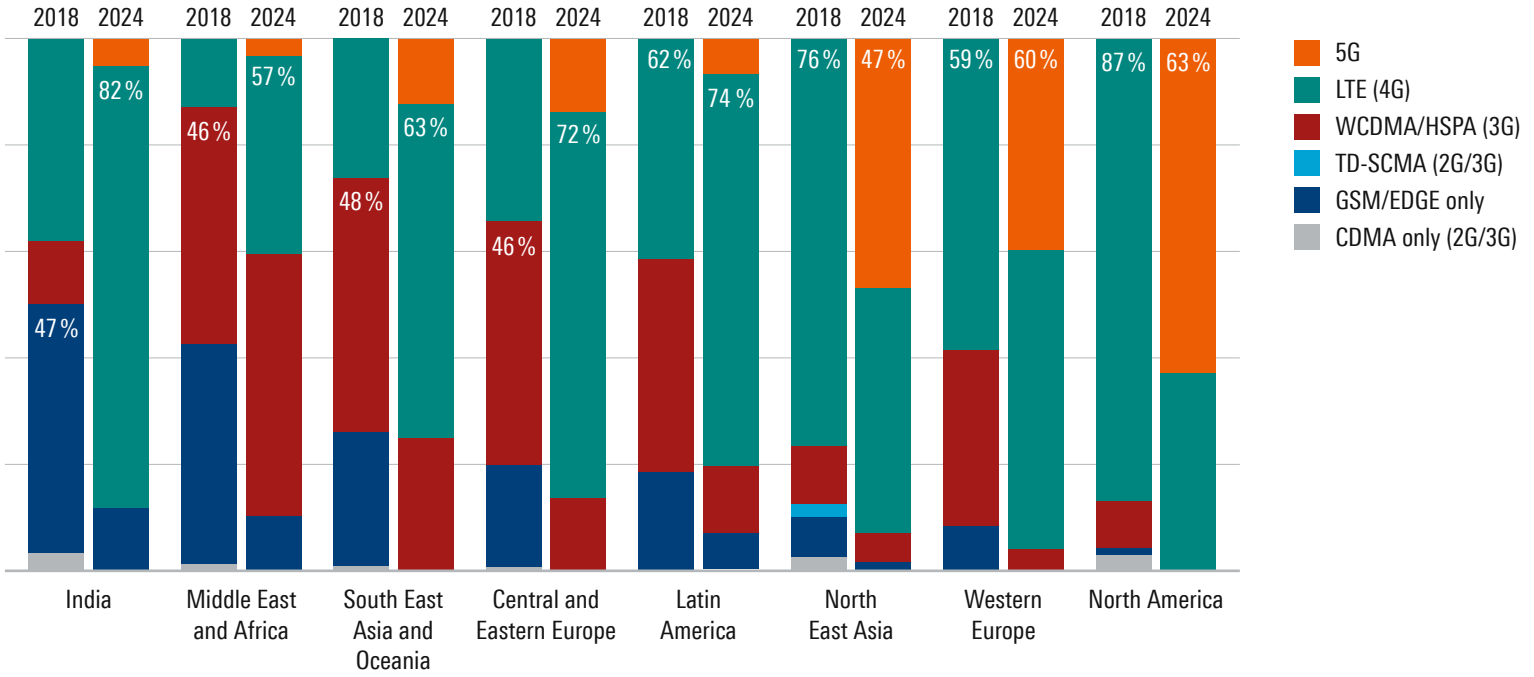
Total traffic (reference Ericsson Mobility Report June 2019)



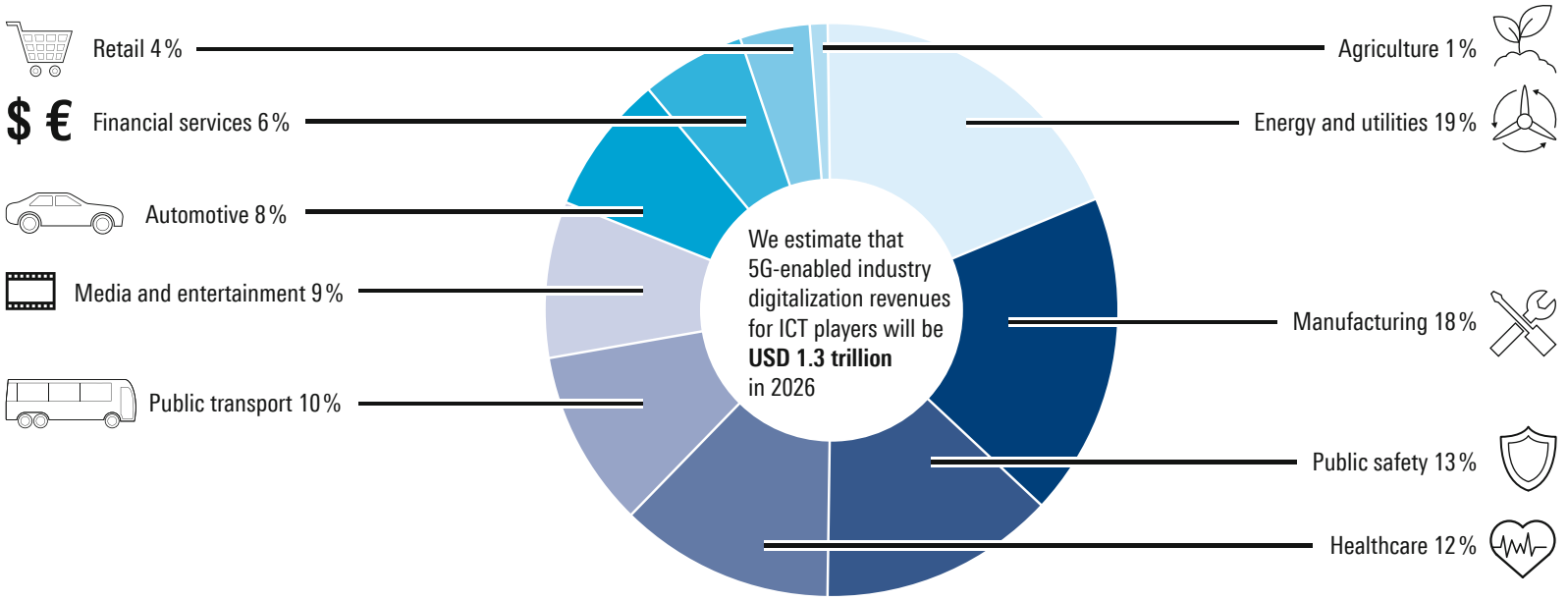
The Ericsson Mobility Report also predicts that the regions with significant portions of 5G subscriptions in 2024 will be predominantly:

- North America (63 %)
- North East Asia (Korea, China, Japan; 47 %)
- Western Europe (40 %)

Mobile subscriptions in 2024 by region and technology (in percent)



5G-enabled industry digitalization revenues for ICT players in 2026



ROHDE&SCHWARZ MOBILE NETWORK TESTING

We are a leading and trusted global supplier of mobile network testing solutions and services throughout the entire network lifecycle to empower our customers to make well-informed decisions, deliver better services with higher quality to end users and reduce time to market.

