5G NR NETWORKS ARE HERE – LET'S TEST!

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Products from Rohde&Schwarz

- R&S®TSME6 ultracompact drive test scanner
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- SmartAnalytics software suite for QoE analytics
- R&S®ROMES4, the unified software solution for PC based drive and walk tests
- QualiPoc Android software for smartphone based QoE testing

This white paper describes 5G NR technology basics like beamforming for synchronization signals and broadcast channel information and how to test a 5G NR network.

1 INTRODUCTION

3GPP Release 15 specifies the initial 5G standardization framework for the radio access network called 5G New Radio (5G NR). The standard contains a high degree of flexibility in radio parameters, which complicates network measurements. However, Rohde&Schwarz has already conducted measurements in precommercial 5G NR trial networks with its commercially available 5G NR network measurement solution. We gained interesting insights into the new technology's performance, capabilities and frequency bands.

The mobile communications industry undertook a paradigm shift in defining the next generation of mobile communications. Before discussing new technologies like in all previous generations, the industry researched and assessed the use cases and needs that 5G should fulfill. After general agreement on the use cases, requirements were defined, including data rates, carrier bandwidths, latency values, number of devices, etc.

It was only after having reached a consensus on use cases and requirements that the 3GPP identified, discussed and evaluated candidate technologies. 3GPP Release 15, issued in March, June and September 2018, specified the initial 5G standardization framework for the radio access network (RAN) called 5G NR.

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

2 TECHNOLOGY BASICS

2.1 How does 5G NR differ from LTE?

LTE radio access (or, in 3GPP terms, eUTRAN) is an OFMD 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.

The 5G NR specification embraces flexibility. It aims to include different use case families – from enhanced mobile broadband (eMBB) and massive machine type communications (MIoT) to ultra-reliable, low latency communications (URLLC) – that span across industries.

These different use cases require a wide variety of air interface characteristics in terms of frequency range, subcarrier spacing, carrier bandwidths, symbol durations, etc.; the network architecture needs to offer many options. Table 1 shows the flexibility of frequency-specific parameters.

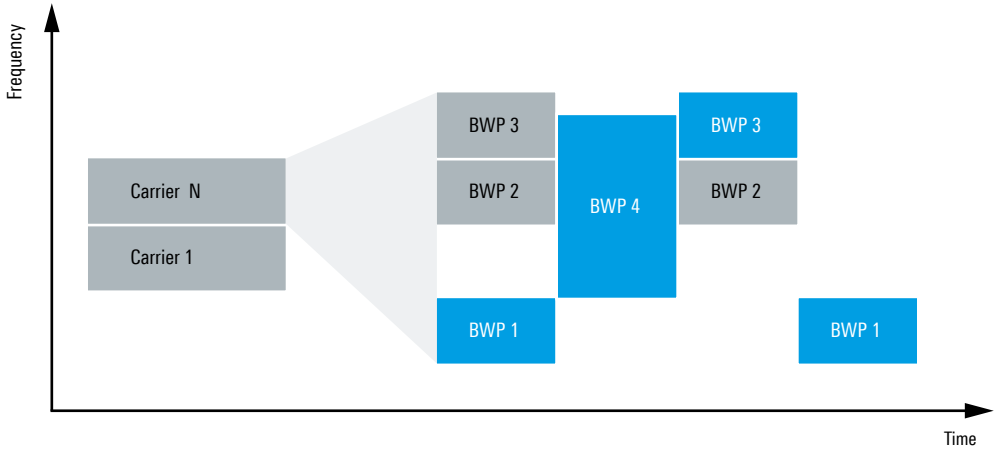
Table 1: 5G NR flexibility in frequency domain parameters

	Frequency range 1 (< 24 GHz, mostly < 6 GHz)	Frequency range 2 (> 24 GHz)
Carrier aggregation	up to 16 carriers	up to 16 carriers
Bandwidth per carrier	5/10/15/20/25/30/40/ 50/60/80/90/100 MHz	50/100/200/400 MHz
Subcarrier spacing	15/30/60 kHz	60/120/240 kHz (not for data)

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.).

