

SIGNAL GENERATOR, SIGNAL AND SPECTRUM ANALYZER AND POWER SENSOR APPLICATIONS FOR 5G

Application Brochure | Version 04.00

ROHDE & SCHWARZ

Make ideas real



When it comes to wideband signal generation and analysis, Rohde & Schwarz provides solutions that go all the way to millimeterwave frequencies and even beyond. Our signal generation and analysis solution portfolio covers the bandwidth and frequency requirements for 5G and offers a wide range of features and application software to address 5G testing challenges.



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5G TEST AND MEASUREMENT CHALLENGES

Three things distinguish the 5G air interface from previous cellular generations: higher carrier frequencies, wider carrier bandwidths and flexible physical layer parameterization to support different requirements. The impact of these features on 5G product development and testing includes the following areas.



Millimeterwave signal generation and analysis

5G is the first cellular technology to tap into the bandwidth reserves in the centimeterwave and millimeterwave frequency bands. The unique radio properties in these bands make component manufacturing very challenging. To master these challenges, test solutions with excellent RF performance even in the millimeterwave range are needed.

Wideband signal generation and analysis

5G supports single carrier bandwidths of up to 100 MHz for carrier frequencies below 6 GHz and up to 400 MHz for carrier frequencies in the millimeterwave range. With carrier aggregation, signal bandwidths in the 1 GHz region come into play, making test solutions with wideband signal generation and analysis capabilities a must.

Over-the-air testing

The short wavelength of millimeterwave frequencies and the higher losses in circuits necessitate tight integration, making it impractical to supply connections for testing. At the same time, the effects of connectors and test fixtures become non-negligible, potentially affecting the validity of conducted measurements. As a result, over-the-air (OTA) testing plays an important role for higher carrier frequencies, which calls for innovative test solutions.

Signal configuration and analysis

The 5G physical layer offers a degree of flexibility never seen before, allowing a multitude of parameter options and combinations. As a result, configuring signals for testing can be complicated, time-consuming and prone to error. What is needed are dedicated solutions that simplify and speed up signal configuration for testing and for subsequent analysis.

Massive MIMO and beamforming/beam-steering verification

5G employs massive MIMO and beamforming to combat the effects of higher attenuation at higher frequencies and to improve capacity. In particular, beam steering and beam sweeping are important techniques to cope with the dynamic nature of the wireless channel. Test solutions need to offer a simple way to verify the accuracy of beamforming and the effectiveness of beam-steering techniques.

Selected Rohde & Schwarz solutions

Vector signal generators

- ▶ Wideband (up to 2 GHz bandwidth) signal generation up to millimeterwave frequencies
- ▶ Base station receiver and performance testing
- ▶ MIMO and beamforming

Analog signal generators

- ▶ Signal generation up to 67 GHz with the highest signal quality and output power
- ▶ LO source, high-power intermodulation tests, blocking tests, test fixture calibration

Signal and spectrum analyzers

- ▶ Wideband (up to 8 GHz bandwidth) signal and spectrum analysis up to 90 GHz
- ▶ Base station transmitter testing

Power sensors

- ▶ Over-the-air 2D/3D power level calibration and beamforming/beam-steering verification up to 90 GHz

Dedicated application software

- ▶ Signal configuration and analysis for 5G NR and generic OFDM
- ▶ Amplifier development and characterization
- ▶ Compensating the effects of test fixtures

For more 5G test solutions, see
www.rohde-schwarz.com/5G

VECTOR SIGNAL GENERATORS

Rohde & Schwarz offers a variety of 5G-ready solutions for wideband signal generation applications ranging from research and development to production testing. Our vector signal generators distinguish themselves in their respective class with excellent RF performance out of the box, intuitive user interface and a fully flexible hardware and software option concept.



The R&S®SMW200A is the vector signal generator for the most demanding applications. As a result of its flexibility, performance and intuitive operation, it is a perfect tool for generating complex, digitally modulated signals of high quality. The picture shows a setup with one R&S®SMW200A and two R&S®SGT100A SGMA RF source modules on top.

Thanks to automatic internal amplitude correction, all Rohde & Schwarz vector signal generators produce extremely flat signals over the entire frequency range up to their maximum rated power (e.g. < 0.4 dB measured over 2 GHz bandwidth for the R&S®SMW200A). They also exhibit excellent spectral characteristics, making them ideal for use in both conducted and over-the-air testing. The outstanding amplitude and frequency characteristics ensure that extremely clean 5G NR signals (measured error vector magnitude of less than 0.3% on the R&S®SMW200A for a 5G NR downlink signal with 100 MHz bandwidth) can be generated to test the true performance of a DUT.

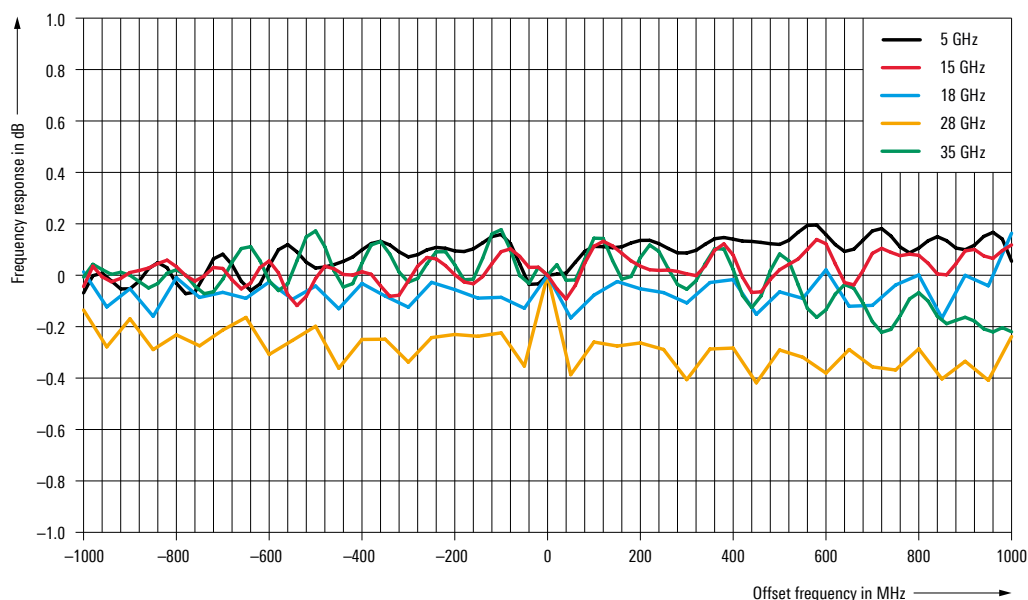
Advanced applications benefit from the full flexibility and scalability offered by the R&S®SMW200A. Up to six R&S®SGT100A SGMA vector RF sources can be connected to a single R&S®SMW200A to provide a compact setup with eight RF outputs, all controlled and configured from the R&S®SMW200A. The setup is scalable and easily duplicated if more RF outputs are required. This capability is especially useful for applications such as beamforming, MIMO, carrier aggregation and multistandard testing. The R&S®SMW200A can also be equipped with an optional real-time fading simulator and an AWGN generator, making it an excellent one-box solution for base station performance testing and as a channel emulator for terminal and base station chipset testing.

