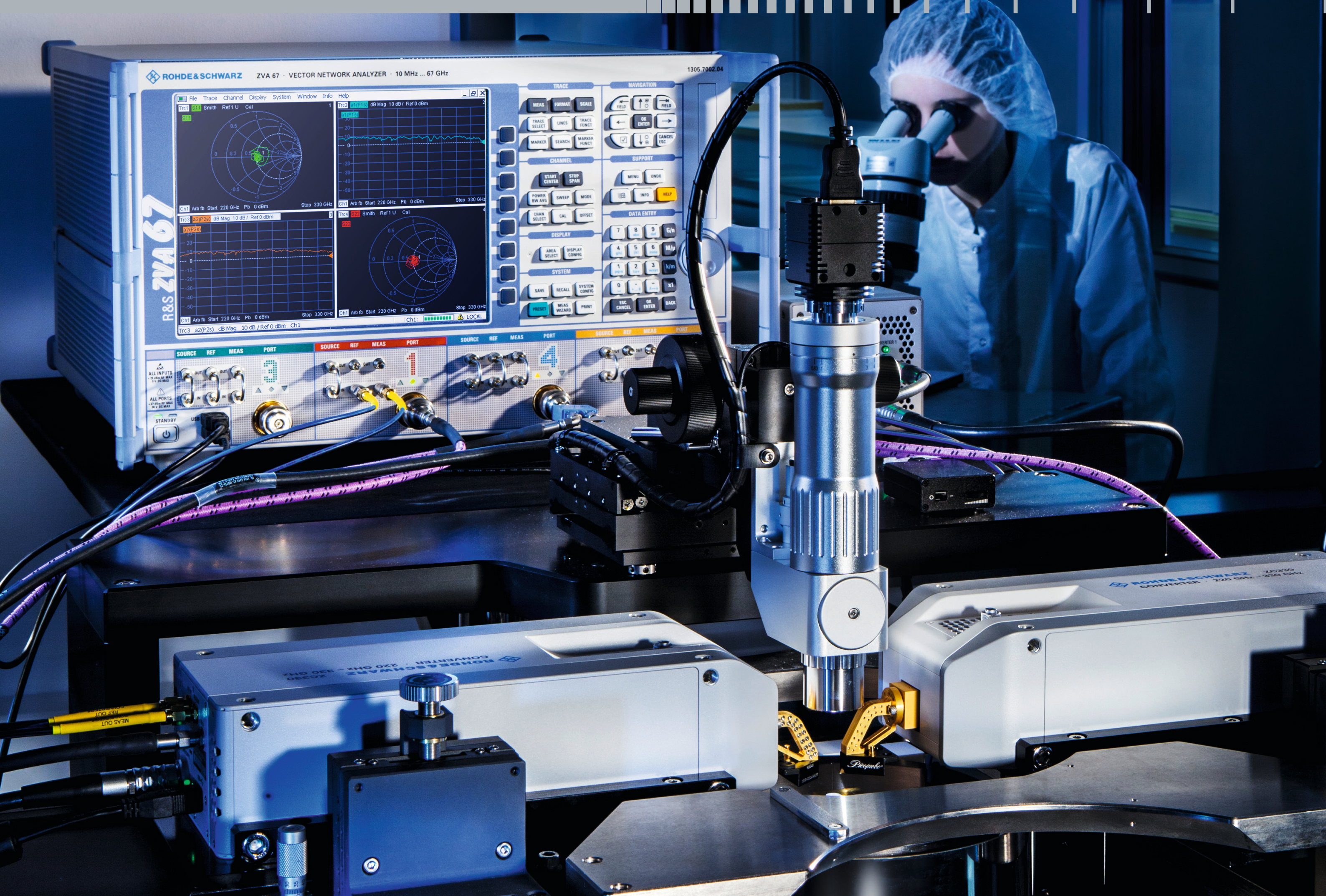
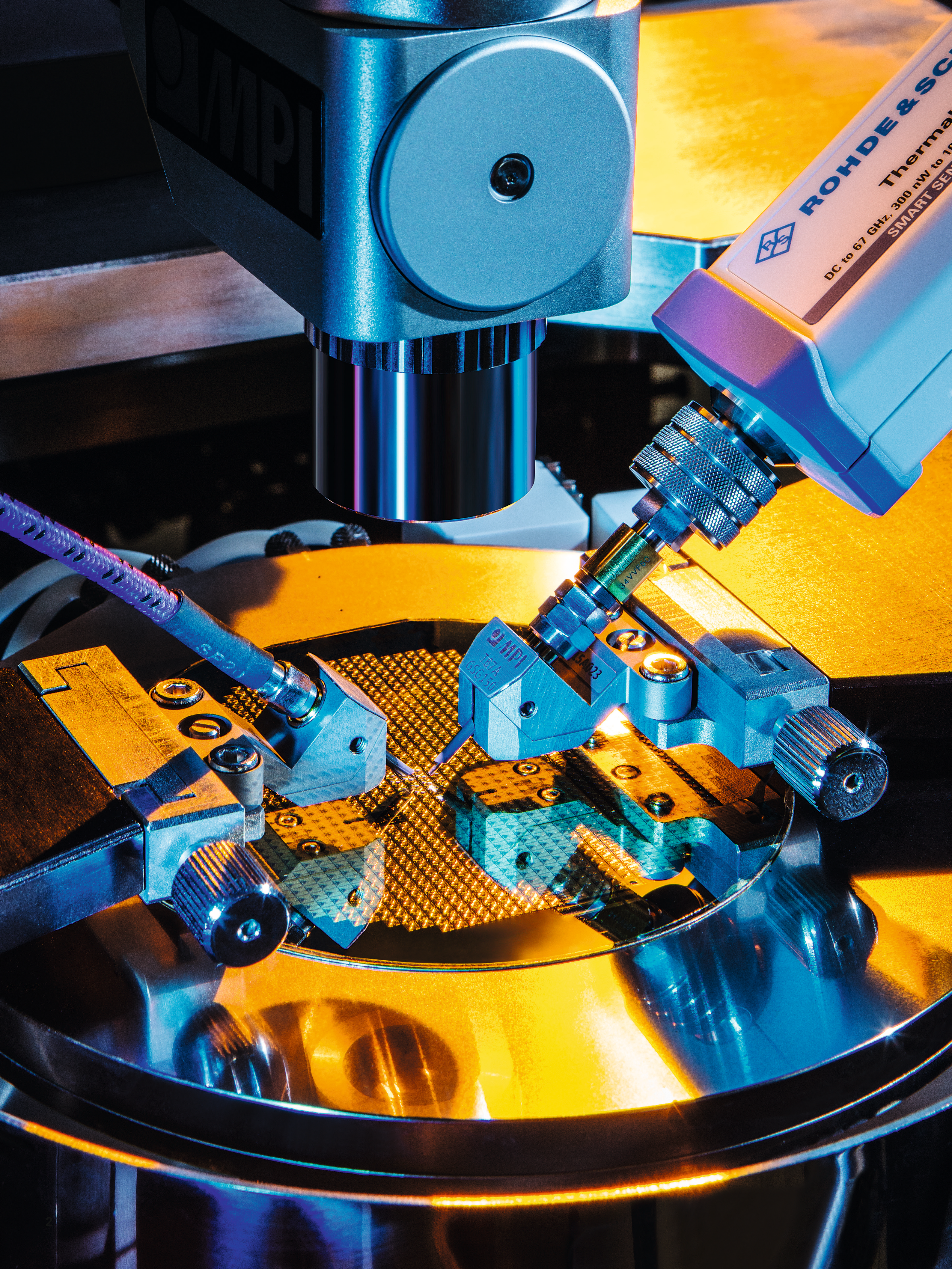
Fully tuned for microwave and millimeterwave testing

ROHDE&SCHWARZ




MPI
ROHDE & SC
Thermal

Testing excellence up to 500 GHz

Starting with the early microwave applications for radar, the advantage of increased bandwidth has been a deciding factor in shifting toward microwave and millimeterwave (mmWave) for communications technologies. It began with satellite transmissions and then came down to earth with cable television and wireless local area networks such as Wi-Fi followed by new applications in the automotive and aerospace fields. The high bandwidth and high capacity demand of 5G – the next generation of mobile networks – also promote the trend toward ever higher frequencies in electronics.

Thriving on innovation

From the very beginning Rohde & Schwarz has driven innovation in RF technology, starting with our first frequency meter in 1933. We have been instrumental in moving the technological benchmark – with developments such as signal and spectrum analyzers with up to 2 GHz analysis bandwidth and unrivalled low noise levels even in the GHz range. Unique multiport network analyzers, highly innovative signal generators with up to two signal paths in one instrument and power meters with R&S®Smart Sensor Technology are further examples of pacesetting Rohde & Schwarz products. In addition, we offer a complete EMC test portfolio that ranges from standalone devices to turnkey test chambers. A broad range of RF and microwave accessories for calibration and measurement complement our innovative product solutions. Rohde & Schwarz measurement and test systems feature extremely flexible hardware and software concepts that allow adaptation to modified requirements at any time.

Unsurpassed product quality

The demands for microwave and mmWave test and measurement equipment are even more exacting than for the devices themselves. Rohde & Schwarz keeps virtually the entire value-added chain in-house. Our core competencies include the development and production of microwave modules and the large-scale integration of test and measurement and communications components. Since we keep all manufacturing in-house, we can maintain the tight control on quality that only colocated engineering and manufacturing can provide.

Fully tuned for mmWave testing

Rohde & Schwarz test and measurement solutions are in demand worldwide wherever signals must be generated or analyzed in labs, production or in the field, from the audio range up to the highest mmWave frequencies. The consumer electronics, communications, aerospace and defense, automotive, healthcare and many other industries use Rohde & Schwarz products to bring their innovations to market on time and in line with specifications.

Numerous Rohde & Schwarz subsidiaries and representatives not only ensure quick and competent on-site support anywhere in the world, they also safeguard customer investments with comprehensive service and support offerings. Our solutions support you every step of the way from R & D through certification, production and service.

Wideband analysis in the mmWave range

New frequency allocations in the E band for microwave links and automotive radar open up the field for very high data rates utilizing wideband signals and modulation techniques. The high frequencies and wide bandwidth pose new T&M challenges for measuring the spectrum or output power of transmitters and determining whether it fulfills spectrum density mask requirements stipulated by relevant standards. In addition, wideband modulation analysis is a must to ensure EVM requirements are met.

Spectrum measurements in the E band

The R&S®FSW signal and spectrum analyzer is the first spectrum analyzer that covers a continuous frequency range from 2 Hz to 86 GHz on a single coax input. This one-box solution simplifies the measurement setup and eliminates the need for external harmonic mixers. An internal preselector filter provides an image-free spectrum for easy measurement of spectrum emission masks or spurious emissions. It also suppresses unwanted mixing products from harmonic mixing. The R&S®FSW85 built-in RF attenuator makes signal level adjustment easy. There is no need for further components such as external attenuators.