5G NR USE CASES

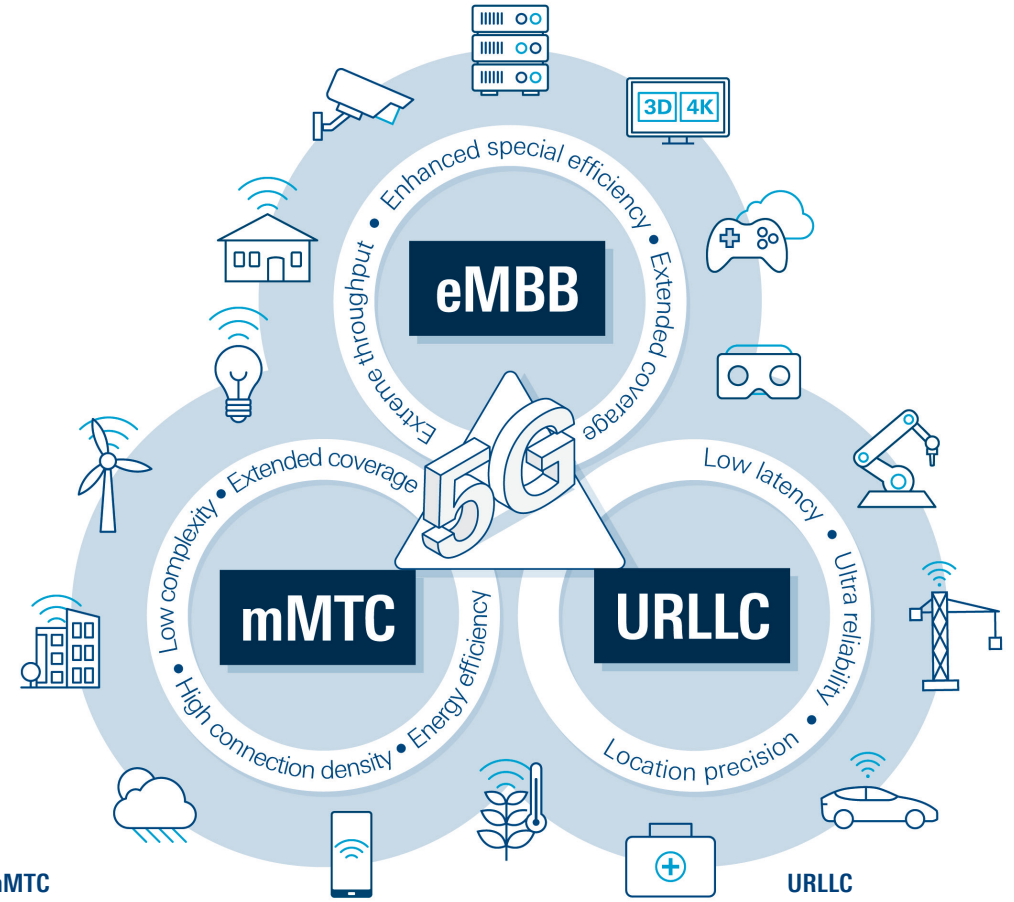
5G NR is the global standard for providing a unified, more capable 5G wireless air interface. It will deliver significantly faster and more responsive mobile broadband experiences and will extend mobile technology to connect and redefine a multitude of new industries.

Enhanced mobile broadband (eMBB)
eMBB will continue to be the industry priority in the early years of commercial deployments. More spectrum and more capacity are needed to cope with the increasing data demand in mobile networks.

Massive machine type communications (mMTC)
mMTC will be handled by evolving the LTE based technologies NB-IoT and LTE-M. 3GPP currently does not specify any 5G NR related solution for massive machine type communications.

Ultra-reliable low latency communications (URLLC)
URLLC is a whole new area for mobile communications. 3GPP provides the flexibility of the 5G NR air interface and the architectural options with e.g. network slicing for low latency, high reliability requirements. With Industry 4.0, this demanding area will become very important for both operators and new customer segments operating private or enterprise 5G networks for e.g. an automated manufacturing site.

eMBB
enhanced mobile broadband
Data-driven use cases require high data rates across a wide coverage area.



mMTC
massive machine type communications
Need to support in a very small area a very large number of devices, which may only send data sporadically, such as internet of things (IoT) use cases.

URLLC
ultra-reliable low latency communications
Strict requirements on latency and reliability for mission-critical communications such as remote surgery, autonomous vehicles or the tactile internet.

5G NR TECHNOLOGY

How does 5G NR differ from LTE?

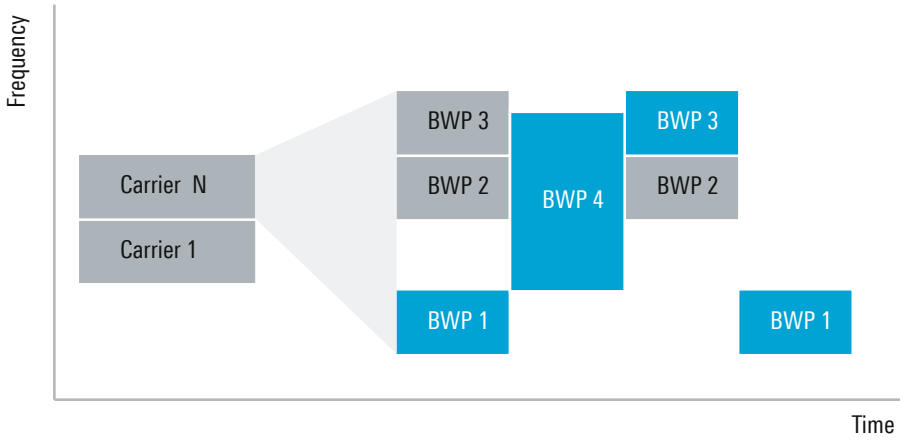
LTE radio access network technology (or, in 3GPP terms, eUTRAN) is an OFDM based technology with a fixed subcarrier spacing of 15 kHz that supports carrier bandwidths from 1.4 MHz to 20 MHz. LTE has a packet-switched architecture that supports a wide range of data applications. Voice is also supported as voice over LTE (VoLTE) or using fallback mechanisms to 3G and circuit-switched technologies.

Parameter	Frequency range	
	< 24 GHz, mostly < 6 GHz	**> 24 GHz**
Carrier aggregation	up to 16 carriers	
Bandwidth per carrier	5/10/15/20/25/30/40/50/60/80/100 MHz	50/100/200/400 MHz
Subcarrier spacing	15/30/60 kHz	60/120/240 (not for data) kHz

The 5G NR specification sticks to OFDM based technology but embraces flexibility. The aim is to include different use case families that were previously discussed across industries.

These different use cases require a wide variety of air interface characteristics in terms of frequency range, subcarrier spacing, carrier bandwidth, symbol duration, etc.; the network architecture needs to offer many options. The table below shows the flexibility of frequency-specific parameters.

Concept of bandwidth parts (BWP)



To cope with the different 5G NR use cases and demands per service, 3GPP defines the concept of bandwidth parts (BWP). Each BWP has a fixed numerology (fixed subcarrier spacing, number and location of the resource block, symbol duration, etc.).

At any given time, only a single downlink/uplink carrier bandwidth part can be active per UE.

At least one BWP carries the cell-defining synchronization signal block (SSB).