Vector signal generator portfolio for 5G applications



	R&S®SMW200A	R&S®SMBV100B	R&S®SGT100A	R&S®SGS100A/ R&S®SGU100A
Application	R&D, integration and verification, conformance testing	R&D, production, integration and verification	Production, automated use, RF source for R&S®SMW200A	Production, automated use, RF source for R&S®SMW200A
Frequency	100 kHz to 44 GHz	8 kHz to 6 GHz	1 MHz to 6 GHz	1 MHz to 40 GHz
Modulation bandwidth	≤ 2 GHz	≤ 500 MHz	≤ 240 MHz	≤ 2 GHz (ext. analog I/Q)
Fading emulation	yes (optional)	no	no	no
RF outputs	1 or 2	1	1	1
RF output power	+18 dBm	+25 dBm (with option)	+17 dBm	+15 dBm

Measured I/Q modulation frequency response of the R&S®SMW200A vector signal generator



The R&S®SMW200A produces extremely flat signals over the entire bandwidth, making it possible to test the true performance of a DUT in both conducted and over-the-air measurements.

ANALOG SIGNAL GENERATORS

Rohde & Schwarz offers industry-leading analog signal generators specifically designed for high performance without any compromises, covering all fields of application from research and development to production, service and maintenance. As the world's leading signal generator, the R&S®SMA100B can handle the most demanding component, module and system test and measurement tasks, covering frequencies up to 67 GHz and delivering ultra-high output power up to +38 dBm with outstanding SSB phase noise performance.



The R&S®SMA100B RF and microwave signal generator offers performance leadership without compromise, delivering the purest signals with the highest output power up to 67 GHz for demanding 5G applications that require extremely clean analog signals. It comes in two form factors, offering flexibility for different test setups.

R&S®SMA100B RF and microwave signal generator

The R&S®SMA100B RF and microwave signal generator is the first choice for all 5G applications requiring extremely clean analog signals, for instance component testing, receiver testing and amplifier characterization. For testing analog-to-digital converters (ADC), the R&S®SMA100B generates signals with extremely low jitter and highest spurious-free dynamic range (SFDR). Specifically for ADC tests with clock signals up to 6 GHz, the R&S®SMA100B offers, in addition to the RF output, an optional independent clock output with exceptionally low wideband noise for extremely clean clock signals. This eliminates the need for two separate generators, which greatly simplifies the test setup.

For base station receiver blocking tests, the combination of high output power, low wideband noise and excellent phase noise performance ensures simple setups that bring out the true performance of the receivers under test. In automated production environments, the ultra high output power capabilities of the R&S®SMA100B make additional amplifiers unnecessary while keeping harmonics extremely low.

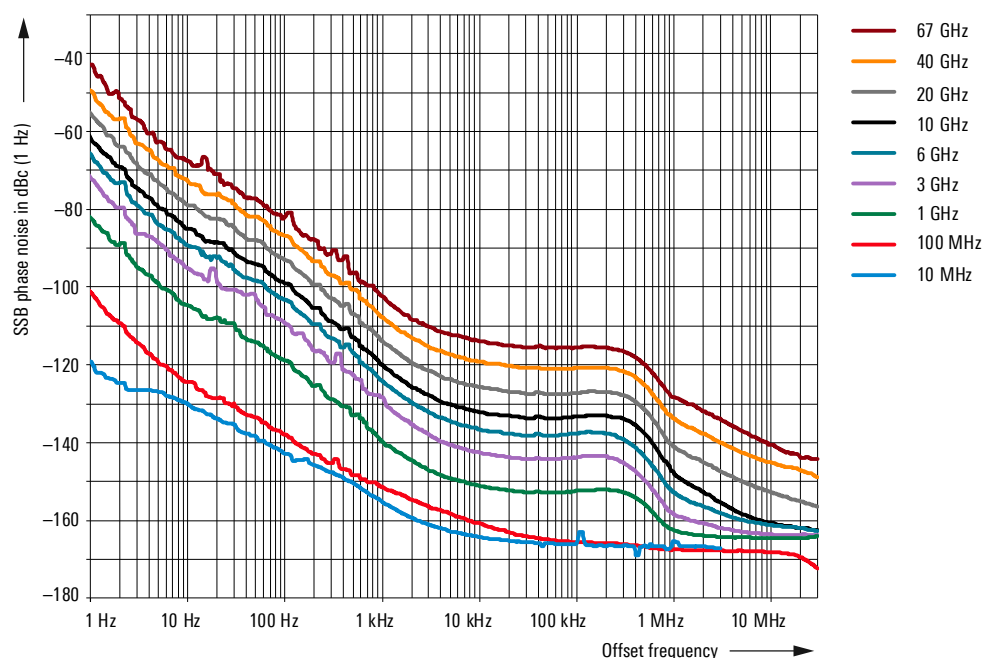
For a wide range of applications in R&D, production, service and maintenance where a good price/performance ratio is a key factor, the R&S®SMA100B is an ideal choice, setting new standards in spectral purity and output power in the mid-range segment.

