223/2020

NEWS

ROHDE&SCHWARZ
Make ideas real

MEASURING IN THE CLOUD

Performing measurements without directly accessing your measuring instruments? An enticing prospect for engineers not only when working from home. A T&M cloud makes it possible.

NEWS

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COVER FEATURE

Hardware engineers belong to the groups of professionals that usually cannot work in their living rooms at home. Without the technical resources of an electronics lab, they are very limited in what they can do. RF developers in particular often need to access a number of measuring instruments that cannot be removed from a shared lab for long periods of time. Imagine how convenient it would be to perform measurements without having the measuring instrument in front of you. Rohde & Schwarz is setting up precisely this scenario with a new cloud solution. R&S®Cloud4Testing allows users to remotely analyze measurement data in detail. After their data is uploaded, they can use powerful tools to analyze parameters of interest in their mobile, radar or other signal data. If customers also want to generate the measurement data remotely, Rohde & Schwarz can help them implement a dedicated cloud to remotely access their T&M equipment. Such a cloud can be used for applications that range from collaborative work on development projects to training and demonstrations and from optimizing the use of resources to offering T&M cloud services for third parties. See the article on page 28 for more details.

OVERVIEW
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COVER FEATURE

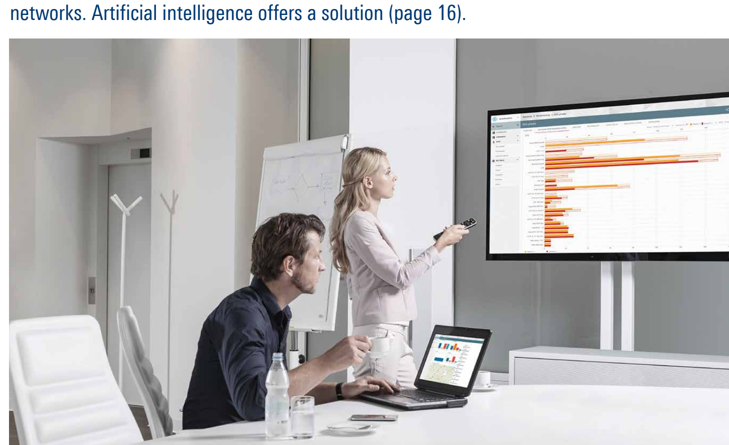
WIRELESS

AUTOMOTIVE

A compact test system consisting of a shielded test chamber and a radar target simulator calibrates even the latest generation of complex automotive radar sensors in less than a minute (page 20).

Four best practice examples of LANCOM Systems customers show which approaches have been successful for school Wi-Fi (page 50).

An enormous amount of data must be evaluated to assess the quality of mobile networks. Artificial intelligence offers a solution (page 16).



Even in the age of fiber optics, satellite links and mobile connections, there is still a need for shortwave radio. New antennas and tuning units make it easier than ever to build high-performance systems (page 52).

GENERAL PURPOSE

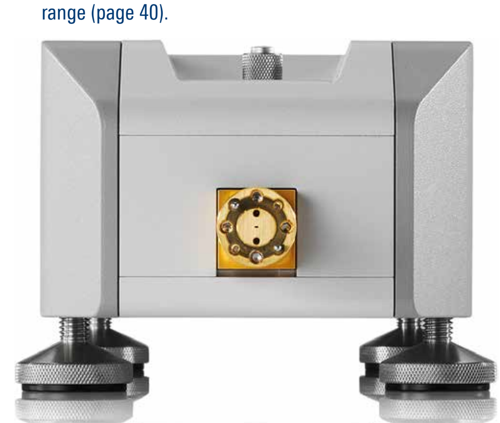
NETWORKS

SECURE COMMUNICATIONS

MISCELLANEOUS

A new DC power supply series for versatile deployment in R&D, test and production environments, quality assurance, service and training (page 36).

