

222/2019

NEWS

ROHDE & SCHWARZ

Make ideas real



RADARS ON THE TEST BENCH

Before radars can be deployed in autonomous vehicles or used to locate targets in the air or at sea, they must be thoroughly tested. State-of-the-art T&M equipment provides the necessary tools.



Uniform quality assessment
of mobile networks

Testing high speed
data interfaces

Optimizing energy consumption
with two-quadrant power supplies

NEWS

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COVER FEATURE

Scottish physicist Robert Alexander Watson-Watt invented radar exactly 100 years ago. The method of using radio waves to locate objects has steadily evolved since then. Radar has repeatedly benefited from advances in radio technology, including digital modulation, beamforming with phased array antennas and the extension of the usable frequency range to the millimeterwave band. Today, short-range radars for vehicles are produced in large numbers and are only as large as the palm of your hand. Radars for military applications utilize all available technologies to achieve information superiority and have to be able to handle complex signal scenarios. Since security and lives often depend on radars functioning properly, it is essential that they undergo extensive tests in development labs and in the field. No special radar T&M equipment is required for these tests. The articles in this issue of NEWS show that intelligently configured standard RF instruments – provided they are top-end in terms of performance – can supply the necessary information. Oscilloscopes are the right tools for testing vehicle radars that operate in the 80 GHz frequency range. Thanks to their multichannel design, they act as phase coherent receivers to compare up to four paths of a radar antenna array (page 22). The performance of radar receivers for electronic support measures must be verified in field tests. This requires radar simulators that subject the receivers to realistic signal scenarios. A small system based on the R&S®SMW200A vector signal generator provides the necessary signals. In a live demo at the EW show in Estonia, receiver manufacturers took advantage of the opportunity to test their receivers with these signals (page 28).



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A vector signal generator and simulation software deliver highly complex radar signals for testing ELINT and radar warning receivers 28

Modern radar receivers must be able to handle complex, densely packed radar scenarios. The solution presented here can generate these scenarios (page 28).



WIRELESS

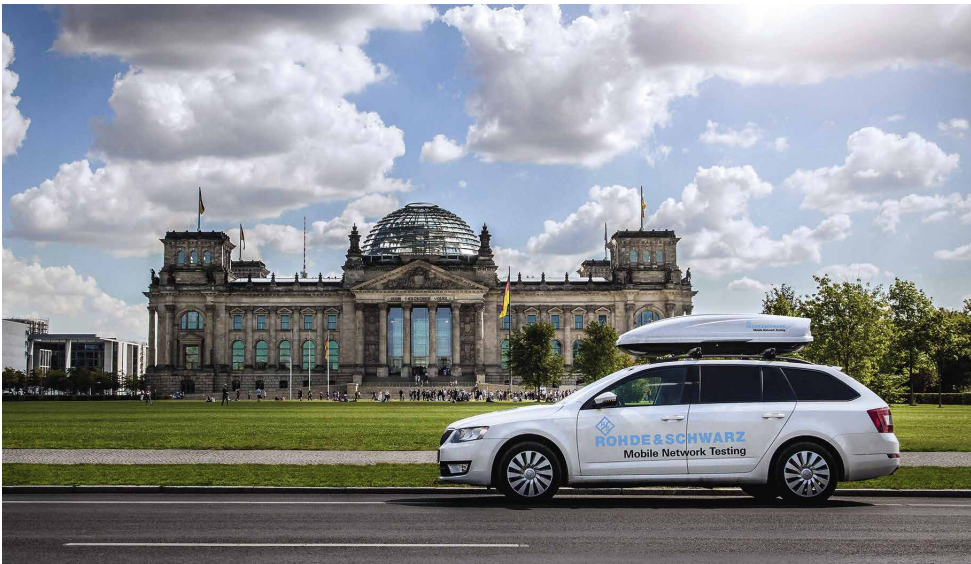
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The quality of mobile networks is regularly assessed in large test campaigns. A new ETSI method makes measurements comparable (page 14).



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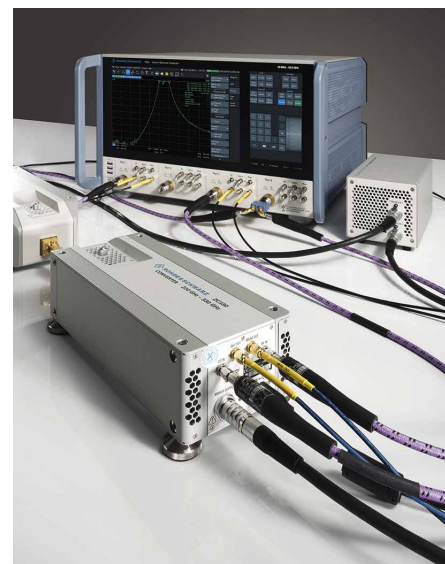
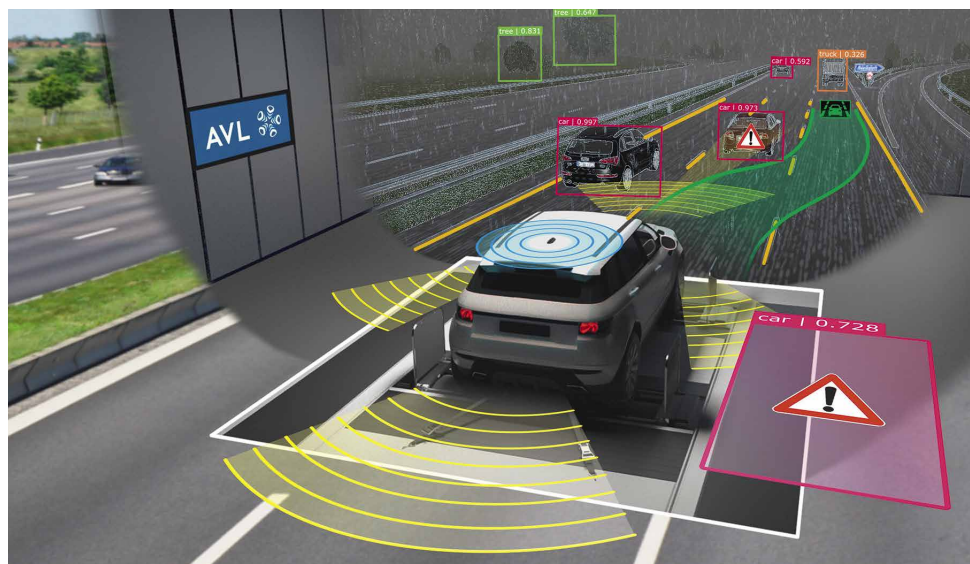
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Collaboration between Rohde & Schwarz and AVL, one of the world's leading suppliers of vehicle test equipment, enables realistic GNSS reception conditions for vehicle tests on a test bench. This is the basis for reliable testing of all aspects of GNSS based vehicle positioning (page 20).



The R&S®ZNA vector network analyzer makes it easy to configure complex test setups for measurements in the mmWave and terahertz ranges. No additional controllers or signal generators are needed (page 56).

NEWS COMPACT

R&S®RTP HIGH-PERFORMANCE OSCILLOSCOPE NOW UP TO 16 GHz

The R&S®RTP oscilloscope family that was launched in 2018 has been expanded with new 13 GHz and 16 GHz models. The higher bandwidths now enable measurements on high-speed serial interfaces such as USB 3.1 Gen1 and Gen2, PCIe Gen2 and Gen3, and DDR4 DRAM. This makes the most compact high-performance oscilloscope on the market even more versatile, especially since all features of the lower-frequency models function up to the new upper frequency limits. These features include high-precision digital triggering on pulse widths as small as 25 ps, the superior signal acquisition rate of 750,000 waveforms per second (competitive products offer 1000 or less) and reliable verification of signal integrity through real-time hardware deembedding.

The R&S®RTP is the first oscilloscope to allow users to trigger on measurement signals that have been corrected using deembedding. A new real-time math module even allows calculations with two corrected differential signals, for example to

enable triggering on the differential voltage. All trigger modes work over the full instrument bandwidth. A new option further exploits the trigger system's capabilities. The high-speed serial pattern trigger, which can be activated via license key, can extract the clock frequency of a high-speed 8 Gbit/s or 16 Gbit/s bitstream and use this reference to trigger on bitstreams up to 160 bits. These bitstreams can either be defined by the user or obtained from a decoding scheme such as 8B/10B or 128B/132B. Another unique feature of the R&S®RTP is optional time domain reflection (TDR) and time domain transmission (TDT) analysis. Combined with an analog input channel, the oscilloscope's 16 GHz pulse source supports characterization and debugging of signal paths, including PCB traces, cables and connectors. The new proven cable/proven probe function can be used to determine transmission losses from cables and probes. The resulting data can be transferred directly to the real-time deembedding system to quickly create a quasi-calibrated test setup.



As a universal instrument, the R&S®RTP can perform all time domain measurements and a wide variety of analyses in the frequency domain. Digitally modulated signals can be converted into I/Q data, saving memory space and enabling more detailed signal analysis with specialized tools installed either directly on the oscilloscope or on an external computer. R&S®VSE vector signal explorer software or standard programs such as MATLAB® are ideal for this task.

New broadband probes have also been introduced together with the new 13 GHz and 16 GHz models. Further information is available on the Rohde & Schwarz website.

SECURE HANDLING OF CLASSIFIED DATA

Government authorities and private companies that handle RESTRICTED



information need an IT security environment that is approved for this purpose.

IT administrators and users appreciate the convenience of an environment that is practical to use and simply implemented. The R&S®Trusted Endpoint Suite solution shifts security to the endpoint devices and, except for the use of smart cards, is entirely software based. The suite consists of R&S®Trusted VPN Client, R&S®Trusted Disk and R&S®Browser in the Box. All components are based on methods and security mechanisms recommended by the German Federal

Office for Information Security (BSI). The suite allows users to continue working with Windows 10™ as usual and does not negatively impact remote administration or software rollout and update mechanisms. It also supports extended system functions such as virtualization with Microsoft Hyper-V™ and virtualization based security functions.

R&S®Trusted VPN Client is ready for use immediately after installation. It protects

network communications that take place over non-secure connections to a company or government authority network. R&S®Trusted Disk provides full disk encryption for user data, programs and the operating system. It works transparently in real time and releases endpoint devices for use only after two-factor authentication. R&S®Browser in the Box, the third component, has been described by the trade media as the world's most secure browser. The virtual browsing environment

developed in cooperation with the BSI completely separates the browser from the computer operating system. Any desired website can be visited without harm, and documents from non-secure sources can be downloaded and viewed without risk. Malware is reliably prevented from entering the computer and the network.

NEW HANDHELD RECEIVER FOR RADIOMONITORING AND INTERFERENCE HUNTING

Portable monitoring receivers have a long history at Rohde&Schwarz and are widely used by regulatory authorities, public safety and security services, and network operators. The R&S®PR200 brings state-of-the-art technology to this instrument class. Regulatory authorities and network operators are confronted with increasingly intensive spectrum use and occupancy. Challenges include not only the growing number of services and standards, but also the fact that the sophisticated radio technologies employed are increasingly susceptible to interference. Products from all over the world are readily available online, and they do not always meet the strict requirements intended to ensure trouble-free co-existence of wireless services.

Modern monitoring receivers must be able to address these challenges, and the R&S®PR200 does just that. Thanks to its high scan speed, it captures every suspect signal up to 8 GHz (or up to 18 GHz with a special antenna). It can monitor and demodulate an up to 40 MHz wide frequency band in real time and record it as I/Q data. Within this band, it even detects signals that transmit for only 1.5 µs with 100 % probability of intercept (POI). The R&S®PR200 is not fazed by weak signals, densely occupied spectra or strong nearby transmitters. This is ensured by a variety of measures, including automatic gain control, sophisticated preselection filters, various operating modes, a switchable preamplifier and high directivity antennas. The scan results are processed into informative displays, which users can conveniently adapt to their needs via the app based user interface. Signals are displayed in parallel in the time and frequency domains. The polychrome real-time spectrum display clearly visualizes spectrally overlapping signals with different frequencies of occurrence.



Interference hunters are usually not only interested in the signal itself. What they really want to know is its source. If the source is relatively distant, it can be located by mobile direction finding (DF) from a vehicle. The R&S®PR200 supports this method with suitable accessories. When configured as a direction finder, it displays DF results on maps from OpenStreetMap. When the R&S®PR200 is connected to a magnetic vehicle roof antenna and a mobile computer, the source of a transmission can be quickly narrowed down to a small area using R&S®Mobile Locator software. On site, manual direction finding leads directly to the source. Locating the source is especially convenient when a smartphone is connected to the antenna and linked to the R&S®PR200 via Wi-Fi. Then the operator can continually keep an eye on the signal strength in the antenna direction without having to look away from the indicated destination.

The R&S®PR200 base unit is available now; special functions are available on request.

WALK-THROUGH SCANNER SECURES HEAVILY USED ACCESS POINTS



The new R&S®QPS Walk2000 scans visitors for suspicious objects.

Security is not only an issue for airports where checkpoints have used security scanners for several years. These scanners have the task of automatically detecting potentially dangerous items carried on the body. Numerous airports on three continents already use R&S®QPS200/201 scanners for this purpose. Airport scanners are

subject to strict approval regulations and require certification by local regulatory authorities. In the unregulated and private sectors, it is not compulsory to have security technology approved but there is a need for comparable protection. There are many potential areas of application, such as sport stadiums, amusement parks, VIP events, museums, public buildings, memorials, military bases, prisons and critical infrastructures. A suitably trained scanner not only covers security aspects, it can also help prevent stock from going missing in factories and warehouses. The new R&S®QPS Walk 2000 is designed for this wide range of applications.

As one of the first walk-through scanners on the market that can detect not only metals but also any other type of material, the system is suitable for count-

less business and government applications. Unlike current airport scanners, the R&S®QPS Walk2000 uses built-in AI to “search” individuals as they walk through the open screening area. It is not necessary to stand still and assume a specific pose, nor remove any clothing. This convenience is due to the scanning method employed, which uses a large number of ultrawideband (UWB) pulses from a variety of angles to generate enough scan data for a reliable analysis in only a fraction of a second. The results are displayed on a gender-neutral avatar just like an airport scanner does, or an indicator lamp gives a simple pass/stop signal. Fast processing enables a throughput of up to 1000 persons per hour. The scanner does not have any moving parts, making it very sturdy and virtually maintenance-free.

FIRST TEST CASES FOR 5G NR VALIDATED

The Global Certification Forum (GCF) and PCS Type Certification Review Board (PTCRB) certification organizations have validated the first 5G test cases in various FR1 and LTE band combinations for the latest configuration level of the R&S®TS8980 conformance test system. Chipset and mobile device manufacturers, test houses and network operators can be sure that a chip, module or mobile device whose conformity has been certified by the tester complies with the standards specified by 3GPP or ETSI and can be used without reservation.

Conformity tests precede every market launch. A mobile device must pass a comprehensive test program to ensure that it works as intended and without disturbance in a real network. The program includes regulatory tests specified by standardization institutions such as ETSI, especially those related to interference, and functional tests that check conformance

with wireless and protocol regulations issued by 3GPP for individual wireless communications standards such as 5G NR. These two test categories are supplemented by customer-specific test programs prescribed by many network operators for mobile devices deployed in their networks. The R&S®TS8980 test systems meet all the requirements for all standards from 2G to 5G. This end-to-end coverage is unique in the industry. Users who already have a previous version can expand their test capability to include 5G NR by adding the new R&S®CMX500 radio communication tester and upgrading the R&S®CONTEST test software. R&S®CONTEST is another plus. This advanced test sequencer integrates all types of tests in a shared user interface and can be used to control other Rohde & Schwarz test systems and devices in preconformance and development environments, creating an end-to-end test philosophy along the value chain.

The set of test cases for 5G NR supported by the R&S®TS8980 is being rapidly expanded. System operators receive regular updates as part of their service contracts.



The R&S®TS8980 test system now also checks 5G mobile devices for conformity with standards.

CAS INDUSTRIAL PIONEER AWARD 2019 GOES TO PROFESSOR ROHDE



Professor Rohde accepted the award at the IEEE International Symposium on Circuits and Systems.

in electrical engineering and microwave engineering at four universities in Germany, Romania and the USA.

Prof. Dr.-Ing. habil. Dr. h.c. mult. Ulrich L. Rohde has been honored with the Circuits and Systems (CAS) Industrial Pioneer Award 2019. The award honors individuals who have made pioneering and outstanding contributions in translating academic and industrial research into industrial applications and/or commercial products. It is sponsored by the IEEE Circuits and Systems Society and was presented to Professor Rohde in May 2019 by the North Jersey Section at the Society's lead conference, the IEEE International Symposium on Circuits and Systems (ISCAS). The IEEE North Jersey

Section coordinates the activities of IEEE members in various US counties. ISCAS President Yong Lian presented the award.

The IEEE Circuits and Systems Society is the leading organization for promoting the development of the theory, analysis, design, tools and implementation of circuits and systems. The annual award is a highly regarded honor. Recipients are nominated by the members of the Society. Professor Rohde is one of the pioneers in RF and microwave engineering and holds numerous patents. He holds professorships

The CAS Industrial Pioneer Award honors individuals who have made pioneering contributions in translating academic and industrial research into industrial applications and/or commercial products.



PROFESSOR ROHDE NAMED HONORARY FELLOW

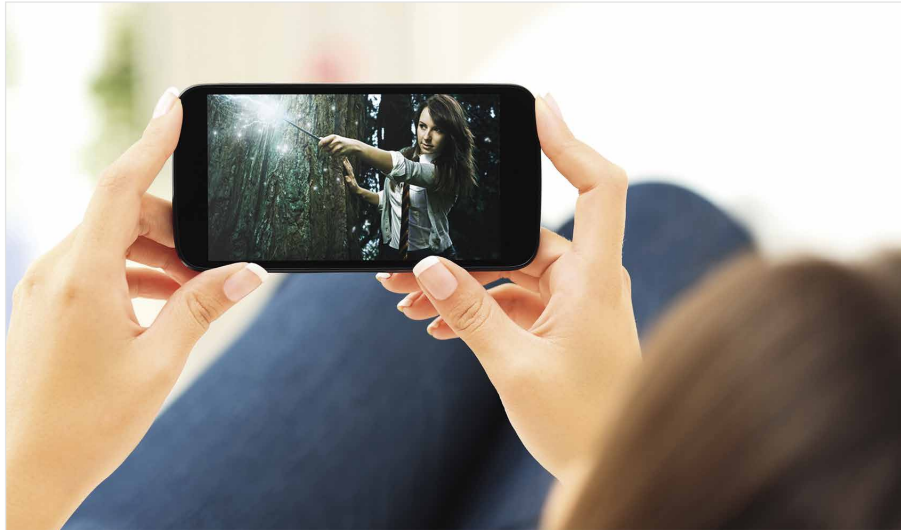
In September 2019, India's Institution of Electronics and Telecommunications Engineers (IETE) conferred its Honorary Fellowship on Prof. Dr.-Ing. habil. Dr. h.c. mult. Ulrich L. Rohde. This distinction honors outstanding individuals in the fields of science, technology, education and industry. Other Honorary Fellowship holders include high-level national and international leaders,

Nobel laureates and influential entrepreneurs. The IETE, headquartered in New Delhi, is an industrial research and education organization that promotes India's development and growth. The ceremony took place at the annual IETE Convention at Dr. Rammanohar Lohia Avadh University in Faizabad in the state of Uttar Pradesh.

Professor Rohde was named honorary fellow in recognition of his outstanding contributions in the field of microwave engineering and his commitment to the IETE over many years.



5G BROADCAST IS GAINING GROUND



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For many years, Rohde & Schwarz has been a driving force in the development of 5G Broadcast. This pioneering concept enables media providers in a constantly changing and converging market to broadcast content to mobile devices for a variety of applications. Advantages such as high video quality, low latency, offloading the mobile network and broad coverage provide incentive for network operators and users to get involved with the new technology.

BRAZIL TRANSMITS FIRST 5G BROADCAST TOGETHER WITH ROHDE & SCHWARZ

Globo, the largest Brazilian and Latin American TV network, has carried out a 5G Broadcast field trial together with Rohde & Schwarz. The Rock in Rio festival was broadcast as a 4K signal using the new technology in late September 2019. Rohde & Schwarz supplied an R&S®TMU9evo transmitter and the

R&S®BSCC network component. The aim was to validate the operability and market potential of the transmission technology. Similar to the 5G TODAY project in Bavaria, this field trial is intended to contribute to the discussion on the further development of TV in Brazil and worldwide.

CHINESE 5G TV TRIAL NETWORK WITH ROHDE & SCHWARZ TECHNOLOGY

The Academy of Broadcasting Science (ABS) and China Broadcasting Network Co. Ltd. (CBN), two public institutions under the regulatory authority Chinese National Radio and Television Administration (NRTA), are jointly conducting a 5G Broadcast field trial in Beijing. Rohde & Schwarz provided the transmitters and the core network components. This trial is the first step on the way to the regular deployment of 5G TV broadcast technology for the 2022 Winter Olympics in Beijing and the planned national expansion of the service by 2025.

The Beijing trial network consists of three stations approximately 10 km apart, operating in a single-frequency network (SFN). The Rohde & Schwarz transmitters with 1 kW output power operate at a center frequency of 754 MHz with 5 MHz bandwidth (later 10 MHz). The scope of delivery includes a software defined radio receiver developed by the Technical University of Braunschweig and measurement software from Kathrein. Using this end-to-end implementation, ABS and CBN plan to carry out a variety of tests, including field strength propagation, network

coverage, mobile reception, potential applications, and cooperation with the LTE Unicast network.

Due to the enormous Chinese market, the project will influence chipset and mobile phone manufacturers and give the new transmission technology a strong boost toward market launch.

INFANTRYMAN OF THE FUTURE COMMUNICATES WITH ROHDE & SCHWARZ RADIOS



The name says it all: the SOVERON® radio family gives its users sovereignty over the implemented waveforms.

The German armed forces will participate in the upcoming NATO Very High Readiness Joint Task Force (VJTF) with their armored infantry system, among others. This integrates the PUMA infantry fighting vehicle – the main weapon system of the armored infantry – and the “infantryman of the future – enhanced system”

modular combat equipment into network centric operations. Technology from Rohde & Schwarz is deployed for the radio connections. Following approval by the Budget Committee of the German Bundestag for the “armored infantry system service package”, the necessary procurement contracts have been signed. As a

subcontractor of Rheinmetall Electronics, Rohde & Schwarz will equip PUMA infantry fighting vehicles and soldiers with state-of-the-art tactical software defined radios (SDR) from the SOVERON® family. The first SOVERON® D batch for command vehicles will be delivered to the troops in the first half of 2020.

SEA LION ROARS VIA SOVERON® RADIOS

In the next few years, the German Navy’s aging Sea King Mk.41 helicopters will be replaced by 18 NH90 Sea Lion helicopters. Rohde & Schwarz is equipping the rotary-wing aircraft with software defined radios from the SOVERON® family, including national cryptology. The deployed R&S®M3AR MR6000A VHF/UHF transceivers use state-of-the-art NATO communications and encryption methods and are SECAN and BSI certified to enable secure communications up to the NATO SECRET level. This order continues the success story of the R&S®M3AR radio family. Nearly 8000 SDRs from this series are now in operation on 70 different platforms worldwide.



The NH90 Sea Lion is replacing the German Navy’s decades-old Sea King helicopters.

APRON COMMUNICATIONS UPDATED AT MUNICH AIRPORT

Munich Airport is modernizing its apron communications technologies. Unlike approach control and en-route communications, which are the responsibility of the German air

navigation service provider (DFS) in Germany, airport operators are responsible for apron communications and have their own staff and radio resources for this.