Analog signal generator portfolio for 5G applications



	R&S®SMA100B	R&S®SMB100B	R&S®SMB100A
Application	R&D, integration and verification, conformance testing	R&D, integration and verification, production	R&D, integration and verification, production
Frequency	8 kHz to 67 GHz	8 kHz to 6 GHz	100 kHz to 40 GHz
SSB phase noise (1 GHz, 20 kHz offset)	< -147 dBc (with option)	< -126 dBc	< -122 dBc
Harmonics (1 GHz)	< -60 dBc	< -30 dBc	< -58 dBc
Nonharmonics (1 GHz)	< -94 dBc (with option)	< -76 dBc	< -64 dBc
RF output power	+30 dBm (with option)	+26 dBm (with option)	+19 dBm (with option)

Measured SSB phase noise performance of the R&S®SMA100B with the R&S®SMAB-B711(N) option



SIGNAL AND SPECTRUM ANALYZERS

Rohde & Schwarz offers the widest range of spectrum analyzers in the industry for all phases of 5G development. The R&S®FSW covers frequencies up to 90 GHz, with a built-in demodulation bandwidth of up to 8 GHz, making it the ideal R&D tool with the highest dynamic range.



The R&S®FSW signal and spectrum analyzer redefines the top of the line for signal and spectrum analyzers, offering superior RF performance in terms of phase noise, displayed average noise level, intermodulation suppression and dynamic range for ACLR and harmonic measurements.

R&S®FSW signal and spectrum analyzer

The R&S®FSW with up to 8.3 GHz internal bandwidth enables research and development for next generation mobile standards, especially in the 5G millimeterwave frequency bands, as well as characterization of wideband signals. It offers a high dynamic range and low input signal distortion, with a spurious-free dynamic range (SFDR) of 65 dBc, allowing users to precisely determine the signal modulation quality.

The error vector magnitude (EVM) generated by the R&S®FSW itself is excellent, ensuring reliable measurements on signals with very good inherent EVM. For example, the bandwidth extension and the R&S®VSE-K96 OFDM vector signal analysis software allow the R&S®FSW to measure EVM values in the order of < 1 %, even with 800 MHz wide signals in the 28 GHz range. The R&S®FSW is capable of an industry-leading 8 GHz of internal demodulation bandwidth in the RF and more than 8 GHz in the analog baseband for analyzing signals between chipsets.

R&S®FSV3000, R&S®FSVA3000 and R&S®FPS signal and spectrum analyzers

For many applications, the R&S®FSV3000 and R&S®FSVA3000 general-purpose analyzers are a cost-efficient alternative.

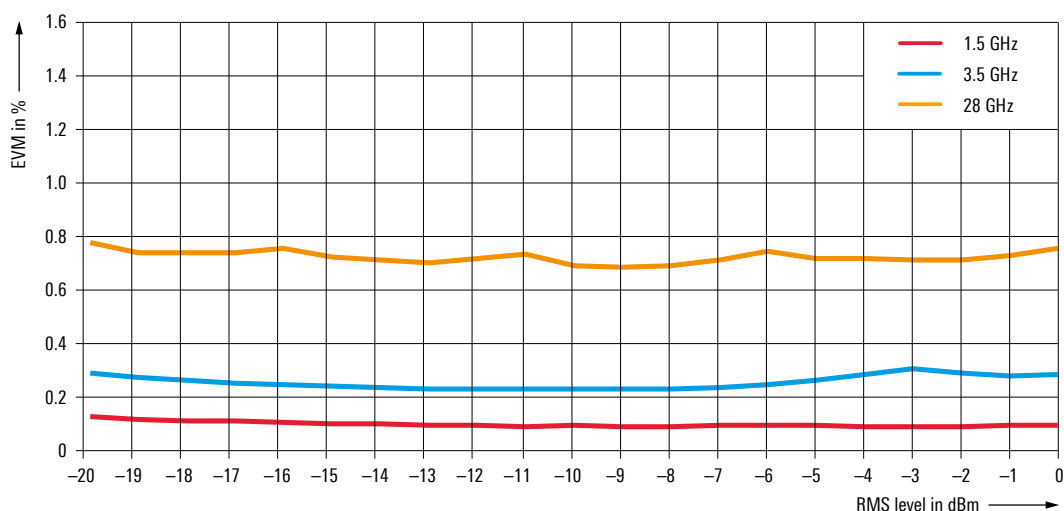
The R&S®FPS, developed especially for automated test systems, is an exceptionally fast and compact spectrum analyzer featuring excellent RF performance.

Vector signal and spectrum analysis solution portfolio for 5G applications



	R&S®FSW	R&S®FSVA3000	R&S®FSV3000	R&S®FPS
Application	R&D, integration and verification	R&D, production	R&D, production	Production, automated use
Frequency	2 Hz to 90 GHz	10 Hz to 44 GHz	10 Hz to 44 GHz	10 Hz to 40 GHz
Internal analysis bandwidth	≤ 8 GHz	≤ 1 GHz	≤ 200 MHz	≤ 160 MHz

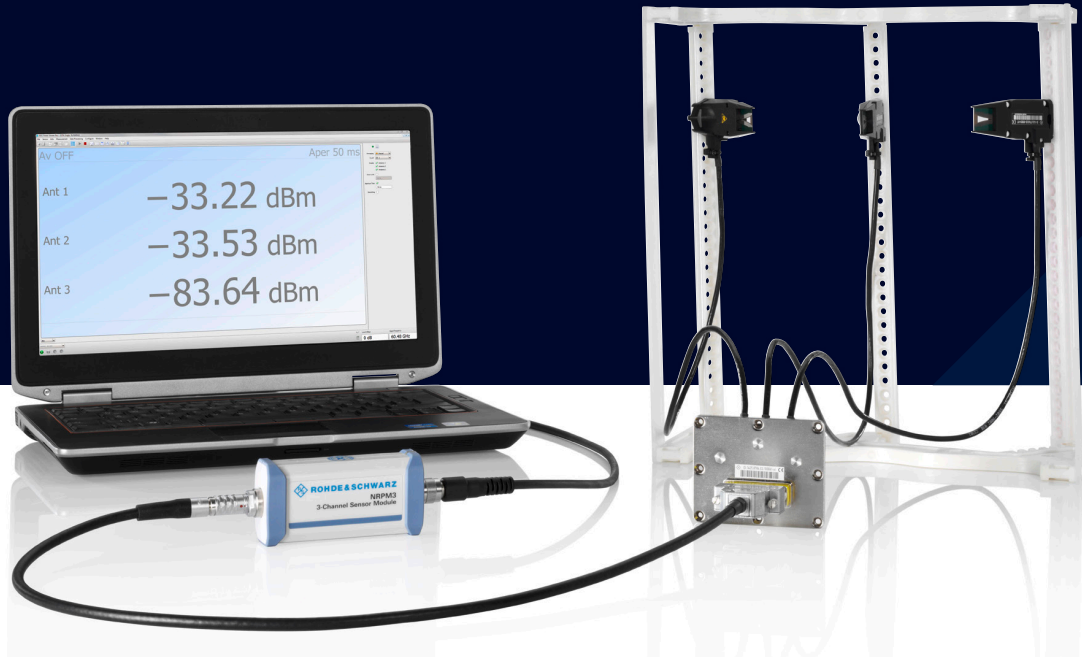
Measured error vector magnitude (EVM) of a 100 MHz downlink 5G NR signal using the R&S®SMW200A vector signal generator and the R&S®FSW vector signal analyzer



A setup consisting of an R&S®FSW with the R&S®FSW-B1200 option in combination with an R&S®SMW200A vector signal generator is easy to operate and provides industry-leading performance and bandwidth for in-depth amplifier and predistortion measurements. The EVM stays below 1% over a wide power range.