Signal analysis up to 2 GHz

Analysis of wideband signals is increasing in importance, for example when developing automotive radar sensors and during mmWave research for 5G – the next generation of mobile networks. The R&S®FSW85 supplemented with the R&S®FSW-B2000 2 GHz analysis bandwidth option is able to analyze 2 GHz wide signals up to 86 GHz. This constitutes an essential innovation in the field of signal and spectrum analysis. Combined with optional measurement applications, the R&S®FSW can measure complex parameters of wideband pulses and chirp signals in radar systems. The R&S®FSW also analyzes the modulation quality of wideband signals using the R&S®FSW-K70 vector signal analysis application. The error vector magnitude (EVM) as a measure of the modulation quality, frequency error, symbol rate error and many more parameters can be measured and displayed in tables and graphs. For example, the phase and amplitude are displayed in a constellation diagram, which enables you to assess the modulation quality at a glance.

Supplemented with the 2 GHz analysis bandwidth extension (R&S®FSW-B2000), the R&S®FSW85 constitutes an essential innovation in the field of signal and spectrum analysis.

512 MHz realtime spectrum analysis

Spectrum monitoring is required to find hidden signals, detect unwanted spurious emissions or validate frequency agile communications. The R&S®FSW measures spectra in realtime up to 512 MHz, enabling seamless spectrum monitoring. Results are displayed, for example, in a realtime spectrogram and a persistence spectrum. The signal amplitude levels use a variable color scheme to show the frequency of occurrence. Frequency-dependent masks reliably detect sporadic events by activating a trigger and capturing I/Q data whenever a spectrum violates the mask. The multistandard radio analyzer transfers the captured realtime data to other applications, such as vector signal or pulse analysis, for in-depth analysis.

Spectrum and signal analysis up to 500 GHz with harmonic mixers

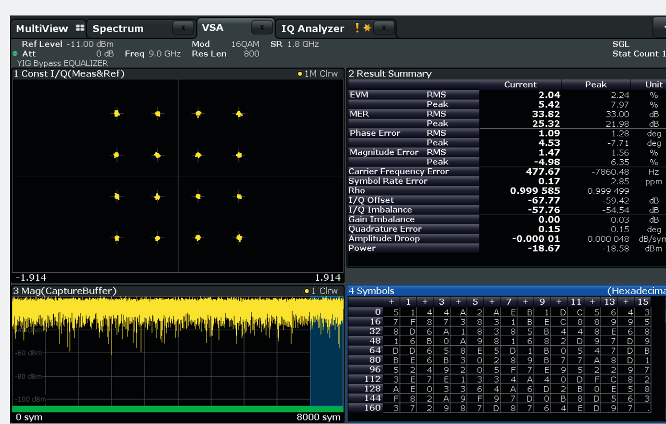
To perform spectrum measurements at extremely high frequencies (EHF) or mmWave, spectrum analyzers are used together with external harmonic mixers. The mixers multiply the spectrum analyzer's local oscillator signal and use a suitable harmonic to downconvert the mmWave signal to the analyzer's intermediate frequency. The multiple responses and image response arising from this setup can be eliminated as long as continuous wave (CW) signals are used. With wideband modulated signals, this becomes more complex.

The R&S®FSW signal and spectrum analyzer offers an unrivaled intermediate frequency of 1.3 GHz, achieving an image-free frequency range of at least 2.6 GHz – and even 4 GHz with the 2 GHz option. Equivalent isotropically radiated power (EIRP) spectrum density mask measurements of wideband-modulated signals can thus be made without the need for signal identification, even if the mask covers several GHz. Together with the latest generation of Rohde & Schwarz harmonic mixers, which extend the frequency range up to 500 GHz, the achievable dynamic range is truly unique.

R&S®NRP110T: power sensor from DC to 110 GHz without interruption

Power measurements on wideband sources up to 110 GHz with 1 mm test ports are carried out with the R&S®NRP110T thermal power sensor. The continuous frequency range from DC to 110 GHz with a power measurement range from 0.3 µW (–35 dBm) to 100 mW (+20 dBm) eliminates the need for multiple sensors and complex setups. The R&S®NRPxxT(N) power sensors are immediately ready for use. In contrast to conventional power sensors, no calibration is required prior to making measurements since the sensors are completely characterized over frequency, level and temperature and feature long-term stability. All calibration data is stored in the sensor. Developed for wideband applications with a sophisticated 1 mm connector, the R&S®NRP110T can also be connected to waveguide interfaces by using a suitable adapter. The sensor's S-parameter correction functionality makes it possible to shift the reference plane directly to the device under test by taking into account the S-parameters of the adapter. The same approach can be used when it becomes necessary to use an additional attenuator in the setup. Storing the sensor's calibration data and the adapter's S-parameters together in the sensor simplifies the test setup and enables highly accurate output power measurements on a direct microwave link transmitter.

Simultaneous display of two spectra in the 512 MHz wide persistence spectra with the R&S®FSW MultiView function: ISM band at 2.4 GHz (top); mobile communications signals at 2.1 GHz and ISM band at 2.4 GHz (bottom).



Modulation analysis of a 1.8 GHz bandwidth 16QAM signal with the R&S®FSW-K70 option: various graphs and tables provide information about the modulation quality at a glance.

Microwave amplifier testing

Power amplifiers in modern communications systems have to fulfill stringent requirements. To meet these demands, a number of parameters must be tested, including maximum gain, harmonics, third-order intercept point (TOI, IP3) and noise figure. Testing the amplifier's maximum output power or the increase in harmonics caused by the amplifier requires a superior signal source, i.e. one that provides high output power and low harmonics.

Benchmark measurement of amplifier harmonics (fundamental, first and second harmonic) using the R&S®FSW. When the R&S®SMB100A internal low harmonic filter is activated (yellow), measurement accuracy can be increased by approx. 25 dB.

Single-tone measurements

An analog R&S®SMB100A signal generator is used for single-tone measurements. The R&S®SMB100A provides high output power reserves while effectively suppressing harmonics. The required internal low harmonic filter can be switched on when needed. For measuring microwave amplifier harmonics at 10 GHz, a specified output power of up to +19 dBm is available (typically, this value is significantly exceeded at 25 dBm).

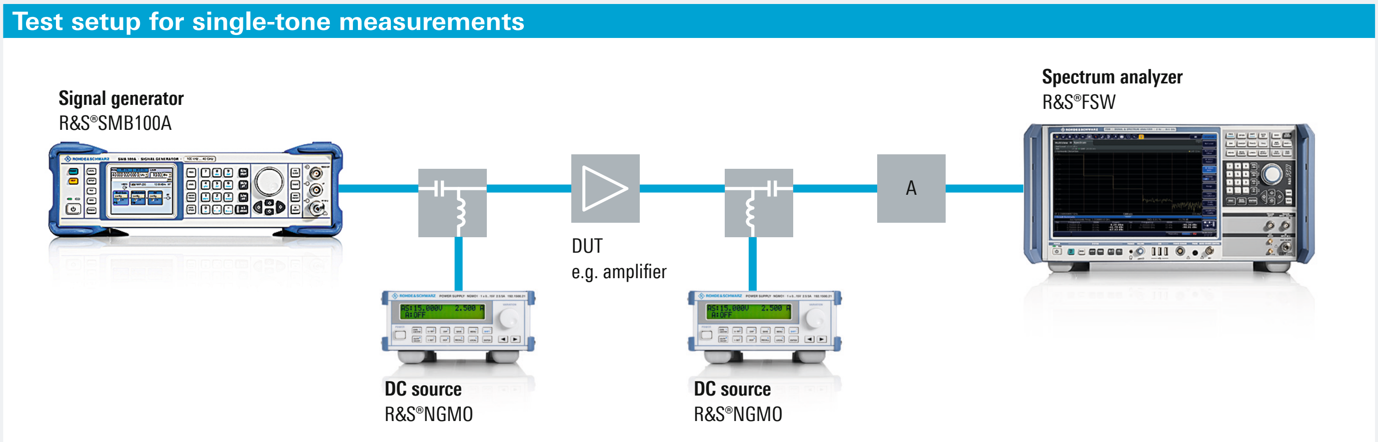
To measure the harmonics of the amplifier, i.e. its real performance and not the performance of the signal generator, the internal R&S®SMB100A filter for low harmonics is switched on (suppressing the R&S®SMB100A harmonics by at least 50 dBc). Using the internal low harmonic filter helps to increase accuracy by approximately 25 dB when measuring amplifier harmonics.

Thanks to YIG preselection in the microwave frequency range, signal and spectrum analyzers such as the R&S®FSW can measure harmonics with a very wide dynamic range of > 100 dB. Optional switchable filters extend the frequency range in which a wide dynamic range is achieved down to a few 100 MHz. A harmonics measurement function determines the fundamental frequency and level at the push of a button and automatically measures harmonics up to a set order in zero span mode.

Two-tone measurements

The most common way to characterize the nonlinear behavior of components is to measure the IP3. The setup consists of two signal generators for generating a two-tone signal, and a spectrum analyzer for measuring the intermodulation ratio. This setup offers the widest measurement range; advanced analyzers such as the R&S®FSW can achieve an intermodulation-free dynamic range of more than 120 dB. An R&S®FSW measurement

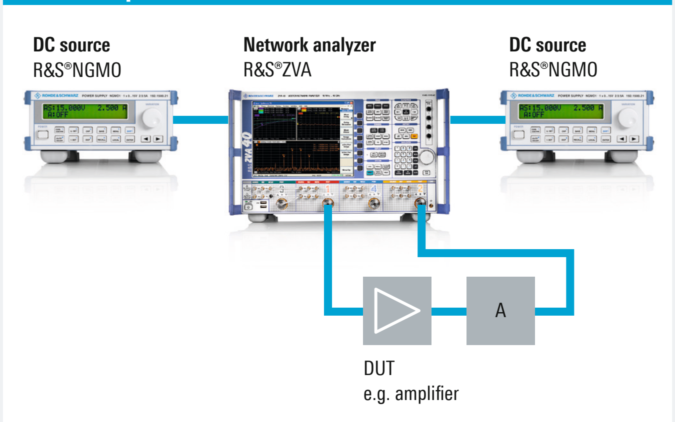
Test setup for single-tone measurements



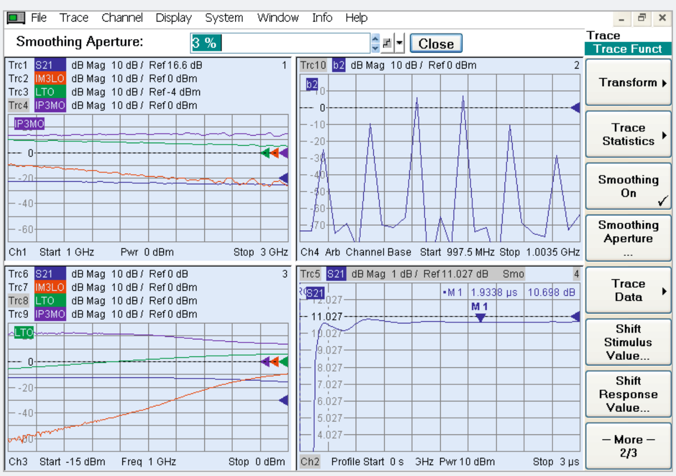
The test setup consists of an R&S®SMB100A signal generator, an R&S®FSW signal and spectrum analyzer for displaying the results, and two R&S®NGMO DC sources for setting the gate and drain voltage. Very high output powers require the use of an additional attenuator (A) to protect the spectrum analyzer's input port.

function automatically determines the level of the two signal carriers and the intermodulation products and calculates the TOI.