Thanks to a novel test method, the R&S®ZNA vector network analyzer now provides full vector correction of frequency converters and mixers up into the terahertz range (page 40).



NEWS COMPACT

DIGITAL COMPACT RECEIVER FOR RADIOMONITORING

One of the many R&S®EM 200 applications is primary/secondary operation in combination with a wideband monitoring receiver like the R&S®ESME.

Regulatory authorities want to know at all times what is going on in the spectrum, whether interference is occurring and whether all transmitters are complying with license terms. Their task is made more difficult by the fact that a wide range of radio technologies are intensively using all available frequencies. The new R&S®EM 200 digital compact receiver helps them maintain an overview, either as a standalone instrument for stationary or (vehicle) mobile use, but especially as a component in large monitoring and direction finding systems. The ½19" wide receiver scans the range between 8 kHz and 8 GHz at up to 40 GHz/s and does not miss any spectral event within its 40 MHz real-time bandwidth. This focal area, in which time domain analysis is also possible, can be output as an I/Q data stream via the optional 10 Gbit interface, analyzed online on a connected PC using the R&S®CA 100 software or recorded for later evaluation, for example with the R&S®DWR 100 I/Q recorder.

A typical R&S®EM 200 application is primary/secondary operation together with a wideband monitoring receiver like the R&S®ESME (figure on left). If, for example, the R&S®ESME detects an interesting emission, the pertinent frequency range can be transferred to a connected R&S®EM 200 for permanent monitoring and precise analysis.

Like any Rohde & Schwarz radiomonitoring receiver, the R&S®EM 200 can be used for direction finding tasks, for instance as a single-channel direction finder in combination with a vehicle roof antenna or as a component in a large-scale radiolocation system. It can use the angle of arrival (AoA) method, the time difference of arrival (TDoA) method or a hybrid approach.

Since it is a system instrument, the R&S®EM 200 is designed for easy integration into receiver networks that are managed using software such as R&S®RAMON and R&S®ARGUS. Precise timestamps for each data packet facilitate correlation with data from other receivers in the network.

The R&S®EM 200 comes with convenient operating and analysis software for standalone operation. However, it will primarily be used in large systems and operated remotely.

PRODUCTION TEST SOLUTION FOR 5G FR2 PRODUCTS

One of the innovations of 5G mobile communications is the use of millimeterwaves. In line with the 3GPP standard, the 5G frequency range 2 (FR2) currently comprises two blocks: 26.5 GHz to 29.5 GHz and 37 GHz to 43.5 GHz. National regulators decide which bands will actually be used in a country. Unlike in the sub6 GHz frequency range (FR1) where conducted tests are possible, OTA test facilities are required for FR2 products. For non-signaling tests, developers and manufacturers can now use the R&S®CMPQ test system. It consists of the R&S®CMQ 200 shielding cube, the R&S®CMP 200 tester and an R&S®CMPHEAD 30 remote radio head. The main field of application is mass production of 5G products. Thanks to its very flexible configuration, it certainly can also be used for preproduction measurements. The R&S®CMP 200, controlled by the cross-product R&S®CMsquares 5G test software, generates and analyzes standard-compliant signals up to 20 GHz. For higher frequencies, the radio heads (24.25 GHz to 31.8 GHz or 37 GHz to 43.5 GHz) take over. Up to three radio heads can be operated in parallel. This allows one R&S®CMP200 to simultaneously manage multiple shielding cubes – a welcome feature in production. By the way, the cubes are not limited to 5G applications. They are suitable for all technologies up to 77 GHz.

The R&S®CMPQ test system consists of the R&S®CMQ200 shielding cube, the R&S®CMP200 tester and an R&S®CMPHEAD30 remote radio head. The main field of application is the mass production of 5G products, but it can also be used for measurements in the development lab.

TEST BENCH FOR AUTOMOTIVE RADOMES

Radar sensors have long been established as suppliers of data for driver assistance systems. They will become even more important in the future for the next development stages in achieving vehicle autonomy (see article on page 20). Since incorrect position data can be safety-critical, both the sensors themselves and their covers (radomes) must comply with defined performance values.