In the future, voice communications with aircraft at gates and on taxiways in Munich will be handled using R&S®Series4200 radios, which DFS already uses for en-route communications. In contrast to the existing analog system, which also came from Rohde&Schwarz, the new digital system can easily be integrated into the airport's IP network. The R&S®VCS-4G voice communications system will also be installed. The order includes air traffic controller consoles, a VoIP recording system, connection to the infrastructure monitoring system, and turnkey integration of all components.



In the future, R&S®Series4200 radios will be used in Munich to communicate with aircraft, also on taxiways and at gates.

ROHDE & SCHWARZ EQUIPS CZECH AIR NAVIGATION SERVICES WITH VCS SIMULATION SYSTEMS

Air Navigation Services of the Czech Republic (ANS CR) is updating its voice communications system (VCS) for simulation and training and has chosen Rohde&Schwarz as the supplier of the new turnkey solution. The core element of the project is the R&S®VCS-4G system, with a total of nearly 200 controller workstations for simulators at the Prague, Brno, Ostrava and Karlovy Vary locations. The system will be installed in stages and completed by 2025. The successful deployment of the R&S®VCS-4G system at three Czech regional airports was a significant factor in the decision.

To ensure aviation safety, every air traffic controller must receive basic and advanced VCS training. Air navigation service providers (ANSP) often install VCS simulators and training systems to avoid disruption of normal operations.

The operator stations for the Czech simulators are equipped with different user interfaces to simulate all the air traffic control environments that controllers could encounter. This is because ANS CR not only trains national air traffic controllers, it also offers training courses for ANSPs worldwide. The training is in line with ICAO and EUROCONTROL standards.

NAV CANADA OPTS FOR ROHDE & SCHWARZ SHORTWAVE TECHNOLOGY

The Canadian air navigation service NAV CANADA is one of the largest air navigation service providers (ANSP) worldwide in terms of the number of monitored aircraft movements. Due to the magnitude of their control area, which includes part of the North Atlantic flight corridor to Europe, communications between air traffic controllers and aircraft on long-haul routes takes place in the shortwave bands commonly used for international air traffic. NAV CANADA is upgrading its large HF radio facility in Gander, Newfoundland, to state-of-the-art technology to be

prepared for the tasks it will face in the coming decades.

After an extensive supplier evaluation, Rohde&Schwarz was awarded the order to supply 17 HF transceivers, each with an output power of four kilowatts. Consisting of components from the R&S®M3SR Series4100 family, the systems are in line with the international EUROCAE ED-137 interoperability standard for voice over IP ATM components and will be operational during the course of 2020.



R&S®Series 4100 is a highly configurable radio platform for professional shortwave users.

DIGITAL AERONAUTICAL RADIO ON THE HORIZON

Aeronautical radiocommunications between the cockpit and the tower is one of the few radio domains that still uses analog modulation. Since 1948, aeronautical radio based on double sideband amplitude modulation (DSB AM) has continued to be used due to its proven robustness and reliability as well as its low implementation

costs. However, supplementary narrow-band radio data communications methods, such as VDL mode 2 with its low transmission rate of only a few kilobits per second, have long since reached their limits. Which is why research and development on a modern ATC radio data communications system began several years ago. As

part of the ICONAV and MICONAV programs funded by the Federal Ministry for Economic Affairs and Energy, a German consortium led by Rohde&Schwarz has now developed a demonstrator for the new method and verified its functionality and capability in flight tests. Dubbed the “L-band digital aeronautical communications system” (LDACS), the new technology is up to 200 times faster than VDL mode 2. It transmits voice and data, enables message prioritization, has low latency and an ensured quality of service, and uses strong encryption for protection against cyberattacks. It can also be used to obtain navigation data to back up satellite navigation and ground based landing approach systems. LDACS avoids interference by using the gaps in the frequency bands reserved for aeronautical radio, so existing radio infrastructures do not need to be changed. The system can be deployed in stages as a supplementary service, for example starting with major airlines hubs.

Comprehensive flight tests carried out in Q1 2019 with a demonstrator (shown in the picture before installation) confirmed the positive results of lab tests.



A working group of the International Civil Aviation Organization (ICAO) has already started the standardization process. The system is not expected to be rolled out before 2025.

FROM THE FROG'S-EYE TO THE BIRD'S-EYE VIEW AND BACK

Making mobile network scores comparable

Assessing mobile networks and their performance has long been a subject of interest to network operators and regulatory authorities, as well as to trade media and T&M equipment manufacturers such as Rohde & Schwarz. Up to now, network scores have been difficult to compare due to a lack of uniform measurement methods. A new ETSI method solves this problem.

There are many assessment methods currently available, based on different interfaces for acquiring measured values and in many cases developed over time. This makes comparison virtually impossible. ETSI, the leading standardization body for mobile communications, therefore launched a project more than two years ago to tackle this issue, analyze existing methods, merge them and adapt them to standardized measurements and KPIs. The final report, TR 103 559 “Best practices for robust network QoS benchmark testing and scoring”, was published in August 2019. Along with general rules for conducting test campaigns, it covers the underlying services, measurements and KPIs and provides detailed descriptions of individual measured values, as well as their weighting and combination to arrive at an overall network performance score.

The report is a joint effort of network operators, T&M service providers, infrastructure manufacturers and measuring equipment manufacturers. As a contributor to the method, Rohde & Schwarz is already determining the network performance score in its R&S®Smart Analytics analysis platform.

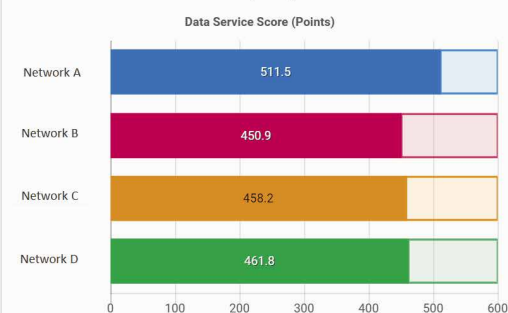
Dashboard

OVERVIEW SERVICES NETWORK PERFORMANCE SCORE

Network Performance Score (Overall)



Network Performance Score (Data)



User perception as a rating scale

Due to the rapid increase in the data transport capacity of mobile networks, users now see smartphones as the primary means of access to digital services and all types of applications; therefore, they are also considered the primary means of access for measuring equipment. These services and applications are based on established transport protocols, but the load profiles in the network and the requirements for satisfactory quality vary greatly, depending on the application. Users have different quality expectations for uploading a photo to a social media network than for watching a soccer match in a livestream video.

Despite their high transport capacity, today's networks still fall far short of being perfect transport media. Interruptions occur or the data throughput needed by an application cannot be ensured or cannot be ensured continuously. The transmission time also leads to a time offset between the sending and receiving of data. Many applications adapt to changing channel conditions and attempt to minimize the negative impact on perceived quality, for example by temporary data decimation or buffering to bridge interruptions in transmission.

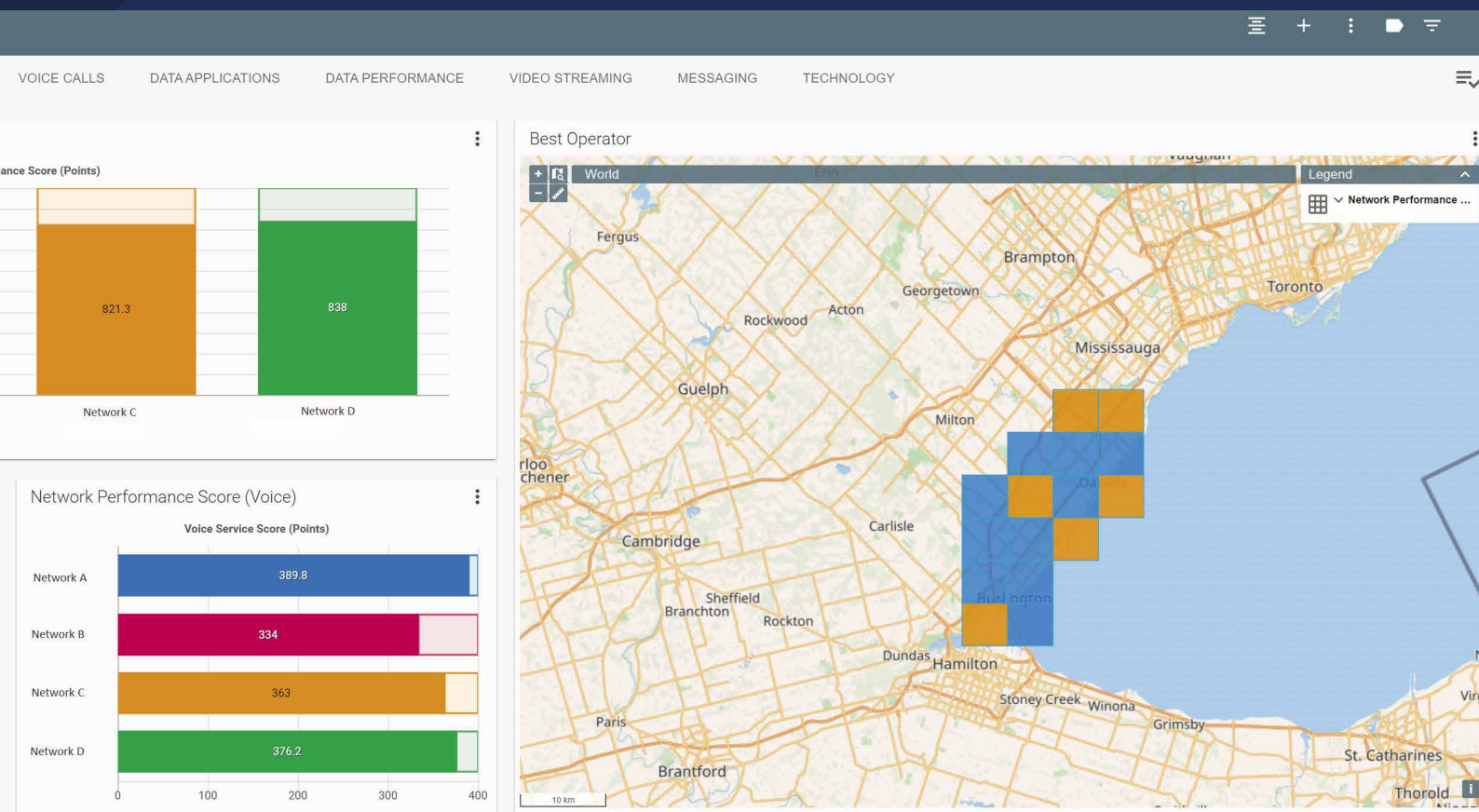


Fig. 1: With the R&S Smart Analytics reporting tool, network operators or independent testers can assess network quality according to various criteria and, in particular, calculate an overall network score in line with ETSI TR 103 559.

Network operators therefore have a strong interest in assessing the performance of their networks from the user perspective and finding out how they can increase it as efficiently as possible. However, technical parameters such as data rate, latency or packet losses are less useful for determining performance than performance-oriented criteria of actual applications, such as phone calls or the voice and video quality of a livestream, as well as simple values such as how long it takes to send an image or successfully load a website.

To obtain meaningful information about the overall performance of a network, the ETSI method proposes a weighted sum of quasi-perceptual quality measurements for typical applications.

What determines the performance of a network from the user perspective?

Data services account for the lion's share of the transmitted data volume, and users spend significantly more time on data applications than on phone calls. These circumstances should be reflected in the overall score. However, data services also differ both technically and in frequency of use.

To properly take all aspects into account, the behavior of a typical user is simulated. For this purpose, automatic mobile test systems establish connections in actual networks with normal smartphones and run a series of data applications in addition to making test phone calls. This includes downloading files, accessing livestream videos, browsing websites, performing load tests and sending media content to a social media network. In this way, from a technical perspective, the various situations are mapped. File downloading emulates data traffic with an individual server in the network (e.g. downloading apps, emails or social media content), while web browsing emulates communications with many different servers over parallel IP connections (along with conventional browsing, most apps also communicate with multiple servers at the same time). The video stream requires a virtually continuous data flow, uploading images to a social media network represents sending data to a network server, and a load test (data transmission over parallel connections from and to a high-performance data server) checks the maximum achievable data rate.

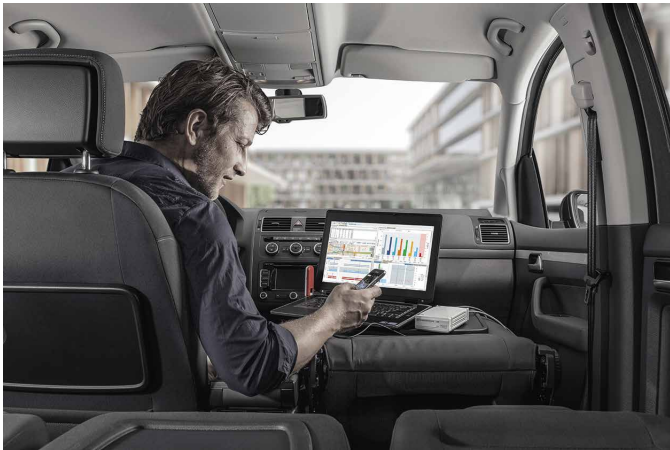


Fig. 2: A fleet of test vehicles and testers on foot spend several weeks collecting seamless data concerning the quality of a network.

Various aspects are tested and scored for each of these cases, including phone calls:

- ▶ Does the application start running at all or within a pre-defined time window, and is the connection maintained over the total time?
- ▶ How long does the start phase take (e.g. call setup or start of video playback)?
- ▶ What is the quality during the application, or how long does it take to complete the task (e.g. uploading an image)?

All of these aspects contribute to the overall score with suitable weighting.

A large number of field measurements – typically several thousand throughout the entire network – are required in order to obtain a statistically reliable score. Automated test systems in vehicles as well as portable systems are used for this (Fig. 2).

Benefits for network operators and users

Nationwide benchmark measurements have a fairly strong public impact, especially in Europe, and are decision factors for many users. Periodic network ratings by consumer magazines are often reported on popular news portals. Catchy quality KPIs are naturally an advantage. To obtain them, the previously described quality measurements are performed in various environments. This includes differentiated scoring for urban and rural areas as well as highways, trains or highly frequented places such as railway stations, stadiums and airports. The weighted scores are combined to calculate the quality score for the overall network. The quality scores for individual aspects, such as coverage along major highways, can be indicated individually. This makes it easy for readers to decide which network operator has the network that best meets their needs.

However, this is only the publicly visible benefit of an integral scoring method. It also gives network operators a tool to improve their networks in the regions and for the applications that provide the most benefits for their customers. Network operators get a quick overview of the performance of their networks and can take targeted measures to remedy any deficiencies.

Along with regional assessment, other criteria can also be used as a basis for scoring, such as technology (e.g. 2G/3G versus 4G) or network performance after installation of new hardware or software. With a clearly defined scoring system, all changes to the network and their impact on the perceived quality can be directly checked and quantified.

Rohde&Schwarz uses the method described by ETSI to calculate the network performance score as a key entry element in the R&S®Smart Analytics analysis and reporting tool, which can be used to evaluate the data collected during a test campaign. Extensive filter and analysis functions allow efficient navigation of the measurement data down to the lowest detail level of communications between devices and the network. The integrated view of the network performance score also shows potential room for improvement for the selected region or application and enables effective focusing on problematic situations in the network.

Dr. Jens Berger

A closer look at the scoring method

The method for calculating and scoring individual services and combining them to obtain an overall score has intentionally been kept simple and clear. The basic principle is weighted addition of point scores for individual aspects of the applications, such as accessibility and the quality or duration of the application.

Various statistical KPIs are calculated for this. Average values of individual parameters have only limited relevance to user perception and are often influenced by high individual values. The performance deficits of a network can be grasped better with percentile values, which specifically capture the share of problematic tests, or by testing compliance with tolerable thresholds, because user perception is ultimately determined by negative experiences.

The individual KPIs determined from a large number of individual measurements are first converted from technical units (e.g. milliseconds or kbit/s) to a neutral points scale. This is based on a simplified model of human perception

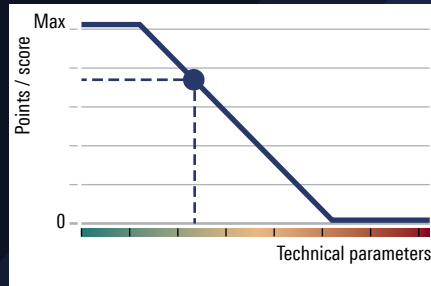


Fig. 3: Conversion of technical measured values into dimensionless points with saturation areas provides a simple simulation of human perception.

with saturation areas at the lower and upper ends of the scale (Fig. 3). The abstracted KPIs obtained in this way can now be directly compared with each other and summed to obtain higher-level quality values.

Point scoring can be performed for individual geographic regions and with regard to other meaningful categories, for example locations of

particular importance, transportation, etc. The point scores for each category are then weighted (taking into account typical aspects, such as population density or data volume at specific locations) and further combined to determine the performance of the entire network.

The aim is to get an overview of the overall performance of the network from this total score (Fig. 4) and to effectively localize weak spots. The uniform points scale makes it possible to easily and verifiably identify problematic regions, applications and even individual KPIs. Maximum achievable scores can be determined for each region and category, and even for each individual parameter. If the score is significantly lower than the maximum, there is a problem at this location or with this service. At the same time, this method also makes potential room for improvement directly visible.

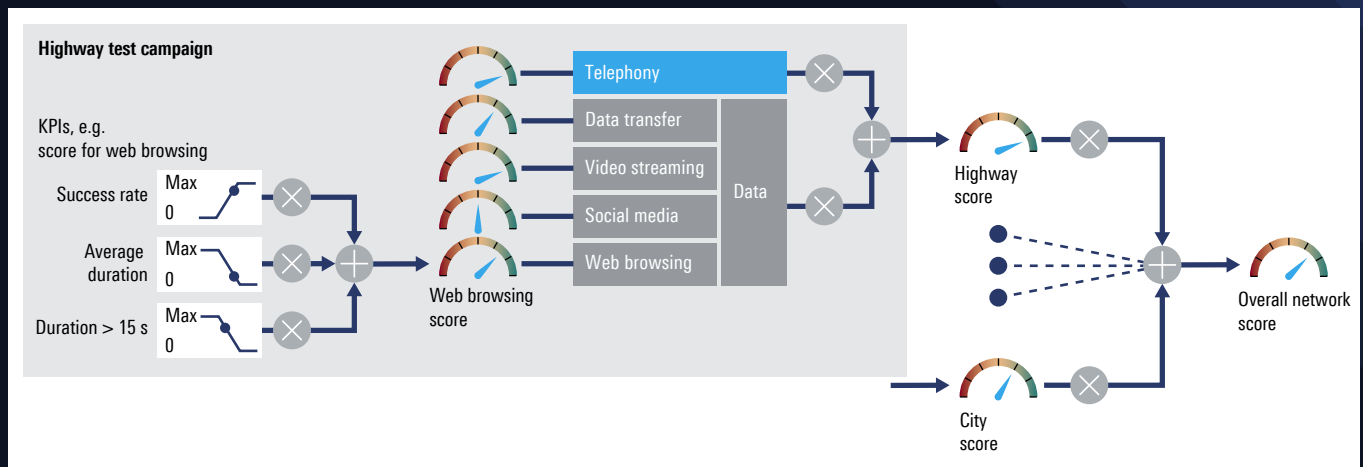


Fig. 4: The ETSI measurement method for obtaining an overall network performance score evaluates a series of typical applications such as web browsing and video streaming, adds the weighted values to obtain individual scores, and adds the weighted individual scores to obtain an overall network score.

IN-DEPTH MIMO TESTING

R&S®CMW tests WLAN RF modules with 2×2 MIMO

Multiple input multiple output (MIMO) is a multi-antenna technology that, together with other methods, increases the data rate in radio-communications and improves signal quality. To reliably assess the implementation of this technology, realistic conditions must be simulated in the lab. R&S®CMW radio communication testers are ideal for this application.

A range of methods for improving data rate and signal quality

In MIMO systems, signals are sent via multiple transmit antennas to multiple receive antennas. Reflections along the path to the receiver produce the multipath propagation that MIMO requires. A prerequisite for this multipath propagation (and for successful decoding in the receiver) is a minimum antenna spacing of half a wavelength ($\lambda/2$) at the transmitter and receiver. This is equivalent to 12.5 cm in the 2.4 GHz frequency band, which means there is only enough room for two MIMO antennas in compact devices like smartphones. Other factors also limit the number of possible antennas. For example, multi-antenna systems consume more power than single-antenna systems and therefore have a shorter battery life. Using a greater number of antennas and RF amplifiers can also cause overheating problems. Various techniques are used to increase MIMO data throughput and improve signal quality.

Spatial multiplexing

Spatial multiplexing significantly increases the data rate compared to single-antenna systems. The outgoing data stream is divided among several spatial streams that are simultaneously transmitted to the receiver on the same frequency via different antennas (Fig. 1).

Decoding in 2×2 MIMO means the receiver has to solve two equations with two unknowns. This is only

possible if these equations are linearly independent. A physical requirement for this is multipath propagation on separate, uncorrelated transmission paths. In order to decode the transmission matrix H , the matrix elements must be known. The receiver autonomously determines these elements using open-loop channel estimation based on known bit sequences in the transmitted data packets. Under ideal conditions, 2×2 MIMO with spatial multiplexing achieves double the data rate of single-antenna systems.

TX diversity

TX diversity is when more transmit antennas are used than receive antennas. This approach lowers susceptibility to interference, increases range and allows the use of higher-order modulation (16/64/256/1024QAM). Various techniques are used to increase the signal-to-noise ratio of the RF signal.

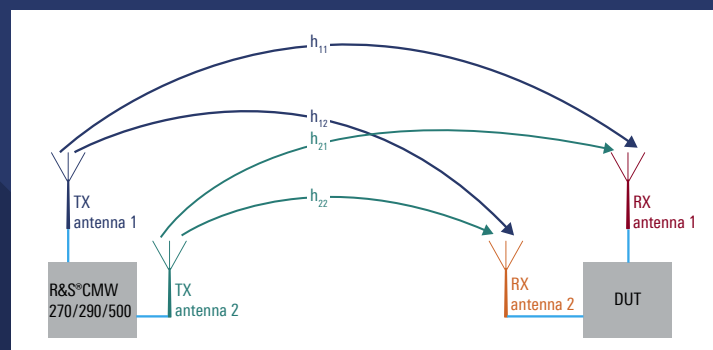
Cyclic shift diversity (CSD) or cyclic delay diversity (CDD)

CSD (also known as CDD) is one of these techniques. Multipath propagation involves transmission paths of different lengths and therefore different path delays. Without any corrective action, multiple versions of the same signal would reach the receiver at different times. CSD compensates for this timing difference by appropriately delaying transmission via the individual transmit antennas. At the receive antenna, the various multipath signals are superimposed, which ideally produces a stronger receive signal. This virtual echo in the transmitter increases the receiver's frequency selectivity in the frequency domain.

Space time block coding (STBC)

In STBC, the outgoing data stream is transmitted redundantly via two transmit antennas (Fig. 2), but is only received by a single antenna. Compared

Fig. 1: In spatial multiplexing, each receive antenna receives a sum signal consisting of all of the transmitted signals. The prevailing channel conditions are represented in a transmission matrix H with elements h_{nm} .



to the original data stream, the signal is permuted in time and complexly conjugated. This type of space time block coding was developed for two antennas by Siavash Alamouti and is named after him (Alamouti code).