Test setup for two-tone measurements



The test setup consists of an R&S®ZVA vector network analyzer for generating the two-tone signal at port 1 and for displaying the results, and two R&S®NGMO DC sources for setting the gate and drain voltage via the internal R&S®ZVA bias tees.



Intermodulation measurements on an amplifier in pulsed mode.

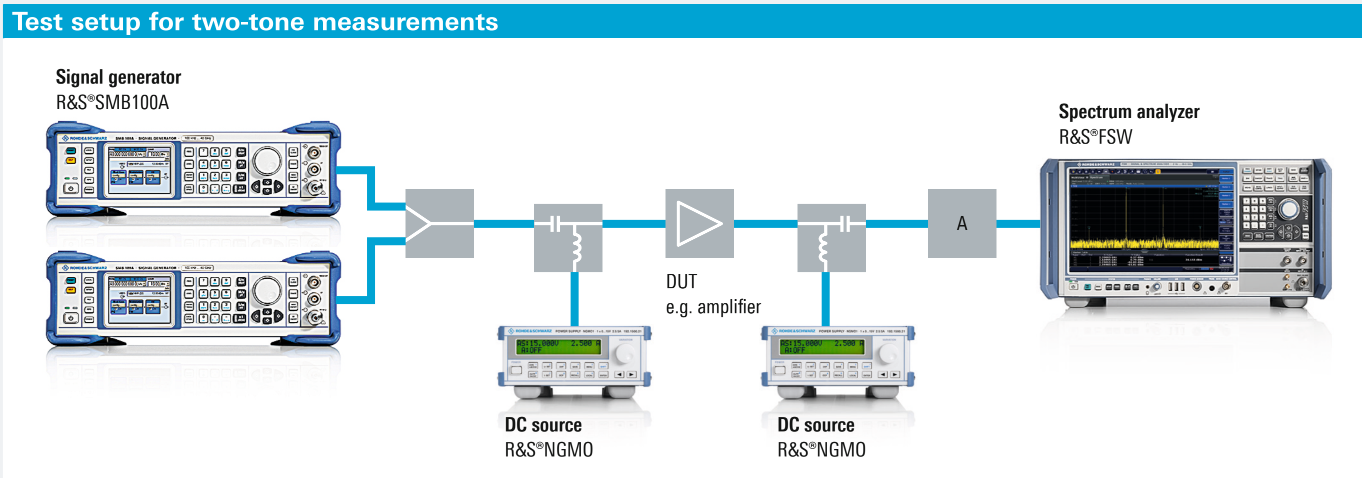
Two-tone measurements using a network analyzer

Another way to perform intermodulation measurements on amplifiers is to use a network analyzer such as the R&S®ZVA. The network analyzer integrates signal sources and receivers in one instrument. Even though the achievable intermodulation-free dynamic range is less than in a test setup with separate instruments, network analyzers measure intermodulation and also determine the amplifier's S-parameters.

The two internal signal sources of the R&S®ZVA generate a two-tone signal that is present at port 1 and serves as a test signal for the amplifier. For DUT output powers of > +27 dBm, an attenuator (A) must be inserted in front of port 2 to protect it from being damaged. An internal step attenuator in the R&S®ZVA prevents receiver compression. The supply voltage can be fed to the test ports via the DC bias inputs on the R&S®ZVA rear panel.

All intermodulation measurement settings are automatically configured via the R&S®ZVA intermodulation wizard. The different intermodulation products, IP3, IP5 and IP7, and the spectrum can be displayed as traces. The two tones can be swept over frequency or power. Frequency sweeps with varying tone spacing and measurements with pulsed test signals are also possible. The comprehensive feature set of the R&S®ZVA simplifies the characterization of microwave amplifiers.

Test setup for two-tone measurements



The test setup consists of two R&S®SMB100A signal generators, an R&S®FSW signal and spectrum analyzer for displaying the results, and two R&S®NGMO DC sources for setting the gate and drain voltage.

Amplifier characterization with modulated signals

Predistortion is the method commonly used to achieve higher output power without increasing power consumption. The calculation of the appropriate predistortion requires characterizing the amplifier and its distortion behavior.

Determining nonlinearities

The R&S®FSW and R&S®FPS signal and spectrum analyzers with the R&S®FSW-K18 and R&S®FPS-K18 amplifier measurements options derive all relevant amplifier parameters with a single measurement. The amplifier parameters are determined under real-world operating conditions, i.e. using digitally modulated signals with the right bandwidth and crest factor for the intended application.

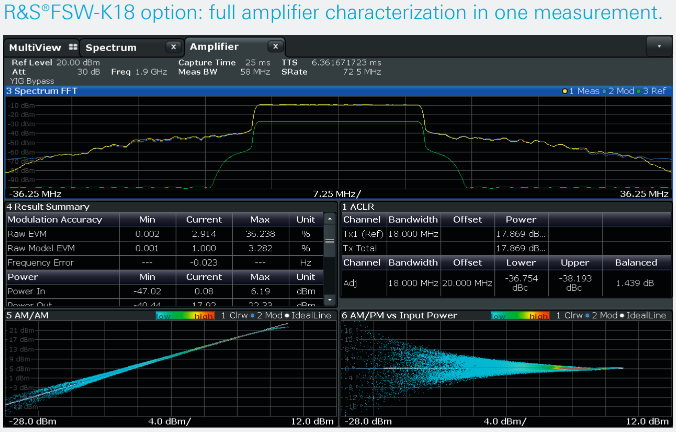
The R&S®FSW/R&S®FPS-K18 compares a reference signal with the signal measured after the amplifier and calculates characteristics such as 1 dB compression point, AM/AM conversion, AM/φM conversion, gain, frequency response as well as ACLR and EVM. It also determines the amplifier models and required digital predistortion (DPD) for compensating amplifier nonlinearity. The resulting DPD table is automatically transferred to the R&S®SMW200A or R&S®SGT100A vector signal generator via LAN in realtime.

Detailed modeling requires a signal analyzer to record a frequency range that is typically larger than the bandwidth of the amplified signal. The R&S®FSW with its analysis bandwidth of up to 2 GHz enables measurement of amplified signals with wide bandwidths, such as anticipated for 5G mobile communications or the 2 GHz bandwidth for IEEE 802.11ad signals.

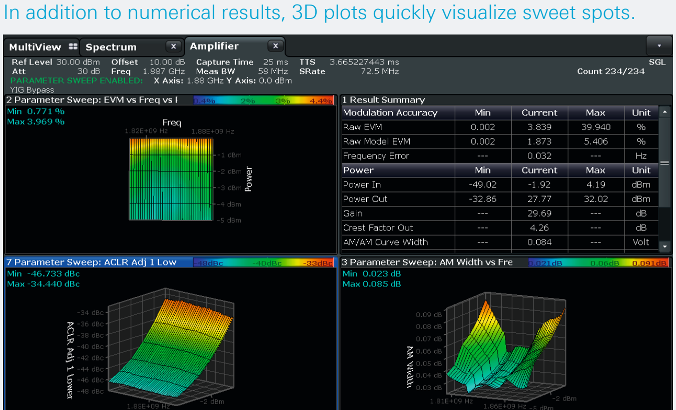
Accelerating amplifier measurements

The number of measurements tends to increase mainly due to amplifiers' increasing complexity. Speed-optimized algorithms enable the R&S®FPS and R&S®FSW to perform a full amplifier measurement, including ACLR and distortion parameters, in less than 8 ms. The R&S®FPS also integrates power-servoing that automatically sets the targeted power level at the amplifier output. Power leveling and a subsequent ACLR measurement can be performed within just 2.7 ms. The R&S®FPS in combination with the R&S®SGT100A SGMA vector RF source offers high accuracy and high speed, both important parameters for improving efficiency in production and design verification.

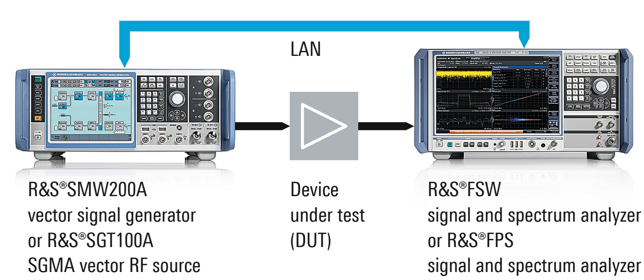
R&S®FSW-K18 option: full amplifier characterization in one measurement.



In addition to numerical results, 3D plots quickly visualize sweet spots.



Compact test setup for power amplifier characterization



On-wafer characterization of amplifiers

On-wafer characterization of transistors and amplifiers usually requires different test setups with multiple, changing DUT connections. This makes it difficult to compare measurements.

Measuring all parameters with a single test setup

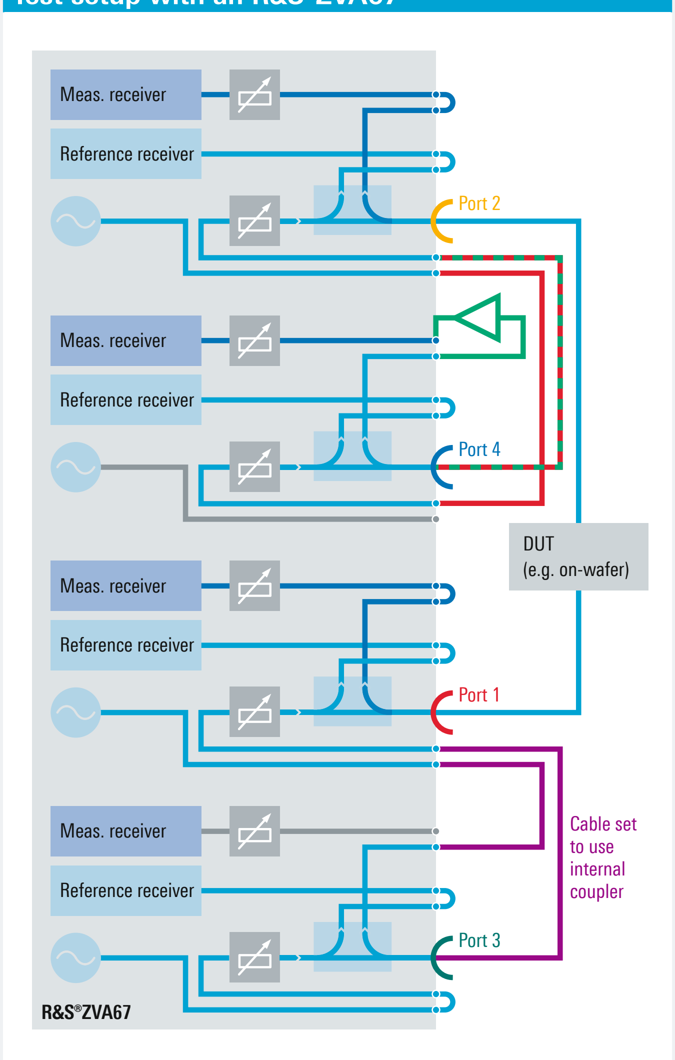
Thanks to its hardware architecture, the R&S®ZVA vector network analyzer measures all relevant parameters with a single test setup, including S-parameters, compression, harmonics, intermodulation and noise figure.