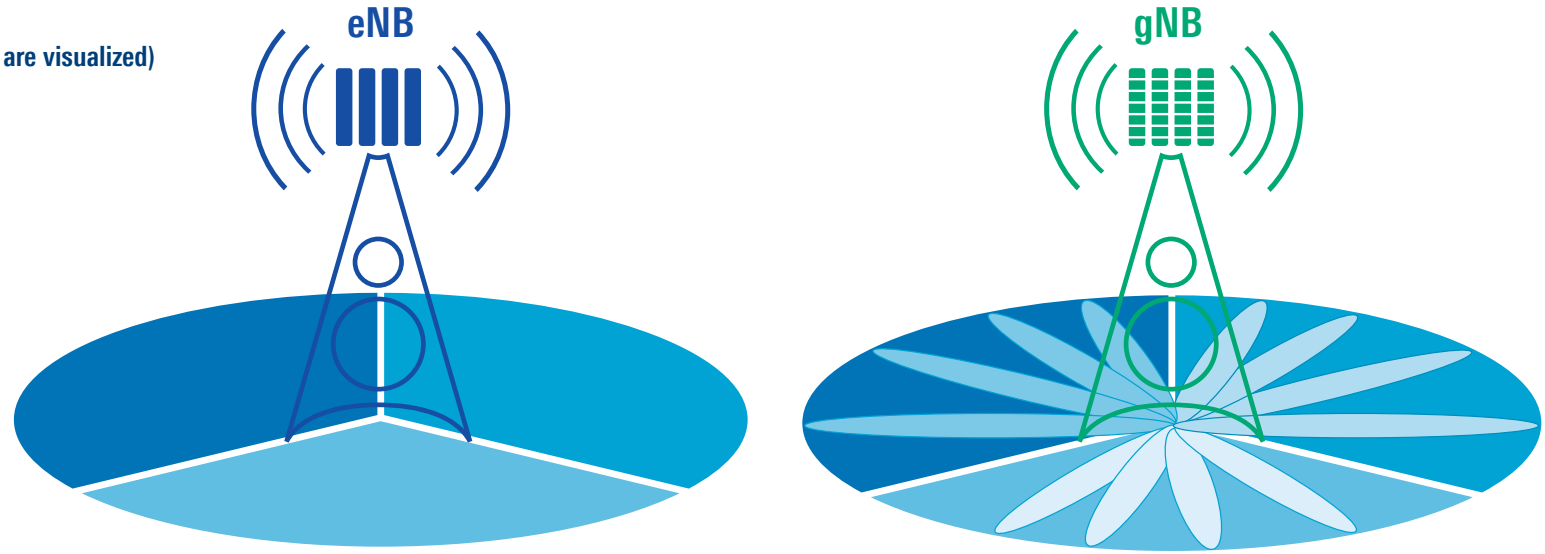
5G NR IN A WORD: FLEXIBILITY

Beamforming of synchronization signals and broadcast channel information

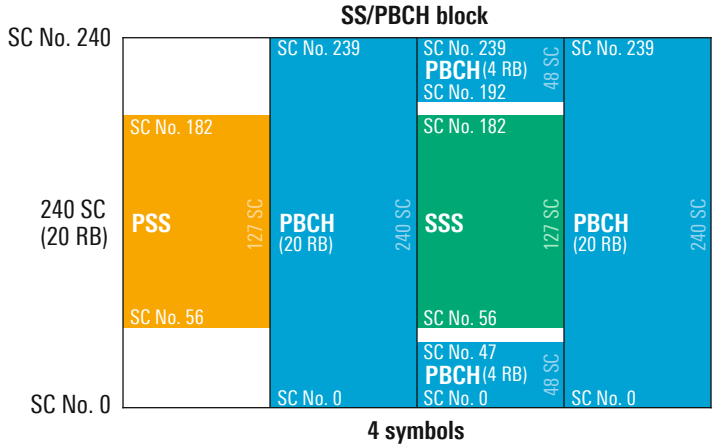
The synchronization signal block (SSB) is the only “always on” signal in 5G NR and can be located anywhere in the 5G carrier. Once identified, UEs find primary and secondary synchronization signals (PSS and SSS) and physical broadcast channel (PBCH) information.

Since up to eight SSB events can occur at 3.5 GHz in a frame, each SSB could carry different beam-specific information (SSB index). With mapping to different antenna ports (groups of antenna elements), up to eight different static beams can be allocated in one base station sector (one PCI). In mmWave frequencies, there can be up to 64 different beams.

Beamforming with static beams (only four static beams per sector are visualized)



SS-PBCH block



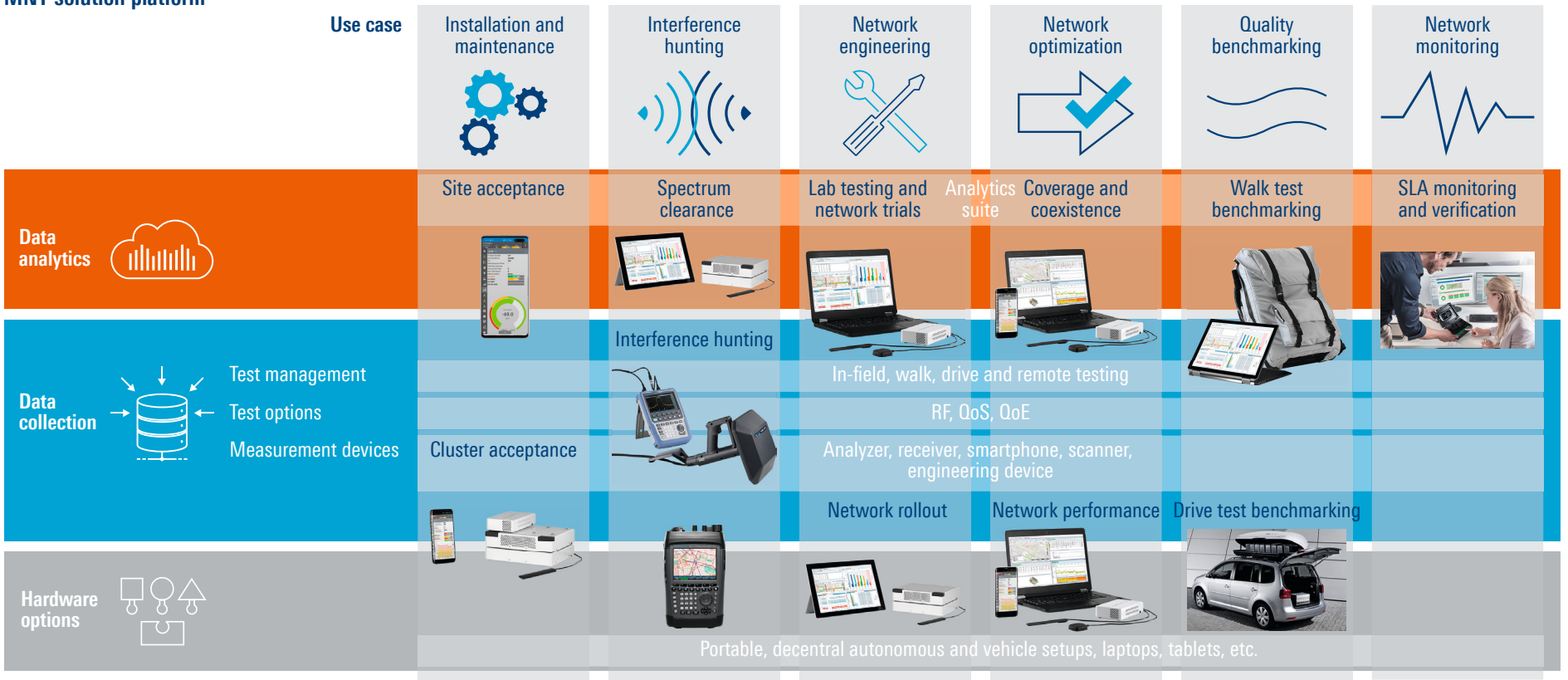
Beamforming as a technology is not new, but it has previously only been applied to user-specific data streams.

With 5G, beamforming is also applied to synchronization signals and broadcast channel information as described before. This ensures wider coverage since synchronization signals also benefit from higher antenna gain due to beamforming.

FULL RANGE OF 5G NR NETWORK MEASUREMENT SOLUTIONS

The MNT solution portfolio is a fully integrated platform covering all use cases and test scenarios throughout the lifecycle of a mobile network. The MT solution platform is logically structured and comprises key components for data analytics, data collection and hardware options. The 5G network measurement solutions for each use case are highlighted in the figure below.

MNT solution platform



The components of the platform can be tailored to the specific application in the user's desired network lifecycle.

ALL 5G NR NETWORK TESTING SOLUTIONS FROM A SINGLE SOURCE

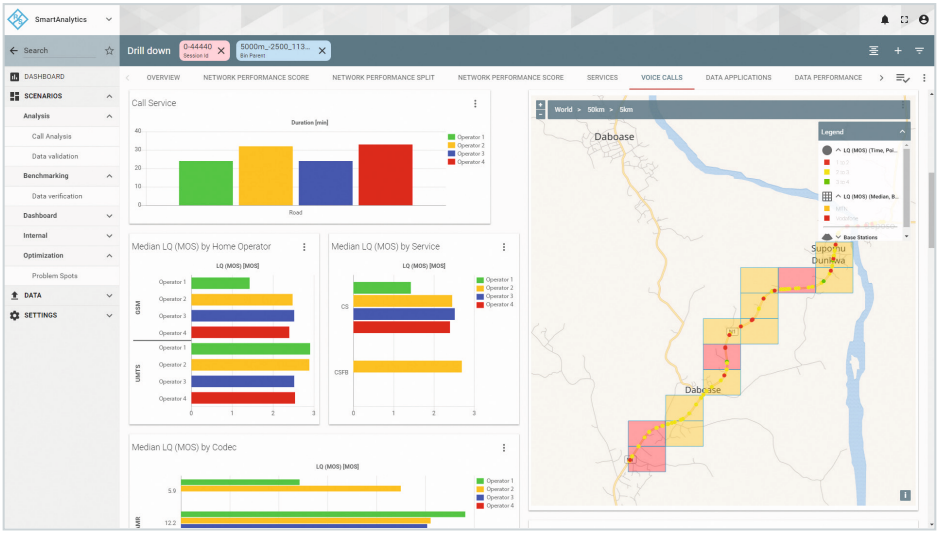
Rohde&Schwarz mobile network testing offers data collection using network scanners for 5G NR measurements as well as cellular 5G NR devices connected to the R&S®ROMES4 drive test software that is already proven worldwide for optimizing networks of all kinds of wireless technologies, including LTE and IoT.

The new generation of the R&S®TSMx drive and walk test scanner supports 5G NR. A variety of commercial and precommercial 5G NR chipsets, modules and smartphones are also supported. Both measurement solutions focus on different test scopes and complement each other.