As in spatial multiplexing, the two data streams can only be decoded if there are separate, independent transmission channels. Under ideal conditions, using two transmit antennas increases the signal-to-noise ratio by 3 dB, thereby doubling it.

Beamforming

Beamforming is a TX diversity technique without multipath propagation. The transmit signal is sent with a timing offset or phase offset via multiple antennas or antenna arrays. Depending on the geometrical arrangement and spacing of the individual transmit antennas, the signal is amplified, attenuated or even canceled out

in various directions. Data streams can be targeted at specific WLAN stations and suppressed for other stations. This technique is useful in applications such as multi-user MIMO (MU-MIMO) where a single access point delivers various MIMO streams to multiple WLAN stations.

Combining multiple techniques

The above techniques can be combined in a variety of ways. For example, the signal-to-noise ratio of a spatial diversity data stream can be improved with STBC. This results in a standard 2x2 MIMO stream being transmitted with 4x2 MIMO (four transmit antennas and two receive antennas). Using beamforming in a MU-MIMO system, it is even possible to direct streams at multiple users that have wireless devices with only a single receive antenna [1].

Thomas A. Kneidel

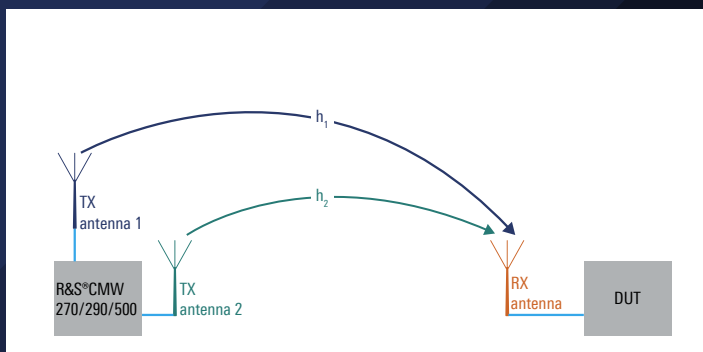
Realistic tests in the lab with the R&S®CMW270/290/500

For some time now, the R&S®CMW platform has supported RF measurements of MIMO transmitter and receiver characteristics in non-signaling mode in various ways [2]. In signaling mode, WLAN testing has so far been limited to single input single output (SISO) technology [3].

The IEEE standardization committee has now specified MIMO multi-antenna technology for the 802.11n/ac/ax standards. 2x2 MIMO (including the spatial multiplexing, space time block coding and cyclic shift diversity MIMO techniques) was quickly added to the existing WLAN SISO signaling solutions based on the R&S®CMW270/290/500 wide-band radio communication testers.

Using realistic simulations, it is possible to measure RF transmitter characteristics, analyze receiver sensitivity and, most importantly, determine data throughput in the transmit and receive directions. The various techniques are designed to maximize this throughput. This makes the R&S®CMW270/290/500 an indispensable tool for WLAN MIMO developers.

Fig. 2: In space time block coding, the modified outgoing data stream is transmitted via multiple antennas and received by a single antenna.



References

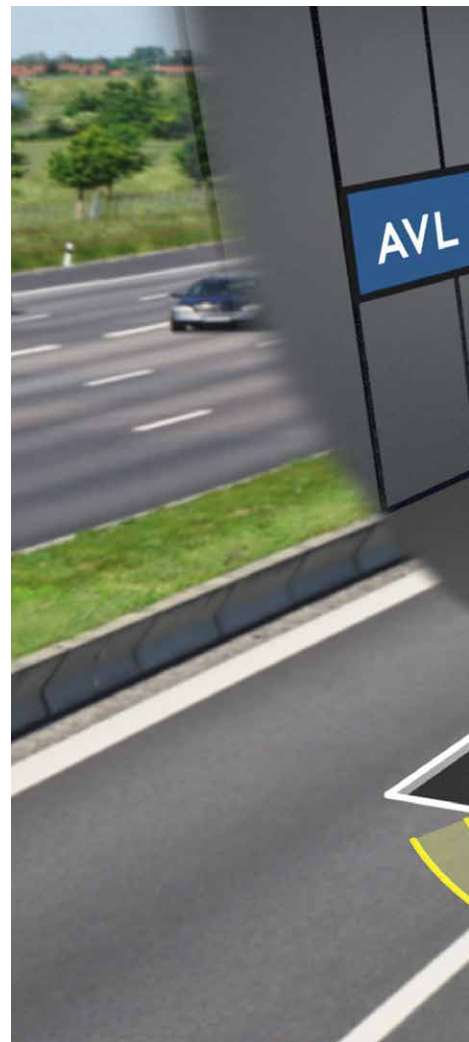
- [1] Small massive MIMO compendium. NEWS (2019) No. 221, pages 14 to 19.
- [2] MIMO measurements on WLAN radio components. NEWS (2018) No. 220, pages 9 to 11.
- [3] Signaling tests on WLAN 802.11ax devices. NEWS (2018) No. 220, pages 12 to 13.

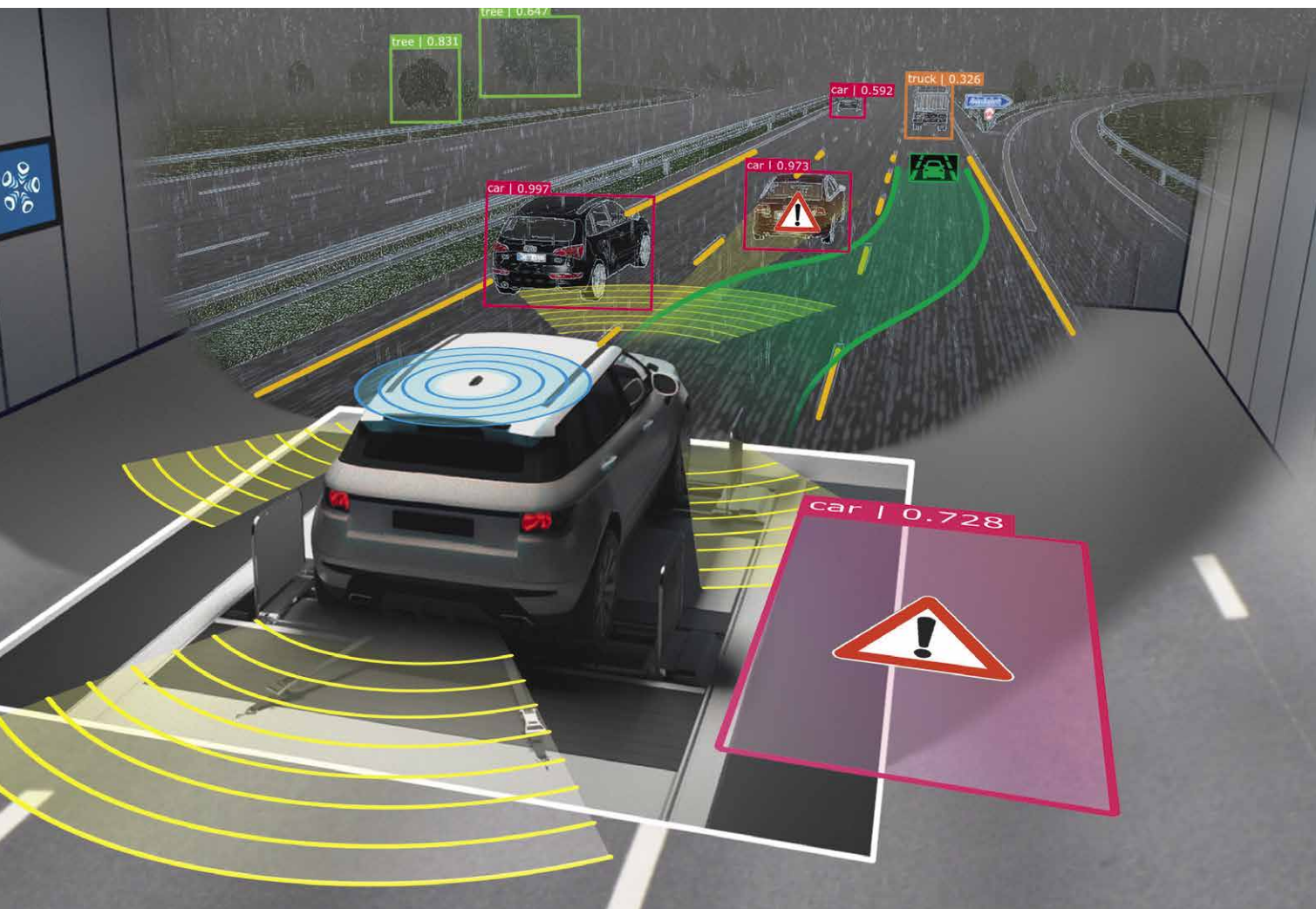
GNSS SIMULATOR FOR VEHICLE TEST ENVIRONMENTS

The R&S®SMBV100B vector signal generator adds a GNSS component to the AVL DRIVINGCUBE™ vehicle test environment for autonomous vehicles

Collaboration between Rohde & Schwarz and AVL, one of the world's leading suppliers of vehicle test equipment, enables realistic GNSS reception conditions for vehicle tests on a test bench. This is the basis for reliable testing of all aspects of GNSS based vehicle positioning, which is a core function of autonomous vehicles.

The R&S®SMBV100B vector signal generator produces signals for all current satellite navigation systems (GPS, GLONASS, Galileo, BeiDou, QZSS and SBAS) in all frequency bands (L1, L2 and L5).





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The AVL DRIVINGCUBE™ vehicle test environment from AVL exposes the vehicle on the test bench to a realistic driving situation. The R&S®SMBV100B vector signal generator produces the required GNSS signals that make the tests more realistic and allow drive tests on the road to be minimized.

Tests with AVL DRIVINGCUBE™

AVL DRIVINGCUBE™ is used to test driver assistance systems and the automatic driving functions of autonomous vehicles in a virtual environment. The drive tests are carried out with a real vehicle on a chassis dynamometer or a powertrain test bench. Environmental sensors, control systems and actuators in the vehicle are tested reliably and reproducibly using realistic virtual driving scenarios.

GNSS simulation with Rohde & Schwarz generator

The environment simulations have now been augmented with GNSS signals, making them even more realistic. During the drive tests, the R&S®SMBV100B vector signal generator acts as a GNSS simulator and generates the GNSS signals required to stimulate the GNSS receiver installed in the vehicle. It generates the signals in real time consistent

with the simulated vehicle motion. GNSS based vehicle positioning, a core function of automated driving, is then possible and can be reliably tested.

The generator produces signals for all current satellite navigation systems (GPS, GLONASS, Galileo, BeiDou, QZSS and SBAS) in all frequency bands (L1, L2 and L5). The signals are also suitable for testing multifrequency receivers, which play an increasingly important role in automated driving.

Adding GNSS simulation not only makes the overall simulation more realistic, it allows more tests to be performed on the test bench instead of on the road. Road tests can be reduced to a much greater extent than before and vehicle mileage can be saved.

Dr. Markus Irsigler

RADAR TESTING

Analyzing automotive radar signals with an oscilloscope

Automotive radar sensors require detailed characterization in the lab. Oscilloscopes are ideal for this because they can simultaneously analyze multiple signals and precisely compare them.



Compact radar sensors with long range and high resolution are currently being developed for driver assistance systems and future fully autonomous vehicles. Operating in the frequency range from 76 GHz to 81 GHz, these sensors use phased array antennas to obtain location information. The accuracy of the obtained data is directly correlated to the accuracy of the relative phase angles of the emitted signals, making precise adjustment of the antenna system a crucial factor for precision.

Characterization of these sensors in the development phase requires sophisticated T&M equipment due to the high frequencies. For many of these measurements, the R&S®FSW85 spectrum analyzer with its large measurement dynamic range and sophisticated analysis features is an excellent choice*, but it has only one input channel and is therefore not able to measure the phase differences of multiple signals. Oscilloscopes have an advantage here. The four-channel R&S®RTP, for example, can act as a phase coherent receiver and simultaneously analyze and compare up to four signals.

* 5 GHz analysis bandwidth for testing automotive radars in the E band.
NEWS (2018)
No. 219, pages 30 to 32.

Test setup

External mixers are used to downconvert the radar signals to the oscilloscope's frequency range (Fig. 1). The R&S®FS-Z90 mixers in this example use the sixth harmonic of a local oscillator (LO) to generate the desired output frequency. An R&S®SMA100B signal generator (see page 50) serves as the LO, while the evaluation board of a commercial radar sensor acts as the radar signal source.

The radar system uses a chirp sequence signal consisting of several high frequency pulses in direct succession. Each of these pulses is a chirp with a bandwidth of approximately 4 GHz. The sensor is configured so that the frequency of the radar signal rises linearly from 77 GHz to nearly 81 GHz (up chirp). The end of the sequence is followed by a break of several milliseconds (interframe time). During this time, the radar processor calculates the locations and speeds of the detected objects.



Test setup

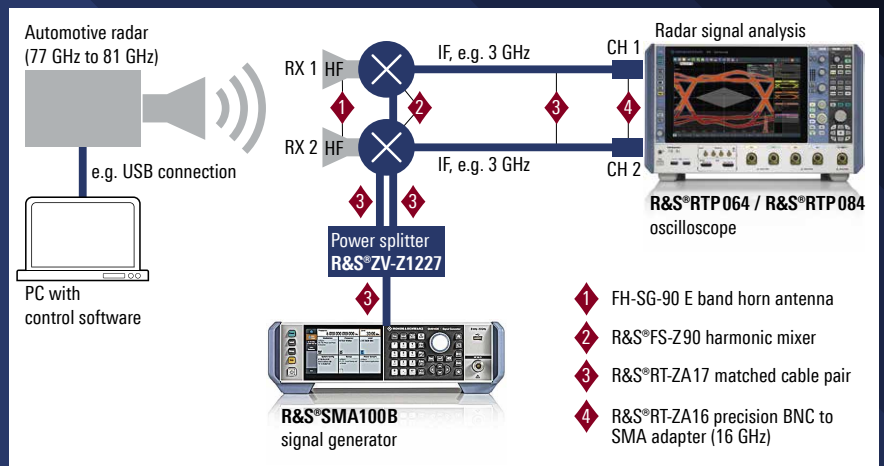


Fig. 1: Test setup for multichannel radar analysis with an oscilloscope. The radar signal is downconverted to an IF frequency of 3 GHz by the harmonic mixers and fed to the oscilloscope. The power splitter and one mixer are not needed for a test setup with only one channel.

The IF signals from the mixers are fed to the oscilloscope inputs. The attenuation and S-parameters of the individual components in the signal path can be taken into account by the hardware and software deembedding functions of the R&S®RTP. The impact of deembedding is illustrated in Fig. 2. The received signal is attenuated over the entire frequency range and detected with decreasing amplitude as the frequency increases (upper screenshot). Deembedding compensates for these losses (lower screenshot), enabling the oscilloscope to analyze the actual signal.

Single-channel analysis

Trigger

Stable trigger conditions are essential for reliable signal analysis with an oscilloscope. Oscilloscopes usually offer advanced trigger options in addition to traditional edge triggering. However,

these options can only be used up to a certain bandwidth, depending on the manufacturer. Thanks to its digital triggering, the R&S®RTP can use the entire range of trigger options up to the maximum bandwidth.

Simple edge triggering is not useful for these measurement tasks since the oscilloscope will trigger on virtually any point of the signal due to the nature of the radar pulse. A pulse width trigger, which can be used to trigger on the interframe time between pulses, is more useful because it allows individual pulses or entire pulse sequences to be detected and analyzed. The trigger condition can be configured for specific radar signal parameters, for example to only display pulses with a specific duration (see the application note at the end of this article).

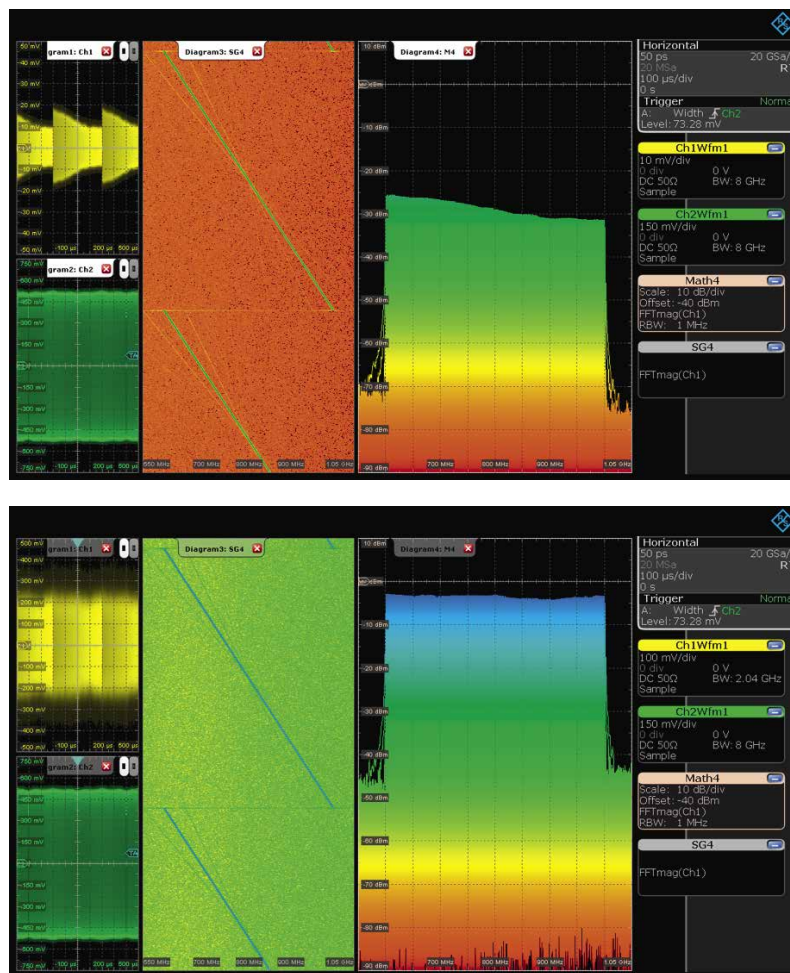
Demodulation

For the best possible spatial resolution, current automotive radars operate with bandwidths up to 4 GHz. The R&S®RTP meets the associated T&M requirements. With its high sampling rate and large memory, it captures the downconverted radar signal with a sufficiently high sampling frequency. The analysis tools included in the base configuration are sufficient to check the modulation in the radar signal. The signal used starts at 1 GHz and rises linearly to 5 GHz. An initial check of these frequencies starts with a frequency measurement that is configured to perform many frequency measurements within one acquisition (frequency tracking). The result is a display of the downconverted frequency versus time $f_{IF}(t)$.

At higher frequencies, the data points are closer together, making the measurement more difficult. Noise often increases, but can be filtered out by the oscilloscope's lowpass filter math function. It is possible to change the scaling of $f_{IF}(t)$. (increase the frequency axis) to display the radar signal in its original frequency range $f_{HF}(t)$ (Fig. 3).

Other measurement functions help users quickly determine important parameters such as the rise time of the linear frequency modulation. For example, the oscilloscope's FFT function creates a spectrogram that shows how the radar signal changes over time. These two analysis methods (Figs. 2 and 3) allow users to perform an initial check of the bandwidth and the modulation.

Fig. 2: An FMCW signal with deembedding disabled (top screenshot) and enabled (bottom screenshot). The frequency response correction reconstructs the signal in its original frequency range.



Pulse analysis with the R&S®VSE software

The R&S®VSE vector signal explorer software offers advanced analysis tools for investigating radar signals, for example to check the linearity of a frequency modulated continuous wave (FMCW) radar signal, which has a large influence on the Doppler properties of a target. The software's R&S®VSE-K60c transient analysis

option performs this measurement with high accuracy (Fig. 4). The R&S®VSE-K60c displays the frequency response $f_{IF}(t)$ and calculates the deviation from the ideal linear phase. The software can be installed directly on the oscilloscope, but also on an external PC. In this case, the data is transferred for example via Ethernet for analysis.

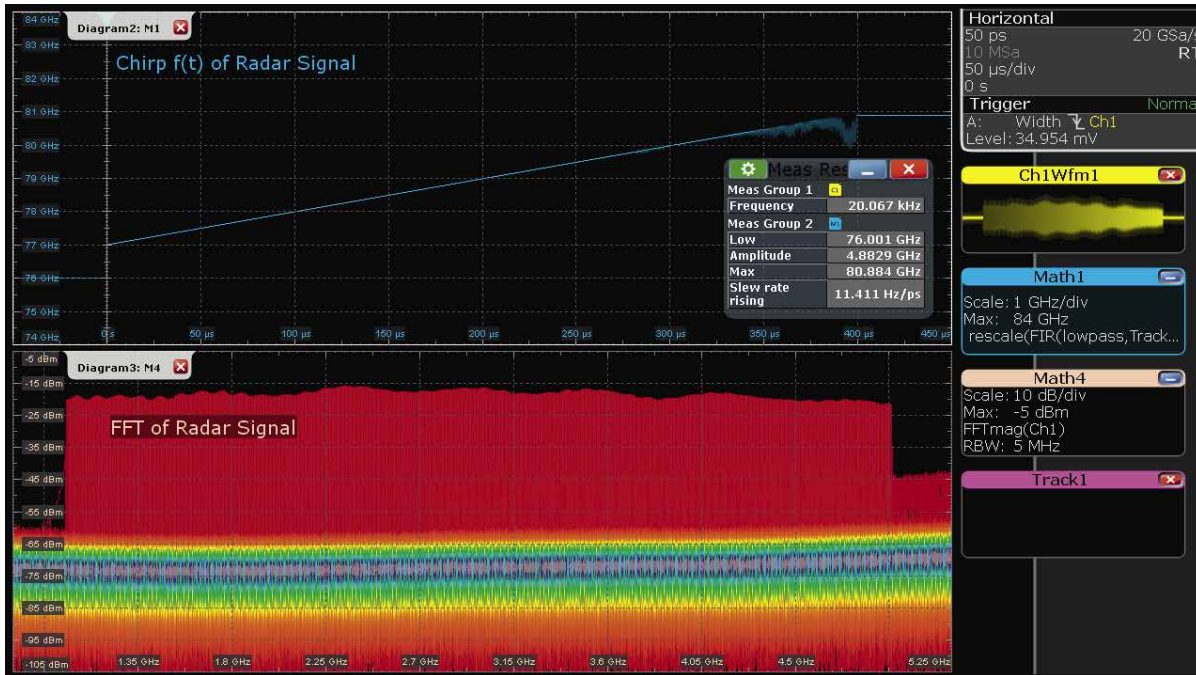


Fig. 3: Top: With suitable scaling and filtering, the radar signal can be displayed in its original frequency range $f_{HF}(t)$. Measurement functions provide important parameters, such as the slow rate of the chirp. Bottom: The FFT shows the power profile of the chirp.



Fig. 4: Transient analysis of a chirp sequence signal with the R&S®VSE-K60c transient analysis option. The pulse power versus time is shown at the top left. The linear frequency response can be seen in the top middle and in the spectrogram on the bottom left. The software lists the properties of the detected pulses in a table (bottom middle). The properties can also be investigated in detail in graphical form. The chirp rate and frequency deviation are shown on the right.

Measuring phase and amplitude differences with multichannel analysis

Many automotive radars are equipped with multiple transmit and receive antenna arrays. These determine the directivity of the antenna and allow beamforming and detection of the direction of the target. To specifically investigate the transmit properties, for example, multiple mixers can be operated simultaneously on the oscilloscope. The setup is similar to that for single-channel analysis; the LO signal simply has to be distributed to all the mixers (Fig. 1).