A two-tone signal for the intermodulation measurement is generated at port 1. Port 2 is used as a receiver port. The noise figure is measured at port 4 in order to loop in a preamplifier for DUTs with low gain. All measurements use the same probe contacts, making results comparable and speeding up measurements.

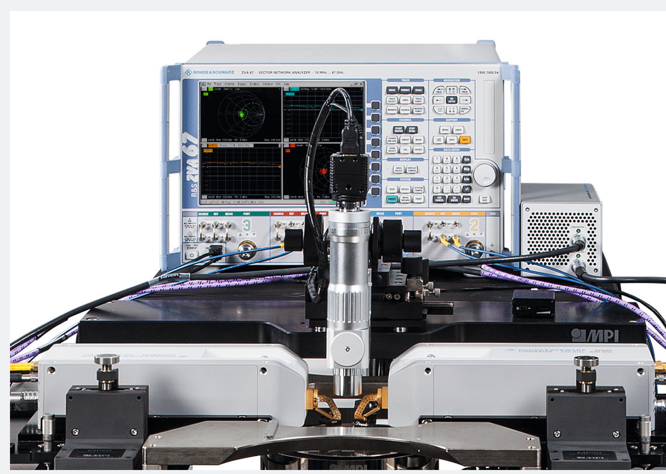
Measurements in the mmWave range

On-wafer measurements often require a wide frequency range from some MHz up to several hundred GHz. The R&S®ZVA offers a continuous sweep from 10 MHz to 110 GHz, which simplifies device characterization. Converters can be used to expand the frequency range even further up to 500 GHz. For on-wafer measurements, the converters are mounted on the wafer prober and can be controlled using the QAlibria® software from MPI corporation or the WinCal XE software from Cascade Microtech, Inc.

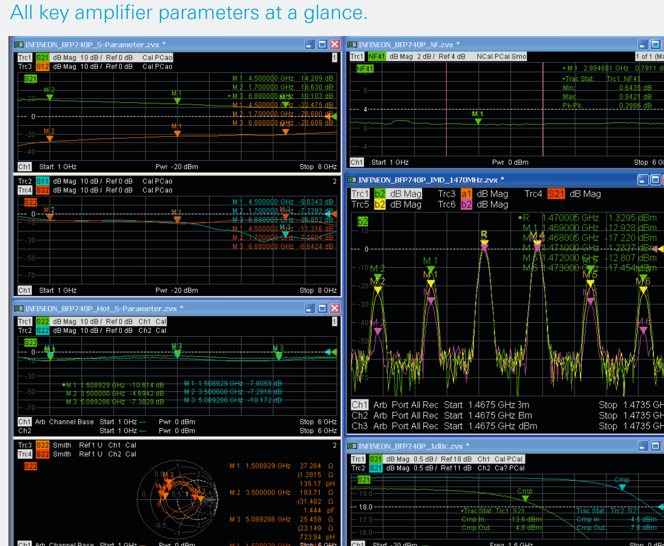
Test setup with an R&S®ZVA67



On-wafer mmWave measurement with MPI probe system.



All key amplifier parameters at a glance.



Group delay measurement

To characterize the quality of a transmission path, phase distortions are determined using group delay measurements.

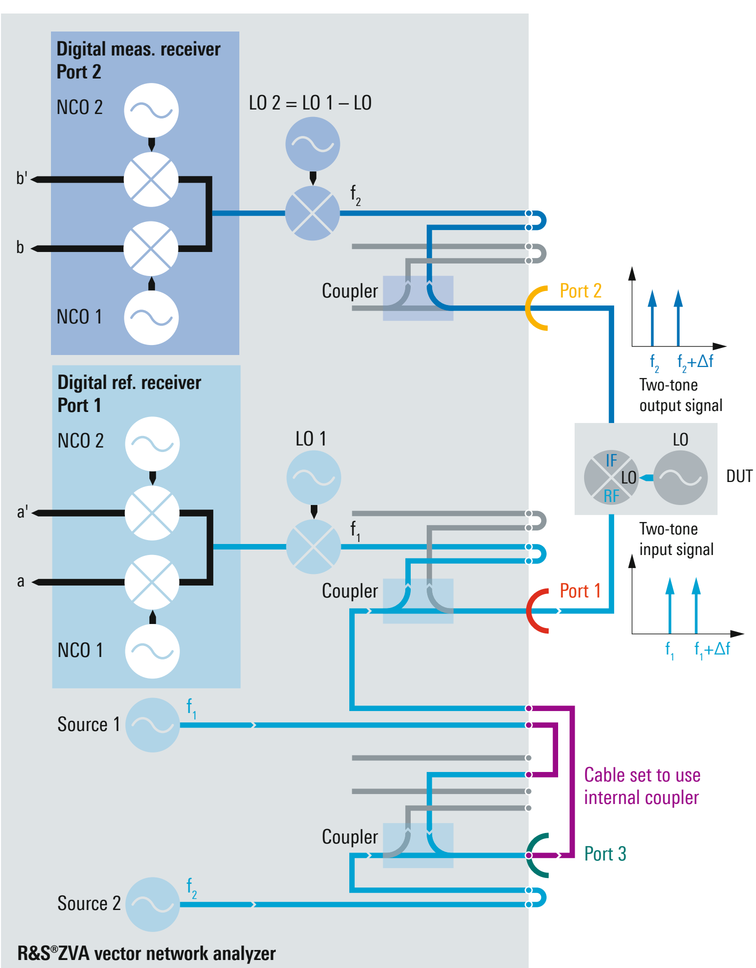
Measurement of group delay without LO access

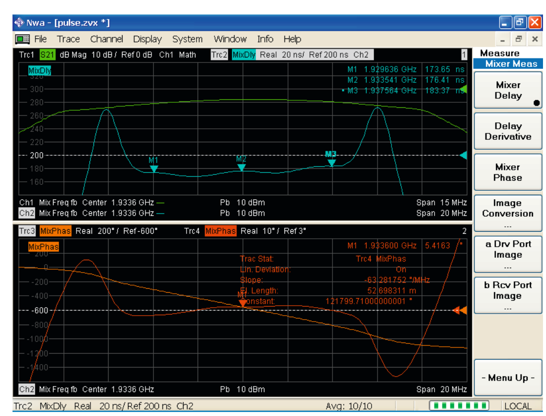
In many cases, group delay and relative phase measurements on frequency converting devices without LO access were only possible if the DUT had a highly stable internal LO. Phase and frequency deviations due to drift, phase noise or frequency modulation considerably limited the accuracy of available methods. The novel two-tone technique from Rohde & Schwarz overcomes all these limitations.

By using a two-tone stimulus signal, the R&S®ZVA vector network analyzer can measure the phase difference between the two signals, both at the input and then at the output of the device under test (DUT). Comparable to the classic S-parameter technique, the group delay is calculated from the phase difference and the frequency offset. The frequency offset Δf between the two signals is the aperture. To measure the phase between two signals with different frequencies, Rohde & Schwarz has developed a unique frontend within the R&S®ZVA. In addition, the much easier calibration requiring only a through connection significantly simplifies the setup for this measurement.

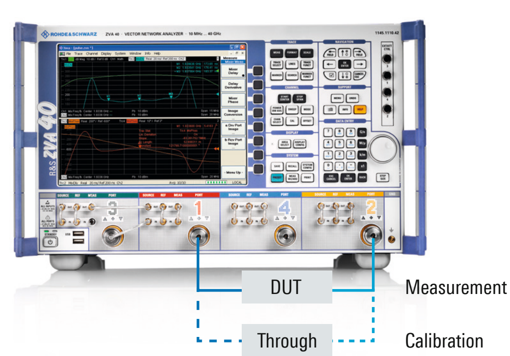
This method is ideal for frequency converting DUTs with unknown or unstable LOs since the frequency and phase deviations of the DUT's internal LO are cancelled out when calculating the phase difference of the carriers. In addition to group delay, the R&S®ZVA also calculates the relative phase and deviation from linear phase by integrating the group delay, and the derivative of the group delay by differentiating the group delay.

Test setup with network analyzer





Simultaneous display of measurement results:
Conversion loss (green)
Group delay (blue)
Relative phase (orange)
Deviation from linear phase (red)



Measurement of group delay with multicarrier method

The R&S®FSW-K17 multicarrier group delay measurement option evaluates relative and absolute group delay and gain flatness with the R&S®FSW signal and spectrum analyzer. A vector signal generator such as the R&S®SMW200A is used to generate the wideband multicarrier signals. This setup measures group delay in just a few milliseconds up to an analysis bandwidth of 512 MHz in one sweep.

Group delay is determined in just two steps. During reference calibration, where the generator is directly connected to the analyzer, the reference phase and amplitudes of the individual carriers are determined. When connecting the DUT, the analyzer determines the relative group delay over the entire carrier frequency range from the phase difference between the reference signal and the multicarrier signal measured at the output of the DUT. By comparing the reference and the measured signal, the R&S®FSW determines the transfer function as a measure of the gain flatness and the group delay as a measure of the phase distortion with high precision. For example, the measurement uncertainty for the relative group delay for a signal with a carrier spacing of 100 kHz and 601 carriers (60 MHz bandwidth) is just ±300 ps.

Intuitive touchscreen operation: example of reference and DUT measurement with bandpass characteristic using the R&S®FSW.

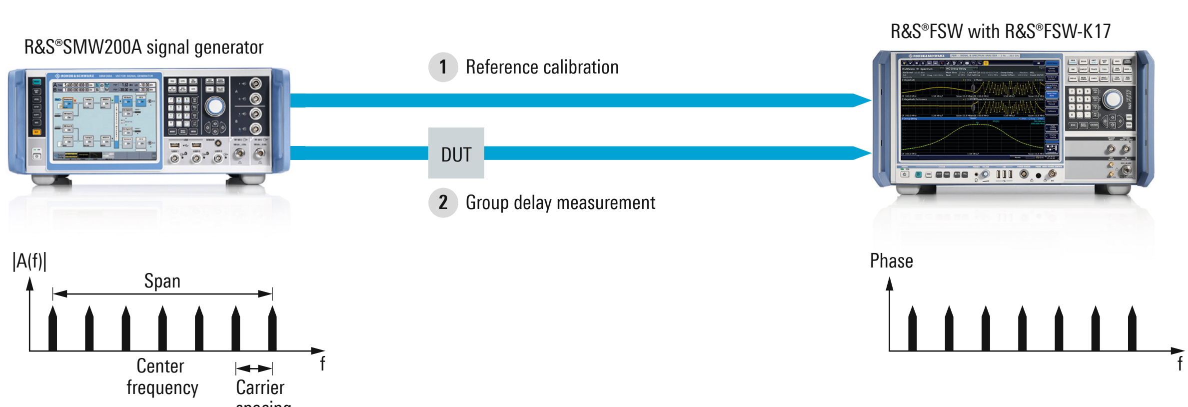
To determine the absolute group delay, the trigger of the generator is connected to the R&S®FSW to create an absolute phase reference. By averaging the group delay over consecutive measurements, a measurement uncertainty of just ±300 ps can be achieved.