The scanner measurements provide accurate and fast 5G NR network DL coverage due to the scanner's RF accuracy and multi-standard measurement in conjunction with LTE. This is important for non-standalone 5G mode where LTE is always needed as an anchor and core network.

Measurements using 5G devices connected to R&S®SmartONE (the unified Rohde&Schwarz solution for PC based drive and walk testing combining R&S®ROMES4 and SmartBenchmarker) and QualiPoc Android software running on commercial 5G smartphones provide insights into the service performance – in particular application layer KPIs, network performance metrics and UL information.

SmartAnalytics complements this solution on the data analytics side and provides deep insights into the 5G NR network performance and end-user QoE.

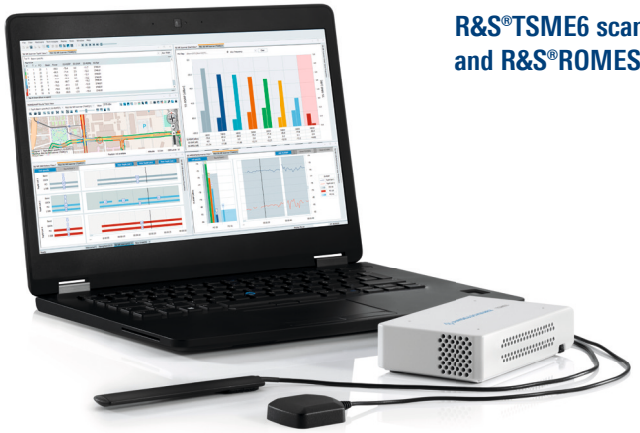


5G NR NETWORK SCANNERS FOR ACCURATE COVERAGE MEASUREMENT AND BEAMFORMING VERIFICATION

Coverage and new features like beamforming

The most accurate and reliable means of identifying network coverage is a network scanner. The radio receiver is a passive device that captures the measurement data directly from the RF air interface. This passive, scanner-based approach enables data capturing from all operators and all available cells within the receiver sensitivity of the scanner.

Significant parameters include power levels (e.g. RSRP) and signal-to-noise ratios (e.g. SINR) of the different signals in the 5G NR SSB. These parameters can be used to draw conclusions about the RF conditions at a certain location that form the basis for network access through 5G NR devices.



R&S®TSME6 scanner, antenna and R&S®ROMES4 software

R&S®TSMA6 scanner and R&S®ROMES4 on built-in NUC PC

The R&S®TSMx6 scanners are supported by all Rohde&Schwarz data collection software modes:

- **Smartphone mode: R&S®QualiPoc Android**
- **Standard mode: SmartBenchmarker**
- **Expert mode: R&S®ROMES**

The R&S®TSMx6 network scanners can also verify the beamforming feature in 5G NR based on the SSB indices (e.g. eight static “micro sectors” in one macro sector due to eight SSB indices per frame in 3.5 GHz). R&S®TSMx6 scanners can operate in a frequency range from 350 MHz to 6 GHz. Together with the R&S®TSME30DC and the R&S®TSME44DC ultracompact downconverters, the R&S®TSMx6 can analyze signals in the 24 GHz to 44 GHz range.

R&S®TSMA6 scanner, R&S®TSME30DC or R&S®TSME44DC downconverter, antenna and R&S®ROMES4 in a convenient backpack

5G NR DATA COLLECTION USING COMMERCIAL 5G NR SMARTPHONES

Another important part of 5G NR network testing is using different 5G NR devices such as evaluation boards, USB dongles, precommercial and commercial smartphones. This provides insights into network quality regarding the quality of experience (QoE) of applications and the ways devices interact with real 5G NR networks, for instance the beam mobility procedure.

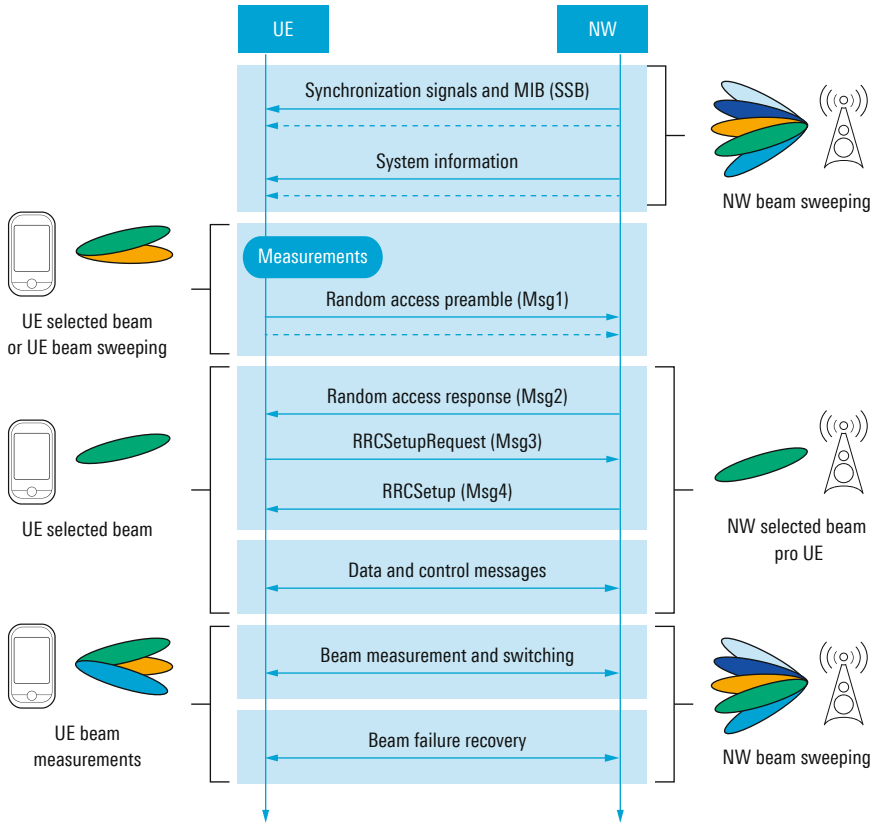
It is also very valuable to test modules connected to a PC since many new 5G modules and devices do not have a screen and application based testing is not possible. R&S®ROMES4 (part of the R&S®SmartONE mobile network testing software) can support those modules and devices running on x50 or x55 modems. Executing this test in various devices prior to mass integration is essential.

QualiPoc Android on Samsung Galaxy 5G

QualiPoc Android is supported on the latest 5G flagship smartphones of all major device vendors. Its ability to decode L3 information in real-time and run an extensive range of service quality tests for voice, data, video streaming and app services in parallel make it a key tool for capturing 5G measurement data and the industry reference for characterization of QoE. All important parameters such as signaling trace and IP trace data as well as fundamental RF metrics are displayed on the smartphone and stored in a measurement file that can be further analyzed with a postprocessing tool.

Critical 5G NR UE based measurements – such as data performance KPIs, serving cell information, signaling and RF metrics using commercially available UEs such as the Samsung Galaxy S20 5G and others based on Snapdragon 865 and Samsung Exynos 990 chipsets – can be conducted using the R&S®ROMES4 universal software platform for network engineering, optimization and troubleshooting. R&S®ROMES4 is compatible with both rooted phones and commercial off-the-shelf (COTS) UEs with open LTE and 5G diagnostic ports.