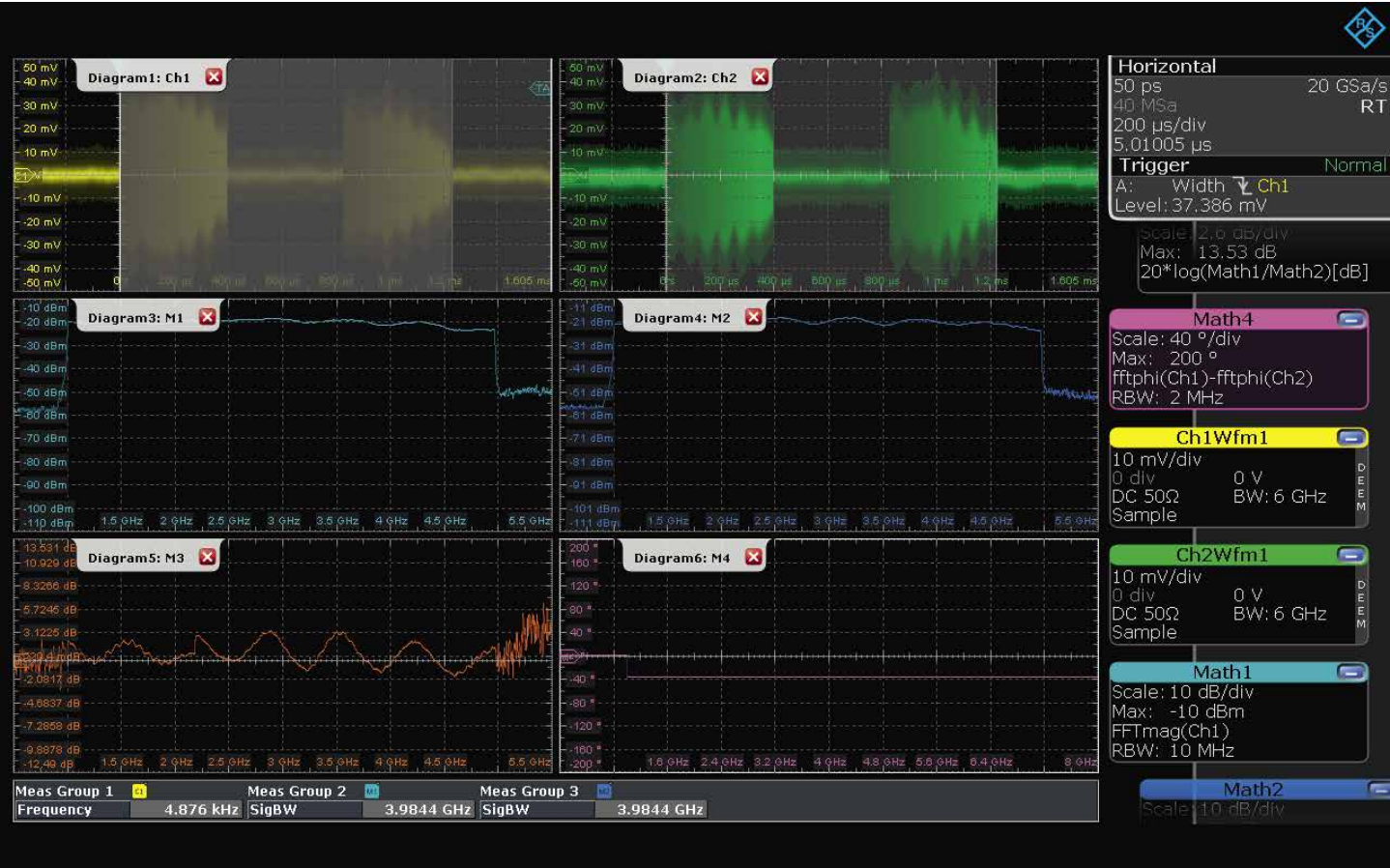
When used as a phase coherent receiver, the oscilloscope analyzes multiple signals relative to each other. Typically, the phase differences and difference between the two spectra are analyzed. The FFT function of the R&S®RTP is also helpful. It is used to calculate the amplitude spectra of the signals in the two channels. The difference is then calculated with another math function and displayed.

For the phase measurement, the analysis range is limited to a narrow time corridor, and the phase difference of the two input channels is calculated from the phase properties determined by FFT (Fig. 5). The advantage of the indirect method using FFT is the larger time analysis range. Whereas a single measurement of the phase difference in the time domain can be strongly dominated by noise, in the frequency domain multiple signal periods are compared with each other, resulting in a significantly smaller measurement uncertainty.

Debugging by correlating radar signals with other signals

The R&S®RTP can measure the amplitude and phase differences of multiple antenna paths signals simultaneously and correlate the radar signals with other signals, such as the supply voltage or digital bus signals (Fig. 6). Simultaneously acquiring CAN bus or automotive Ethernet

Fig. 5: Multichannel measurement of a chirp sequence. The pulses are shown in the time domain (top), the spectra of the individual channels in the middle, and the amplitudes and phase difference are shown on the bottom left and bottom right, respectively.

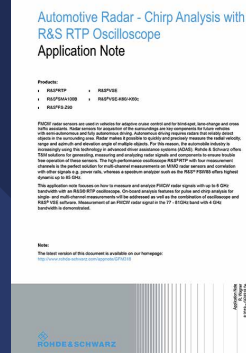


signals together with radar signals is particularly helpful during development and debugging. The analysis time of the radar sensor can be determined from the delay between the radar signal and the bus protocol signal. If the measured delay exceeds a specified time, deployment in autonomous vehicles is not acceptable.

Summary

The R&S®RTP oscilloscope is ideal for characterizing the new generation of radar sensors. The radar signals are either acquired directly from the radar sensor as baseband signals or down-converted by a mixer to the oscilloscope's bandwidth. The oscilloscope's advanced trigger and analysis tools and the powerful R&S®VSE pulse analysis software facilitate characterization and debugging.

Dr. Ernst Flemming, Dr. Andreas Ritter



Analysis of radar signals is described in detail in the application note “Automotive Radar – Chirp Analysis with R&S®RTP Oscilloscope”.

Fig. 6: Measurement of the delay between the radar signal (left) and the CAN protocol frame (right). The oscilloscope triggers on the radar signal and, using the “Trigger to Frame” function, measures a delay of 9.54 ms from when the radar signal is transmitted to when the protocol transfer starts (bottom).



REALISTIC RADAR SIGNALS FOR THE TEST RANGE

A vector signal generator and simulation software deliver highly complex radar signals for testing ELINT and radar warning receivers



Ongoing progress in the fields of radar electronic intelligence (ELINT) and radar early warning create ever more challenges for radar receiver testing. Radar receivers must be able to handle complex, densely packed radar scenarios. The solution presented here can generate these scenarios.

ELINT systems are used to collect and analyze unknown radar signals, while the task of radar warning receivers is to instantly identify and evaluate radar signals so that countermeasures can be initiated immediately in case of danger. Both types of products must demonstrate their capabilities in lab and field tests before their operational deployment. This calls for specific test signals in order to create realistic and representative signal environments for the equipment under test.

Rohde & Schwarz offers a suitable solution based on its R&S®SMW200A vector signal generator. The generator together with the PC based R&S®Pulse Sequencer software delivers a powerful radar simulator and provides everything needed for thorough testing. The simulator generates densely packed scenarios with multiple complex, high-resolution radar signals for use in all test phases in the equipment lifecycle, from early design tests in the lab and integrated system tests in production to tests in the field and during maintenance.

Radar simulation in the lab

The radar simulator can generate all current and future radar signals. For lab tests, the user simply connects the generator's RF output to the DUT input (Fig. 1). The radar signals are configured in the R&S®Pulse Sequencer software, which offers a multitude of functions and provides signals with up to 3.3 million pulses per second from one or more static or moving emitters. Simulation of colliding pulses (pulse-on-pulse situations), which occur when multiple radars transmit simultaneously, creates a highly realistic scenario in the lab.

Radar warning receivers use input signals from multiple antennas to determine the direction of arrival (DOA) of a signal from an emitter. This functionality can also be tested in the lab. For this purpose, multiple generators are coupled, and the signals to be applied to each antenna element are calculated and played synchronously.

Fig. 1: Compact, powerful radar simulator for the lab. The setup consists of an R&S®SMW200A vector signal generator and PC based R&S®Pulse Sequencer software.



Key features

- ▶ Precise simulation of multiple, individually configurable radar emitters (movements, modes)
- ▶ Generation of up to 3.3 million pulses per second
- ▶ Complex I/Q modulated pulses, including AMOP, FMOP, PMOP, and linear and nonlinear chirps
- ▶ Simulation of scenarios with colliding pulses (pulse-on-pulse situations)
- ▶ Definition of pulse-to-pulse and burst-to-burst RF agility through any interpulse modulation
- ▶ Configuration of up to 256 emitters
- ▶ Definition of antenna patterns and scans
- ▶ Definition of moving and static emitters
- ▶ Coupling of multiple generators to test DF capability



Fig. 2: OTA live demonstration at Tartu Airport in Estonia.

Radarsimulation on the test range

At the EW Live 2019, a regularly occurring event that took place in Tartu, Estonia, this year, the expert audience received an impressive demonstration of the radar simulator’s performance (Figs. 2, 4 and 5). The simulator was operated in an over-the-air (OTA) setup covering a free-space distance of 1.3 km to the ELINT and radar warning receivers. Signals in the frequency range from 3 GHz to 10 GHz were generated.

The signal source was an R&S®SMW200A with two RF paths up to 20 GHz, controlled by the R&S®Pulse Sequencer software. Four compact R&S®SGT100A RF sources were also integrated into the system to simulate additional radars up to 6 GHz. This setup allowed the creation of scenarios with ten simultaneous radar emitters.

An R&S®BBA150 broadband amplifier for signals up to 6 GHz and two R&S®AC008 microwave directional antennas with different feeds were used to cover the distance to the receivers. The signals up to 6 GHz were added in an RF combiner, and the resulting signal was amplified and applied to one of the directional antennas. The X band signals were radiated by the second antenna. Due to the higher antenna gain in the X band, no additional amplifier was needed.

Fig. 3 shows a signal plan for the dual-path R&S®SMW200A. The generator’s large internal modulation bandwidth of 2 GHz makes it possible to generate radar signals from multiple emitters in a single RF path. In this scenario, the simulator generates six radar signals simultaneously (three per RF path). The R&S®Pulse Sequencer software uses an algorithm to interleave signals

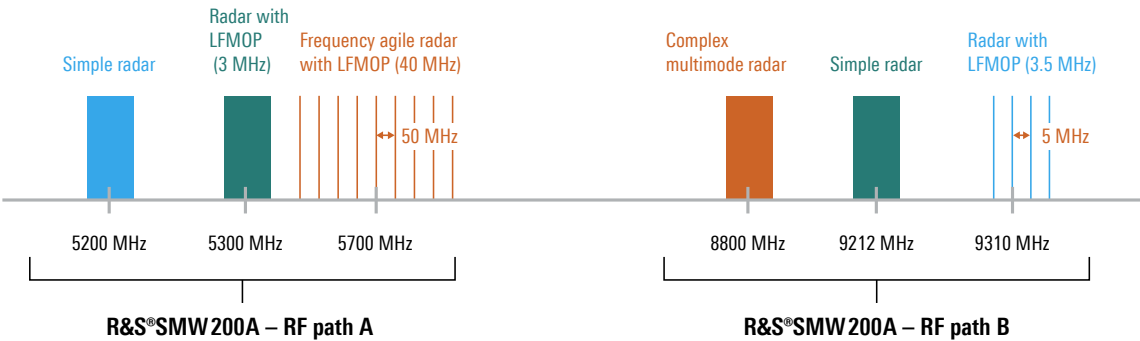
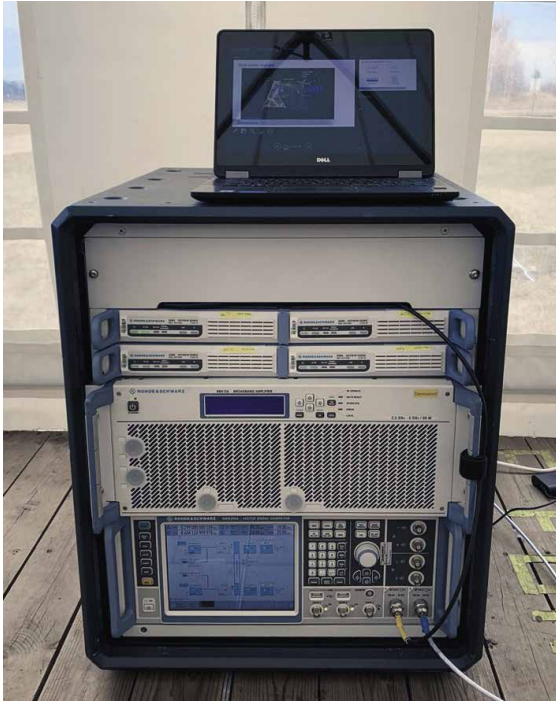


Fig. 3: Example signal plan for the EW Live 2019 in Tartu. The two RF paths of the R&S®SMW200A generator simulate six radar emitters of different complexity in two frequency ranges.

within a path and to reject colliding pulses based on a user-defined priority scheme. The signals are arranged to minimize the number of dropped pulses.

Fig. 4: The signal generators and amplifier fit into a small rack. The R&S®Pulse Sequencer software runs on a commercial laptop.



In RF path A, signals from radar systems with operating frequencies between 5 GHz and 6 GHz were simulated, while RF path B was used to generate radar signals in the 9 GHz range. By splitting radar signal generation between two paths, it is possible to create very realistic scenarios, including those with colliding pulses.

The signal plan defines different radar signal types, from simple, unmodulated pulses to complex I/Q modulated pulses (e.g. AMOP, FMOP, PMOP, chirps and Barker coded pulses). Diverse interpulse modulation profiles such as pulse repetition interval (PRI) staggering and frequency hopping are used in addition. A complex multi-mode radar featuring frequency and time agile operation as well as diverse antenna patterns and scans is also included.

The radar simulator live demonstration has shown that radar field tests are possible at a high performance level and relatively low cost and effort using standard components. Equipment suppliers and users can very quickly install a setup at any desired location and verify the performance of their systems.

Sebastian Kehl-Waas

Fig. 5: Transmitter station accommodated in a tent with two R&S®AC008 microwave directional antennas set up outdoors.



TARGETING ELECTROMAGNETIC INTERFERENCE

Reliable precompliance tests even on a limited budget

The R&S®FPL1000 general purpose spectrum analyzer is now encroaching on the domain of specialized instruments. With the EMI measurement application, it gets right to the bottom of a DUT's EMC behavior.

Fig. 1: A wide range of measurement functions combined with high accuracy make the R&S®FPL1000 suitable for all standard measurements in development, service, production, research and education.



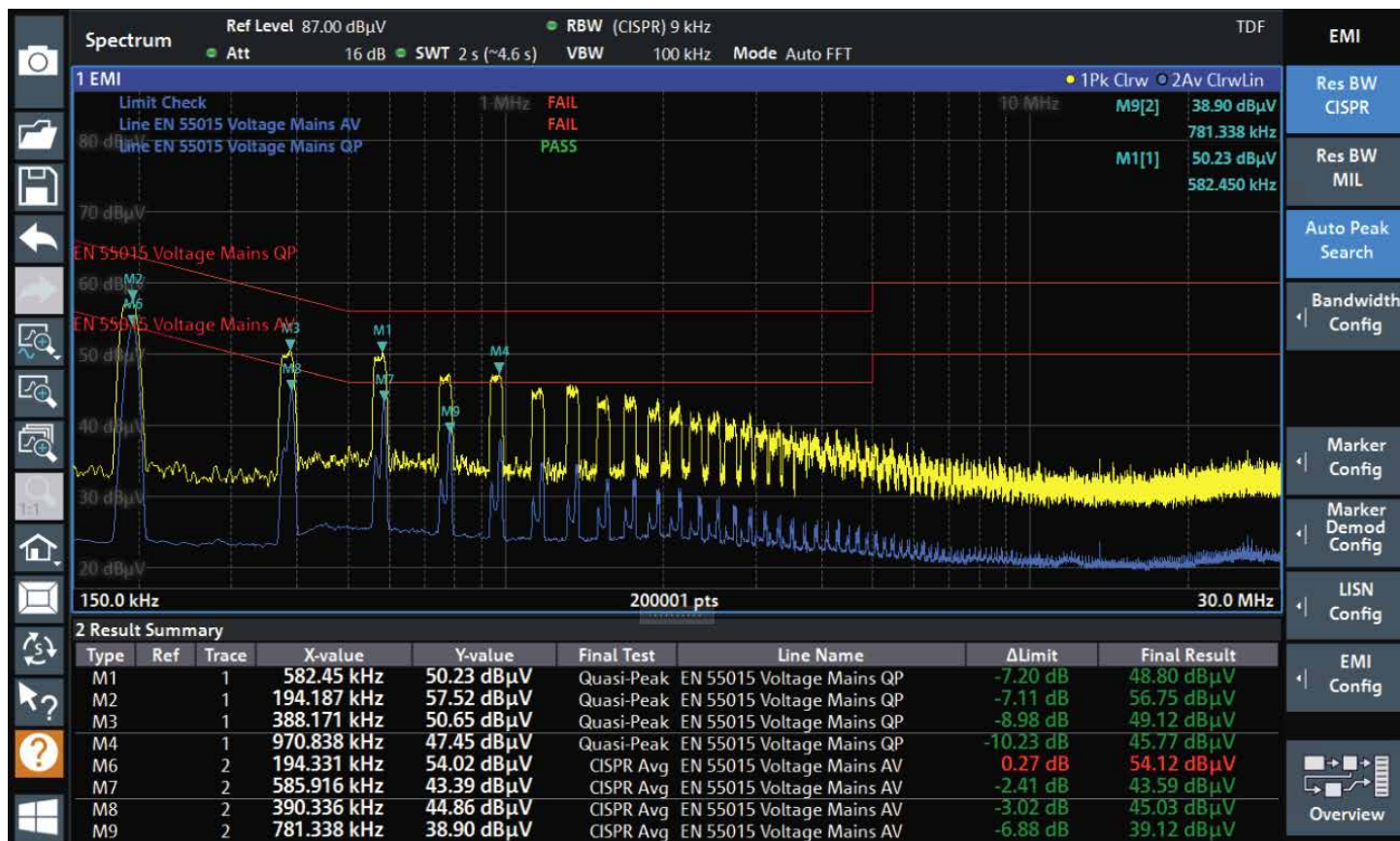


Fig. 2: Sample measurement with the R&S®FPL1-K54 EMI measurement application option. Two detectors are used for the sweep: positive peak (yellow trace) and average (blue trace). In accordance with the selected standard, limit lines indicate out-of-limit conditions (red). Identified maxima (Auto Peak Search) are listed in the table. Measurement results from the automatic final test (quasi-peak and CISPR-average) are also included with a final result.

The R&S®FPL1000 spectrum analyzer (Fig. 1) boasts features that were previously unavailable in its price class (see also the article starting on page 36). The R&S®FPL1-K54 EMI measurement application option extends its functionality for EMI applications to cover detection of conducted and radiated interference (Fig. 2) up to a frequency of 3 GHz (R&S®FPL1003) or 7.5 GHz (R&S®FPL1007). Thanks to the spectrum analyzer's sophisticated RF signal processing, its measurement results are often very close to the results obtained with specialized (and much more expensive) EMI and compliance test instruments. This makes the R&S®FPL1000 a cost-effective solution for precompliance applications.

Measurements in line with all common standards

In spectrum analyzers, the filter shape and width can normally be selected from a wide range of predefined values. The width of the RBW filters for common analyzers is determined based on the filter 3 dB points. For EMI measurements, however, the standards require special filters with 6 dB points, thus necessitating steeper filter edges. These filters are defined

in the CISPR 16-1-1 and MIL-STD-461 standards (CISPR 16-1-1: 200 Hz, 9 kHz, 120 kHz and 1 MHz; MIL-STD-461: 10 Hz, 100 Hz, 1 kHz, 10 kHz, 100 kHz and 1 MHz). They are all included with the R&S®FPL1-K54 option.

CISPR 16-1-1 also defines EMI-specific detectors: quasi-peak, CISPR-average and RMS-average. The quasi-peak detector was introduced to model the effect of interference on analog (AM) radio reception based on the pulse repetition frequency. The perceived interference decreases at lower pulse repetition frequencies. As a result, interference levels for low pulse repetition frequencies are displayed as lower values than when using the peak detector. The quasi-peak detector thus never produces higher values than the peak detector. It requires a minimum measurement time of 1 s according to the standard.

Like the quasi-peak and RMS-average detectors, the CISPR-average detector has a time constant in order to model the display behavior of an analog meter (for compatibility with older analog instruments). This can lead to higher values being displayed than with the RMS-average detector. The latter is used to model the effect of

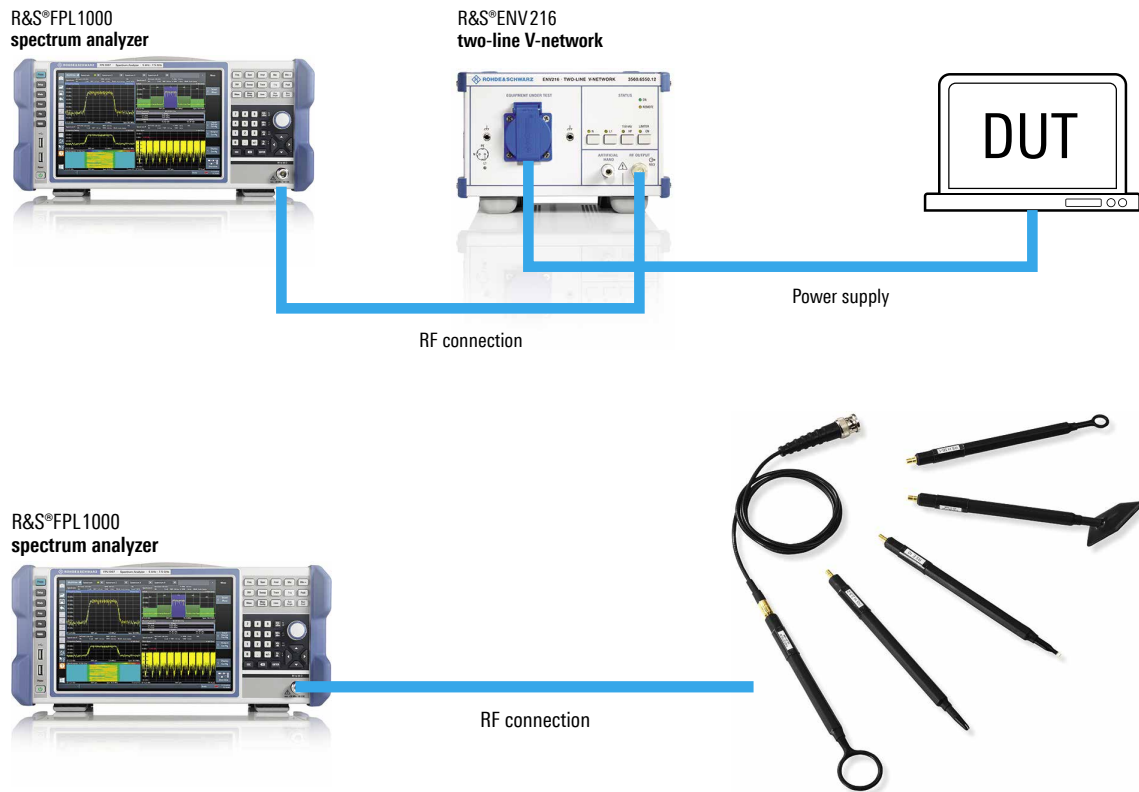


Fig. 3: Top: conducted measurements with two-line V-network.
Bottom: radiated measurement with probes.

interference on digital radio reception based on the pulse repetition frequency.