POWER SENSORS

Rohde & Schwarz offers a comprehensive portfolio of power sensors covering DC up to 110 GHz. Ongoing additions to the portfolio bring features to simplify power level calibration for conducted and over-the-air measurements for 5G.



The R&S®NRPM OTA power measurement solution is unique on the market. It uses single- or dual-polarized Vivaldi antennas with integrated power sensors to perform over-the-air power measurements up to 90 GHz. The compact setup can be used on a benchtop and in a shielded box.

Frequency selective power sensor

For highly accurate power measurements, even at low power levels, Rohde & Schwarz offers the unique R&S®NRQ6 frequency selective power sensor. This compact device, with its receiver-based architecture, can perform frequency selective power measurements up to 6 GHz and capture I/Q data at the same time, thanks to its 100 MHz analysis bandwidth, making it ideal for calibration and functional software regression testing. Integration with the R&S®VSE vector signal explorer PC software simplifies I/Q capture and analysis.

The R&S®NRQ6 also offers a cost-effective solution for calibrating multiple active antenna modules for beamforming applications. Multiple R&S®NRQ6 devices can be set up in a master-slave configuration to measure and calibrate the phase difference between multiple sources.

Power level calibration and beamforming/beam-steering verification

Over-the-air power level calibration and beamforming/beam-steering verification have never been easier, thanks to the unique R&S®NRPM OTA power measurement solution. At its core is the R&S®NRPM-A90/R&S®NRPM-A90D antenna module. This module consists of a single- or dual-polarized Vivaldi antenna with an integrated diode power detector with a frequency limit of up to 90 GHz. The detector connects to the R&S®NRPM3 sensor module for signal processing. The entire system is calibrated ex-factory, making fast and accurate OTA power level measurements extremely straightforward.

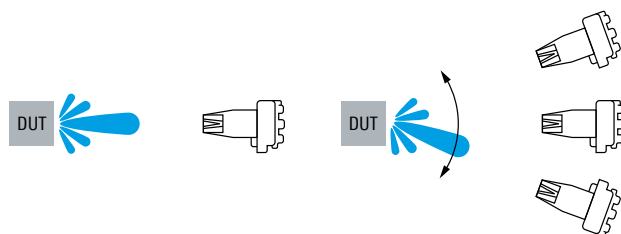
The flexibility and scalability offered by the R&S®NRPM OTA power measurement solution makes it the ideal setup for multidimensional power level calibration and verification of beamforming and beam steering.

Power sensor portfolio for 5G applications



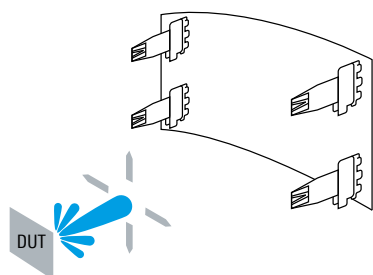
	R&S®NRQ6 frequency selective power sensor	R&S®NRPM OTA power sensor	R&S®NRPxxS/SN three-path diode power sensor	R&S®NRPxxT/TN thermal power sensor
Application	Frequency selective power measurements, phase coherent measurements, I/Q capture	Over-the-air power level calibration, beamforming verification	R&D, production	Calibration
Frequency	50 MHz to 6 GHz	18 GHz to 90 GHz	10 MHz to 50 GHz	DC to 110 GHz
Power measurement range	-130 dBm to +20 dBm	-76 dBm to -19 dBm	-70 dBm to +45 dBm	-35 dBm to +20 dBm

The R&S®NRPM OTA power measurement solution



Power level calibration

2D power level calibration and beamforming/beam-steering verification



3D power level calibration and beamforming/beam-steering verification

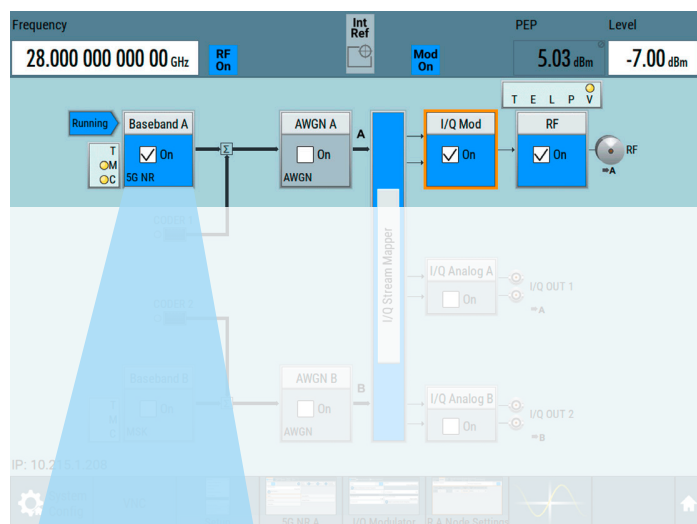
The R&S®NRQ6 frequency selective power sensor is a power sensor and an I/Q data capturing device all in one, making it ideal for calibration and functional software regression testing. Multiple R&S®NRQ6 devices can be set up in a master-slave configuration to perform phase coherence measurements for low-power modulated signals.