User equipment (UE) can be configured with up to four carrier bandwidth parts in the downlink/uplink, but at any given time only a single downlink/uplink carrier bandwidth part can be active. The downlink control information (DCI), radio resource control (RRC) or a timer can trigger switching of the active BWP.

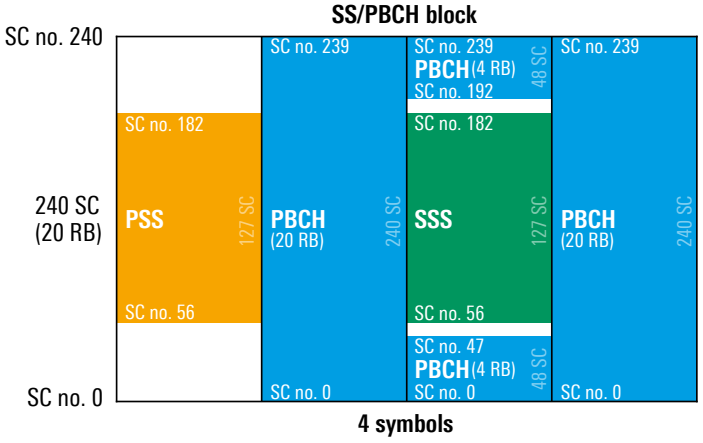
Fig. 1: Bandwidth parts (BWP) in 5G NR



Another significant difference between LTE and 5G NR is the position of the synchronization signals within the carrier, specifically the primary (PSS) and secondary synchronization signals (SSS). Synchronization signals are very important. They are the first information that mobile devices need to identify in order to access the network.

In LTE, the sync signals are always located in the center of the carrier bandwidth; this makes them easy to find. In 5G NR, the sync signals are part of the SS/PBCH block (also called synchronization signal block, SSB) containing the physical broadcast channel (PBCH) information. These SS/PBCH blocks can be located at multiple positions all over the carrier bandwidth and are broadcast periodically as defined symbols in the radio frames and different beams versus time.

Fig. 2: Details of the SS/PBCH block in 5G NR

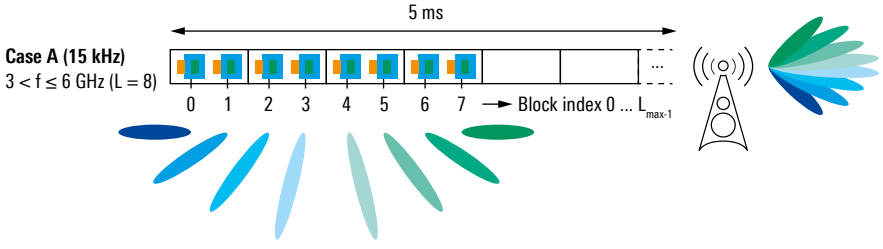


2.2 Beamforming for synchronization signals and broadcast channel information

Beamforming as a technology is not new, but with 5G, beamforming is not only applied to user-specific data streams but also to synchronization signals and broadcast channel information. Beamforming can be implemented with antenna arrays on the base station end, where different groups of antenna elements (dynamically allocated) form beams to different users depending on their phases and amplitudes relative to each other.

Using beamforming for synchronization signals and broadcast channel information provides better overall coverage thanks to the higher antenna gain. The synchronization signal block (SSB) in 5G NR can carry beam-specific information (SSB index). These SSB index "beams" are static and can be considered micro sectors, e.g. eight micro sectors in one macro sector for the 3.7 GHz case.