The R&S®FPL1-K54 option includes all three of these detectors.

According to the CISPR standard, an EMI test instrument must correctly measure the levels of specially defined pulses with repetition rates ranging to a single pulse within certain tolerances. Single-pulse measurements can be performed only by specialized instruments with a very wide dynamic range, which generally entails (costly) preselection. However, if the DUT only generates pulses with repetition rates ≥ 20 Hz, less costly instruments such as the R&S®FPL1000 are also capable of performing standards-compliant measurements.

Conducted and radiated interference

The main purpose of EMI measurements is to compare the disturbance signals produced by the DUT with the applicable limits. Conducted disturbance signals, e.g. on connected power and data cables, as well as radiated disturbance signals are measured (Fig. 3). The applicable limits and frequency range are specified in

the different product standards. For commercial products, the frequency range for conducted measurements is between 9 kHz and 30 MHz, while the range for radiated measurements is between 30 MHz and typically 6 GHz. The 7.5 GHz model (R&S®FPL1007) supports the majority of product standards in the commercial sector. Some DUTs can also be tested in line with MIL-STD-461.

More than 130 limit lines are included in the R&S®FPL1-K54 option, allowing the analyzer to independently detect and mark out-of-limit conditions. The instrument typically makes preview measurements with the positive peak detector, automatically detects the peaks and then remeasures them with an individually configurable detector. This is especially useful in cases where the standard dictates use of a detector with a longer measurement time, e.g. the quasi-peak detector. The longer measurement time is required only for the critical peaks.

Additional functions for EMI applications

The R&S®FPL1-K54 option equips the spectrum analyzer with additional functions that are useful in EMI applications (requiring further options

in some cases). Using the tracking generator, transducer factors for components such as cables and adapters can be easily determined and stored in the instrument. The R&S®FPL1000 automatically corrects the measured level to compensate for the influence of the components. The built-in loudspeaker allows AM or FM demodulation of signals on selected frequencies for acoustic analysis.

For disturbance voltage measurements, the DUT is connected to a line impedance stabilization network (LISN). This network supplies power to the DUT, simulates a standardized load impedance, decouples the RF disturbance voltage for measurement and decouples the measuring circuit from line disturbances. The R&S®FPL1000 supports remote control of a connected LISN such as the R&S®ENV216 two-line V-network. This simplifies performing the measurement in case of a large distance between the test instrument and the LISN.

Thanks to the DC voltage input as well as the ability to power the instrument from a built-in battery pack, the analyzer can also be deployed in mobile applications, e.g. in vehicles. For use

in larger test systems or for software-guided EMI measurements, the analyzer can be integrated into the R&S®ELEKTRA test software.

The EMI measurement application option is also available for other, more powerful spectrum analyzers (Fig. 4). For these analyzers, Rohde & Schwarz offers calibration of the CISPR detectors. If it is certain that the DUT does not emit any pulses with a repetition rate below 20 Hz, these calibrated spectrum analyzers can also be used for standards-compliant EMI measurements.




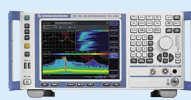

Report function coming soon

Extension of the EMI measurement application to include a report function is planned for the start of 2020. The extension will be available as a free firmware update for the R&S®FPL1000 (including previously delivered analyzers).

The EMI software is preinstalled by default and can be activated with a keycode. For further details, refer to the option sheet (internet search: "FPL1000 option sheet").

Thomas Tobergte

Fig. 4: Tabular overview of spectrum analyzers for which the R&S®x-K54 EMI measurement application option is available.

Type	R&S®FSW	R&S®FSVA	R&S®FSV	R&S®FSVR	R&S®FPL1000
					
Lowest frequency	2 Hz	10 Hz	10 Hz	10 Hz	5 kHz
Highest frequency (depending on model)	8 / 13.6 / 26.5 / 43.5 / 50 / 67 / 85 GHz	4 / 7 / 13.6 / 30 / 40 GHz	4 / 7 / 13.6 / 30 / 40 GHz	7 / 13.6 / 30 / 40 GHz	3 / 7.5 GHz
Calibration certificate (pulse repetition rate > 20 Hz)	■	■	■	■	—
Meas. points per trace (with R&S®x-K54 option)	Up to 100 001 / 200 001	Up to 32 001 / 200 001	Up to 32 001 / 200 001	Up to 32 001 / 200 001	Up to 100 001 / 200 001
Real-time spectrum analysis (persistence display, spectrogram, frequency mask trigger)	Up to 800 MHz	—	—	Up to 40 MHz	—
Tracking generator	Control of external generators	■	■	—	■
DC operation	—	■	■	—	■
Battery operation	—	■	■	—	■

FOR LAB AND FIELD

If you are looking for a first-class universal RF T&M instrument, the R&S®FPL1000 is the right choice

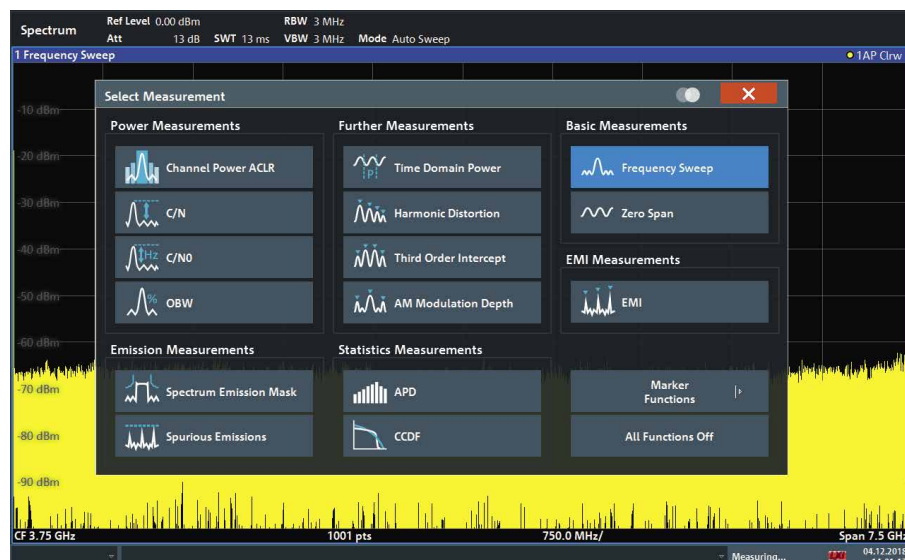
Fig. 1: With suitable power sensors, the R&S®FPL1000 also delivers precise power measurements.



Impressive performance wherever you need it

Even in its basic configuration, the R&S®FPL1000 (Fig. 1) is a true all-rounder. In addition to classic spectrum analysis, the instrument provides functions such as spectrogram measurements and a wealth of spectral measurements, including CP, ACLR, C/N, C/N₀, OBW and many more (Fig. 2), plus gated sweep measurements for pulsed signals. Additional measurement functions, such as analysis of analog and digitally modulated signals and amplifier measurements (noise factor, gain, Y factor), are available as options.

Fig. 2: Various advanced spectrum measurement modes are supported as standard.



The R&S®FPL1000 signal and spectrum analyzer packs a lot of performance into a very compact design. This handy instrument not only offers numerous spectrum measurement functions, it also analyzes digitally modulated signals and measures power with high precision. It can even be battery powered.

The R&S®FPL1000 offers excellent specifications that make it unique in its class. Noteworthy features include phase noise of -108 dBc (10 kHz offset, 1 GHz carrier), third-order intercept (TOI) of $+20$ dBm and, thanks to the built-in preamplifier, a displayed average noise level (DANL) of -167 dBm (10 MHz to 2 GHz).

The instrument is only 235 mm deep, leaving plenty of bench space for the DUT. The 10.1" display visualizes multiple measurements simultaneously in MultiView mode. The user interface is simple and intuitive. Weighing only 6 kg (including battery pack and carrying bag), the R&S®FPL1000 is also convenient for use in the field.

Signal analysis up to 7.5 GHz

The R&S®FPL1000 comes in two base models with frequency ranges from 5 kHz to 3 GHz and 7.5 GHz. The base models can be enhanced with a variety of options, such as AM/FM/φM analog demodulation, noise figure measurements and EMI measurements (see article starting on page 32), to suit individual measurement tasks. Two options are described in more detail below.

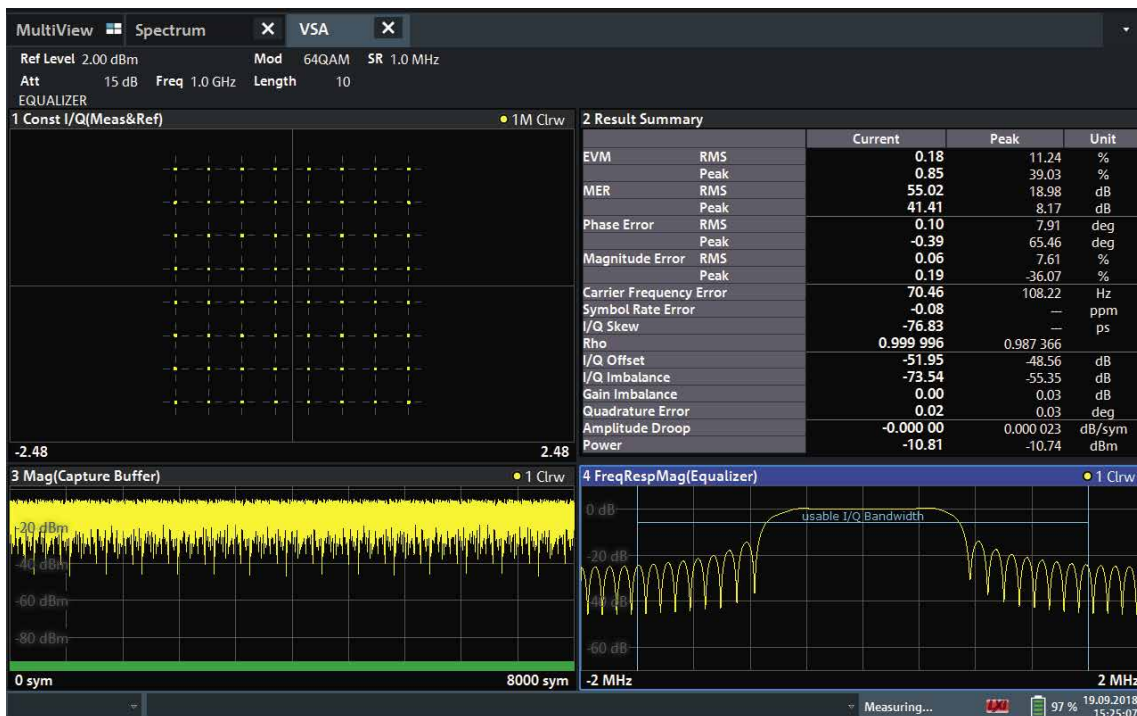


Fig. 3: With the vector signal analysis option, the R&S®FPL1000 analyzes digitally modulated signals in detail, as shown here with a 64QAM signal.

Vector signal analysis

The R&S®FPL1-K70 software option supports demodulation of digital signals, from simple MSK to 4096QAM signals, with up to 40 MHz analysis bandwidth. It can also demodulate numerous standard formats, including Bluetooth®, Zigbee, DECT, DVB-S2, and many more. Users can also define their own modulation formats and save them as standard measurements. The R&S®FPL1-K70 option includes a digital equalizer for channel response correction and I/Q error correction, and displays measured values in graphic and tabular form (Fig. 3).

The R&S®FPL1-K70M multi modulation analysis option extends the R&S®FPL1-K70 option to support DVB-S2X modulation analysis. The R&S®FPL1-K70P option, another extension to the R&S®FPL1-K70, adds bit error ratio (BER) measurement capability.

Scalar network analysis with internal signal generator

The R&S®FPL1-B9 internal signal generator hardware option comes in two variants with frequencies up to 3 GHz and 7.5 GHz for the two R&S®FPL1000 models. It can be operated as an independent CW source or as a tracking generator (Fig. 4). The generator's spectral purity and wide level range from -60 dBm to +10 dBm enables measurements with a large dynamic range.

Fig. 4: Dialog box for configuring the internal generator.

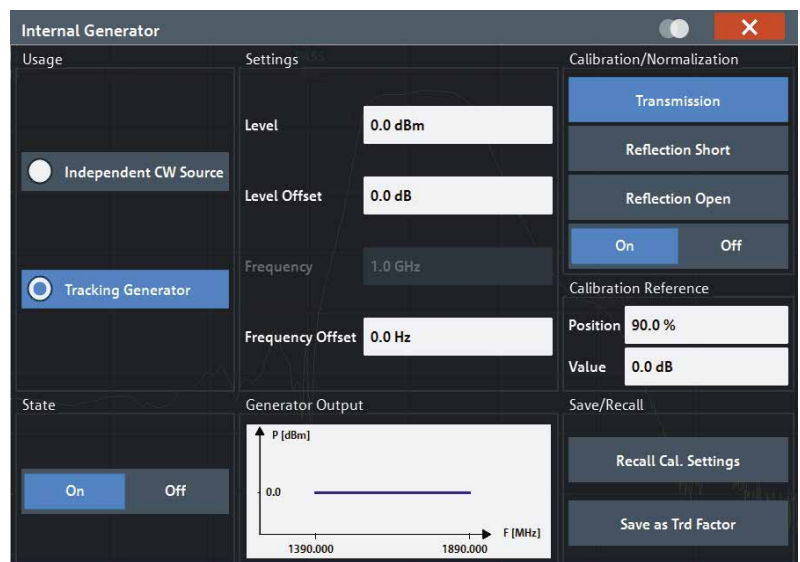




Fig. 5: Measurement of a SAW filter. The filter passband and quality are determined, and compliance with relevant requirements is verified using a filter mask.

Using the option as a CW source, users can easily determine the harmonics of active components. When operated as a tracking generator, the option delivers scalar network analysis functions – e.g. measuring the frequency response of a bandpass filter, which is displayed in absolute or normalized values. Various calibration methods (transmission, short, open) are available to correct e.g. the loss occurring on RF cables to the DUT.

Numerous standard functions simplify measurement analysis and automation. These include the “n-dB down” marker function for checking filter passbands, as well as a filter mask (limit lines) for verifying filter compliance with relevant requirements (Fig. 5).

Summary

The small footprint, independence from the power grid, wealth of measurement functions and high precision make the R&S®FPL 1000 a true allrounder for use in development, service and production, as well as in education, labs and the field.

Klaus Theißen

10 GBIT/S IN REAL TIME

Signal integrity tests and debugging on digital interfaces

High speed interfaces such as USB 3.1 Gen1/2, PCI Express Gen2/3 or DDR3/4 require capable T&M equipment for startup and debugging during development. The new R&S®RTP oscilloscopes provide all the features and functions necessary to effectively and accurately handle these tasks.

Testing serial interfaces with data rates up to 10 Gbit/s

The USB and PCI Express interfaces in many electronic devices, as well as display and camera interfaces with high data rates, require lab T&M equipment for development that can keep pace. In the design of high speed modules and interfaces, it is necessary to ensure that signal paths through connectors, PCB tracks, vias, etc. are properly dimensioned to avoid impairing the targeted maximum data rate and minimum error-free transmission time (bit error rate).

Real-time oscilloscopes are ideal for the required signal integrity measurements. However, their bandwidth must be at least three times the fundamental frequency of the digital signal. For example, measurements on a third generation PCI Express interface with a maximum data rate of 8 Gbit/s require a 12 GHz oscilloscope, and 15 GHz bandwidth is needed for USB 3.1 Gen2 with 10 Gbit/s signals. For protocol data decoding, the measurement bandwidth should match the data rate of the interface being tested.

Fig. 1: R&S®RTP164 oscilloscope (16 GHz) with R&S®RT-ZM160 probe (16 GHz).



Fig. 2: Data eye of a 5 Gbit/s USB signal using CDR based triggering.

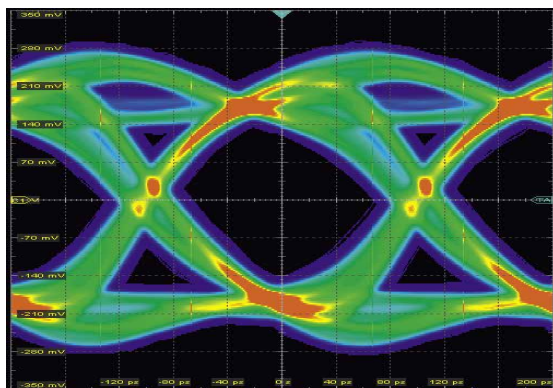


Fig. 3: Settings for the serial pattern trigger with hardware CDR for fast and continuous eye diagram tests.

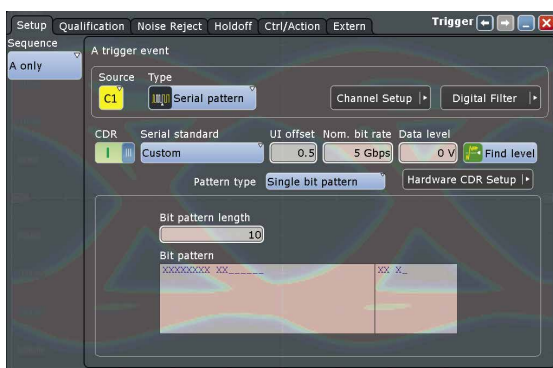


Fig. 4: Using vertical and horizontal histograms to investigate the jitter and noise behavior of a third generation PCI Express signal (8 Gbit/s).

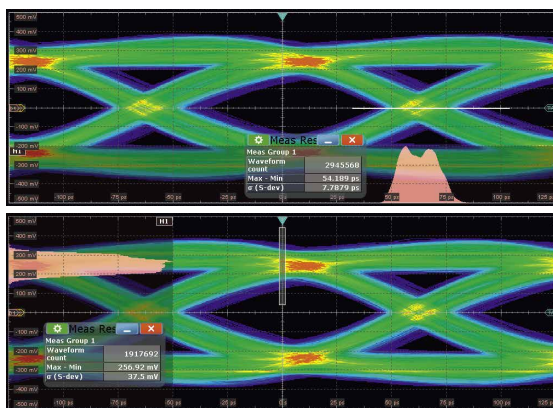
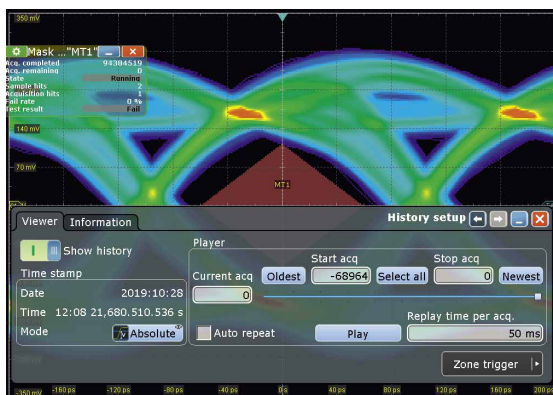


Fig. 5: Acquisition stopped after a mask violation and history viewer for accessing waveforms in the acquisition memory.



The new oscilloscopes in the R&S®RTP family (Fig. 1), with bandwidths of 13 GHz or 16 GHz, are suitable for measurements on typical high speed interfaces with data rates up to 10 Gbit/s. Unlike typical high-end instruments from other manufacturers, the compact design and whisper-quiet operation of the R&S®RTP make it very suitable for long-term lab use.

Integrated hardware clock data recovery for fast eye diagram tests

Eye diagram tests are one of the main tools for assessing transmission quality. Error-free data transmission can only be confirmed by an open eye diagram. However, the jitter (signal edge deviations on the time axis) and noise (signal level deviations) must be observed over an extended period to obtain statistically adequate measurement reliability. This is very time-consuming with existing eye diagram functions because they can only perform eye diagram calculations for individual waveforms in postprocessing.

Eye diagram tests with the R&S®RTP oscilloscopes are hardware accelerated. The new R&S®RTP-K141 serial pattern trigger option includes integrated hardware clock data recovery (CDR) that supports data rates up to 16 Gbit/s. CDR extracts the embedded clock signal from the serial interface signal and can be selected for every input channel of the oscilloscope. The extracted clock signal acts as a time reference for triggering and displaying the waveform and eye diagram. With this CDR based triggering, the oscilloscope “sees” the data exactly the same way as the serial interface receiver, which also uses CDR. Fig. 2 shows an example eye diagram with CDR used as the trigger reference.

If the user selects an “X” as the trigger condition with CDR based triggering, the symmetrical eye diagram of the interface signal is displayed on the screen by superimposing arbitrary bits (Fig. 3). The R&S®RTP has the highest acquisition rate commercially available and achieves up to 750,000 waveforms per second, so the eye diagram is quickly formed from superimposed bit sequences to provide statistical results and infrequent errors are quickly detected.

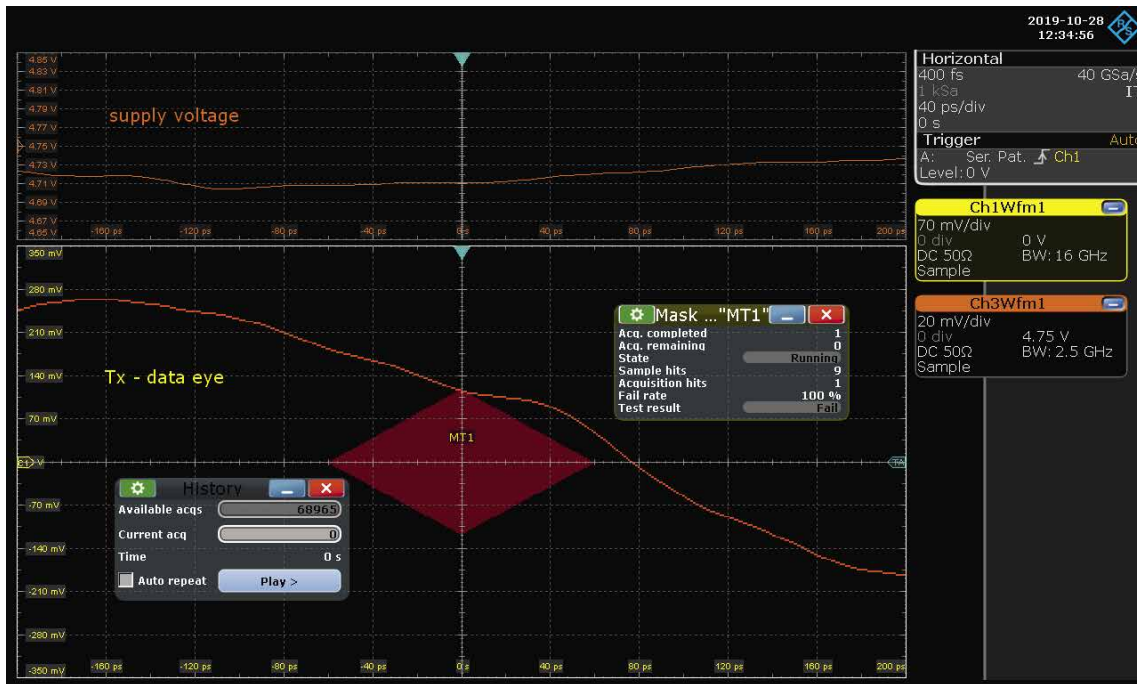


Fig. 6: Root cause analysis with the history viewer: time-correlated analysis of the high speed signal and the supply voltage for all waveforms in the acquisition memory.