5G NR beam mobility procedure

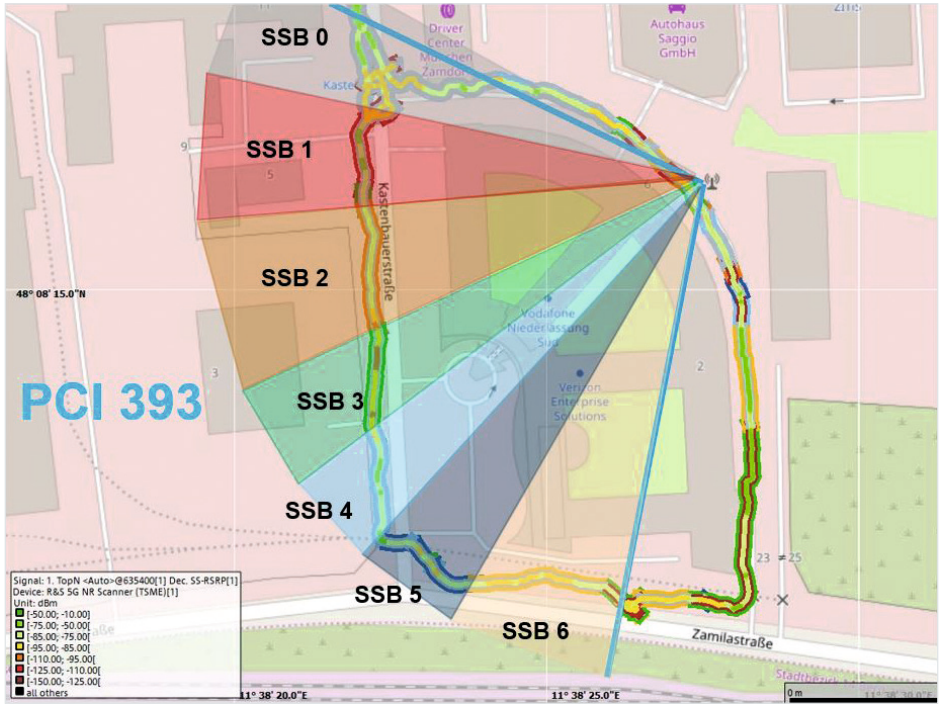


5G SITE TESTING AND TROUBLESHOOTING

Commercial 5G rollout is happening now and service teams face the challenge of successfully deploying and operating a new network infrastructure that has a radically different architecture than in previous cellular generations. During site acceptance and troubleshooting of each new cell site, new capabilities such as beamforming and 5G/LTE dual connectivity must be tested to verify correct installation and performance and ensure the required quality of service (QoS) is delivered to end users.

For NSA mode, the link to the anchor site (usually low frequency LTE) needs to be checked in parallel. Deployment will take place in both the FR1 (sub 6 GHz) band and in the FR2 (microwave, usually 28 GHz and higher) band. The tests must also work in deployments where the radio interface is fully integrated (combined remote radio head and antenna) or split into RRH and antenna (connected by jumper cables).

5G NR FR1 site, three sectors (PCI), seven beams per sector



The sequence below defines a test procedure for a newly installed 5G site to ensure the fundamental cell site performance, verify that all parameters are inside the specified range and check that additional 5G capacity is present in the related LTE anchor cells (SIB 2).

Installation procedure

- Check VSWR reflections via OSS counters
- Ensure the PCI and beams are visible in the expected location (SS-RSRP, SS-SINR)
- Conduct power measurements on the allocated LTE anchor cell (RSRP, SINR, etc.)
- Run functional tests to ensure the 5G cell is correctly integrated into the network

Troubleshooting procedure

- If reflection counters show problems, measure the reflection/DTF with a cable and antenna tester
- If beams/PCI are not visible, check and correct the 5G site configuration file
- Check cable and antenna
- If the 5G cell is not utilized or the throughput is too low, check if the 5G cell is visible on LTE-SIB 2
- If the SINR is not as expected, check for internal interference (e.g. sidelobes) and external interference

The 5G site testing solution (5G STS) is a solution that combines all the necessary functional, RF and signaling tests for 5G installation and troubleshooting in an integrated package with a single user interface.

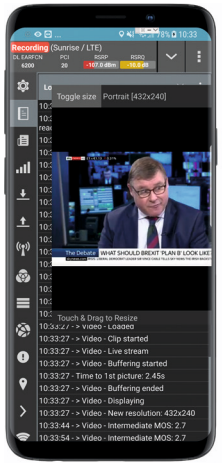
The required tests can be executed in a logical sequence starting with the R&S®TSME scanning receiver, which uses automatic channel detection (ACD) to show all LTE and 5G signals, identify channel frequency and decode the PCI/SSB information in order to analyze the quality of the signal. Adding a R&S®QualiPoc Android smartphone to the solution enables the presence of a 5G carrier to be determined and the fundamental functional tests of uplink speed, downlink speed and latency to be conducted.

The R&S®ZPH combo spectrum analyzer and cable and antenna tester or the R&S®FPH handheld spectrum analyzer can measure the occupied bandwidth of the 5G carrier and use a time gate to isolate the uplink signal, which is important for interference hunting in TDD networks. The zero span feature enables the SSB to be viewed in the time domain and determine how many beams there are. The R&S®ZPH can also perform conducted measurements of VSWR and distance to fault at the cell site.

The 5G STS from Rohde&Schwarz can conduct cell and beam quality measurements and also verify the presence and quality of the LTE anchor cell, which is essential in 5G non-standalone (NSA) mode. The 5G STS has the advantage of being able to use ACD to automatically configure the receiver with the correct measurement settings rather than manually entering them into the instrument. It is also significantly faster and more sensitive than a traditional spectrum analyzer. It is able to test 5G and LTE simultaneously and executes all necessary tests for efficient 5G site verification and troubleshooting in one integrated package.

5G QualiPoc Android smartphone

- Layer 1 parameters of anchor cell (LTE)
- Layer 1 parameters of secondary cell (5G)
- Scheduled and net throughput (LTE and 5G cell)
- Block error rate, BLER (LTE and 5G cell)
- Layer 3 signaling, MIB and SIB
- Functional tests (ping, data DL/UL)
- Dropbox transfer and Facebook test
- Traceroute (UDP only)



R&S®Cable Rider ZPH cable and antenna analyzer

- Occupied bandwidth
- Spectrum emission mask
- ACLR and channel power
- Interference hunting
- VSWR and distance to fault
- Optional optical power measurement

FR1: R&S®Cable Rider ZPH cable and antenna analyzer (FR2: R&S®Spectrum Rider FPH handheld spectrum analyzer, 30 GHz without cable tests)

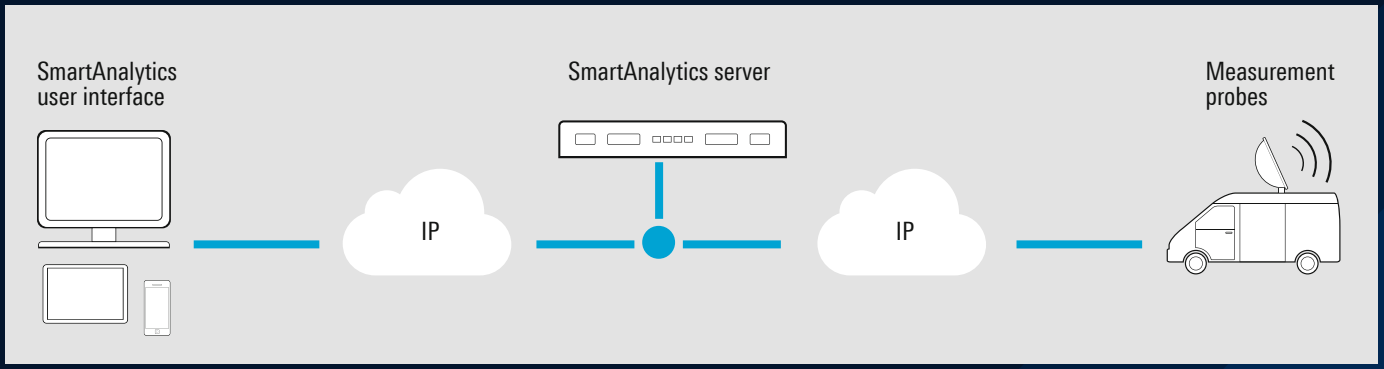
R&S®STS 5G site testing solution

- Automatic channel detection
- SS/PS/PBCH/DM-RS-RSRP over PCI and beam
- RSSI over PCI and beam
- SS/PS/PBCH/DM-RS-SINR over PCI and beam
- SS/PS/PBCH/DM-RS-RSRQ over PCI and beam
- Parallel measurements for LTE and 5G NR
- FR1 and FR2 (FR2 via R&S®TSME30DC ultra-compact downconverter)

5G NR DATA ANALYTICS WITH SmartAnalytics

To measure and analyze precommercial 5G NR trials and very early deployments, a real-time, in-field analysis tool (such as R&S®ROMES4) is the best choice. Network measurements in commercial 5G NR networks require a sophisticated, efficient and "big data" optimized postprocessing tool for data analytics.