Fig. 3: The SSB index beams are static and can be considered micro sectors



3 HOW TO TEST A 5G NR NETWORK

3.1 5G NR scanner based data collection in the field

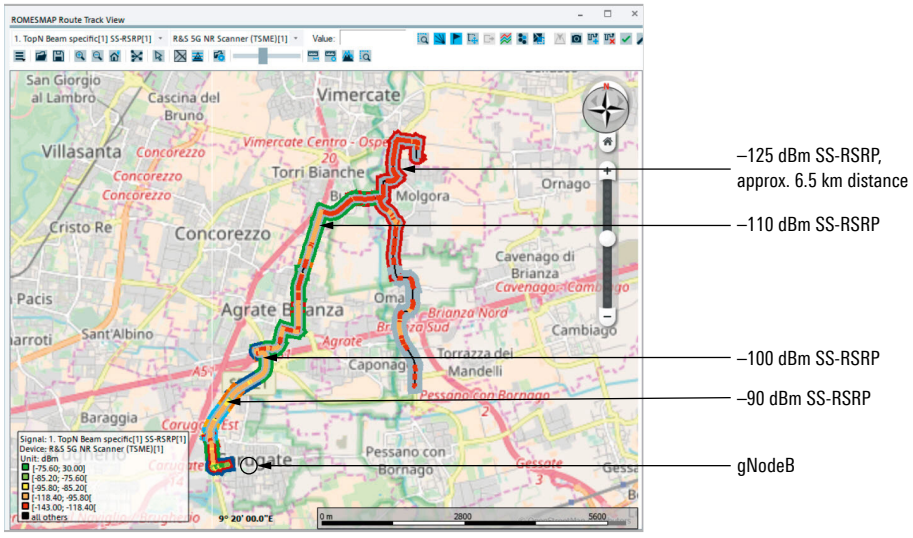
Understanding 5G NR coverage in real-world environments is just as important as it is for all other technologies. The introduction of new frequencies and features such as 3.7 GHz and beamforming make testing particularly important and challenging, despite numerous simulations executed by industry players. Conducting measurements in precommercial network trials is the only way to gain new insights and to overcome doubts and uncertainties before the technology is commercially launched.

With precommercial 5G NR network trials underway, the Rohde&Schwarz mobile network testing (MNT) team has already had the opportunity to execute 5G NR field measurements. In collaboration with a tier 1 mobile network operator, measurements in the 3.7 GHz frequency band were conducted in a European country as early as 2018.

3.1.1 Coverage in 3.7 GHz frequency range

Bearing in mind the higher than normal frequency band, it was surprising how the 5G NR beamforming capabilities improve the achievable coverage. In a suburban environment, the test engineers could measure a reference signal's received power (RSRP) on the synchronization signals of –125 dBm at a distance of 6.5 km from the base station. They expected that 5G NR UEs could connect to base stations at signal levels down to –120 dBm.

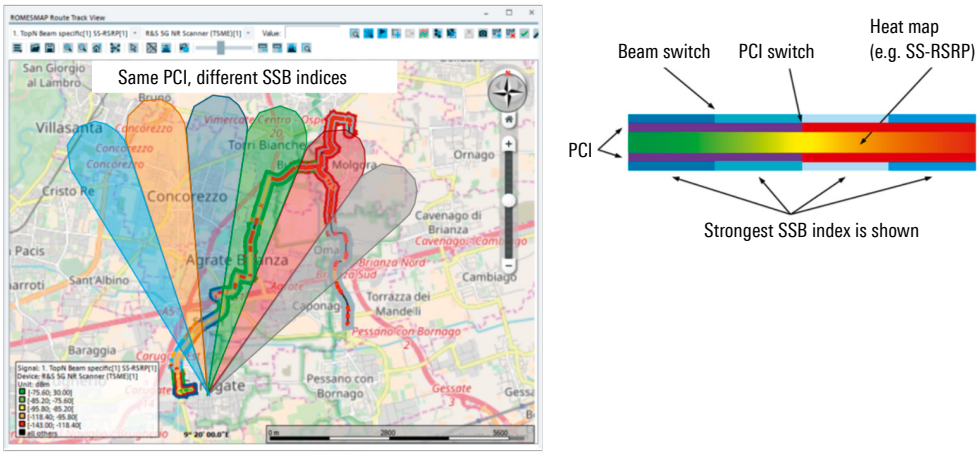
Fig. 4: The 5G NR beamforming capabilities improve the achievable coverage



3.1.2 Beamforming for synchronization signals and broadcast channel information

Figure 5 shows the SSB index "beams" or the "micro sectors" very clearly. The outer color layer represents the SSB indices as explained in the color code. For a better overview, the colored micro sectors have been added to the screenshot.