Histogram measurements for jitter and noise

Tools such as mask testing or the histogram function are available for further eye diagram analysis. These analysis functions of the R&S®RTP run in hardware, enabling users to benefit from the oscilloscope's fast acquisition rate without restriction.

Fig. 4 shows the jitter and noise behavior of a PCI Express signal (8 Gbit/s). This is obtained by taking vertical and horizontal histograms of the eye diagram. The jitter histogram shows a bimodal characteristic, which arises from deterministic jitter. The standard deviation, which is dominated by random jitter, can also be determined by automatic measurements on the histogram. This data provides important insights regarding the signal integrity of the interface under test.

Masking tests capture intermittent errors

Intermittent errors in a serial interface can be detected by observing a continuous eye diagram based on the embedded clock signal. Masks in the eye diagram are defined for this purpose. Violation of the mask area by a signal waveform indicates an error. If the oscilloscope is configured to stop on violation, it terminates acquisition for further analysis (Fig. 5). The

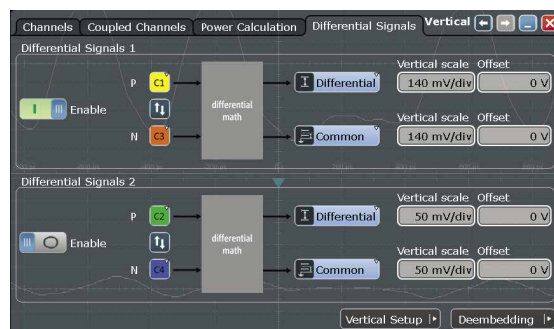


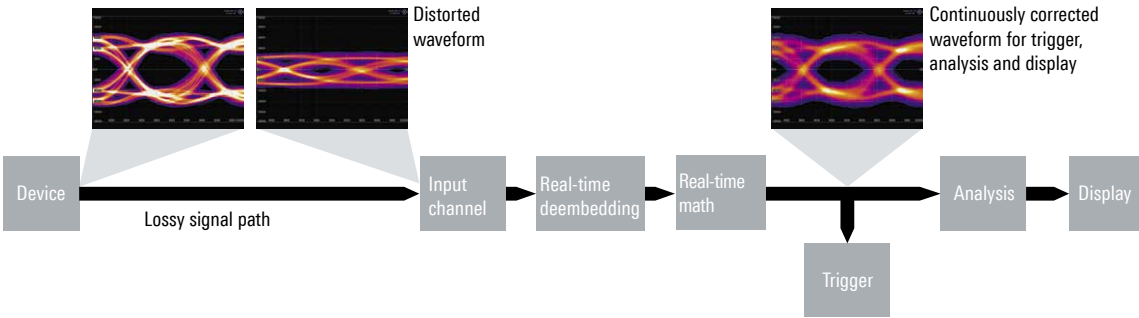
Fig. 7: Dialog box for real-time calculation of the differential and common mode signals.

history function can be used to access previous waveforms in the acquisition memory in order to deduce the root cause of the error, which may involve other signals such as the supply voltage. Fig. 6 shows an example where a marginal mask violation by the high speed signal coincides with a supply voltage dip.

Differential signal math in real time

High speed serial signals are usually carried over differential lines. Depending on the contact options, differential signals can be measured either with a differential probe or by connecting two separate lines to two input channels of the oscilloscope.

Fig. 8: Equalization filter and differential math in the real-time path ahead of the digital trigger system.



For measurements with two channels, the R&S®RTP offers an innovative function for calculation of differential signal components (Fig. 7). As a special feature, the math module immediately follows the A/D converter and equalization filter in the acquisition path (Fig. 8). The user can select any two oscilloscope channels as the input signals. The differential and common-mode signals are both available for further processing and analysis.

The Rohde&Schwarz digital trigger system uses the data from the A/D converter, which can optionally pass through the user-defined equalization filters and the math module. For the first time, users can trigger on the corrected differential signal component, for example to track down errors in the common-mode signal faster.

Targeted triggering on protocol data with the serial pattern trigger

Along with signal integrity testing for circuit commissioning, it is also frequently necessary to analyze the data of high speed serial interfaces at the protocol level. This is necessary if, for example, state machine errors occur when the data link is booted. The new serial pattern trigger option allows users to trigger on the data sequences of specific protocols (Fig. 9). It supports decoding schemes such as 8-bit/10-bit (e.g. USB 3.1 Gen1 and PCI Express Gen2 up to 5 Gbit/s) or 128-bit/132-bit (e.g. USB 3.1 Gen2 at 10 Gbit/s). Another important aspect is that the embedded clock signal recovered by hardware CDR provides the time reference for the serial trigger.

Fig. 9: Serial pattern trigger with 8-bit/10-bit decoding.

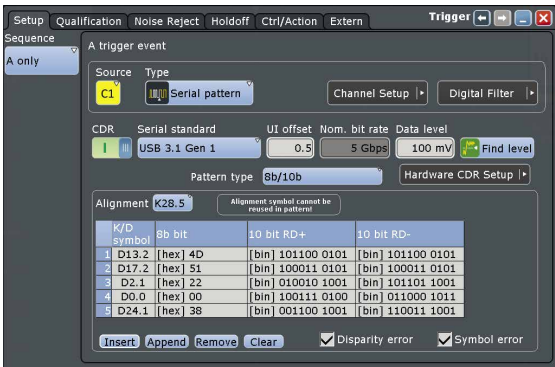
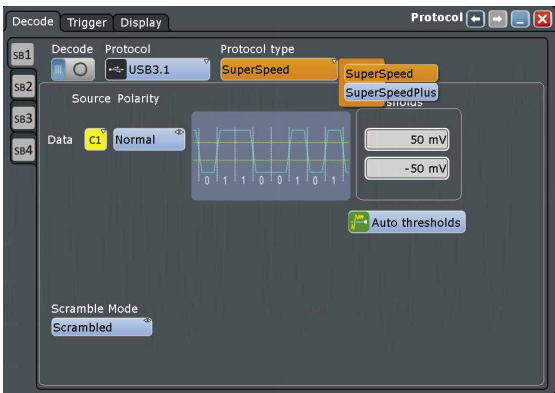


Fig. 10: Dialog box of the USB 3.1 (Gen1 and Gen2) trigger and decoding option.



USB 3.1 Gen1 and Gen2: triggering and decoding

A large number of trigger and decoding options are available for the R&S®RTP to support debugging of data streams even at higher protocol levels. The market launch of the R&S®RTP models for 13 GHz and 16 GHz was accompanied by the launch of the new trigger and decoding option for USB 3.1 Gen2. This allows detailed analysis of the protocol elements of the USB Super Speed Plus interface, with a data rate of 10 Gbit/s (Fig. 10).

Modular probes

The R&S®RT-ZM family of modular probes has been extended with two new models with 13 GHz or 16 GHz measurement bandwidth and rise time less than 35 ps or 28 ps, respectively (Fig. 11). Each individual probe is precisely measured in production. The characteristics defined by the S-parameters are stored in the EEPROM of the probe connector housing and used by the oscilloscope for correction. This enables the R&S®RT-ZM modular probes to achieve excellent RF performance with a flat frequency response. They also boast low input capacitance (77 fF, measured) and an unusually large DC offset range of ± 16 V.

At high frequencies, solder-mount fittings are usually used for contacting the probes to test points. The new R&S®RT-ZMA14 probe tip module with interchangeable solder-mount flex connect tips extends the contact options of the modular probes. The flex connect tips allow fast switching between different contact points. The R&S®RT-ZMA14 comes with ten flex connect tips. Additional tips are available as service parts.

Option bundle for signal integrity tests

The functions and options of the R&S®RTP make it ideal for debugging high speed serial interfaces. A signal integrity bundle (R&S®RTP-SIBNDL) simplifies the selection of suitable options. It contains:

- ▶ Jitter analysis (R&S®RTP-K12)
- ▶ Zone trigger (R&S®RTP-K19)
- ▶ Deembedding base option (R&S®RTP-K121) and deembedding real-time extension (R&S®RTP-K122)
- ▶ 16 Gbit/s high speed serial pattern trigger (R&S®RTP-K141).

Summary

The new R&S®RTP oscilloscopes with 13 GHz and 16 GHz bandwidth offer unparalleled support for startup and debugging of electronic circuits with fast digital interfaces, such as USB or PCI Express, with data rates up to 10 Gbit/s. Users benefit from the high acquisition rate and powerful functions for serial differential signals. The combination of real-time equalization and real-time math, serial pattern trigger with integrated 16 Gbit/s hardware CDR, and hardware based analysis tools provides a complete and powerful function chain specifically for effective signal integrity tests and debugging.

Guido Schulze

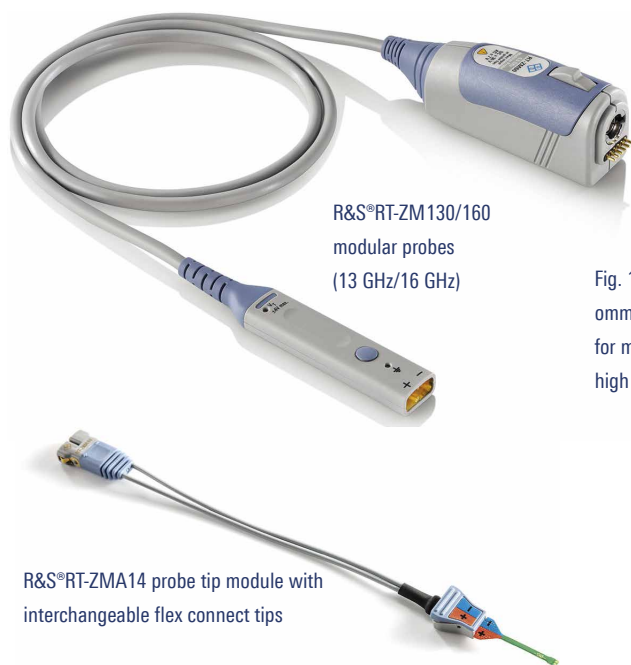
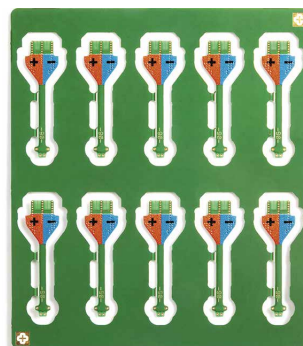


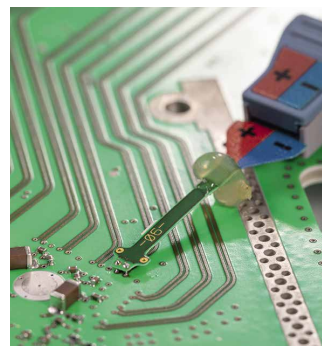
Fig. 11: Probes and recommended tip module for measurements on high speed interfaces.



Set of ten flex connect tips



Quick and reliable switching between different contact points with solder-mount flex connect tips.



SWISS ARMY KNIFE

A universal problem solver for countless RF measurement tasks

The R&S®NRQ6 frequency selective power sensor combines the accuracy of a power meter with the sensitivity of a measuring receiver. The latest extensions make it a universal tool for sophisticated 5G measurements.

Fig. 1: The R&S®NRQ6 frequency selective power sensor enables high-precision phase measurements on up to 64 RF ports with relatively moderate outlay.



"Inherited"
features:

Spectrum
analyzer

RF power
sensor

Network
analyzer

Component
tester

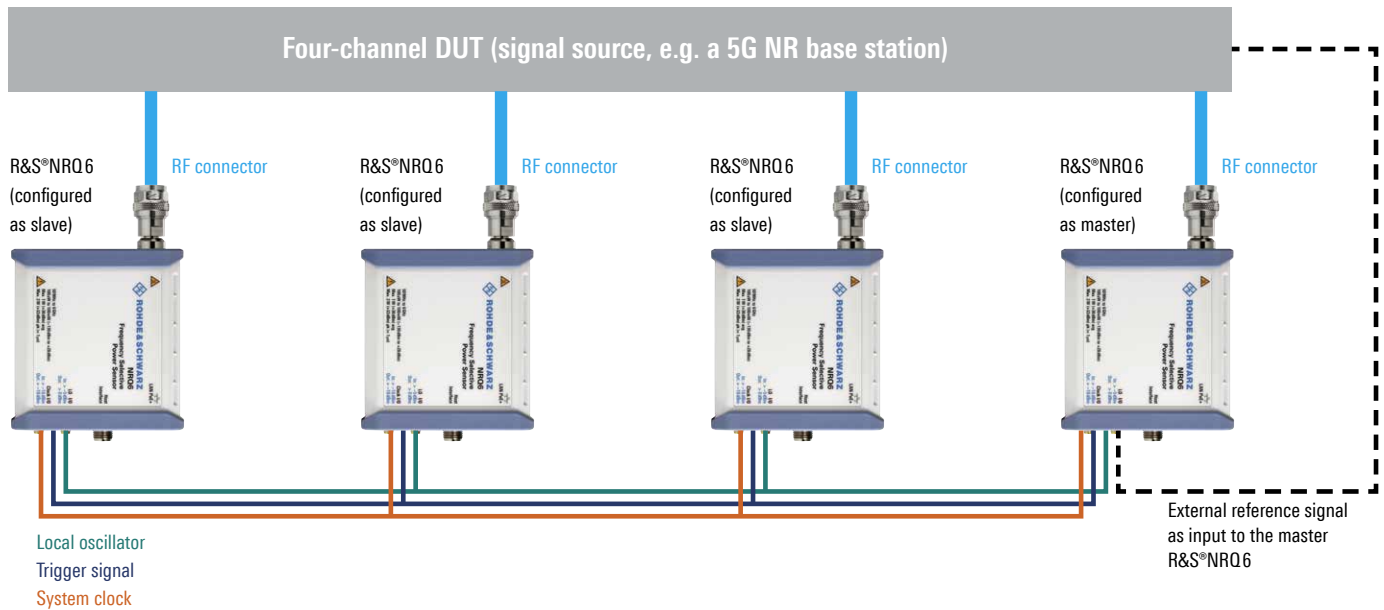


Fig. 2: Four-channel phase coherent measurement with four R&S®NRQ6 power sensors.

Phase measurement with the R&S®NRQ6-K3 phase coherent measurements option

Demands on test equipment are rising rapidly to be able to handle 5G NR, the latest generation of wireless communications. While the biggest challenges in the FR2 frequency band (24 GHz to 43.5 GHz) are microwave technology and the transition from conducted to over-the-air (OTA) test and measurement equipment, new approaches to phase measurement are required in the FR1 frequency band (450 MHz to 6 GHz).

Beamforming as a technology driver

This is due to using beamforming, which makes sure every device receives the radio signal intended for it at maximum power while attenuating the signals intended for other devices in the same direction. Although beamforming has a positive impact on data rate and coverage, it requires complicated phased array antennas, typically with 64 individual elements, for base stations. Manufacturers are therefore compelled to measure and evaluate the levels and phase angles of modulated RF signals at up to 64 ports during development and in production.

This demanding task cannot be handled by today's spectrum analyzers because they do not have coherent input channels, nor by network analyzers because they are not able to measure complex modulated RF signals. The only available solution up to now has been to use high-end oscilloscopes, which are not only high priced but also have the disadvantage of relatively low input sensitivity.

Precisely this niche is filled by the R&S®NRQ6 frequency selective power sensor (Fig. 1) with the R&S®NRQ6-K3 phase coherent measurements option. Its highly coherent design and compact size allow high-precision phase measurements on up to 64 RF ports with relatively moderate outlay.

Fig. 2 shows the basic setup with four measurement channels. One R&S®NRQ6 acts as the master and the others are configured as slaves. For RF phase measurements, all of the measurement channels must be consistently and coherently designed. A basic prerequisite is coupling of the individual baseband sections via shared system clock signals and trigger signals, as well as coupling of the RF sections via a shared local oscillator signal.

GENERAL PURPOSE

When a measurement is initiated, the master sends a trigger signal to all the slaves, which then start measuring simultaneously. The delay between the master and slave measurements and all other effects resulting from the cabling can be compensated with prior calibration. Calibration of the group delay and phase only has to be repeated after strong temperature variations, not after every measurement or sensor restart.

Alternatively, an additional R&S®NRQ6 can be used as the master. It does not make any measurements itself but distributes the signals symmetrically to all of the slaves. This makes calibration unnecessary, simplifying practical use.

High-precision phase measurement even with low signal levels

Fig. 3 shows the phase measurement accuracy of the R&S®NRQ6. The indicated standard deviations for phase measurements were measured at the maximum carrier bandwidth of 100 MHz for 5G FR1 and the very commonly used carrier frequency of 3.5 GHz.

With suitable splitters, the setup shown in Fig. 2 can easily be extended to as many as eight R&S®NRQ6 units or measurement channels. Even more channels are available if the trigger, system clock and local oscillator signals are amplified or an RF switch matrix is used e.g. to sequentially distribute 64 signals to eight R&S®NRQ6 units.

Of course, along with phase measurement the power sensors can also be used to measure power or modulation quality (EVM) (see page 47). Since phase measurement is based on analysis of the I/Q samples, it is even possible to measure power, EVM and phase with the same set of sample values.

Ultrafast characterization of RF amplifiers using the R&S®NRQ6-K2 option

A problem when characterizing RF amplifiers is that parameters such as ACLR must be determined at a specific output power but the output power depends on the individual compression behavior of the DUT. The gain of the DUT is usually not known exactly, and it depends on the temperature and the input level. Power servoing is used to set the output level of the DUT to the target value before starting the actual measurement process.

Conventional approach

This can be achieved using a control computer running a control algorithm, combined with a signal generator and a power sensor that can both be remotely controlled via SCPI (Fig. 4). The control algorithm runs in a loop. It retrieves the latest measured value from the sensor, calculates a new generator level and sets this level. This process is repeated until the level at the sensor equals the target level (Fig. 5).

A disadvantage of this setup is that two SCPI commands must be sent or received for each pass through the loop. Depending on the initial estimate, the linearity of the characteristic curve and the allowable deviation, it can take up to 20 ms to reach the target value. This might be too long for applications where every millisecond counts, such as in production.

Test signal	Bandwidth 100 MHz, carrier frequency 3.5 GHz				
Total signal power	−40 dBm	−50 dBm	−60 dBm	−70 dBm	−80 dBm
Measured standard deviation σ of 1000 successive phase measurements	0.04°	0.06°	0.1°	0.18°	0.40°

Fig. 3: Standard deviation of measured phase difference between two R&S®NRQ6 units at 23 °C.

Fast feedback control with R&S®SGT100A and R&S®NRQ6-K2

Significantly shorter settling times can be achieved with an R&S®SGT100A signal generator and an R&S®NRQ6 power sensor with the R&S®NRQ-K2 option (Fig. 6). This is due to the following factors:

- The very short level settling time of the R&S®SGT100A signal generator ($\approx 250 \mu\text{s}$)
- Measurement data transfer from the sensor to the signal generator via a direct FPGA-to-FPGA data link
- Moving the control algorithm to the signal generator
- Automatic level control (ALC) to compensate for small deviations
- High speed remote control via PCIe or Fast Socket

The level at the DUT output can be set to the target value in typically 1 ms to 1.5 ms – comparable to the settling time of many signal generators without feedback control.

To compensate for slow changes in the gain of the DUT, for example due to thermal effects (droop), the control loop has a switchable tracking function that continuously monitors the output level right from the initial setting.

Measurements with the R&S®NRQ6

After the target level is set, the sensor can perform the measurement tasks (Fig. 7).

Measurements with a spectrum analyzer

For especially demanding measurement tasks, a spectrum analyzer can also be connected through a splitter (Fig. 8). The advantage of this setup over the previously described solutions is that the tedious power serving task not only runs several times faster, the time it takes is often completely unnoticeable since it can run nested with the actual measurement – a major advantage for all manufacturers of RF amplifiers.

Measuring the modulation quality of 5G signals with the R&S®VSE vector signal explorer software

Right from market launch, I/Q samples recorded by the R&S®NRQ6 could be imported into the R&S®VSE vector signal explorer software and analyzed there. This requires the R&S®NRQ6-K1 I/Q data interface option. Version 1.70 of the software now also supports the R&S®NRQ6

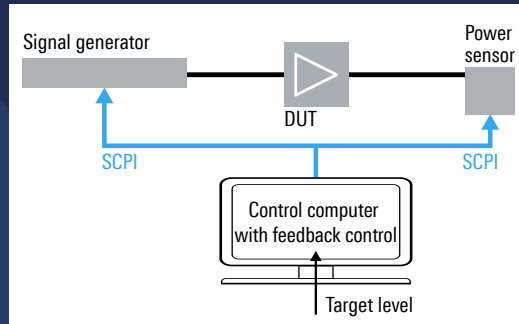


Fig. 4: Conventional setup for level control with a signal generator and a power sensor.

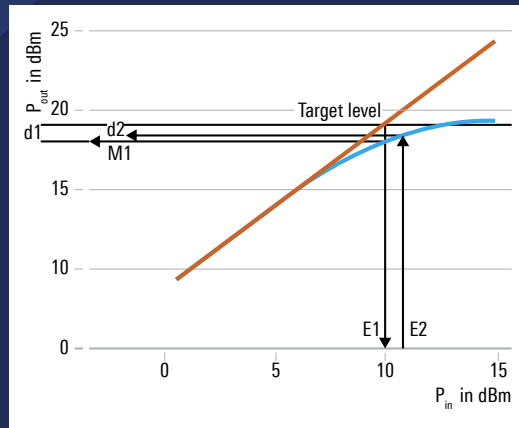


Fig. 5: Assuming an ideal characteristic curve (orange), the first setting value E1 is determined from the target level. Measurement M1 shows a deviation d1 from the target value, which is used to determine a better setting value E2.

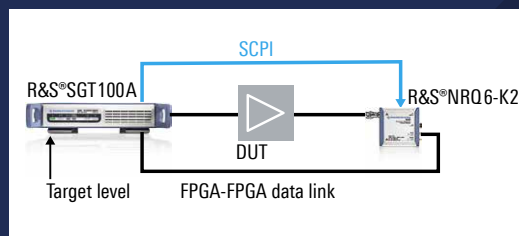


Fig. 6: Power serving with the R&S®SGT100A and the R&S®NRQ6-K2 option.

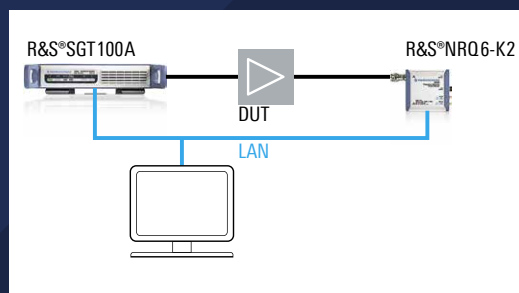


Fig. 7: Power serving and measurement with the R&S®NRQ6.

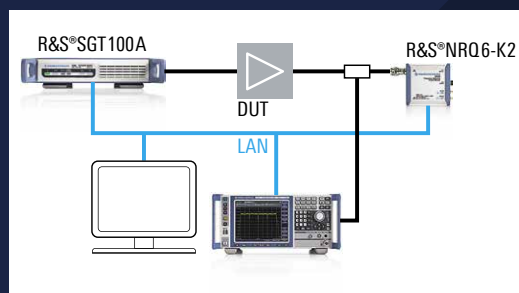


Fig. 8: Measuring with a spectrum analyzer.

GENERAL PURPOSE

directly, so all analysis features are immediately available.