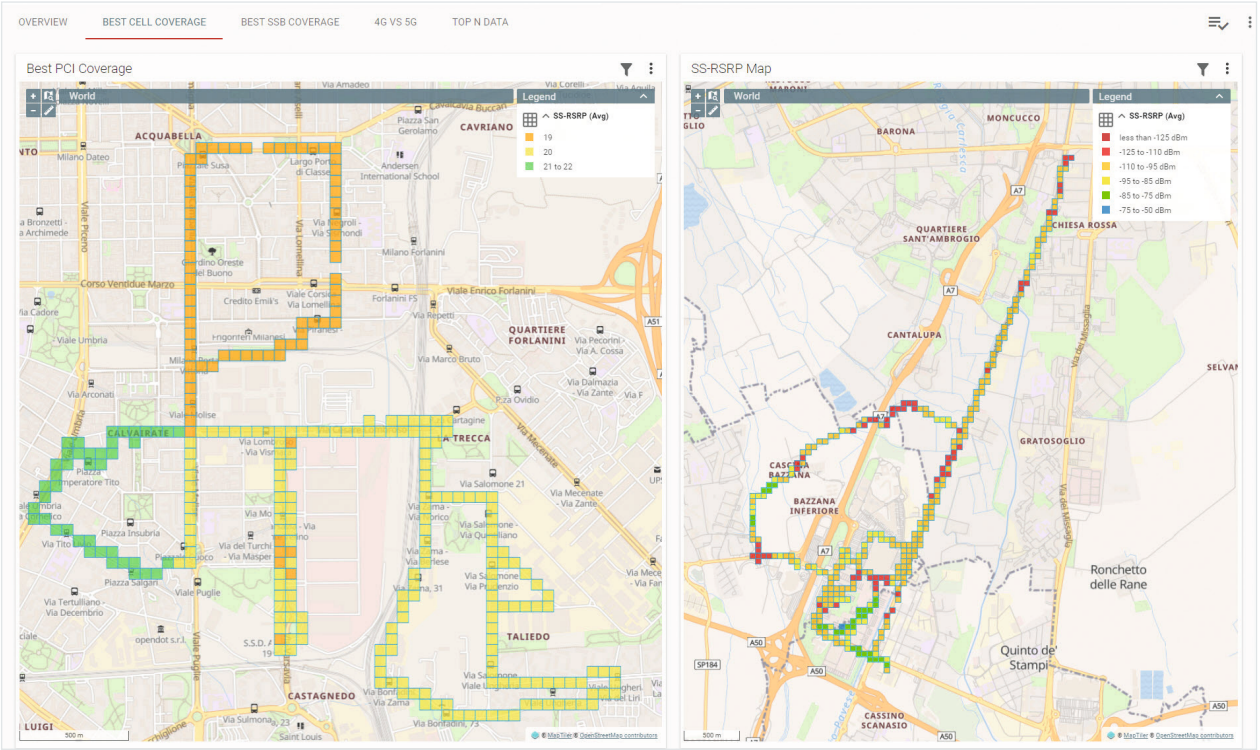
SmartAnalytics network diagram



SmartAnalytics is a flexible tool that encompasses different mobile network testing use cases, such as engineering, optimization, monitoring and benchmarking, using the same web based user interface and platform. The SmartAnalytics server, which stores all the collected data from the measurement probes, is located in the cloud (or installed locally).

It eliminates the need for separate test platforms, eliminates compatibility issues, and provides a seamless interface across each stage of the network testing lifecycle. This results in OPEX and CAPEX efficiency in terms of test resources, equipment and execution.

SmartAnalytics provides an overview of the main factors that influence network performance and QoE status, the context, development trends, issues and potential causes of degradation. The cloud based approach with web based GUI offers real-time, highly responsive filtering and drilldown capability.



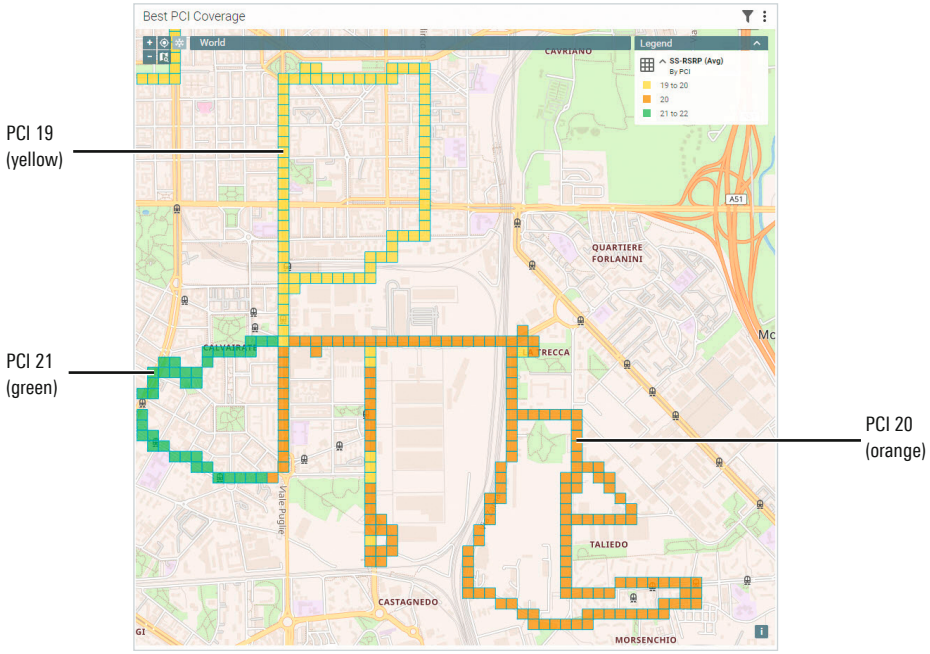
5G NR scanner workspace
SmartAnalytics provides a freely configurable GUI. This example shows a best cell coverage map (best received PCI) and a receive signal strength visualization (RSRP) along the route.

5G NR BEAM SPECIFIC ANALYSIS IN SmartAnalytics

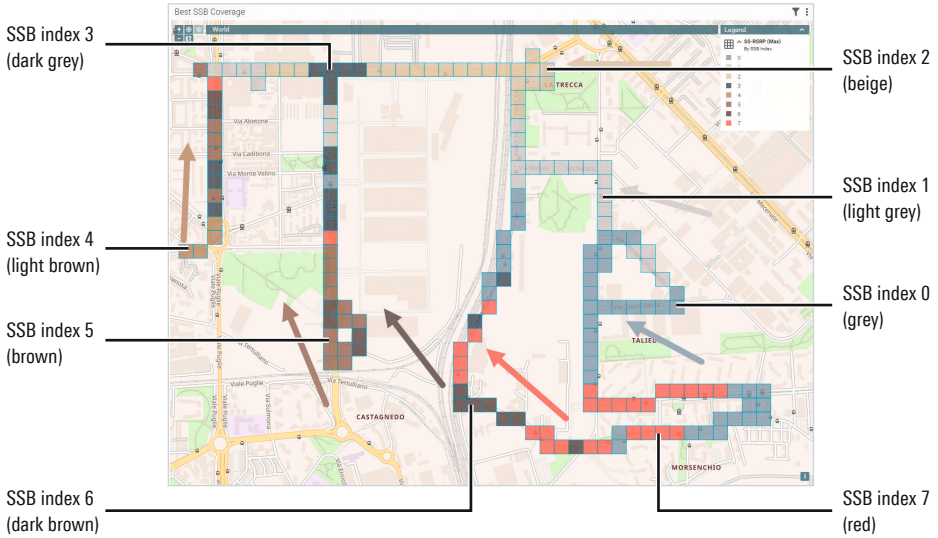
In the diagram below, it can be seen that there are measurement bins in the PCI 20 coverage area where the PCI 19 is received with higher RSRP, i.e. a PCI 19 reflection can be stronger than the directly transmitted PCI 20 signal. The higher the 5G NR frequency, the more significant the reflections become.

In the SSB picture, the best received SSB indices (or beams) of PCI 20 are visualized in different colors. The different directions of the beams can be clearly seen. SSB index 3 seems to be transmitted with a higher downtilt to realize an inner area with a shorter range than SSB index 7.

5G NR site with 3 cells (PCIs)



8 SSB indices of PCI 20



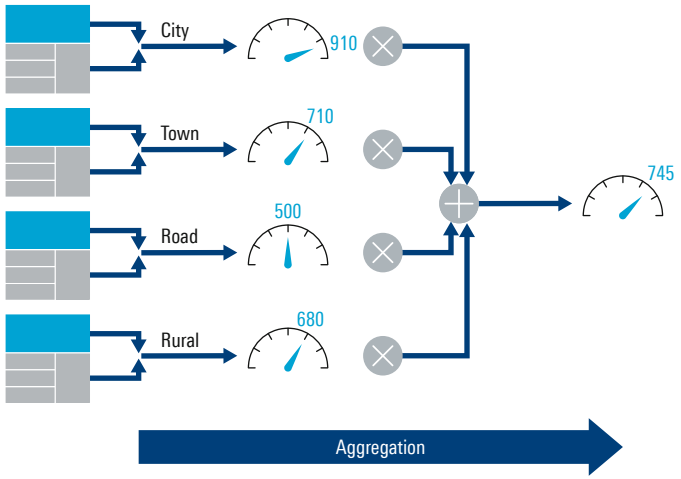
The drive/walk test is essential to validate the planned network coverage and identify areas for initial 5G NR network optimization.