Fig. 5: The SSB index "beams" of one PCI with color code added



3.1.3 Rohde&Schwarz 5G NR scanner based network measurement solution

For the trials, the tier 1 mobile network operator relied on the commercially available Rohde&Schwarz 5G NR network measurement solution. It comprises an R&S®TSME6 or an R&S®TSMA6 network scanner for data collection and the R&S®ROMES4, a universal network engineering software platform. In Fig. 6 the expert UI provided by the R&S®ROMES4 application software is shown. Equipped with an antenna, the 5G NR measurement solution fits into a backpack or shoulder bag for convenient and efficient drive and walk testing.

Fig. 6: The 5G NR network measurement solution comprising an R&S®TSME6 scanner, antenna and R&S®ROMES4 software

Fig. 7: The 5G NR network measurement solution with its handy shoulder bag
(here: R&S®TSMA6 scanner and R&S®ROMES4)

Fig. 8: The 5G NR network measurement solution
(here: R&S®TSMA6 scanner and QualiPoc Android 5G)

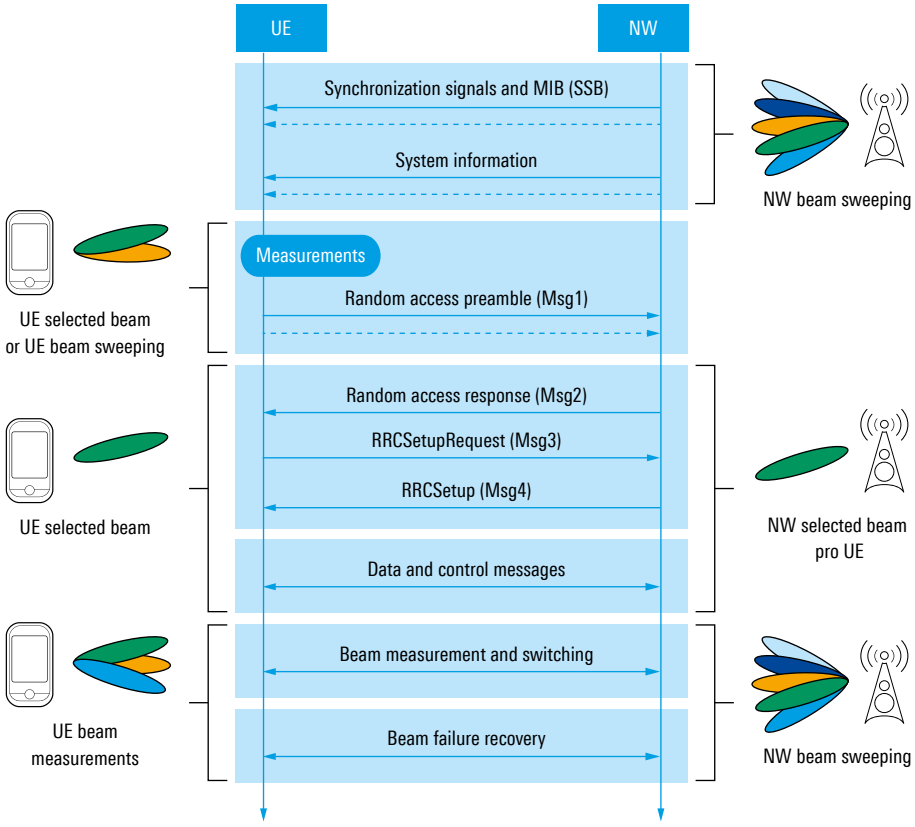
The described 5G NR network measurement solution can be expanded to a frequency range of up to 44 GHz (FR2) with the R&S®TSME30DC and R&S®TSME44DC downconverters. To prevent the test engineer's body from influencing the measurement results, Rohde&Schwarz offers a backpack that allows the 5G NR mmWave receive antenna to be mounted above head level.