The R&S®FSW in combination with a signal generator such as the R&S®SMW200A and R&S®SMBV100A offers a fast, highly accurate and easy-to-use test solution for relative and absolute group delay measurements using the multicarrier method. Moreover, the powerful and versatile measurement capabilities make this solution ideal for characterizing the quality of components and modules used, for example, in satellite, radar and communications systems.

The vector network analyzer solution is advantageous
- for narrowband measurements (CW signals)
- when network analysis applications predominate
- for high accuracy and dynamic range of S_{xx}

The setup with a signal generator and spectrum analyzer is beneficial
- when digital demodulation is also required
- for group delay measurements in addition to spectrum measurements
- when scalar network measurements are sufficient

Test setup with signal generator and spectrum analyzer



Radar transmitter testing

Extensive pulse and chirp analysis functions and fast spurious identification are essential prerequisites when testing modern radar systems with their wideband signals, intrapulse modulation techniques and frequency hopping capabilities.

Fast and comprehensive radar signal analysis

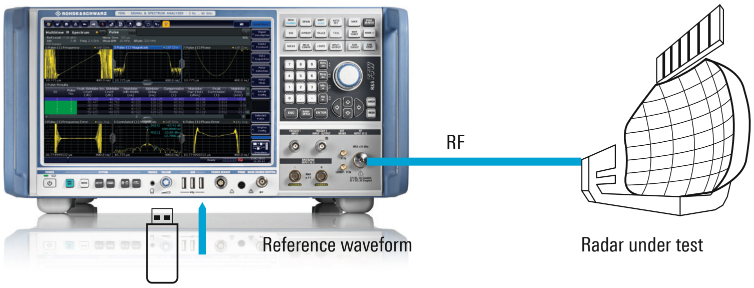
Pulsed radar signals are analyzed by the R&S®FSW signal and spectrum analyzer with the R&S®FSW-K6 pulse measurement option. The analyzer measures all relevant RF pulse parameters such as transmit frequency and power, pulse rise and fall times, pulse duration, pulse repetition interval, frequency deviation and linearity of a frequency ramp. Moreover, phase, frequency and amplitude differences between pulses can be determined. For pulsed signals with chirp modulation, this setup determines chirp rate, frequency error and phase error as a measure of tuning linearity. The optional 2 GHz analysis bandwidth enables measurement of pulses as narrow as 2 ns and rise times down to 0.6 ns. And a large I/Q memory depth and the possibility to capture only relevant parts of a pulse train enable detailed analysis of even longer pulse trains.

Detailed pulse compression radar measurements

The R&S®FSW-K6S time sidelobe measurement option is an important tool for developing and designing pulse compression radars. It measures the pulse compression parameters that are essential for assessing the performance of pulse compression radars such as mainlobe width, sidelobe suppression, sidelobe delay, and mainlobe and sidelobe integrated power. It also helps evaluate the degradation of radar performance caused, for example, by modulators and exciters.

The R&S®FSW-K6S performs a cross-correlation between the received pulse waveform and an ideal reference pulse waveform, similar to a radar receiver. You can import any I/Q-based reference waveform in I/Q data file format, allowing the use of confidential, proprietary waveforms. The R&S®FSW-K6S also supports reference waveforms captured with the R&S®FSW and stored in I/Q data file format as well as built-in waveforms such as Barker and polynomial FM.

Pulse compression measurement setup with the R&S®FSW signal and spectrum analyzer and the R&S®FSW-K6/-K6S measurement options



Characterization of transient chirp and hop signals

The R&S®FSW-K60/K60C transient analysis with chirp measurement option is used to characterize FMCW signals such as are used in car radar sensors. The chirp linearity of the FMCW chirp is an important parameter that influences the range-Doppler accuracy of the radar sensor. The R&S®FSW automatically calculates the deviation from the ideal FMCW chirp and the chirp rate to enable efficient radar sensor optimization.

The R&S®FSW-K60 with the R&S®FSW-K60H transient hop measurement option is a convenient tool for analyzing signals with fast channel-switching characteristics such as occur in frequency hopping radios. Results include dwell time/hop, switching time, frequency, deviation and much more.

The analyzer shows trends and performs statistical analyses on all pulse, chirp and hop parameters. Trend analysis allows you to quickly identify effects arising from supply voltages (or their frequencies, such as 50 Hz or 400 Hz) and to rapidly verify frequency hopping patterns or changes in the pulse repetition interval. The statistical analyses show the mean values, maxima, minima and standard deviation for all selected pulse parameters.

Intrapulse modulation that is more complex than frequency ramps or Barker-coded BPSK modulation is analyzed with the R&S®FSW-K70 vector signal analysis option, which is capable of testing higher-order modulations (up to 2048QAM) as well as complex, user-defined constellations.

Fast and reliable detection of spurious emissions

Extremely low levels have to be measured over a wide frequency range to identify spurious emissions. It is essential for the analyzer to have a low displayed average noise level and high dynamic range. The R&S®FSW provides both: a high dynamic range and a low inherent noise floor. With the optional preamplifier, the R&S®FSW achieves a noise floor (DANL) of typically –164 dBm (1 Hz) at 40 GHz, providing ideal conditions for fast measurement of small signals.

In order to measure the low levels of spurious emissions, it is often necessary to reduce the resolution bandwidth, which increases the measurement time. The R&S®FSW-K50 spurious measurement option automates and speeds up the spurious search compared to standard spurious search measurements available in spectrum analyzers. You only need to enter the frequency range and the desired spur detection level. The option calculates the optimum resolution bandwidth (RBW) for measuring at each frequency. Narrow RBWs will only be used at frequencies where needed. The R&S®FSW-K50 spurious search option can be up to 20 times faster than traditional spurious search measurements.

Analysis of a 2 GHz wide chirp signal at 76.5 GHz using the R&S®FSW-K60/-K60C measurement options.

Phase noise testing and VCO characterization

Phase noise is one of the key parameters that limit the system performance of communications and radar systems. To develop high-performance RF and microwave systems, the phase noise of oscillators and transmitters has to be minimized.

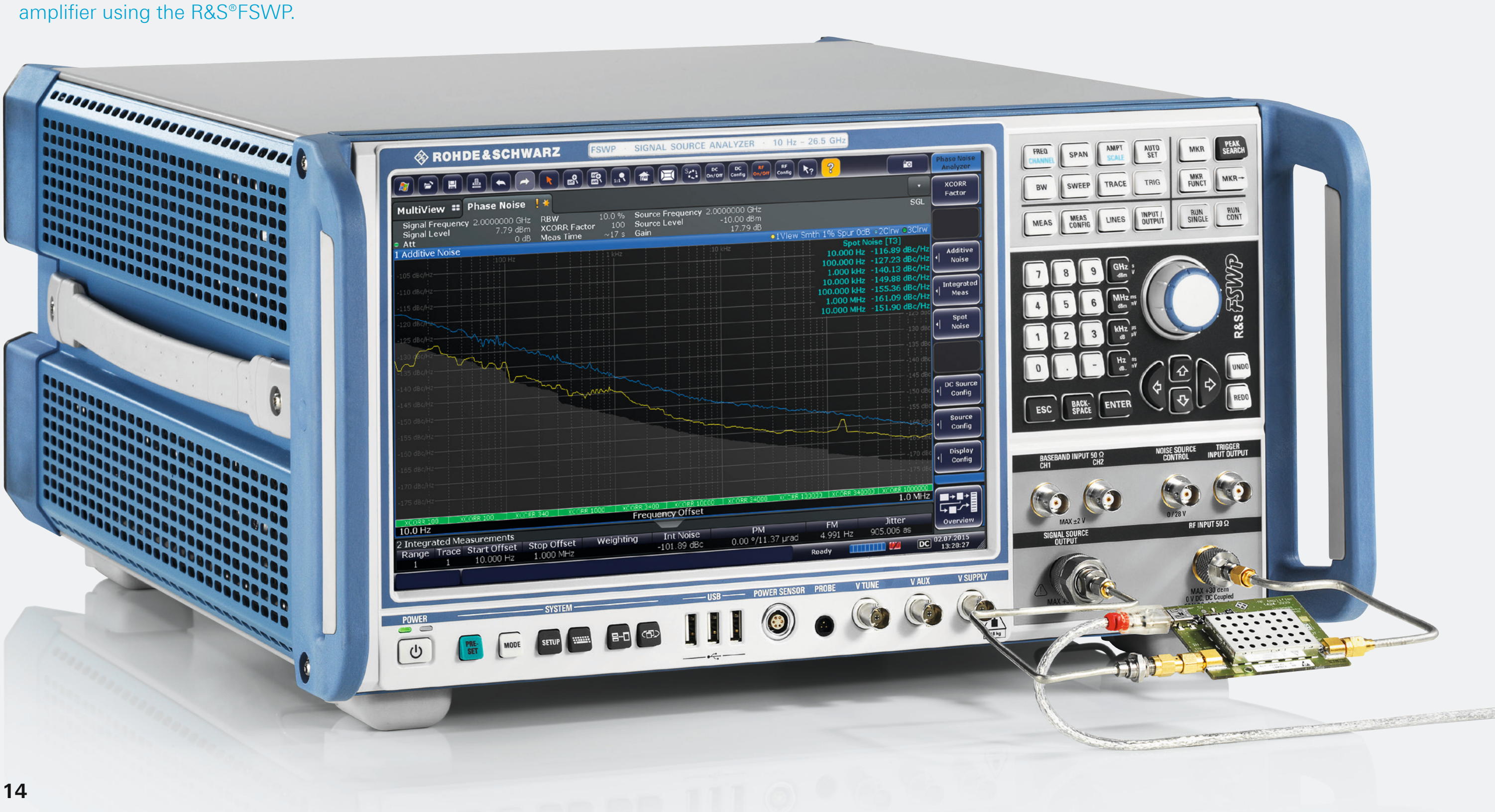
Fast phase noise measurement, even on pulsed signals

The R&S®FSWP phase noise analyzer and VCO tester brings a new level of performance and improved user experience to RF and microwave phase noise measurements. The instrument's low-noise internal local oscillator makes it possible to measure most commercially available synthesizers and oscillators without any additional options. The R&S®FSWP measures amplitude noise as well as phase noise. It permits an offset frequency of 10 mHz to 300 MHz for phase noise measurements and even up to 1 GHz for the sum of amplitude noise and phase noise. The results of both measurements can be simultaneously displayed in a diagram or in two separate windows.

Residual phase noise measurement of individual components traditionally required costly and complex systems using external sources, splitters and phase shifters. Equipped with an additional internal source (R&S®FSWP-B64 option), the R&S®FSWP simplifies residual phase noise measurement by simply connecting the internal signal source to the input of the DUT and the DUT output back to the instrument. The additive phase noise of the DUT is then available at the push of a button.