And this can only be confirmed through testing. To test the radomes, Rohde&Schwarz has developed the R&S®QAR, the first tester on the market for testing these DUTs quickly and over their full surface area. It is primarily intended for lab tests and measurements during development. In order to be able to use it for volume tests on the assembly line, Löhnert Elektronik has developed a test bench around it.

The end-of-line test bench from Löhnert Elektronik uses the R&S®QAR tester to examine the usability of vehicle radomes (typically the brand emblem).

The rotary indexing machine contains different type-specific holders for the objects under test (component nests) and two test stations for transmission and reflection reference measurements. The machine is driven by the Löhnert instant scripting RunTime (LisRT) software together with a Siemens SPC controller. The radomes can be placed in the test holders either manually or by a robot. The system identifies them by a barcode or a data matrix code (DMC).

The test bench machine can be easily and quickly adapted to changed operating conditions, such as new radome types, directly on the line. Löhnert Elektronik simply exchanges the component nests and modifies the evaluation masks in the software.

These test benches make it possible to extremely reliably and quickly perform end-of-line measurements on automotive radomes with diameters up to around 200 mm. Details of the test solution are available at www.loehnert-elektronik.de and www.rohde-schwarz.com/qar.

USA TIGHTENS REQUIREMENTS ON THE POSITION ACCURACY OF EMERGENCY ALERT SYSTEMS AND EMERGENCY CALL SERVICES

911 emergency call system enhanced with altitude information

The USA has long played a pioneering role in the implementation of location based emergency call services. For example, a mobile phone call to the nationwide emergency number 911 already had to provide GPS-accurate location information in order to guide rescue services and police to the exact location of the incident. At the end of last year, the US regulatory authority FCC further tightened the requirements. By April 2021, the 911 system will be required to transmit vertical location information in addition to 2D coordinates. This would make it possible to quickly identify the floor in question when making emergency calls from high-rise buildings. For reliable identification, the FCC paper (FCC-CIRC1911-02) requires a z-axis accuracy of 3 meters. This information cannot be obtained from the GPS data. The FCC specification does not specify a technology, but the tendency is toward barometric pressure sensors in smartphones. There is a functional relationship between air pressure and altitude, but this relationship also depends on the local temperature, humidity and weather conditions (high or low pressure). But temperature and humidity sensors are not currently installed in smartphones, and pressure sensors are only found in top-of-the-range models. The goal is therefore ambitious and can only be achieved with workarounds.

Up-to-date information on temperature, humidity and reference pressure on the ground will have to be obtained from external sources. Major US cities have a dense grid of measuring networks. A smartphone will obtain its location values from a server and use this information to determine its altitude – provided its pressure sensor is calibrated. A new Rohde & Schwarz solution can help verify this feature. Together with an R&S®CMW500 wideband radio communication tester and an optional R&S®SMBV100B GNSS simulator, a small pressure chamber is used to subject the DUT to defined pressures. The test reveals whether a smartphone can measure the set values with the necessary accuracy (approx. 35 Pascal) and transmit them to the public safety answering point (PSAP) as specified.

More accurate targeting of public alerts

In the future, the wireless emergency alert (WEA) public safety system that has been in operation in the USA since 2012 will more accurately target specific geographic areas. WEA uses mobile phone networks to broadcast alerts to the public about imminent threats to public safety, such as an approaching hurricane. It is also used to send alerts issued by the President of the United States and emergency alerts about missing persons. At the end of 2019, the Federal Communications Commission (FCC) published the specifications for WEA 3.0, the next development stage of the system. In this update, a message must cover 100 % of a specified target area, which is specified either via a circle (center point and radius) or a polygon. The whole thing is made more demanding by the additional requirement that the boundary of the area must be maintained to within a tenth of a mile. This prevents the alerts from causing unnecessary concern among unaffected citizens.