Fig. 9: The 5G NR network measurement solution for mmWave frequencies in a convenient backpack
(here: R&S®TSMA6 scanner, R&S®TSME30DC downconverter, antenna and R&S®ROMES4)

3.2 5G NR UE based data collection

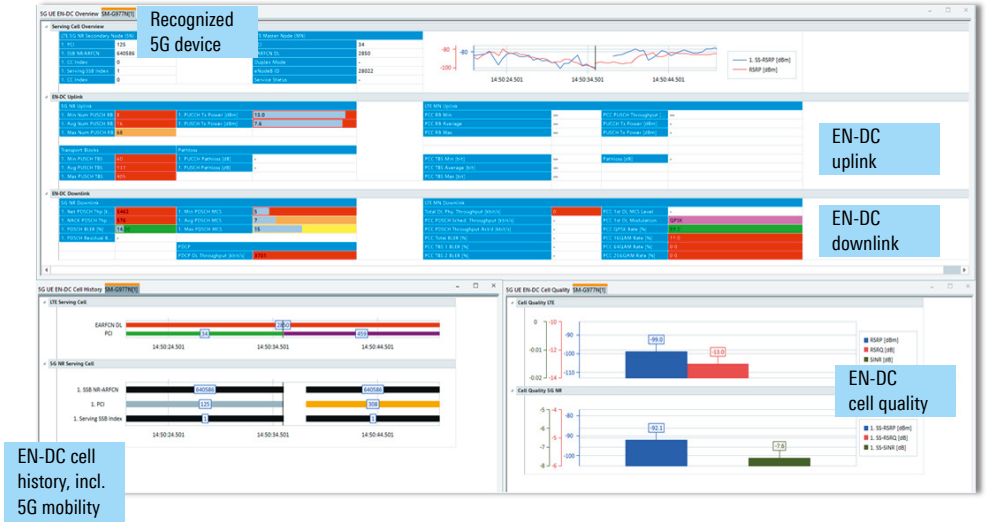
Another important part of 5G NR network testing is using different 5G NR devices such as evaluation boards, USB dongles, precommercial and commercial smartphones to make UE based measurements. This provides insights into network quality regarding quality of experience (QoE) of applications and the ways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

Fig. 10: 5G NR beam mobility procedure



Such 5G NR UE based measurements include NR serving cell information such as NR DL ARFCN, PCI and SSB index, layer 1 RSRP/RSRQ, layer 2 PDSCH, PDCP, PUSCH information, LTE-NR EN-DC L3 signaling and application layer information.

Fig. 11: 5G user equipment measurements

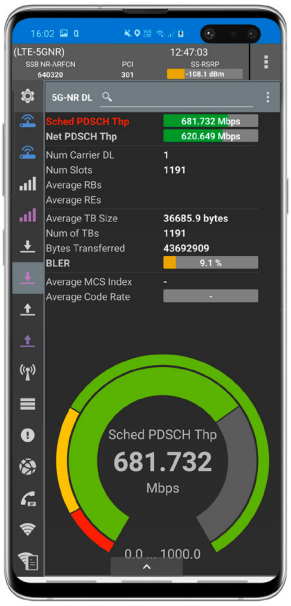


Critical 5G NR UE based measurements such as data performance KPIs, serving cell information, signaling and RF metrics using commercially available UEs such as the Samsung S10 5G and others based on Qualcomm Snapdragon 855 and Samsung Exynos 9820 chipsets can be conducted using the R&S®ROMES4 universal network engineering software platform. R&S®ROMES4 is compatible with either rooted phones or commercial off-the-shelf (COTS) UEs with open LTE and 5G diagnostic ports.

Rohde&Schwarz has demonstrated this capability in its network measurement solutions during the introduction of previous mobile communications technologies.

The first 5G smartphones are on the market and the number will significantly increase in the future. Leading smartphones are supported with the corresponding 5G software package for QualiPoc Android that delivers results from application layer tests ranging from end-user QoE to layer 1 RF measurements.