Fig. 9 shows the R&S®VSE software in a setup for measuring 5G NR signals with the R&S®NRQ6 (2 GHz carrier frequency, -30 dBm power level, 100 MHz bandwidth, 256QAM modulation). The R&S®NRQ6-K1 and R&S®VSE-K144 options are required for this measurement. An impressive EVM value of 0.84 % is measured.

R&S®VSE and R&S®NRQ6: the perfect team for phase measurement

Combining multiple R&S®NRQ6 units with the vector signal explorer can be used for high-performance measuring of the phase angle between two 5G NR signals.

For beamforming measurements on 5G NR signals, the R&S®VSE-K144 option (3GPP 5G NR DL/UL measurements) and the R&S®VSE-K146 option (5G MIMO) are required. If a third R&S®NRQ6 is used as a master while the other two perform the measurements, the delay calibration of the measuring setup is not necessary.

All power sensors must be defined in the R&S®VSE program in a group of instruments. The synchronization mode (master or slave) must be set in the configuration window “Info & Settings” of each power meter.

Fig. 10 shows the measurement results. The phase values can be read in R&S®VSE in the three display areas “Beamforming Summary”, “RS Phase” and “RS Phase Diff”.

Summary

The latest options R&S®NRQ6-K3 (phase coherent measurements) and R&S®NRQ6-K2 (power servoing with SGT) turn the R&S®NRQ6 frequency selective power sensor into a universal tool for mastering numerous test and measurement tasks. The compact size of this solution and its scalability for multichannel measurements make it unique.

Thomas Braunstorfinger, Wilhelm Kurz, Habib Sellami

Fig. 9: The R&S®VSE vector signal explorer software thoroughly analyzes measurement data from an R&S®NRQ6, as illustrated here with a 5G NR signal.

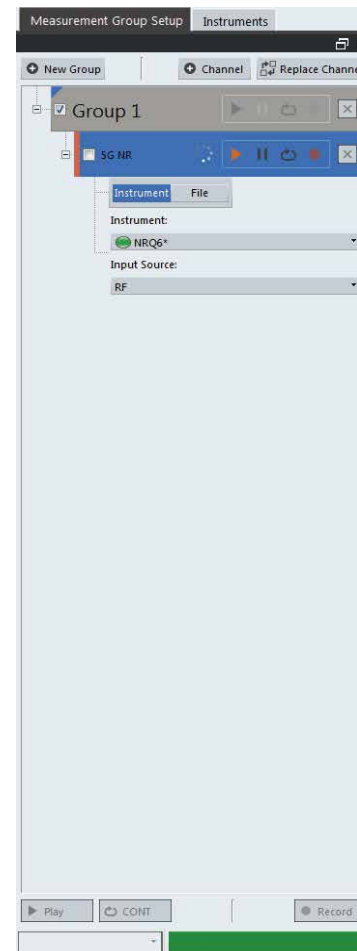


Fig. 10: 5G NR MIMO analysis with the R&S®VSE software, based on measurement data from two R&S®NRQ6 units.



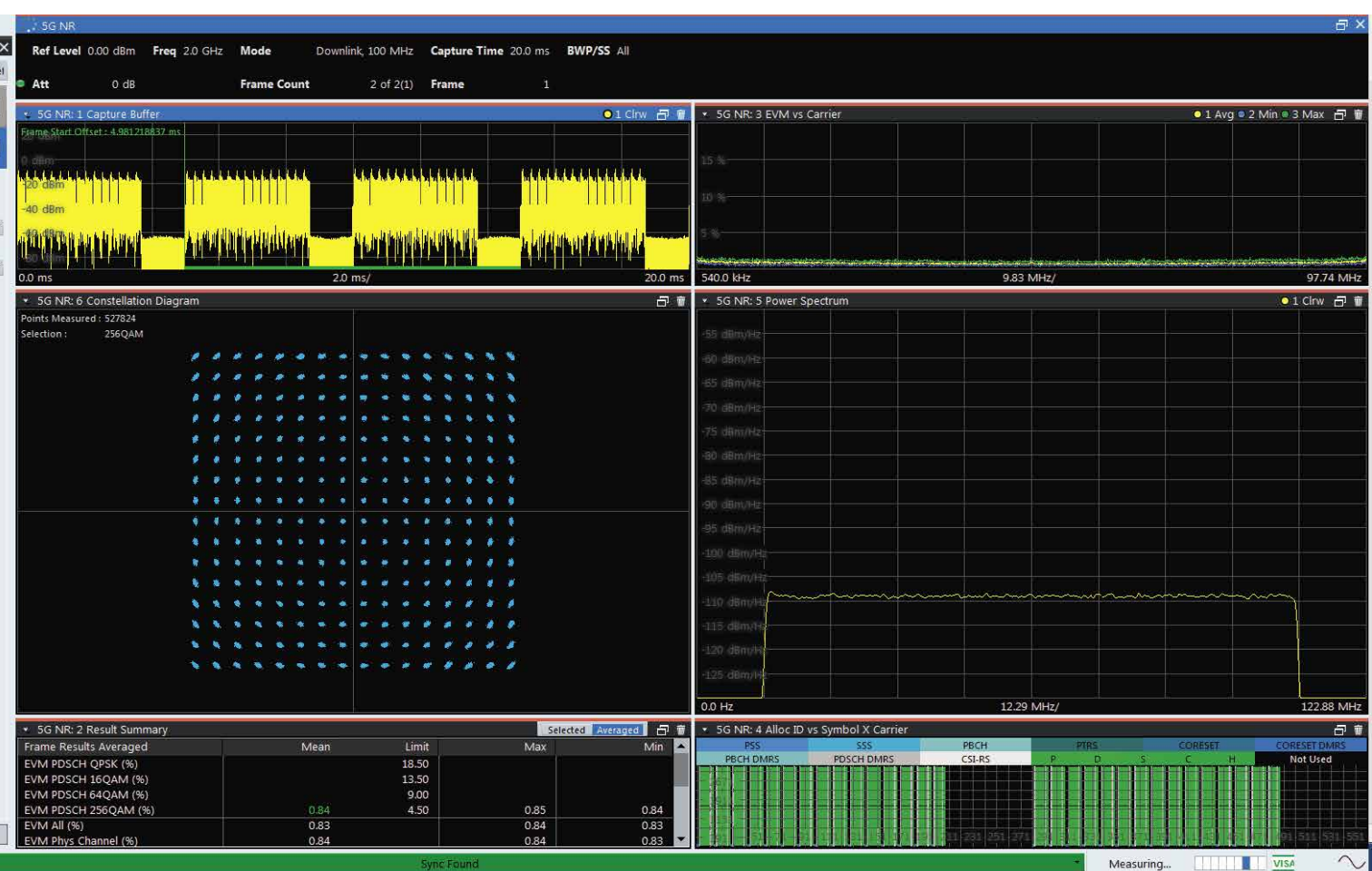




Fig. 1: The new upper frequency limit of 67 (72) GHz considerably increases the application range of the R&S®SMA100B.

EXTENDED FREQUENCY RANGE

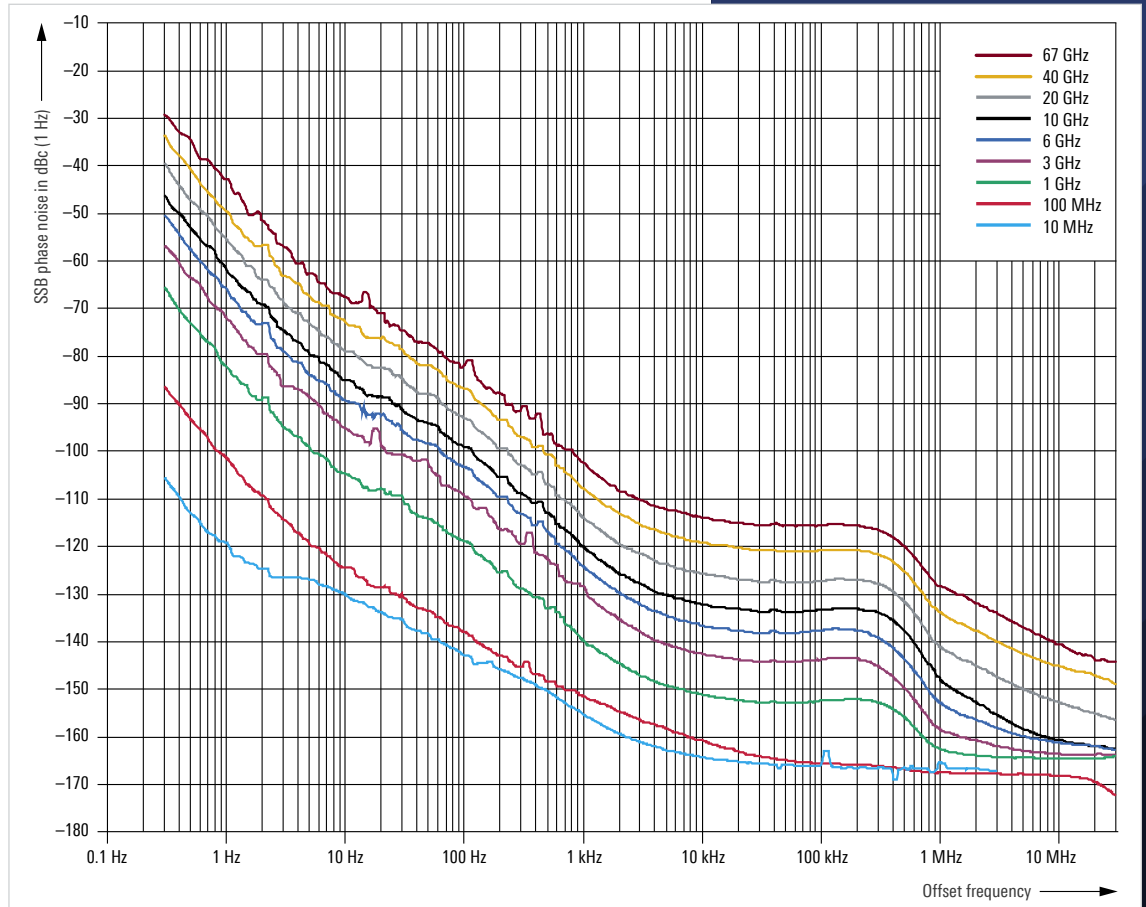
The R&S®SMA100B signal generator offers top-class signal quality in the millimeterwave range

With new frequency options, the R&S®SMA100B offers a significantly wider frequency range, extremely low phase noise, and high output power in combination with extremely low harmonics. These features make it ideal for applications in aerospace and defense, telecommunications and RF semiconductor industries.

The R&S®SMA100B previously had an upper frequency limit of 20 GHz. New frequency options up to 31.8 GHz, 40 GHz, 50 GHz and 67 GHz have significantly increased its range. The

40 GHz option covers all major radar bands used in development or during the integration and test phase. Initial commercial 5G deployments use frequencies up to 39 GHz and higher.

Fig. 2: SSB phase noise (meas.) with the R&S®SMAB-B711 (N) ultra low phase noise option.



With the 67 GHz option, the instrument generates signals in the millimeterwave range such as will be used for satellite links in the emerging Q/V band. It also supports component tests in the 60 GHz band, including non-cellular standards such as IEEE 802.11ad. In overrange operation up to 72 GHz (Fig. 3), it even supports IEEE 802.11ay.

The R&S®SMA100B is the only analog signal generator on the market that features a large spurious-free dynamic range and can simultaneously generate output signals with high levels, low harmonics, low phase noise and low wideband noise. The new frequency options also have these unique characteristics. The generator sets new standards with its uninterrupted level sweep with very large dynamic range and the ability to generate chirp signals.

Extremely pure signals for first-class products

The R&S®SMA100B is the ideal source for local oscillator (LO) signals when integrating radar systems where extremely low phase noise is crucial. Equipped with the ultra low phase noise option, the generator achieves a measured phase noise of -120 dBc (1 Hz) for a 40 GHz carrier and 20 kHz offset (Fig. 2).

Sampling rates increase with each new generation of A/D and D/A converters. Pure RF carriers with extremely low phase noise of -120 dBc/Hz (40 GHz; 20 kHz offset; measured) and lowest wideband noise are required to measure the true performance of a device under test. The R&S®SMA100B features an impressively low wideband measured noise of -150 dBc (1 Hz), for example for a 30 GHz carrier and 40 MHz offset.

Minimum harmonics even at maximum output level

In the microwave range, attenuation resulting from cables and test setups must be taken into account. The ultra high output power option (Fig. 3) with integrated harmonic filters compensates for these losses. It eliminates the need for external amplifiers and harmonic filters, considerably simplifying test setups.

In this configuration, the R&S®SMA100B is the ideal analog signal generator for measuring the transfer function and saturated output power of modern power amplifiers. These amplifiers are increasingly based on GaN technology. GaN solid-state amplifiers have a higher saturated output power than, for example, GaAs amplifiers. They therefore require significantly higher input power to measure the

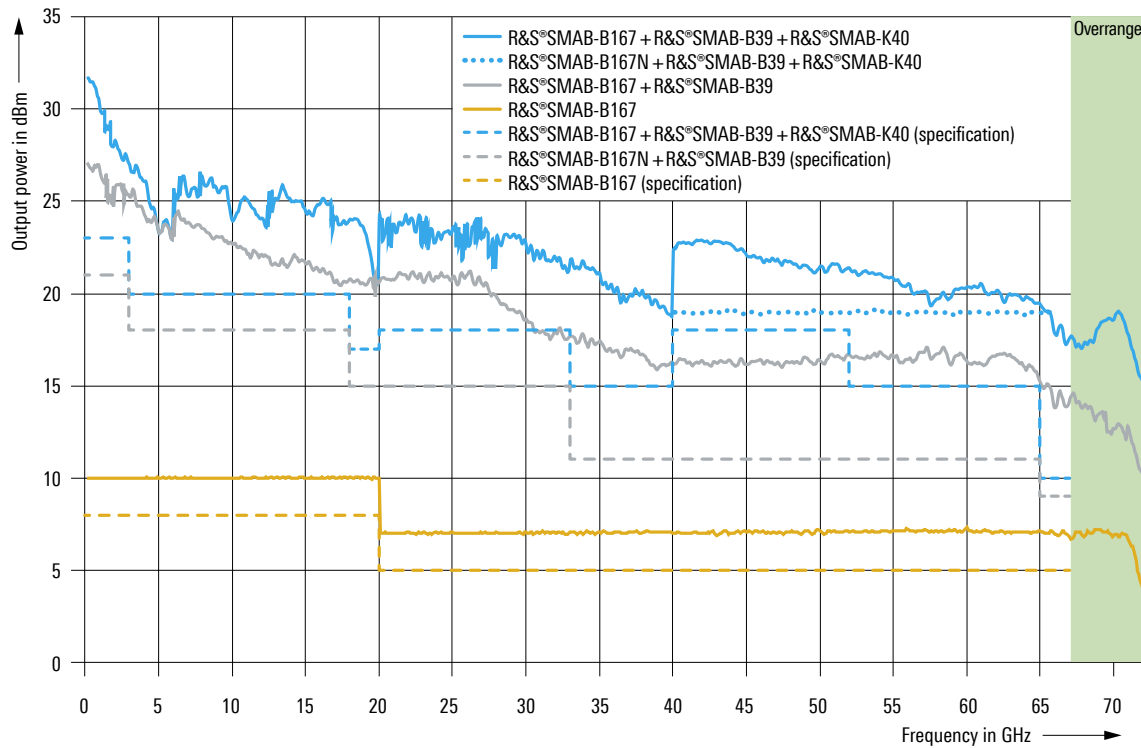


Fig. 3: Maximum output power (meas.) versus frequency with the ultra high output power option.

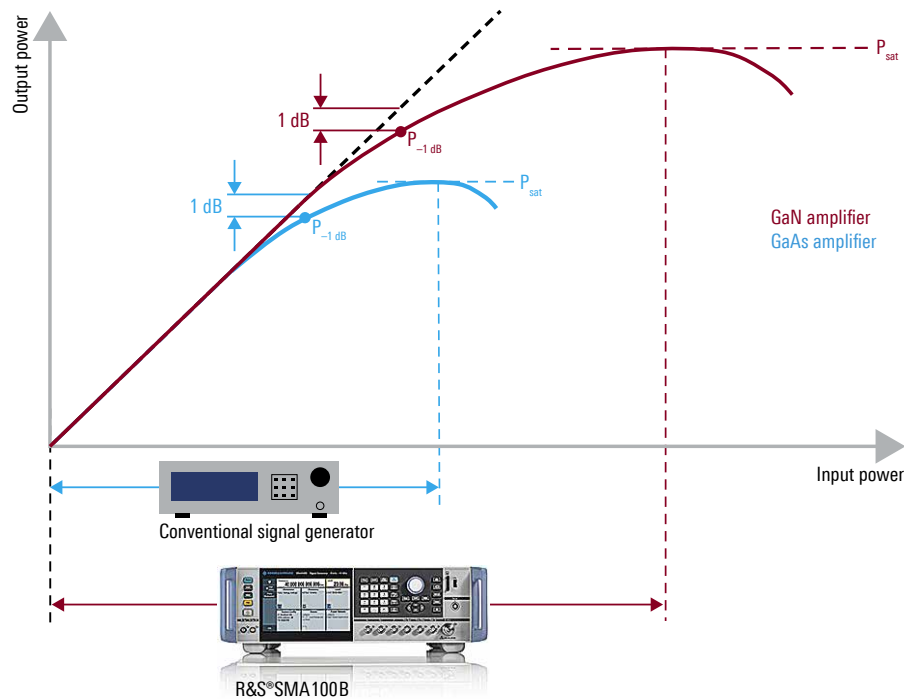


Fig. 4: Even GaN amplifiers can easily be driven into saturation with the high output power of the R&S®SMA100B.



Fig. 5: Uninterrupted level sweep with over 70 dB dynamic range.

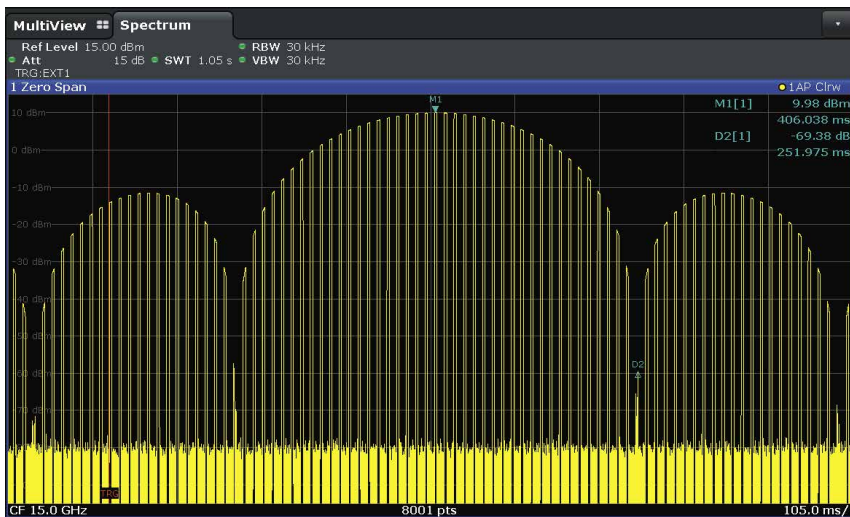


Fig. 6: Simulated amplitude variation of pulsed signals at the receiver input due to a rotating antenna. The amplitude envelope is fed in through the external modulation inputs.

Fig. 7: Chirp signal generated with the R&S®SMA100B (10 µs duration; 30 MHz bandwidth).



saturated output power (a key characteristic) starting from the 1 dB compression point ($P_{-1\text{ dB}}$) (Fig. 4).

Uninterrupted linear level sweep with large dynamic range

To measure amplifier transfer functions with an analog signal generator, the level sweep must cover a high dynamic range without interruptions. Blanking can lead to an unpredictable reaction of the amplifier's automatic level control (ALC), which must always be avoided. The R&S®SMA100B features an uninterrupted RF level sweep range of more than 70 dB without blanking or spikes (Fig. 5).

ScanAM option for realistic measurements on radar receivers

Receivers often have to process pulsed radar signals with superimposed amplitude modulation. This can be caused, for example, by radar transmitters that use rotating antennas with narrow lobes, which means the receiver only receives short input signals. With the ScanAM option, the R&S®SMA100B generates pulsed signals with superimposed amplitude modulation. The generator achieves a modulation depth larger than 70 dB, enabling it to quickly and easily simulate amplitude variation coming from scanning radar antennas in order to perform receiver tests (Fig. 6).

Chirp signals for testing radar systems

A wide variety of radar systems, for example weather radars and long-range surveillance radars, benefit from pulse compression techniques. Therefore, they use modulation on pulse such as linear frequency modulation (chirps). This makes it possible to improve the range resolution, which is a measure of the radar's ability to distinguish in the radar image between two objects that are close to each other. The R&S®SMA100B generates chirp signals with adjustable chirp duration and bandwidth. Impairments such as AM noise and AM drift can also be superimposed on the chirp signals to take into account the influence of receiver hardware (Fig. 7).

Frank-Werner Thümmeler

MINIMIZING POWER CONSUMPTION

High-precision two-quadrant power supplies generate current profiles and simulate batteries

More and more devices are battery powered or need to have low power consumption for other reasons. In order to minimize your electronics device's power consumption, you need to know the exact current profile. The R&S®NGM200 power supply series provides this information.

The single-channel R&S®NGM201 and the dual-channel R&S®NGM202 (Fig. 1) deliver up to 60 W of output power per channel. The linear two-quadrant design of their output stages enables the power supplies to operate as a source and sink. With four current measurement ranges and up to 6½ digit resolution for measuring voltage, current and power, the R&S®NGM200 power supplies are ideal for characterizing circuits with high peak currents and low power consumption in standby mode. Their fast recovery time of less than 30 µs and very low overshoot even during a demanding load change are additional key features for measurements on IoT modules and other battery powered devices. The power supplies are operated via a 5" touchscreen that provides quick and easy access to all parameters.