US network operators are meeting the requirements with individual solutions that will eventually have to be implemented in the subscriber devices for their networks. These requirements can be verified using a test solution consisting of the R&S®CMW500, R&S®SMBV100B and R&S®CONTEST software. The solution currently supports the test plans of Verizon, AT&T, TMO and US Cellular.

For location based services, Rohde & Schwarz offers customers a large number of test solutions under the product name R&S®TS-LBS. They can then choose the best solution for their application. Only a single setup is required for the test cases described here. It consists of an R&S®CMW500 wideband radio communication tester, an R&S®SMBV100B GNSS simulator, a pressure chamber and R&S®CONTEST software.

FIRST WI-FI 6 ACCESS POINTS

The Rohde & Schwarz subsidiary LANCOM Systems has launched its first access points based on the Wi-Fi 6 standard (IEEE 802.11ax): LX-6400, LX-6402 and LW-600. Significantly lower latency and up to 25 % more throughput per client make them a future-proof basis for high-performance WLANs and networks with high mobile device density. While the LX-640x series is intended for locations with a high user volume such as schools, universities, shopping centers, hospitals and arenas, the LW-600 addresses scenarios with a small to medium number of users, for example hotels, small offices and doctor's offices.

All three models are available now. By the end of the year, the portfolio will be expanded to include additional models for indoor and outdoor use.

LANCOM LX-640x: for high user traffic

The access points have two IEEE 802.11ax radio modules for parallel operation in the 2.4 GHz and 5 GHz bands and offer 4×4 multi-user MIMO (MU-MIMO) in the uplink and downlink for simultaneous control of a large number of clients. The access points can handle channel bandwidths of 20 MHz, 40 MHz and 80 MHz (with 4 streams) and 160 MHz (with 2 streams). Mobile devices with two antennas that can handle 160 MHz wide channels benefit from data rates of up to 2400 Mbps in the 5 GHz band. Thanks to the parallel use of 1150 Mbps in the 2.4 GHz band (supported channel bandwidths of 20 MHz and 40 MHz with 4 streams), a total throughput of up to 3550 Mbps is achieved.

The models have different antenna designs. The LX-6400 transmits via eight 180-degree sector antennas discreetly integrated into the housing, while the LX-6402 uses four external dual-band omnidirectional antennas. These can be replaced with sector antennas if desired. Both models feature a 2.5 Gigabit Ethernet PoE (IEEE 802.3at up to 30 W) and a Gigabit Ethernet port. WPA3-Personal and IEEE 802.1X (WPA3-Enterprise) provide state-of-the-art security, although the predecessor variants WPA2-Personal and WPA2-Enterprise can still be configured. The access points also support virtualization functions such as Multi-SSID and VLAN. Power is supplied either via PoE (IEEE 802.3at) or a power supply unit.

Like all current access points from LANCOM, the new Wi-Fi 6 models offer the greatest possible operational flexibility. They can be configured separately via the web GUI or managed centrally via a WLAN controller or via zero-touch deployment in the LANCOM Management Cloud.

Both LX-640x models cost EUR 699 (plus VAT).

LANCOM LW-600: professional entry into Wi-Fi 6 technology

The LANCOM LW-600 can simultaneously serve clients in the 2.4 GHz and 5 GHz bands and achieves a cumulative throughput rate of up to 1775 Mbps (1200 Mbps at 5 GHz plus 575 Mbps at 2.4 GHz).

In standalone operation, the intuitive web interface provides the ideal overview for comprehensive management and monitoring. Dashboards display the current WLAN status and enable easy network setup and maintenance. For networks with multiple access points, management via a WLAN controller or the LANCOM Management Cloud (LMC) is recommended. LMC represents the latest generation in software defined networking and completely frees the operator from all technology issues. The network is automatically set up and maintained via the internet.