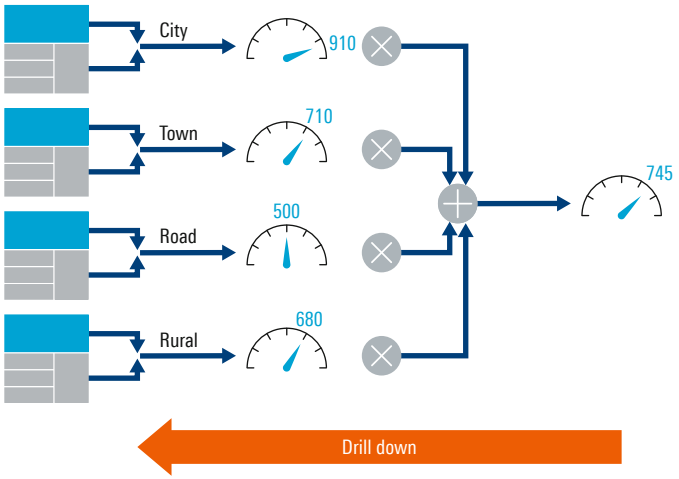
THE NETWORK PERFORMANCE SCORE: AGGREGATION AND DRILLDOWN

The network performance score (NPS) is an integrated metric that evaluates, weights and aggregates all key quality indicators for services and applications into a single value. The ETSI-ratified methodology can be used as the basis for benchmarking and optimization campaigns.

By definition the NPS is technology agnostic, i.e. it also supports 5G NR.

The network performance score





Level 1: The QoE of each service class (voice and data) in a specific region is evaluated.

Level 2: The QoEs of all service classes in one region are weighted and aggregated to a regional score.

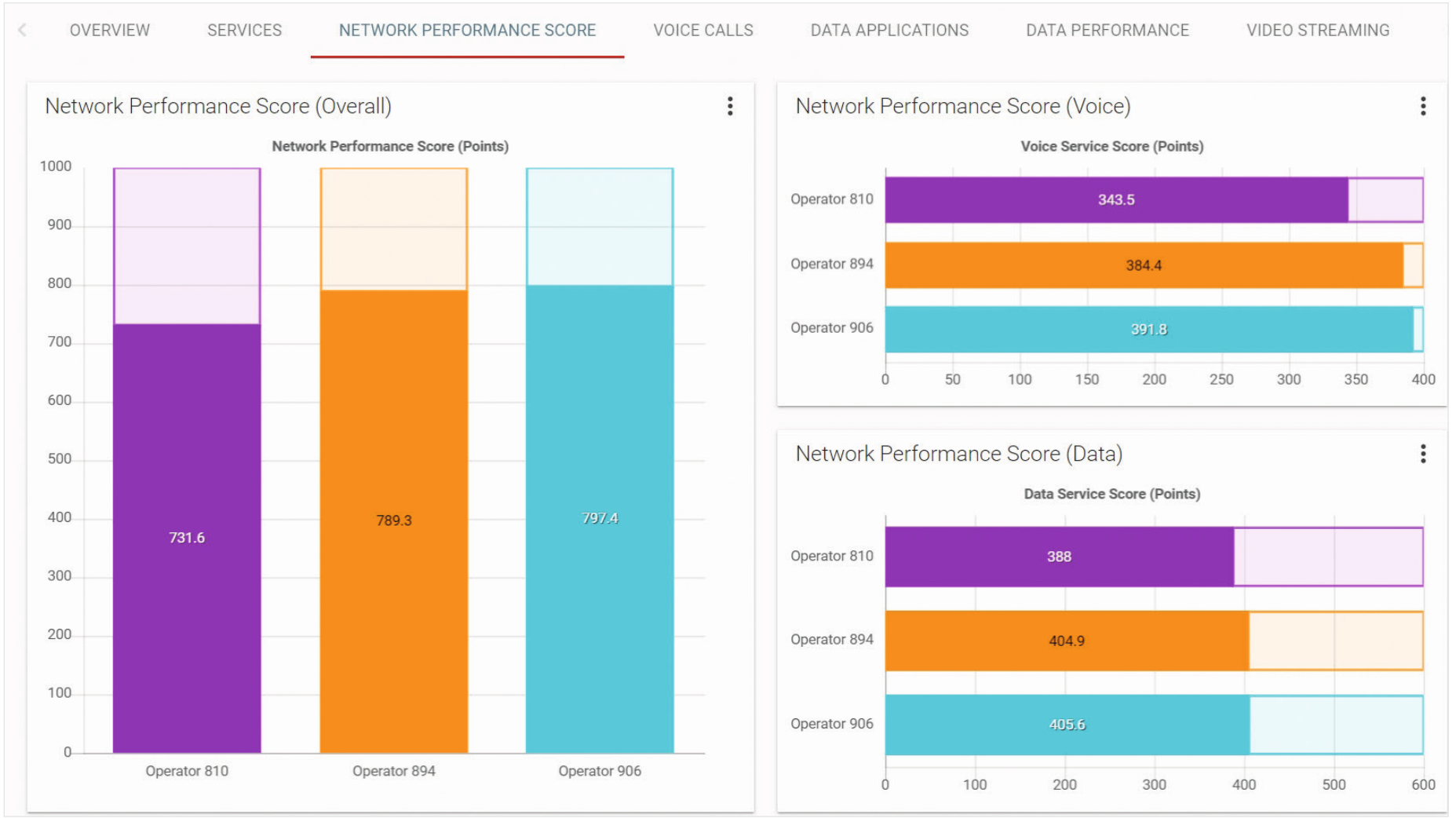
Level 3: The QoEs of all service classes in all regions are weighted (according to traffic, population, etc.) and aggregated to a final networkwide or countrywide score.

Starting from the nationwide score, a drilldown can be done in SmartAnalytics to identify a critical region, non-optimal performance of a service class, or even a single critical dimension of a specific service class (e.g. call setup time in voice service).

This drilldown capability provides the basis for targeted network optimization.

NPS implements ETSI TR 103559: "Best practices for robust network QoS benchmark testing and scoring."