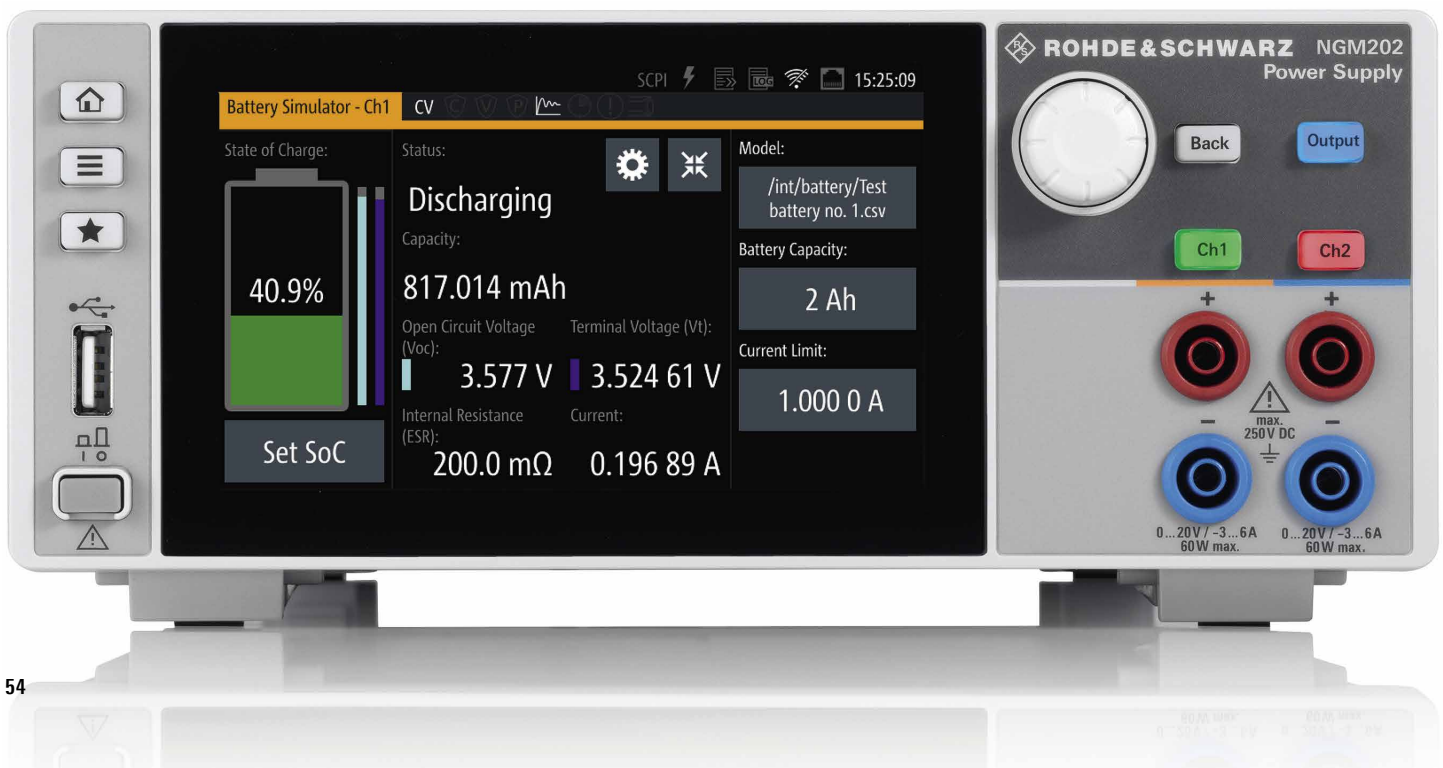
This article briefly describes two of the many outstanding features of these new power supplies.

FastLog for more detailed measurements

The FastLog function can be activated for demanding applications. In addition to the 6½ digit measurement data resolution of the R&S®NGL200 series, this function offers high speed acquisition and related analysis functions. Voltage and current can be simultaneously measured with a temporal resolution down to 2 µs. The resulting data can be saved to a USB flash drive or other data storage media for subsequent analysis. Or the data can be sent in real time to an external computer via USB or LAN, e.g. in a production environment.

In the example shown in Fig. 2, an R&S®NGM201 powers a radio-controlled clock and the FastLog function records current consumption. The current clearly shows the movements of the second hand. Every 10 seconds, a pulse advances the minute hand. The logged data is so precise

Fig. 1: An R&S®NGM202 power supply in battery simulation mode. The battery's key parameters are displayed on a single screen.



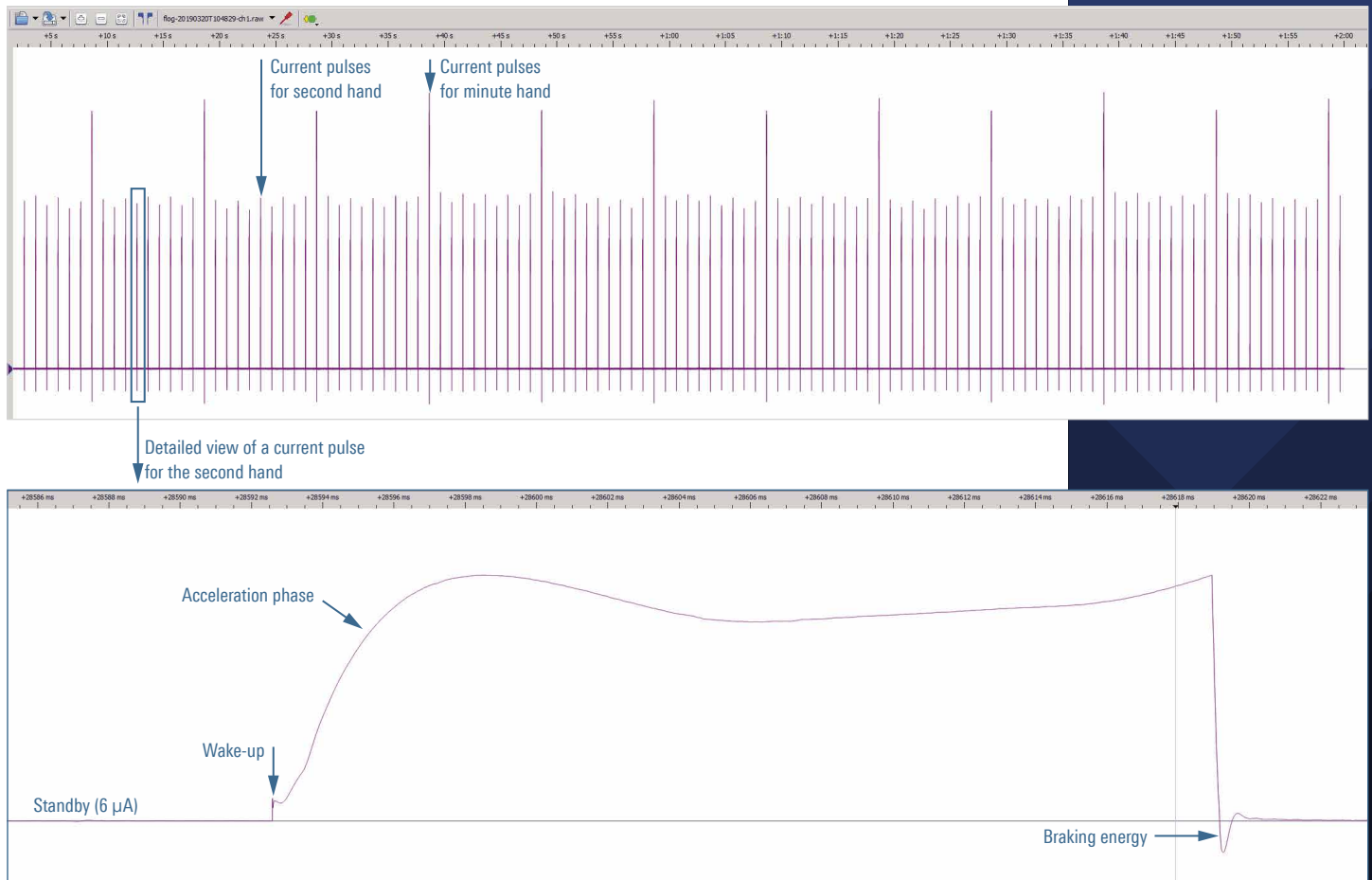


Fig. 2: Recording the current of a radio-controlled clock. Top: current pulses for advancing the second and minute hands; bottom: detailed view of a current pulse for the second hand.

that an individual hand movement can be analyzed. The zoomed-in view shows how the microcontroller wakes up from the sleep state, accelerates the hand and then brakes it. It is even possible to see that energy is fed back into the power supply when the hand is braked.

Battery simulation

The R&S®NGM200 power supplies can optionally be used to simulate (rechargeable) batteries. In this mode, the power supply behaves like a predefined battery (Fig. 1). The battery's parameters can be conveniently edited on the power supply. Several standard battery types are pre-installed for testing. Since R&S®NGM200 power supplies both source and sink energy, they can simulate discharging and charging a rechargeable battery. The dual-channel R&S®NGM202 is the first model on the market that can take on the role of two independently defined

(rechargeable) battery types, such as a fully charged battery and an empty battery connected in series. To accurately simulate power sources with high discharge currents, such as lithium-ion batteries, an intricate control circuit was developed that quickly and precisely adjusts the internal impedance.

Summary: For developers of IoT modules, wearables, gadgets and other mobile electronic devices, low current consumption is key. Not only do the R&S®NGM200 power supplies help developers achieve this goal, they are state-of-the-art universal instruments that can be used for countless everyday lab applications.

Andreas Schütz

TERAHERTZ CONVENIENCE

Network analysis with up to four mmWave converters

The R&S®ZNA vector network analyzer makes it easy to configure complex test setups for measurements in the mmWave and terahertz ranges. No additional controllers or signal generators are needed.

Growing demand for testing at very high frequencies

Network analyzers that can perform measurements in the mmWave and terahertz ranges are more in demand than ever. In the E band (60 GHz to 90 GHz), they are used, among other applications, to characterize active and passive components in wafer prober systems. At even higher frequencies, network analyzers can be used in a broad range of applications for testing transistors, sensors and antennas, and in imaging systems, radio astronomy and material measurements. The 5G wireless communications standard and the production of automotive radar sensors also create a large demand for testing.

While measurements at frequencies of several GHz are part of the standard repertoire of network analyzers, tests in the mmWave and terahertz ranges are significantly more demanding as they require external frequency converters.

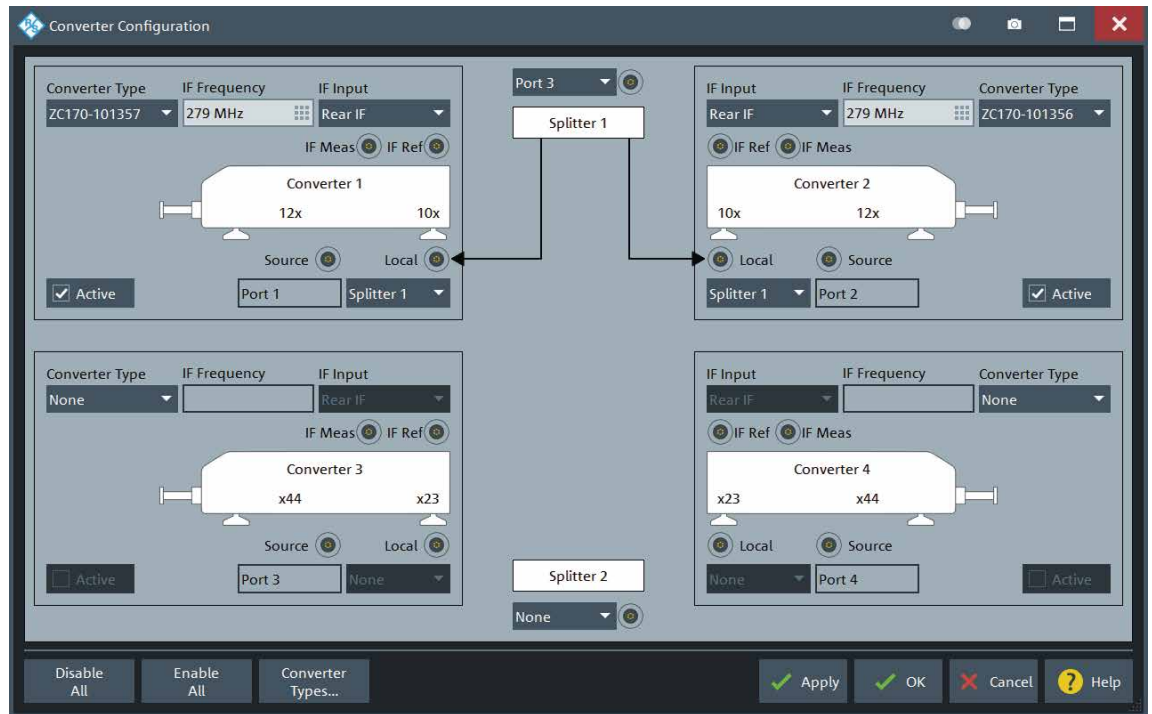
Compact setup and top-notch performance

The external mmWave converters for the R&S®ZNA vector network analyzer can be conveniently configured in the analyzer's graphical user interface, saving time and avoiding errors. Up to four converters can be operated on a four-port network analyzer, with no need for additional

With the R&S®ZNA vector network analyzer, measurements in the terahertz range using mmWave converters are configured just as conveniently as in lower frequency ranges.



Configuration menu on the R&S®ZNA network analyzer. Up to four mmWave converters can be configured, even in two different bands.



controllers or signal generators. An extra LO output at the back of the instrument, delivering up to +23 dBm signal power, provides the LO signal to all of the converters through a splitter, and is able to compensate for the cable losses in the test setup even with relatively long cables. The optional rear panel direct IF inputs for the reference and measurement signals from the converters increase the test system's dynamic range by several dB compared with the direct receiver inputs on the front panel. Compromises between a compact setup and high performance are no longer necessary.

Analogously, a two-port R&S®ZNA with rear-panel LO output and IF inputs can be operated with two converters without an external test set or additional signal generator.

Test setups with different types of converters

Upconverter, downconverter, multiplier, harmonic measurements – up to now tests on frequency-converting components at mmWave and terahertz frequencies have been difficult or even impossible to implement. That is all relatively easy with the R&S®ZNA vector network analyzer. Its four phase-coherent signal sources can generate

a wide range of RF and LO signals for frequency-converting measurements using one or more mmWave converters of the same or different types. For example, downconverters can be characterized in the mmWave range on the input side and in the R&S®ZNA basic frequency range on the output side.

On-wafer characterization of active components

Characterizing active components in the linear and non-linear ranges requires defined input power at the probe tip. Since on-wafer power calibration is not possible, the power at the waveguide output is calibrated, and losses in additional waveguides, 1 mm cables and the probe tip are taken into account in the calibration process. For power sweeps and compression point measurements, the R&S®ZNA has an integrated calibration routine that is able to compensate for mmWave converter nonlinearities. The measurements commonly performed on active components at lower frequencies can be carried out with the R&S®ZNA just as conveniently at high frequencies using mmWave converters.

Andreas Henkel

CHANGING OF THE GUARD

Transistor based uplink amplifier with unprecedented power

Following the 400 W class, the next power level is now ready for the Ku band. The compact R&S®PKU100-0750 uplink amplifier generates up to 750 W.

For direct to home (DTH) applications, network operators need high-power uplink amplifiers with outstanding signal quality and high intermodulation suppression so that they do not cause interference in adjacent channels. Traditionally, amplifiers with traveling wave tubes (TWT) have been used for this application since it was previously impossible to build compact solid-state amplifiers.

Now that the R&S®PKU100* uplink amplifier series has been extended, Rohde & Schwarz has advanced into a higher power class (Fig. 1). The R&S®PKU100-0750 generates an average linear power of 350 W and saturated power of up to 750 W. An in-house developed waveguide combiner combines the output power from the 16 final amplifier stages (Fig. 2). The combiner's design allows uninterrupted operation even when power output stages fail.

The amplifier conforms to the IP65 protection class and is suitable for outdoor use. From -40°C to $+55^{\circ}\text{C}$, it functions as specified. At temperatures above 55°C , it can be operated with reduced output power. The outdoor model

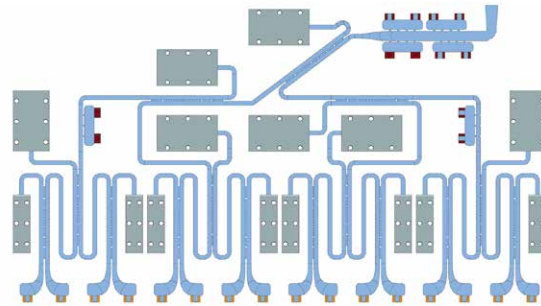


Fig. 2: A waveguide combiner developed in-house combines the output power from 16 final stages to deliver saturated power of up to 750 W.

weighs only 36 kg. Comparable amplifiers weigh up to 80 kg and are not practical for use in many applications. The rack installation model is only three rack units high, making it second to none in terms of compactness.

The final-stage microwave integrated circuits (MIC; Fig. 3) based on proven GaN technology were also developed in-house. They produce peak power of almost 70 W and are mounted directly in the RF combiner. The high degree of integration is the key to the system's compact design and low weight.

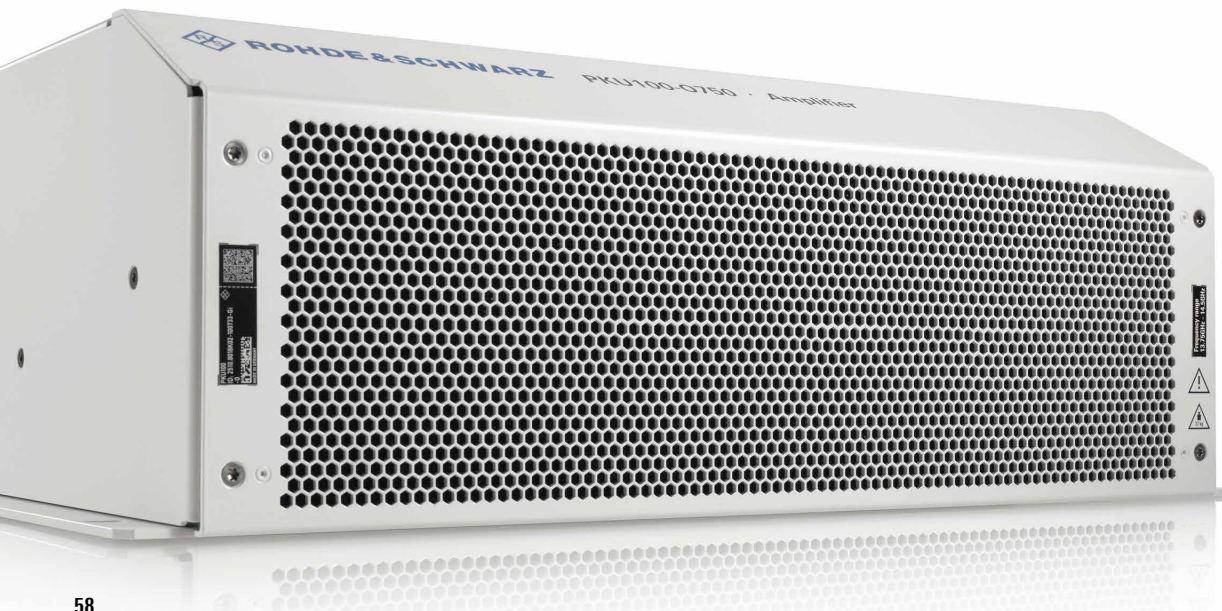
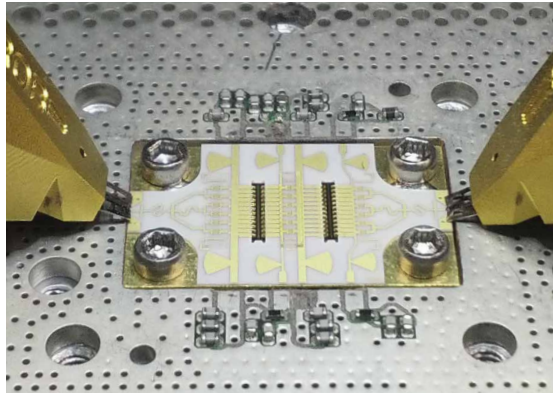


Fig. 1: The outdoor model with 750 W output power.

Fig. 3: The final-stage MICs are a Rohde & Schwarz in-house development.



The R&S®PKU100 amplifiers can be supplied with a block upconverter (BUC) to convert signals from the L band (950 MHz to 1700 MHz) to the Ku band. The indoor model can be equipped with a redundant power supply. If a main power supply fails, the amplifier automatically switches over to the redundant power supply with no power interruption. Customers can also swap out the power supply of the outdoor model.

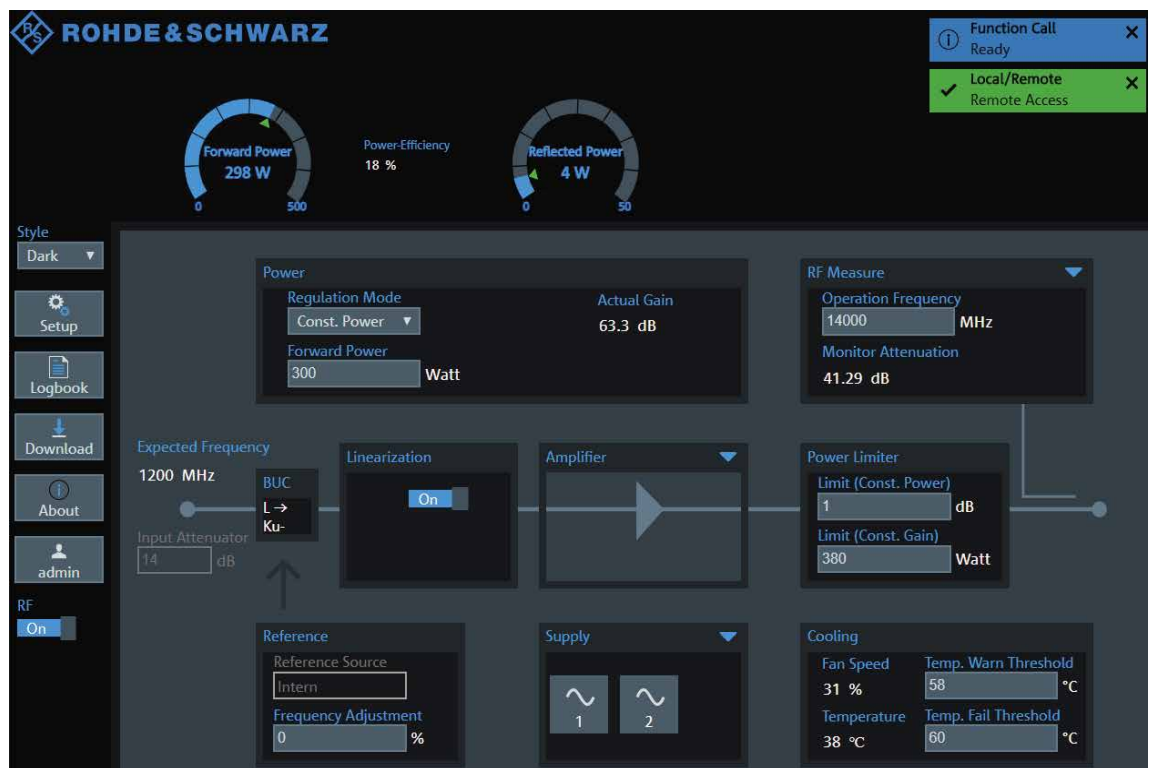
For control purposes, traditional interfaces such as RS-232/485 as well as digital I/O contacts are provided. However, the easiest way to remotely control the amplifier is by using the web interface (Fig. 4). The amplifier can also be monitored and controlled using the simple network management protocol (SNMP). There are two built-in Ethernet interfaces for multiple access.

Using an optional linearizer, the amplifier can be operated in quasi-linear mode within an effective bandwidth of 100 MHz. This function is unrivaled on the market and is especially advantageous when transmitting higher order modulation schemes. Linearization is fully adaptive and can equalize signals at the Ku band level. A third order intermodulation suppression (IM3) of almost 40 dB is achieved without the user having to change settings.

Christian Baier

* Better than tubes: solid-state amplifiers for satellite uplinks. NEWS (2018) No. 219, pages 60 to 63.

Fig. 4: The R&S®PKU100 can be remotely operated via a web interface.



No matter where you watch films – in the movie theater, at home in front of the TV or on your tablet – for full film enjoyment, you need perfect picture and sound quality. From Hollywood to Netflix, the film industry swears by the R&S®CLIPSTER mastering system. Studios use R&S®CLIPSTER to give their productions the final touch and convert them into the countless versions the market needs, for instance into a digital cinema package for digital theaters or a host of other format, resolution, image rate and language combinations.

R&S®CLIPSTER – the gold standard for video mastering.

www.rohde-schwarz.com

A young man and woman are shown in profile, smiling and looking towards the right. The woman is holding a large red and white striped popcorn bucket. They appear to be in a movie theater, with the background being dark and out of focus.

**COMING SOON
IS NOT AN OPTION**

ROHDE & SCHWARZ

Make ideas real