Phase noise of pulsed sources is available with the R&S®FSWP-K4 option. The R&S®FSWP records the signal and calculates all pulse parameters. It then demodulates the signal and displays the phase noise and amplitude noise.

Typical setup for measuring and displaying the residual phase noise of an amplifier using the R&S®FSWP.



Cross-correlation improves phase noise sensitivity

For high-end applications, the R&S®FSWP can be equipped with a second receive path, which enables cross-correlation and, depending on the number of correlations used, increases sensitivity – by up to 25 dB. Thanks to the analyzers low-noise internal sources, often only a few correlations are needed to measure a high-quality oscillator. You receive reliable results faster, which shortens development and manufacturing times. The R&S®FSWP high-precision sources in combination with cross-correlation surpass the accuracy of diode detector based measurements, with a sensitivity of up to 20 dB better.

For pulsed signals, cross-correlation compensates for desensitization caused by lower average signal power due to longer pulse off times. This enables the R&S®FSWP to achieve a large dynamic range even for phase noise measurements on pulsed signals. The R&S®FSWP with cross-correlation takes just minutes to display the phase noise of high end oscillators – a measurement that often took several hours in the past.

Low-noise internal DC sources for VCO characterization

VCO measurement is made easy with the R&S®FSWP and its extremely low-noise internal DC sources to supply and control voltage-controlled oscillators (VCO) and other components. At the press of a button, the R&S®FSWP measures all the parameters needed to characterize a VCO: frequency versus voltage, tuning slope versus voltage, output power versus voltage and current drain versus voltage. You can decide whether to vary the tuning voltage or supply voltage and whether the current should be measured at the tuning voltage or supply voltage input.

High-end phase noise and spectrum analysis in one box

Spectrum analysis is used to determine, for example, if the desired signal is available and to examine harmonics and spurious emissions. By adding the R&S®FSWP-B1 option, the R&S®FSWP phase noise analyzer can easily be upgraded to include a high-end signal and spectrum analyzer. The internal preamplifier lowers the displayed average noise level (DANL) to below –165 dBm (1 Hz). Additional noise cancellation brings the DANL close to the theoretical limit of –174 dBm (1 Hz).

Operated as a signal analyzer, the R&S®FSWP offers an analysis bandwidth of up to 80 MHz and internal, I/Q data based options for signal analysis. This makes it possible, for example, to analyze pulses automatically (R&S®FSWP-K6 option).

Spectrum analysis and phase noise measurement are carried out in parallel on different measurement channels – there is no need for additional cabling or test equipment. Simply switch between various measurement channels to obtain the spectrum and the phase noise at a glance.

The R&S®FSWP measures phase noise (left) and amplitude noise (right) simultaneously: the gray area shows the correlation gain of the R&S®FSWP; if the gray area is clearly below the trace, the DUT is measured and the sensitivity is not limited by the local oscillator.

Pulsed signal measurement in time and frequency domain using the R&S®FSWP spectrum analyzer function: phase noise of pulsed source up to an offset equal to one half of the pulse repetition rate (upper left) and amplitude noise (upper right).

T/R module measurements

State-of-the-art AESA radars contain several thousand transmit/receive modules (TRM) to achieve active electronic beam steering. Containing the main elements of the radar frontend, each TRM must be tested separately during development and production.

Configurable solution for TRM measurements

Characterizing TRMs for AESA radars places high demands on a test solution's performance and flexibility. The test solution needs to support a variety of test scenarios. In many cases, it must measure high output powers while simultaneously delivering very low, highly accurate stimulus powers. Intermodulation measurements on pulsed signals are required, as are noise figure and/or spectral measurements. DUTs with separate TX and RX paths and an antenna connector call for three-port measurements and typically two additional LO signals.

The R&S®ZVAX-TRM extension unit together with the R&S®ZVA vector network analyzer support this wide range of measurements in a compact, individually configurable design. Depending on the measurement settings, the signals from the R&S®ZVA are processed in the R&S®ZVAX-TRM and either routed back to the network analyzer or output at the R&S®ZVAX-TRM ports. This powerful test solution is ideal for demanding TRM measurements during development and, integrated into a test system, during production.

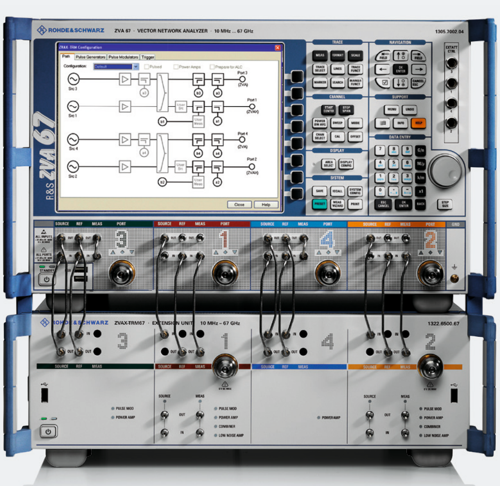
Automated TRM measurements

With a multitude of TRMs per radar system and typically 25 000 individual measurement values for the complete characterization of a TRM, test speed is a critical parameter. To handle the large number of different measurements involved, testing requires a high degree of automation.

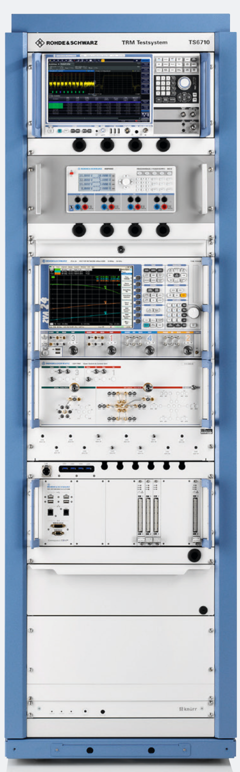
The R&S®TS6710 TRM radar test system is an all-in-one solution that combines the advantages of the R&S®ZVA vector network analyzer for TRM measurements with a complete automatic solution including:

- Flexible TRM control and power supply
- Performance-optimized test software
- Modular system concept

The test routines are optimized for fast module control and handover to measurement. This results in test times that are 10 to 100 times faster than traditional legacy TRM test systems without compromising measurement accuracy. By parameterizing the tests in the test sequencer, the R&S®TS6710 easily and quickly performs the measurement task at hand: complete TRM characterization at high speed for more efficient development and production.



Test solution consisting of R&S®ZVA and R&S®ZVAX-TRM.



The R&S®TS6710 TRM radar test system.

EMC and RSE measurements

Electromagnetic compatibility (EMC) is an important product quality criterion. Electrical devices and systems need to operate correctly in an electromagnetic environment.

From the early design phase to the final product, modular test systems for electromagnetic interference (EMI) and electromagnetic susceptibility (EMS) measurements are used to ensure compliance with the relevant EMC standard. The EMC test solutions from Rohde & Schwarz are customizable and range from standalone instruments to turnkey test chambers. They are ideal for diverse applications – from precompliance measurements during design to full standard-compliant testing – and cover all relevant commercial, automotive, military and aerospace standards as well as ETSI and FCC standards for radiated spurious emissions (RSE).

EMS microwave tests up to 40 GHz

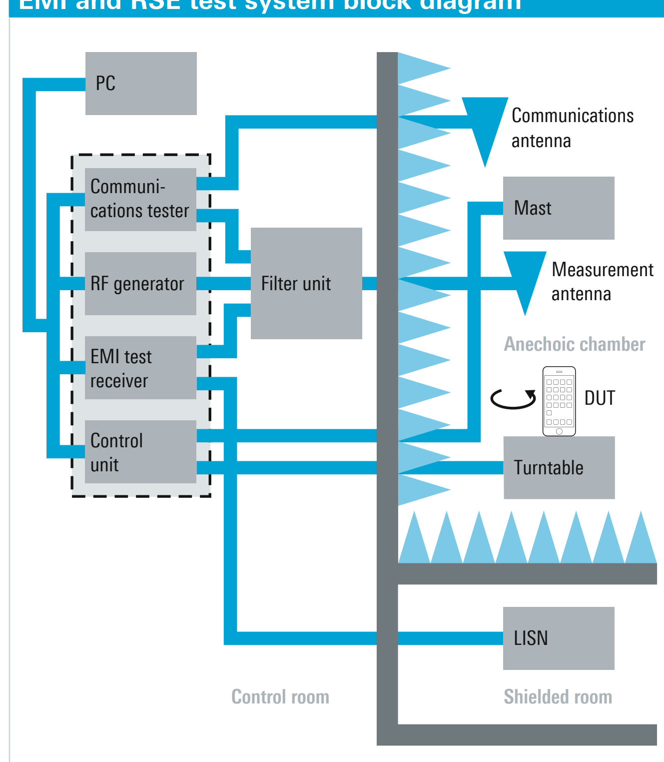
EMS measurements are carried out to ensure that a product is immune to electrical interference. The R&S®TS9982 is a test system for conducted and radiated EMS measurements in line with commercial, wireless, automotive and MIL standards. All necessary equipment, such as signal generator, power amplifier and power meter, are included in a mobile rack for 1 GHz to 18 GHz or 40 GHz measurements. This prevents cable losses, allowing more amplifier power to be used for field generation. The system can be configured for different test levels up to 3000 V/m and more at a 1 m test distance. It is controlled by the EMC software from outside the chamber via fiber optic link. R&S®EMC32 EMC test software is a convenient and reliable tool enabling fast and easy system operation and high throughput. The extended test and configuration capabilities ensure high reproducibility of results.

EMI microwave tests up to 220 GHz

Electrical devices and systems generate electromagnetic fields that can influence or interfere with other systems. The R&S®TS9975 is the base system for conducted and radiated EMI measurements up to 40 GHz, or even up to 220 GHz with harmonic mixers. The test system can be easily adapted to the measurement task at hand – from conducted measurements and small precompliance systems with a compact test cell to accredited test systems for complete motor vehicles. The core of the systems is the EMI test receiver. It evaluates and displays emissions in line with the relevant standards. The test systems are controlled by the proven R&S®EMC32 EMC test software that ensures reliable collection, evaluation and documentation of measurement results.

Example of an EMS test system for microwave tests.

EMI and RSE test system block diagram



Fully tuned for microwave testing

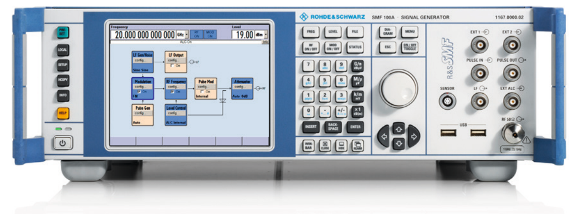
Rohde & Schwarz has the right instrument for all types of microwave testing.

Rohde & Schwarz offers a broad portfolio that includes signal generators, spectrum and signal analyzers, network analyzers, power meters, oscilloscopes and EMC test equipment. Whatever your application, whether you are dealing with pulsed, swept or modulated signals, our instruments generate and analyze with utmost accuracy and support you every step of the way, from R & D to production to service.