5G SIGNAL CONFIGURATION AND ANALYSIS AT YOUR FINGERTIPS

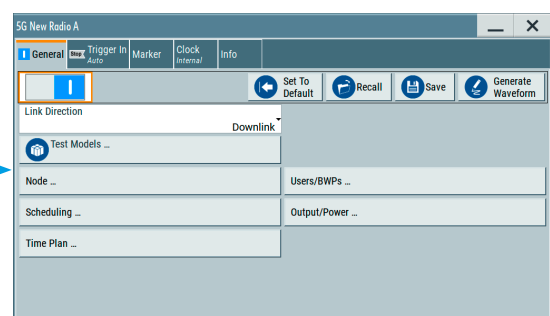
Rohde & Schwarz offers dedicated applications for generating and analyzing 5G signals. Standard-compliant 5G NR signals can be configured directly on a Rohde & Schwarz vector signal generator or by using the R&S®WinIQSIM2™ simulation software. Powerful signal analysis applications running directly on Rohde & Schwarz signal and spectrum analyzers provide deep insights, displaying a wide array of performance metrics. The R&S®VSE vector signal explorer PC software brings these powerful signal analysis capabilities to the desktop.

Dedicated applications for generating and analyzing 5G signals



OFDM Standards
EUTRA/LTE/loT...
5G NR...
V5GTF...
OFDM Signal Generation...

Rohde & Schwarz offers dedicated signal generation and analysis solutions for 3GPP 5G NR standard. A generic OFDM solution is also available to generate and analyze user-defined OFDM signals.



OFDM Signal Generation A: General Settings (OFDM)	
Physical	Filter
Total Number of Subcarriers	4 096
Subcarrier Spacing	120.000 0 kHz
Cyclic Prefix Length	320 Samples
Alt. Cyclic Prefix Length	288 Samples
Occupied Number of Subcarriers	3 300
Sequence Length	112 Symbols
CP No. Symbols	1 Symbols
Alt. CP No. Symbols	6 Symbols
Sampling Rate	491.520 MHz
Number of Left Guard Subcarriers	398
Number of Right Guard Subcarriers	398
Occupied Bandwidth	396.000 MHz

3GPP 5G New Radio (5G NR)

The 5G NR software options (-K144, -K444) simplify uplink and downlink 5G NR signal generation. They support all waveforms, channel bandwidths, modulation schemes and numerology options specified in the standards. The intuitive GUI allows users to configure these and many other parameters, such as bandwidth parts, directly on the instrument. Predefined settings are also available to quickly configure fixed reference channels (FRC) for uplink tests and test models (TM) for downlink tests. When equipped with the 5G NR software options (-K144, -K145), the R&S®FSW signal and spectrum analyzer detects and sets many parameters automatically, performing detailed signal analysis and displaying many user-configurable performance metrics.

Generic OFDM signal generation and analysis

The OFDM signal generation software options (-K114, -K414) enable user-defined OFDM signal configurations that go beyond the standards, providing full parameterization flexibility for even the most sophisticated applications. The R&S®VSE software, with its OFDM signal analysis option (-K96), offers a powerful, standard-independent and user-configurable OFDM signal analysis solution.



Analysis of a 5G NR downlink signal with R&S®FSW-K144.



Analysis of a generic OFDM signal with R&S®VSE-K96.

SOLUTIONS FOR POWER AMPLIFIER DEVELOPMENT

Not only do power amplifiers for 5G need to deliver higher output power, they must do so at higher carrier frequencies, over wider bandwidths and with improved efficiency. Effective digital predistortion (DPD) techniques are essential to meet the linearity requirements over wider bandwidths.

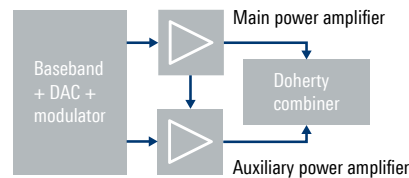
A dual-path R&S®SMW200A serves as the ideal platform for developing and testing advanced power amplifier architectures such as envelope tracking, Doherty, outphasing, load-modulated balanced amplifiers and their variants. With dedicated applications such as the digital Doherty option (-K546), power amplifier designers can obtain unparalleled insights into their designs while

shortening the design cycle. The R&S®FSW signal and spectrum analyzer with the amplifier measurements option (-K18) provides the necessary measurements, capturing not only scalar quantities such as spectral regrowth and EVM, but also vectors such as AM/AM and AM/PM.

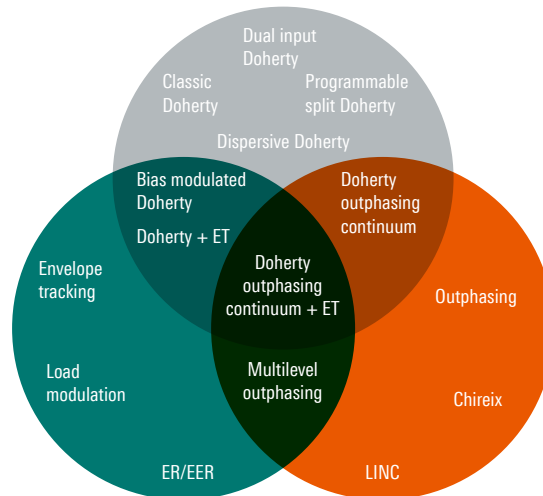
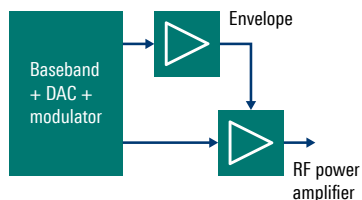
The digital predistortion option (-K541) on the vector signal generators, together with the amplifier and direct DPD measurement options (-K18, -K18D) on the signal and spectrum analyzers, provides a complete solution for digital predistortion. Additional techniques such as crest factor reduction (-K548) can also be applied to the signal to help push the limits of power amplifier designs.