The LW-600 can be operated via power over Ethernet on any PoE powered Ethernet port. Alternatively, power is supplied by the provided power supply unit. The access point features the latest security with WPA3-Personal or WPA3-Enterprise and costs EUR 399 (net price).

The LANCOM LX-6402 transmits via four external omnidirectional antennas. If you prefer a more discreet solution, choose the LX-6400 with integrated sector antennas.

Thanks to its smoke detector design, the LW-600 can be inconspicuously installed on ceilings or walls.

ATC NEWS

NEW GENERATION OF RADIOS COMPLEMENTS SUCCESSFUL SERIES

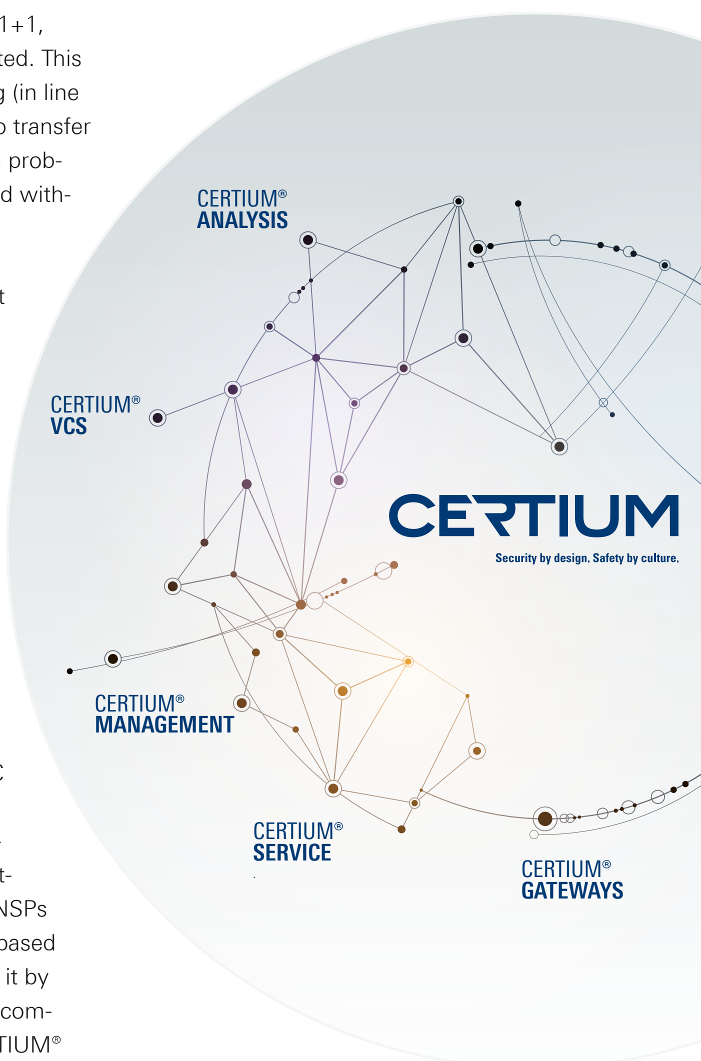
The R&S®Series 4200 ATC radios have written an unprecedented success story. Many thousands of these radios connect air traffic controllers to aircraft at airports and ATC centers all over the world. Their outstanding technical characteristics and high reliability were compelling arguments that convinced airport operators and air navigation service providers (ANSP) of the value of this product line. The new R&S®Series 5200 builds on these qualities – and goes a large step further in terms of connectivity, ease of service, operational reliability and total cost of ownership.