Signal generation

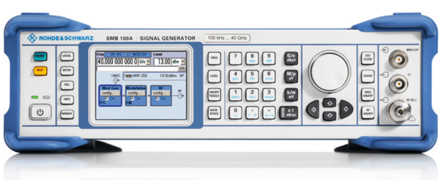
R&S®SMW200A vector signal generator

- Frequency range from 100 kHz to 40 GHz
- One RF path up to 40 GHz or two RF paths up to 20 GHz
- Up to 2 GHz I/Q modulation bandwidth (in RF) with calibrated internal baseband hardware
- Optional integrated fading simulator with up to 160 MHz bandwidth



R&S®SMF100A microwave signal generator

- Frequency range from 100 kHz to 43.5 GHz
- Up to 170 GHz with R&S®SMZ frequency multiplier
- Excellent SSB phase noise of typ. –120 dBc (at 10 GHz; 10 kHz carrier offset)
- Very high output power of typ. +25 dBm
- Unique pulse train generation



R&S®SMB100A RF and microwave signal generator

- Frequency range from 9 kHz to 40 GHz
- Up to 170 GHz with R&S®SMZ frequency multiplier
- Excellent signal characteristics with low SSB phase noise of typ. –128 dBc (at 1 GHz; 20 kHz offset)
- High output power of typ. up to +27 dBm
- Support of all main analog modulations with AM, FM/φM and pulse modulation

R&S®SMZ frequency multiplier

- Frequency range from 50 GHz to 170 GHz
- Wide frequency range
- Wide dynamic range
- Extremely easy handling
- High signal quality

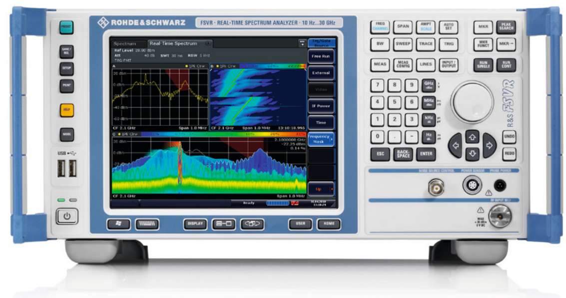
R&S®SGS100A SGMA RF source

- Frequency range from 1 MHz to 12.75 GHz
- Up to 40 GHz with R&S®SGU100A SGMA upconverter
- Smallest fully integrated vector signal generator
- High throughput due to very short frequency and level setting times of typ. 280 µs
- Maximum output level of typ. +22 dBm

Signal and spectrum analysis

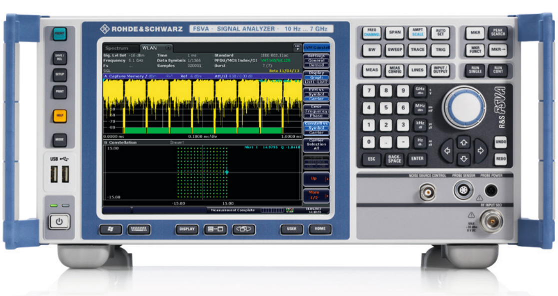
R&S®FSW signal and spectrum analyzer

- Frequency range from 2 Hz to 86 GHz
- Unmatched phase noise of –137 dBc (1 Hz) for a 1 GHz carrier
- Excellent dynamic range for spurious measurements thanks to low DANL of typ. –159 dBm (1 Hz) at 2 GHz and –150 dBm (1 Hz) at 25 GHz
- Up to 2 GHz analysis bandwidth
- High spurious-free dynamic range of > 100 dBc



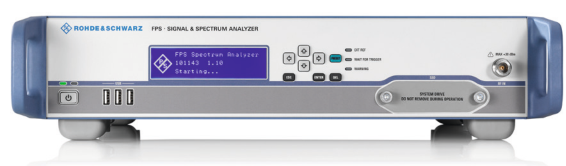
R&S®FSVR realtime spectrum analyzer

- Frequency range from 10 Hz to 40 GHz
- Realtime spectrum analyzer with up to 40 MHz bandwidth
- Frequency mask trigger standard
- Intuitive setup of frequency mask trigger via touchscreen
- Full-featured spectrum analyzer included (see R&S®FSVA)



R&S®FSVA signal and spectrum analyzer

- Frequency range from 10 Hz to 40 GHz
- Analysis bandwidth up to 160 MHz with optional YIG preselector bypass
- 0.4 dB level measurement uncertainty up to 7 GHz
- Low DANL of typ. –168 dBm (1 Hz)
- High third-order intercept (TOI) of typ. 20 dBm
- Very low phase noise of typ. –118 dBc (1 Hz) at 1 GHz and 10 kHz offset



R&S®FPS signal and spectrum analyzer

- Frequency range from 10 Hz to 40 GHz
- Signal analysis bandwidth of up to 160 MHz
- Low level measurement uncertainty of 0.4 dB up to 7 GHz
- Phase noise of –110 dBc (1 Hz)
- TOI of +15 dBm
- DANL of –155 dBm (1 Hz)

R&S®FS-Zxx/RPG FS-Zxx harmonic mixers

- Frequency range from 40 Hz to 500 GHz
- Wide dynamic range
- High IF for wide unambiguous frequency range
- High LO frequencies for low number of harmonics and reduced multiple responses

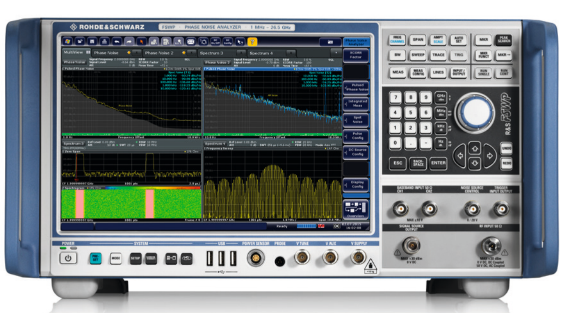
R&S®FSL spectrum analyzer

- Frequency range from 9 kHz to 18 GHz
- I/Q demodulation bandwidth 28 MHz
- DANL of –152 dBm (1 Hz)
- Low weight of < 8 kg
- Internal battery option with typ. 1 h operating time
- Models with built-in tracking generator

R&S®FSH handheld spectrum analyzer

- Frequency range from 9 kHz to 20 GHz
- Handheld with up to 4.5 h of battery operation
- Rugged, splash-proof housing for field applications
- Built-in preamplifier
- Models with built-in tracking generator and VSWR bridge
- DANL of typ. –163 dBm (RBW 1 Hz)

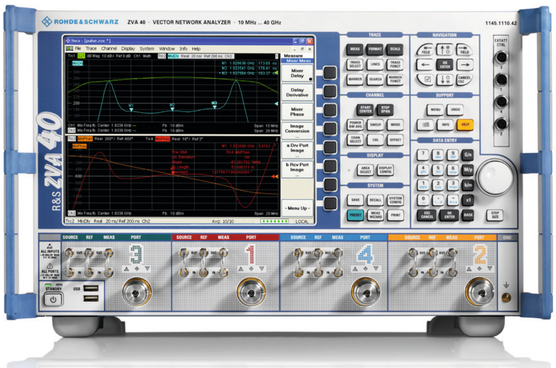
Phase noise measurements

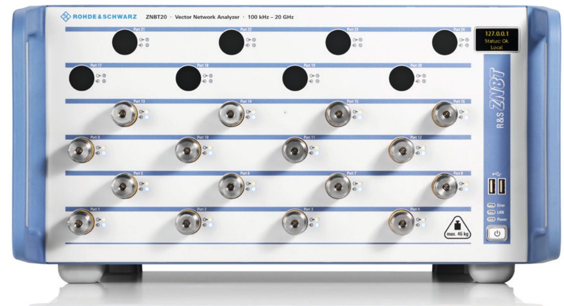


R&S®FSWP phase noise analyzer and VCO tester

- Frequency range from 1 MHz to 50 GHz
- High measurement sensitivity thanks to cross-correlation and extremely low-noise internal reference sources
  - typ. –172 dBc (1 Hz) at 1 GHz carrier frequency and 10 kHz offset
  - typ. –153 dBc (1 Hz) at 10 GHz carrier frequency and 10 kHz offset
- Simultaneous measurement of amplitude noise and phase noise

Network analysis



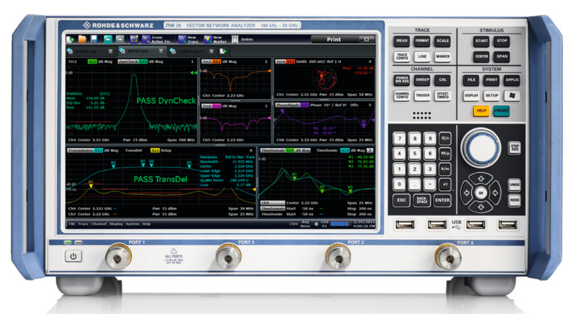


R&S®ZVA vector network analyzer

- Frequency range from 300 kHz to 110 GHz
- High dynamic range up to 140 dB
- Up to 4 independent coherent sources
- 8 parallel receivers
- Wide IF bandwidths up to 30 MHz
- Wide power sweep range up to 60 dB
- R&S®ZVAX-TRMxx modular extension unit for nonlinear applications up to 67 GHz, containing pulse modulators, combiners, amplifiers and high power couplers

R&S®ZNBT vector network analyzer

- Frequency range from 100 kHz to 20 GHz
- Four-port R&S®ZNBT8 base unit, upgradeable up to 24 ports
- Eight-port R&S®ZNBT20 base unit, upgradeable up to 16 ports
- Up to 24/16 fully phase-coherent receivers
- Wide dynamic range of up to 140 dB



R&S®ZVT vector network analyzer

- Frequency range from 300 kHz to 20 GHz
- High dynamic range up to 140 dB
- Up to 4 independent coherent sources
- Up to 16 parallel receivers
- Wide IF bandwidths up to 30 MHz
- Wide power sweep range up to 60 dB

R&S®ZNB vector network analyzer

- Frequency range from 9 kHz to 40 GHz
- Wide dynamic range of up to 140 dB
- Wide power sweep range of 98 dB
- Short sweep times of 4 ms for 401 points
- Large, high-resolution 12.1" screen

R&S®ZVA-Zxx/R&S®ZCxxx millimeterwave converters

- Frequency range from 50 GHz to 500 GHz
- High dynamic range up to 110 dB
- Easy setup and configuration
- High measurement stability

R&S®ZVL vector network analyzer

- Frequency range from 9 kHz to 13.6 GHz
- High dynamic range
- Distance to fault measurement
- Noise figure measurement
- Full spectrum analysis with signal analysis
- Low weight and battery operation

Power measurements

R&S®NRP power sensor family

- Average power measurements up to 110 GHz
- Peak power measurements up to 44 GHz
- Connectable to base units and Rohde & Schwarz instruments and via USB/LAN to PC/laptop

Three-path diode power sensors
Fast, accurate and packed with features for CW and modulated signals

Wideband power sensors
Time domain analysis and automatic pulse analysis for radar applications and universal use