Fig. 12: QualiPoc Android 5G



3.3 5G NR data analytics

Delivering excellent quality of experience to end users is a primary objective for mobile network operators in order to retain subscribers, attract new customers and competitively position themselves.

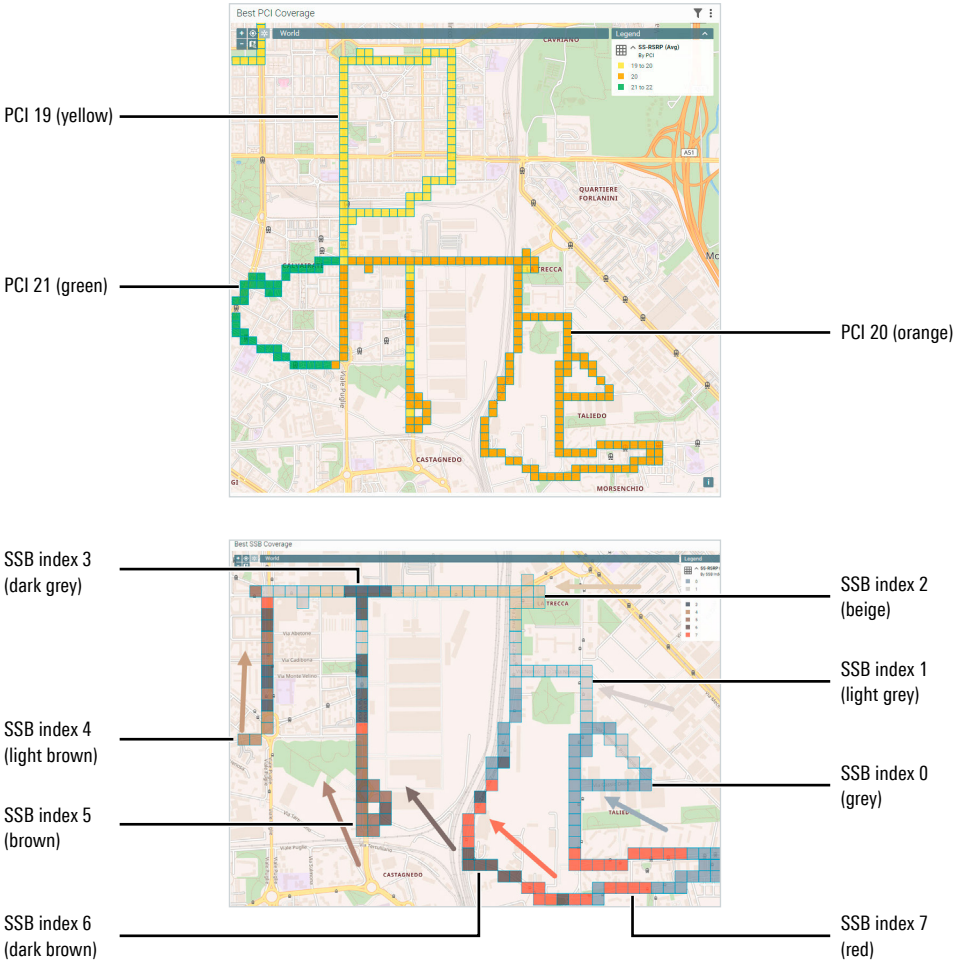
Network complexity will increase with the emergence of new cellular use cases and more demanding subscriber and machine QoE – enabled by the rollout of technologies such as 5G and internet of things (IoT). It therefore becomes more critical to understand the current network situation and pinpoint areas for development that will efficiently deliver the required performance. To measure and analyze precommercial 5G NR trials and very early deployments, all that is needed is a real-time analysis tool (such as R&S®ROMES4). Network measurements in commercial 5G NR networks require a sophisticated post-processing tool for data analytics.

For accurate network engineering, benchmarking, monitoring and optimization, it is necessary to process a large quantity of complex data and produce clear, easy-to-understand intelligence in a network in order to make better decisions. Correct decisions can only be made when they are based on reliable and accurate data that is processed quickly and appropriately.