Ideal platform for power amplifier development

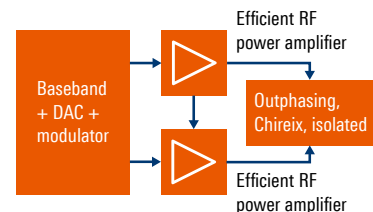
Doherty and its variants

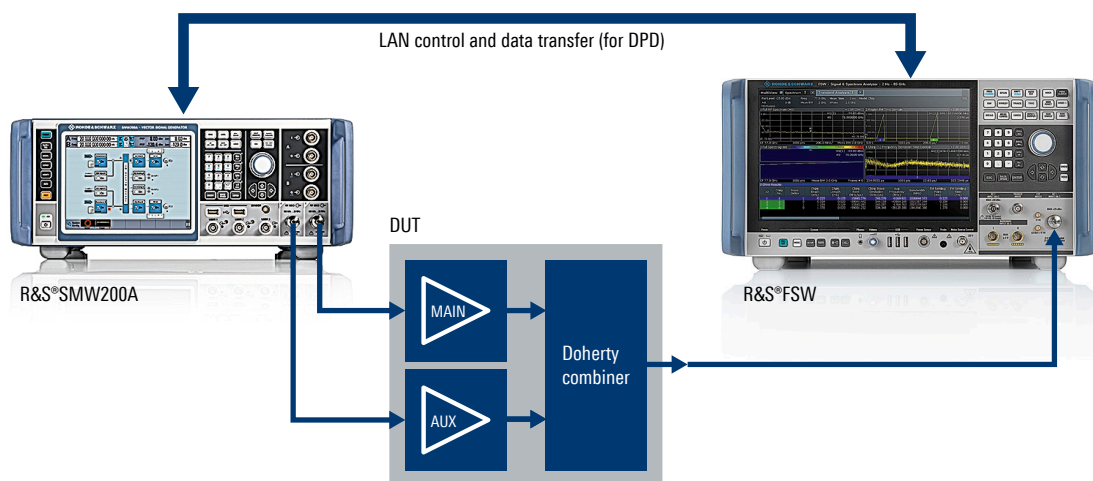


Envelope tracking and its variants

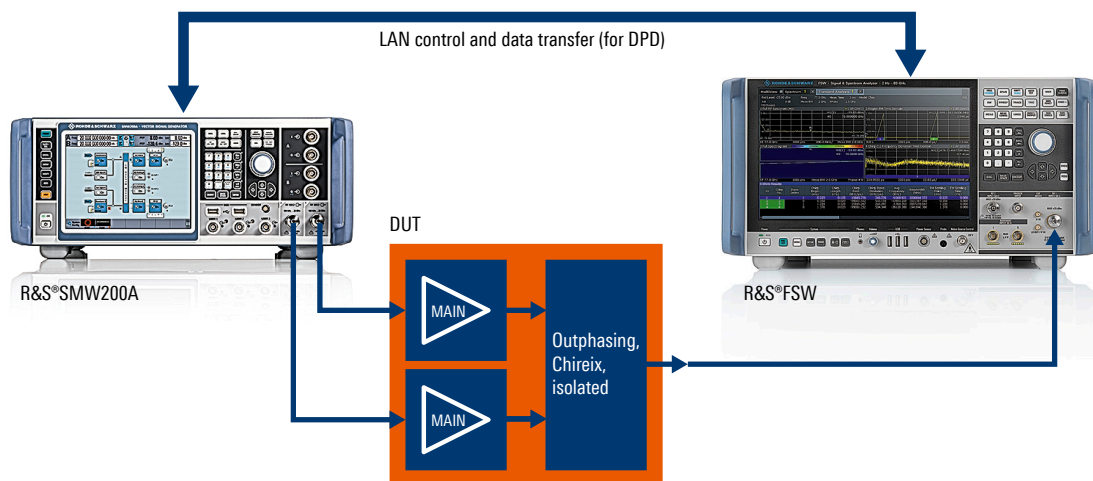


Outphasing and its variants

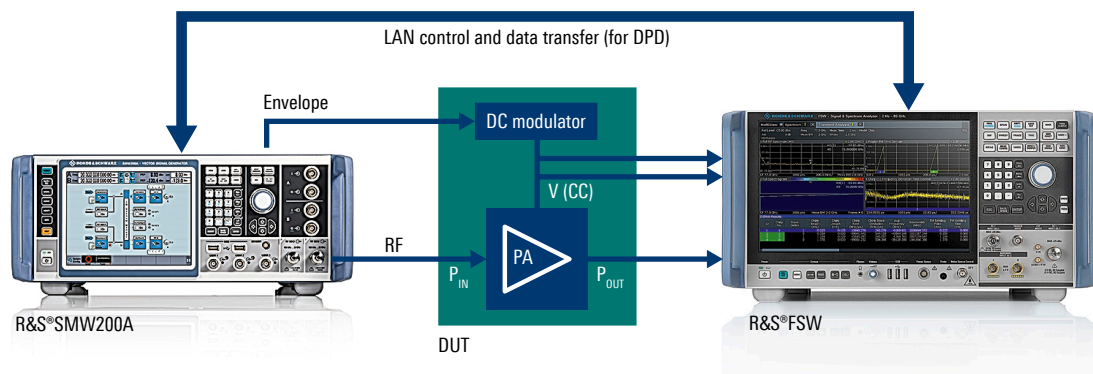




Outphasing and its variants



Envelope tracking and its variants



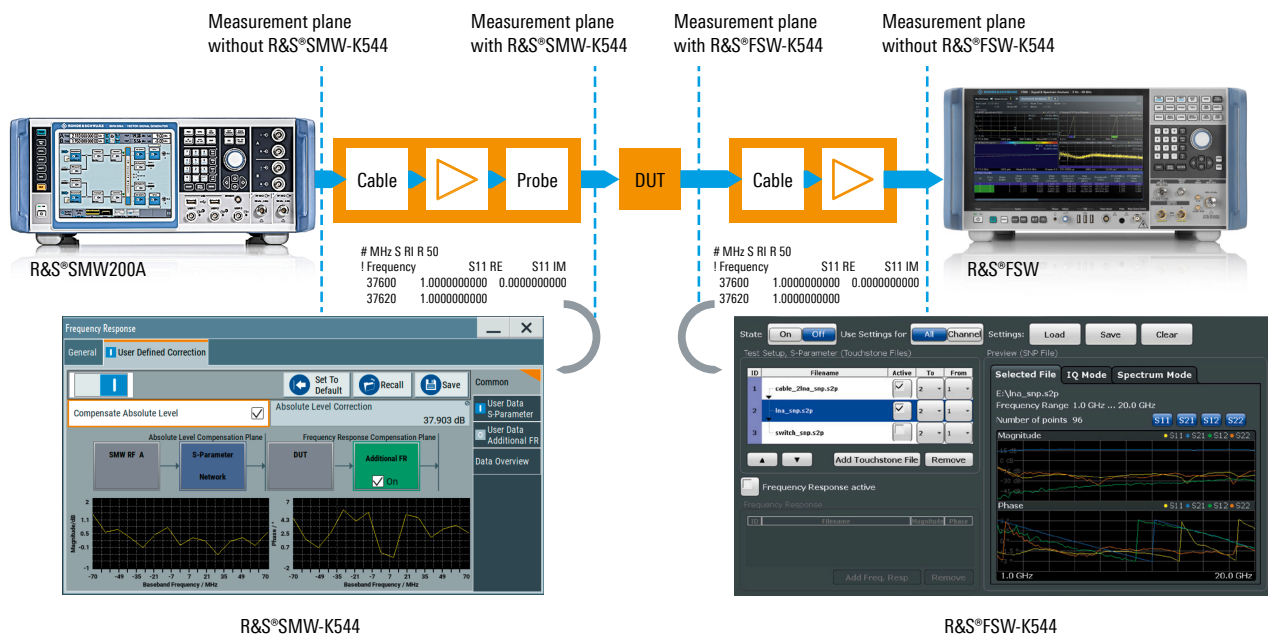
The dual-path capabilities of the R&S®SMW200A make it a compact, powerful, easy-to-use platform for developing and characterizing advanced power amplifier architectures. The DPD option (R&S®SMW-K541, R&S®SMBVB-K541), together with the amplifier and direct DPD measurement options on the signal and spectrum analyzers (-K18, -K18D), offers a complete solution for digital predistortion and amplifier characterization.