Thermal power sensors
Most accurate power measurements for reference applications and use in calibration labs

Two-path diode power sensors
Cost-efficient power measurements for production

Average power sensors
Accurate average power measurement for EMC applications

Level control sensors
Highly accurate signal level generation in conjunction with a signal generator

Power sensor module
Level calibration of signal sources in conjunction with the R&S®FSMR measurement receiver

Test systems

R&S®TS6710 TRM radar test system

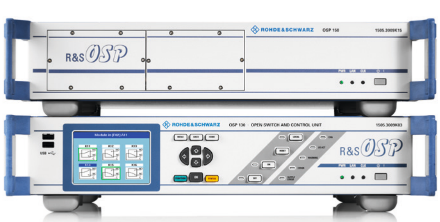
- Frequency range from 1 GHz to 40 GHz
- Automatic characterization of TR modules for AESA radars
- Compact setup with few system components
- Capable of integrated multiplexing and parallel testing

R&S®TS6600 radar test generator

- Frequency range from 1 GHz to 12 GHz
- Generation of multiple phase-coherent, modulated signals
- Fast level and phase variations
- Very high level and phase accuracy over a wide dynamic range
- Integrated two-step calibration routine for fast recalibration without disconnecting the DUT

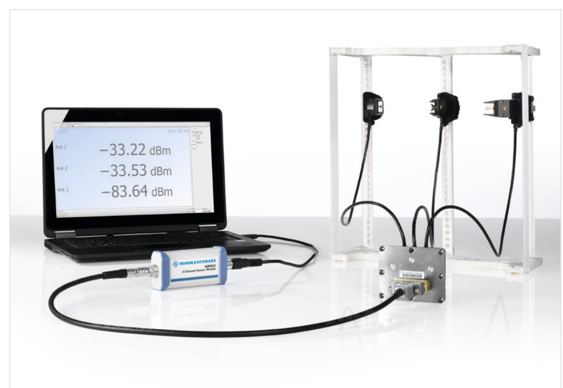
R&S®TS7124 RF shielded box

- Frequency range from 300 MHz to mmWave
- Very compact test setup in combination with R&S®NRPM OTA power measurement solution
- Highly reproducible environment
- Total flexibility for custom antenna configuration



R&S®OSP open switch and control platform

- Frequency range of RF modules from DC to 40 GHz
- Modular design for optimal system integration and configuration
- Various switch and control modules, and special modules for EMC applications
- Path control for independent switching of different switching paths



R&S®NRPM OTA power measurement solution

- Frequency range from 27.5 GHz to 75 GHz
- For WLAN IEEE 802.11ad, IEEE 802.11ay and 5G
- Ideal for beamforming tests
- Antenna module with integrated diode detector

EMC measurements and calibration

R&S®ESW EMI test receiver

- Frequency range from 2 Hz to 44 GHz
- Compliant with automotive, commercial and military standards
- Integrated preselection and preamplifier
- Ultrafast FFT-based time domain scan
- Realtime spectrum analysis, 80 MHz span (option)
- Automated measurement procedures

R&S®ESR EMI test receiver

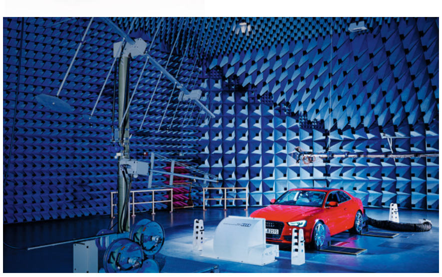
- Frequency range from 10 Hz to 26.5 GHz
- Compliant with CISPR 16-1-1 Ed. 3.1
- Ultrafast time domain scan (option) or conventional stepped frequency scan
- Realtime spectrum analysis, 40 MHz span (option)
- Automated measurement procedures

R&S®TS8996 RSE test system

- Up to 220 GHz with R&S®FS-Zxx/RPG FS-Zxx harmonic mixers
- Compliant with latest ETSI and FCC standards
- Fully automated testing with R&S®EMC32 measurement software
- Fully automated filter switching

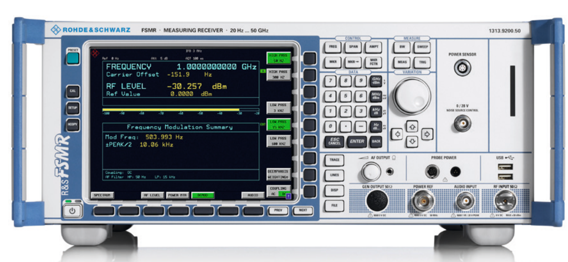
R&S®TS9975 EMI test system family

- Up to 220 GHz with R&S®FS-Zxx/RPG FS-Zxx harmonic mixers
- EMI measurements in compliance with automotive, commercial and military standards
- Compact setup with few system components
- Fully automated testing with R&S®EMC32



R&S®TS9982 EMS test system family

- EMS measurements in compliance with automotive, commercial and military standards
- Fully automated EUT monitoring
- Fully automated testing with R&S®EMC32



R&S®FSMR measuring receiver

- All-in-one calibration of signal generators and attenuators
- Single-box solution incorporating tuned level measurements, power meter base unit, analog modulation meter and audio analyzer
- Very good relative level accuracy
- High stability

Transmitter testing
Suitable products

	Signal generation				Network analysis					Signal and spectrum analysis						Phase noise meas.	Power meas.	Test systems	
	R&S®SMW200A	R&S®SMF100A	R&S®SMB100A	R&S®SGS100A	R&S®ZVA	R&S®ZNBT	R&S®ZVT	R&S®ZNB	R&S®ZVL	R&S®FSW	R&S®FSVR	R&S®FSVA	R&S®FPS	R&S®FSL	R&S®FSH	R&S®FSWP	R&S®NRP	R&S®TS6710	R&S®TS6600
ACP	●																		
AM/φM conversion	●	●	●	●	●	●	●	●		●	●	●	●						
Compression	●	●	●	●	●	●	●	●		●	●	●	●				●	●	
Efficiency (PAE)	●	●	●	●	●		●										●	●	
Frequency	●	●	●	●						●	●	●	●	●	●	●			
Frequency settling	●	●	●	●						●	●	●	●	●		●		●	
Gain	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
General OFDM analysis	●									●	●	●	●			●		●	
Conversion gain	●	●	●	●	●	●	●	●		●	●	●	●	●	●		●	●	
Group delay					●	●	●	●		●								●	
Harmonic distortion		●	●		●	●	●	●		●	●	●	●	●	●	●		●	
Hot S_{22}					●		●											●	
Intermodulation distortion	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●		●	
Mixed-mode S-parameters					●	●	●	●											
Noise figure					●		●			●	●	●	●	●		●			
Occupied bandwidth (OBW)										●	●	●	●	●	●	●			
Phase coherence	●				●		●			●	●	●	●						
Phase linearity					●	●	●	●	●										
Phase noise										●	●	●	●			●			
Power (average)	●	●	●		●	●	●	●		●	●	●	●	●	●	●	●	●	●
Power (peak)	●	●	●		●		●			●	●	●	●	●	●	●	●	●	●
Predistortion	●									●	●	●	●						
Pulse parameters																			
Barker coding										●	○	○	○	○		●			
Chirp										●	○	○	○	○		●			
Droop		●			●		●			●	○	○	○	○		●	●	●	
Overshoot/undershoot		●			●		●			●	○	○	○	○		●	●	●	
PRF (PRI/PRP); pulse width; duty cycle		●			●		●			●	○	○	○	○		●	●	●	
Profile		●			●		●			●	○	○	○	○		●	●	●	
Rise/fall time		●			●		●			●	○	○	○	○		●	●	●	
S-parameters (point in pulse, pulsed)					●		●											●	
RF spectrum									●	●	●	●	●	●	●	●		●	●
S-parameters					●	●	●	●	●						●			●	
Spurious emissions										●	●	●	●	●	●	●		●	
Switching speed (frequency-agile)										●	●	●	●	●		●			
Time domain analysis (TDR)					●	●	●	●	●						●				
VCO settling										●	●	●	●	●		●			
VSWR					●	●	●	●	●						●		●	●	
Vector signal analysis																			
Modulation formats QPSK, QAM, BPSK	●									●	●	●	●			●			
EVM	●									●	●	●	●			●			
Demodulated bits	●									●	●	●	●			●			
Impairments – I/Q	●									●	●	●	●			●			

Receiver testing
Suitable products

	Signal generation				Network analysis					Signal and spectrum analysis						Phase noise meas.	Power meas.	Test systems	
	R&S®SMW200A	R&S®SMF100A	R&S®SMB100A	R&S®SGS100A	R&S®ZVA	R&S®ZNBT	R&S®ZVT	R&S®ZNB	R&S®ZVL	R&S®FSW	R&S®FSVR	R&S®FSVA	R&S®FPS	R&S®FSL	R&S®FSH	R&S®FSWP	R&S®NRP	R&S®TS6710	R&S®TS6600
AFC (auto frequency control)	●	●	●	●															
AGC response	●	●	●	●	●		●												
Bandwidth	●	●	●	●	●	●	●	●	●									●	
Clutter rejection	●	●	●	●															
Doppler accuracy	●																		
Dynamic range	●	●	●	●	●	●	●	●	●										
Gain compression (1 dB and 3 dB)	●	●	●	●	●	●	●	●									●	●	
Gain versus frequency	●	●	●	●	●	●	●	●	●								●	●	
Harmonic distortion		●	●		●	●	●	●		●	●	●	●	●		●		●	
I/Q gain imbalance	●				●		●			●	●	●				●			
Insertion loss	●	●	●	●	●	●	●	●	●						●			●	
Intercept point	●	●	●	●	●	●	●	●		●	●	●	●	●		●		●	
Intermodulation distortion	●	●	●	●	●	●	●	●		●	●	●	●	●		●		●	
Minimum detectable signal	●	●	●	●	●	●	●	●											
Mixed-mode S-parameters					●	●	●	●											
Mixer image rejection	●	●	●	●	●	●	●	●											
Modulated signals	●	●	●	●															●
Noise figure					●		●			●	●	●	●	●		●		●	
Phase versus frequency	●	●	●	●	●	●	●	●	●									●	
Probability of detection	●	●	●	●															
Probability of false alarm	●	●	●	●															
Quadrature error	●									●	●	●	●			●			
Quantization error (ADC)	●	●	●	●															
S-parameters					●	●	●	●	●						●			●	
Saturation	●	●	●	●	●		●	●									●	●	
Sensitivity	●	●	●	●	●		●	●											
Signal simulation																			
Frequency hopping	●	●	●	●	●		●												●
Chirp waveforms (LFM, NLFM)	●	●																	●
Clutter	●	●	●	●															
Doppler shift	●																		●
Jamming	●	●	●	●															
Moving targets	●																		●
Multiple targets	●																		
Noise	●	●																	
Spurious emissions										●	●	●	●	●	●	●		●	
Phase coherence	●			●	●		●												●
Time domain analysis (TDR)					●	●	●	●	●						●				

● Measurement.
○ Manual evaluation.

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Data without tolerance limits is not binding | Subject to change

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