By processing data acquired from the end-user perspective, the Rohde&Schwarz data analytics tool SmartAnalytics provides a precise and clear assessment of an operator's network quality (QoE from the end-user perspective) and its competitive position in the market.

SmartAnalytics provides visibility of the main factors influencing network performance and QoE status, the context, development trends, problems and possible degradation causes. Thanks to the network performance score integrated in SmartAnalytics, network operators can identify strategic areas for investment. As a result, mobile operators can efficiently deliver optimal end-user QoE and move ahead of the competition, which leads to a higher number of subscribers, a lower cost base and access to new revenue streams.

Fig. 13: 5G NR beam specific analysis in SmartAnalytics



In the PCI picture (top), there are even bins in the PCI 20 area where PCI 19 is received with higher RSRP, i.e. a received PCI 19 reflection can be stronger than the directly transmitted PCI 20. The higher the 5G NR frequency, the more significant the reflections become. In the SSB picture (bottom), 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. The drive/walk test is essential to validate the planned network coverage and to identify areas for initial 5G NR network optimization.

SmartAnalytics is a flexible tool that encompasses different mobile network testing use cases, such as engineering, optimization, monitoring and benchmarking – using the same user interface and a single platform. It eliminates the need for separate test platforms, removes compatibility issues and provides a seamless interface across each stage of the network testing lifecycle. This results in OPEX and CAPEX efficiencies in test resources, equipment and execution.

Fig. 14: Network benchmarking (radio technologies) with SmartAnalytics

4 CONCLUSION

With the 5G NR network rollout clearly on the horizon, network operators worldwide are planning precommercial network trials or even starting commercial network rollouts. The aim is to overcome the challenge of a more demanding and complex air interface and deliver the commercial and technical benefits offered by 5G.

A 5G NR measurement solution should provide accurate and reliable data collection with coverage measurements, application QoE measurements, and verification of the device's interaction with a real 5G NR network.

The data analytics of this solution should cover the entire network testing lifecycle, from network engineering and optimization to benchmarking and monitoring, and have the following objectives:

- To effectively store, process and visualize big data
- To gain deep network insights
- To ultimately build intelligence for investment prioritization based on the most critical factors influencing network performance and QoE

Rohde&Schwarz fulfills all these requirements from a single source with its end-to-end 5G NR network measurement solution in line with the slogan “Be ahead in 5G. Turn visions into reality”.

5 ORDERING INFORMATION

Designation	Type	Order No.
Ultracompact drive test scanner	R&S®TSME6	4900.0004.02
Autonomous mobile network scanner	R&S®TSMA6	4900.8005.02
5G NR scanning	R&S®TSME6-K50	4900.2436.02
5G NR scanning	R&S®TSMA6-K50	4901.0966.02
Simultaneous measurement in all bands	R&S®TSME6-KAB	4900.2107.02
Simultaneous measurement in all bands	R&S®TSMA6-KAB	4901.0708.02
Drive test software	R&S®ROMES4	1117.6885.04
R&S®TSME6 driver for R&S®ROMES4 drive test software	R&S®ROMES4T1E	1117.6885.82
R&S®TSME30DC downconverter driver	R&S®ROMES4T30D	4900.5293.02
Ultracompact downconverter, 24 GHz to 30 GHz	R&S®TSME30DC	4901.1004.02
Ultracompact downconverter, 24 GHz to 44 GHz	R&S®TSME44DC	4901.2600.02
Automatic channel detection	R&S®ROMES4ACD	1506.9869.02
Qualcomm 5G NR UE (R&S®ROMES4 5G NR option for x50 Qualcomm chipset support)	R&S®ROMES4NRQ	4900.5341.02
Samsung 5G NR Exynos (R&S®ROMES4 5G NR option for Samsung 9820 chipset support)	R&S®ROMES4NRS	4900.5370.02
QualiPoc Android 5G RF software package	QP-RF-5G	1900.3027.06
QualiPoc Android 5G quality assessment software package	QP-QA-5G	1900.3027.07
QualiPoc scanner license	QP-SCANNER	1900.5794.04

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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