COMPENSATING THE EFFECTS OF TEST FIXTURES

Since the effects of test fixtures become non-negligible at higher carrier frequencies, simple and quick solutions are needed to compensate these effects and measure the true performance of the DUT. The user-defined frequency response correction option (-K544) provides a simple and user-friendly means to accomplish this on both the vector signal generators and the signal and spectrum analyzers. Simply load the n-port network parameter data of the test fixture once (e.g. from data sheets or directly measured with a vector network analyzer) and activate the correction parameters of the desired fixtures during testing.

The instruments automatically compensate the effects of the activated fixtures internally in real time, ensuring calibrated measurements directly at the DUT plane, irrespective of waveform, signal level, frequency and bandwidth.

User-defined frequency response correction



The user-defined frequency response correction option (-K544) for the R&S SMW200A, R&S SMBV100B, R&S FSV(A)3000 and R&S FSW is easy to use, compensating the effects of test fixtures in real time, independent of waveform, signal level, frequency and bandwidth.

5G NR BASE STATION CONFORMANCE TESTING

Selected products from Rohde & Schwarz

- ▶ R&S®SMW200A/R&S®SMBV100B vector signal generator
- ▶ R&S®SMA100B RF and microwave signal generator, R&S®SMB100B RF signal generator (analog signal generators)
- ▶ R&S®FSW/R&S®FSVA3000 signal and spectrum analyzer
- ▶ Shielded RF boxes and chambers

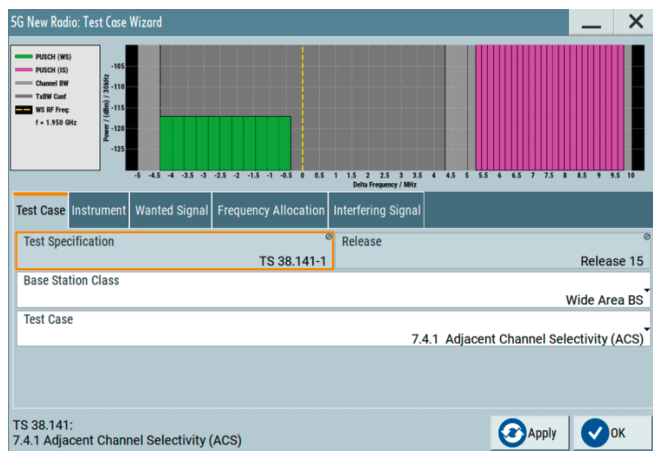
The R&S®SMW200A vector signal generator with its high output power and wideband signal generation capability serves as an excellent signal source for conducted and over-the-air testing of receivers and antenna modules. The R&S®FSW signal and spectrum analyzer, with its wide analysis bandwidth and powerful analysis capabilities, makes an outstanding companion for testing transmitters and receiver spurious emissions.

With the help of the user-defined frequency response correction option (-K544), measurements can be calibrated to the plane of the link and measurement antennas, allowing the true performance of the DUT to be measured in both benchtop and shielded OTA measurement setups.

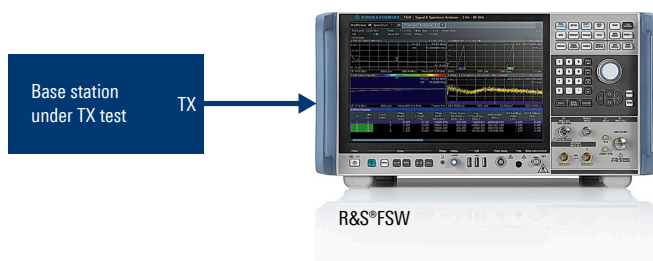
A test case wizard that comes with the 5G NR option helps users quickly configure the relevant test cases specified in 3GPP TS38.141 by using built-in presets for the FRCs and TMs.

When equipped with the optional fading simulator, the R&S®SMW200A turns into a single-box solution for performance testing. The R&S®SMW200A is able to generate the wanted and interference signals, perform fading using presets for the corresponding channel models, add AWGN and provide the real-time HARQ feedback signals required for 3GPPTS38.141 Chapter 8 testing.

5G NR test case wizard



Base station transmitter characteristics



Setup for testing base station transmitter characteristics with the R&S®FSW. The R&S®FSW signal and spectrum analyzer with its wide analysis bandwidth and powerful analysis capabilities is an outstanding tool for testing transmitters and receiver spurious emissions.

Base station receiver characteristics and performance



The R&S®SMW200A is the perfect platform for testing base station receiver characteristics and performance. When fully equipped, it is able to generate the wanted and interference signals, perform fading using predefined presets, add AWGN and generate real-time HARQ feedback all in a single box.

SOLUTIONS FOR HIGH-VOLUME TESTS AND BASE STATION PRODUCTION

Selected products from Rohde & Schwarz

- ▶ R&S®SGT100A SGMA vector RF source
- ▶ R&S®SGS100A SGMA vector RF source
- ▶ R&S®SGU100A SGMA upconverter
- ▶ R&S®FSVA3000 signal and spectrum analyzer
- ▶ R&S®NRQ6 frequency selective power sensor

The R&S®SGMA family of vector signal generators (i.e. R&S®SGT100A, R&S®SGS100A and R&S®SGU100A) and the R&S®FSVA3000 signal and spectrum analyzer have been developed with both size and test speed in mind, without compromising on performance. The result is a significant reduction in test time and floor space, making them the ideal instruments for production environments.