NETWORK PERFORMANCE SCORE INTEGRATED INTO SmartAnalytics

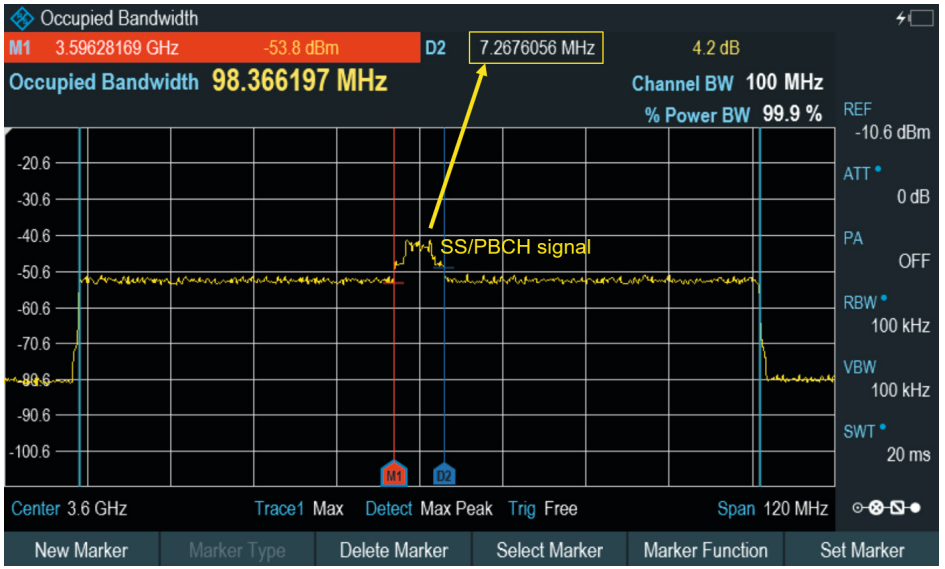


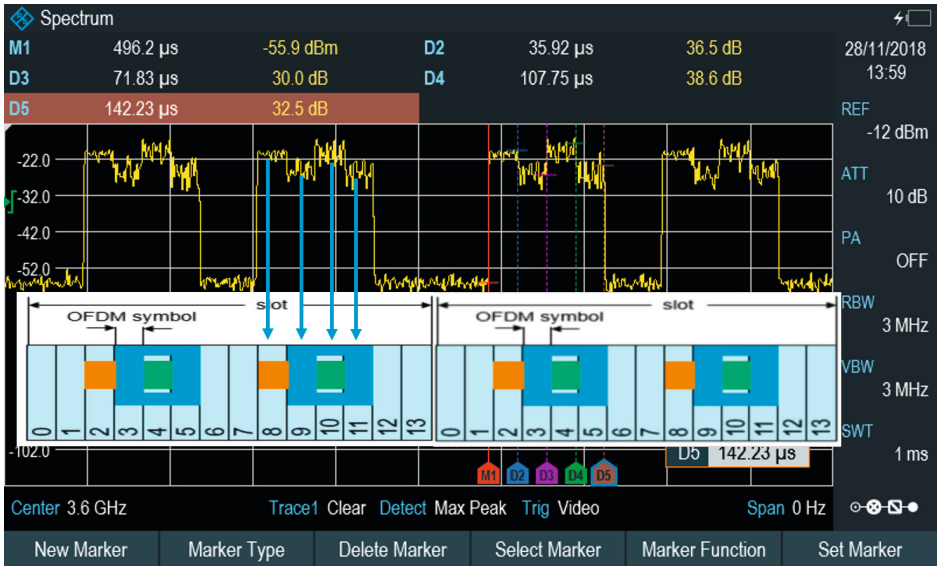
Thanks to the network performance score integrated into SmartAnalytics, network operators can identify strategic areas for investment, efficiently deliver optimal end-user QoE and stand out from the competition, which leads to a higher number of subscribers, a lower cost base and access to new revenue streams. The NPS implementation supports all radio access technologies, including 5G NR.

FAST 5G NR WAVEFORM VERIFICATION IN THE FIELD

The state-of-the-art R&S®Spectrum Rider FPH is an economical, intuitive and rugged instrument. It supports spectrum monitoring, RF design validation, interference hunting and RFtransmitter testing. In the occupied bandwidth (OBW) mode, the R&S®Spectrum Rider FPH automatically displays the occupied bandwidth of the 5G downlink signal. In figure below, the occupied bandwidth is approximately 100 MHz, matching the specified 5G channel bandwidth. The bandwidth of the captured SSB (SS/PBCH signal) also matches the theoretical value of 7.2 MHz (240 subcarriers × 30 kHz SC spacing).

The figure below shows a 5G NR downlink signal in the time domain. Based on the SSB occurrence, this is easily recognized as the SC spacing case C. In line with the standard, the theoretical length of a slot is 500 µs and 33.3 µs per symbol, fully matching the transmitted downlink signal. In conclusion, the lightweight R&S®Spectrum Rider FPH handheld spectrum analyzer can help operators quickly verify transmitted 5G downlink signals in the field.



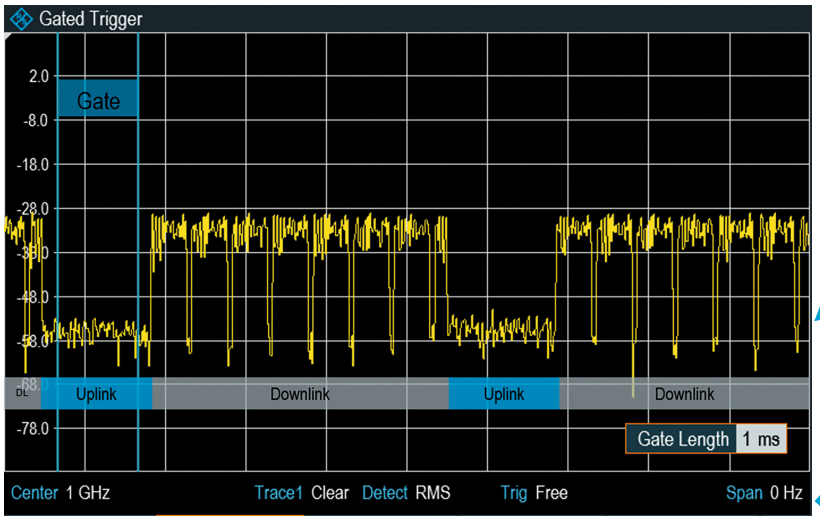


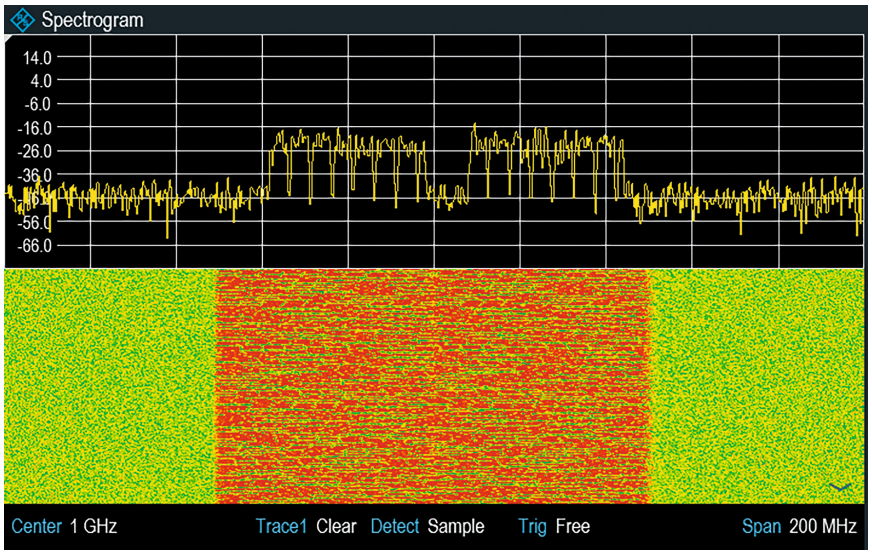
R&S®Spectrum Rider FPH

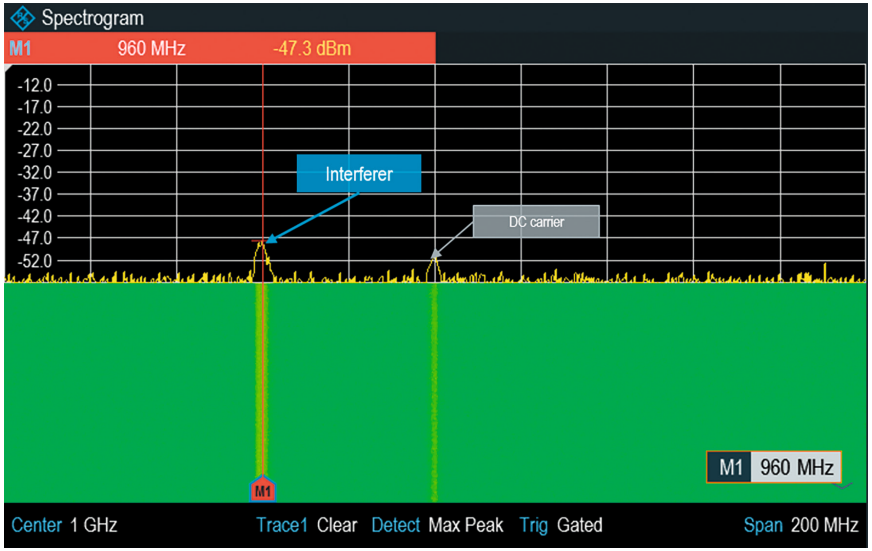
IDENTIFY UPLINK INTERFERENCE IN A TDD NETWORK

When the configured gated trigger in the R&S®Spectrum Rider FPH is enabled, interference that was previously masked by DL signals in the spectrum measurement can also be detected in the UL.

In TDD networks, the downlink and uplink use the same frequency, which means that downlink signals mask the uplink and any other signals that are present. The R&S®Spectrum Rider FPH can configure a gated trigger to focus only on UL slots.







Small form factor delivers huge performance gain: the R&S®Spectrum Rider FPH in combination with a directional antenna makes it possible to identify and locate interferers, even in TDD networks.

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The company's broad and diverse product portfolio for mobile network testing addresses every test scenario in the network lifecycle – from base station installation to network acceptance and network benchmarking, from optimization and troubleshooting to interference hunting and spectrum analysis, from IP application awareness to QoS and QoE of voice, data, video and app based services.

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