For power level calibration, the R&S®NRQ6 offers a compact solution for fast, highly accurate frequency selective power sensing and I/Q data capturing in a single instrument.



The R&S®SGMA compact vector signal generators and the R&S®FSVA3000 signal and spectrum analyzer are optimized for speed, without compromise on performance, making them ideal for production environments.

Server based testing

Rohde&Schwarz offers a novel server based approach to increase test efficiency and flexibility in automated transmitter tests. It leverages the advantages of a cutting-edge, scalable and upgradable processing environment to achieve significant speed and flexibility benefits in production environments.

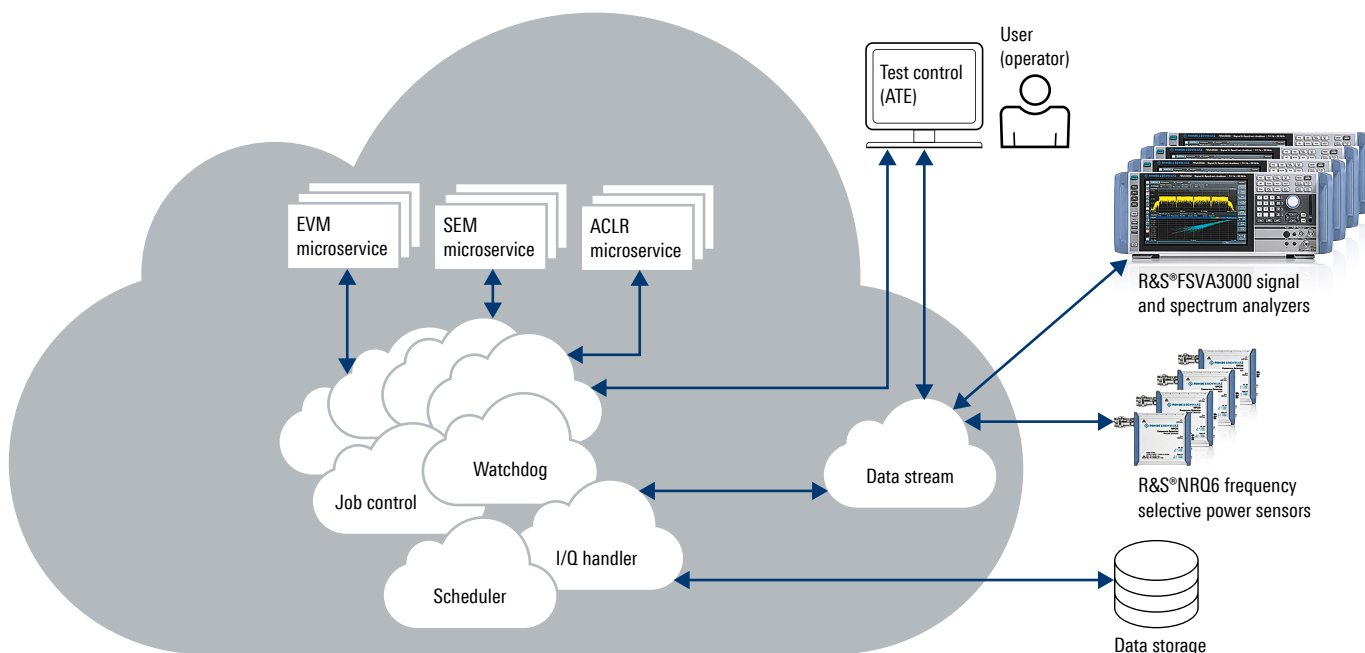
This novel approach separates I/Q data collection from signal processing and analysis, resulting in significant speed improvements and better equipment utilization. I/Q data collection is performed by Rohde&Schwarz RF instruments, while signal processing and data analysis are performed in the cloud or on an edge server or on-premise server.

RF instruments (e.g. R&S®FSVA3000) transfer captured I/Q data through a network connection to the cloud or edge server or on-premise server with a speed of up to 10 Gbit/s. The server(s) run(s) different highly optimized, application-specific microservices that are dedicated to one single specific measurement task, e.g. 5G NR EVM, ACLR or SEM.

A job scheduler optimally distributes the incoming I/Q data to the available microservices. The number of microservices can be dynamically adapted based on the amount of measurement data, measurement tasks and available server resources.

Once the signal processing has been performed, the results can be collected by the automatic test environment (ATE) or sent to data storage for further processing.

Rohde & Schwarz server based solutions for automated transmitter tests



This approach separates I/Q data capture from signal processing, resulting in test speed improvements and better equipment utilization.

5G APPLICATION SOFTWARE

Standard testing

	5G NR	Custom OFDM
Vector signal generators		
R&S®SMW200A	-K144 option, -K444 option ¹⁾	-K114 option, -K414 option ¹⁾
R&S®SMBV100B	-K144 option, -K444 option ¹⁾	-K114 option, -K414 option ¹⁾
R&S®SGT100A	-K444 option ¹⁾	-K414 option ¹⁾
Signal and spectrum analyzers		
R&S®FSW	-K144 option (downlink), -K145 option (uplink) R&S®VSE-K146 option (MIMO measurements) ²⁾	R&S®VSE-K96 option ²⁾
R&S®FSVA3000	-K144 option (downlink), -K145 option (uplink) R&S®VSE-K146 option (MIMO measurements) ²⁾	R&S®VSE-K96 option ²⁾
R&S®FPS	-K144 option (downlink) R&S®VSE-K144 option (uplink) ²⁾ R&S®VSE-K146 option (MIMO measurements) ²⁾	R&S®VSE-K96 option ²⁾

¹⁾ Using R&S®WinIQSIM2™ PC software.

²⁾ Using R&S®VSE vector signal explorer software.

Amplifier development

	Envelope tracking	Doherty	Digital predistortion	Crest factor reduction
Vector signal generators				
R&S®SMW200A	-K540 option	-K546 option	-K541 option	-K548 option
R&S®SMBV100B	-K540 option	–	-K541 option	-K548 option
R&S®SGT100A	-K540 option, -K543 option	–	-K541 option	-K548 option
Signal and spectrum analyzers				
R&S®FSW	-K18 option	-K18 option	-K18 option, -K18D option	-K18 option
R&S®FSVA3000	-K18 option	-K18 option	-K18 option, -K18D option	-K18 option
R&S®FPS	-K18 option	-K18 option	-K18 option, -K18D option	-K18 option

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