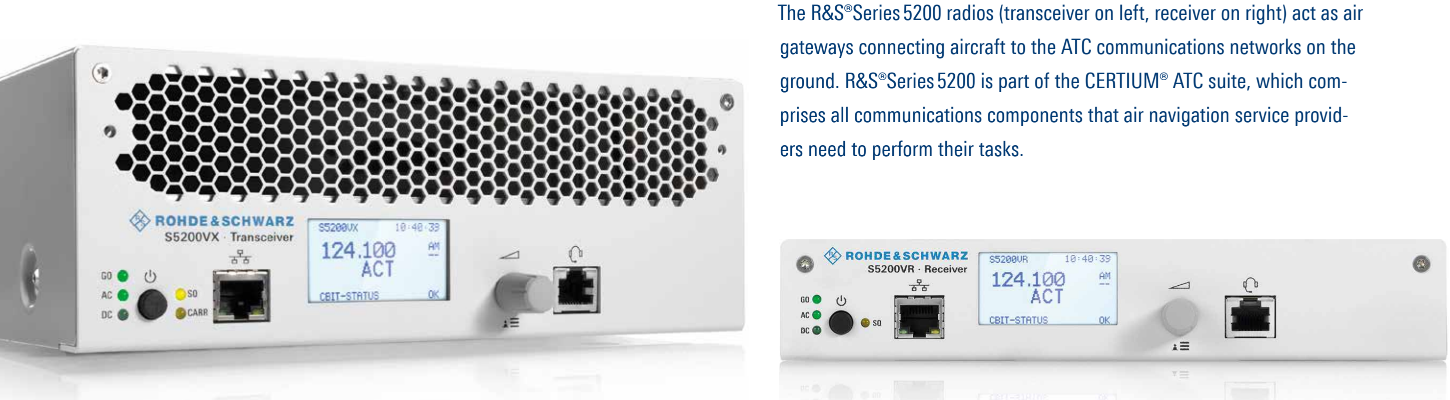
From the very beginning, the focus was on connectivity. In an ATC communications network, an R&S®Series 5200 radio serves as an air gateway between the ground station and the aircraft. The radio can operate both the analog voice links and the ACARS and VDL2 data links commonly used in civil aviation. Each radio can be simultaneously connected to three independent networks within the ATC ground infrastructure, e.g. to the main and backup voice networks and a monitoring network. The hardware and software architectures are hardened to meet the cybersecurity requirements of critical infrastructures, so that security problems in one of the connected networks cannot spread to another through the radio.

The usual redundancy strategies (1+1, m+n) can be elegantly implemented. This is ensured by virtual IP addressing (in line with IPv4 or IPv6). If a radio has to transfer its task to a backup radio due to a problem, this is done without delay and without affecting the network.

An installed radio usually does not need to be touched thanks to autocalibration of the oscillator and the remote maintenance options, including software updates via the network. If, however, a radio needs to be replaced, the service technician simply has to insert the radio's easily removable radio identity card into the new radio and use it to configure the new radio.

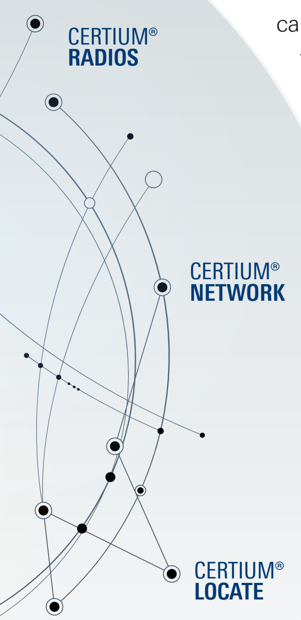
The R&S®Series 5200 is a core component of the CERTIUM® ATC solution portfolio. CERTIUM® is a complete ATC ecosystem of optimally coordinated hardware, software and service components. ANSPs who choose an R&S®Series 5200 based radio system can further enhance it by adding the CERTIUM® VCS voice communications system and the CERTIUM® MANAGEMENT software.





The R&S®Series 5200 radios (transceiver on left, receiver on right) act as air gateways connecting aircraft to the ATC communications networks on the ground. R&S®Series 5200 is part of the CERTIUM® ATC suite, which comprises all communications components that air navigation service providers need to perform their tasks.

HUNGAROCONTROL INCREASES FLIGHT SAFETY WITH DIRECTION FINDERS FROM ROHDE & SCHWARZ



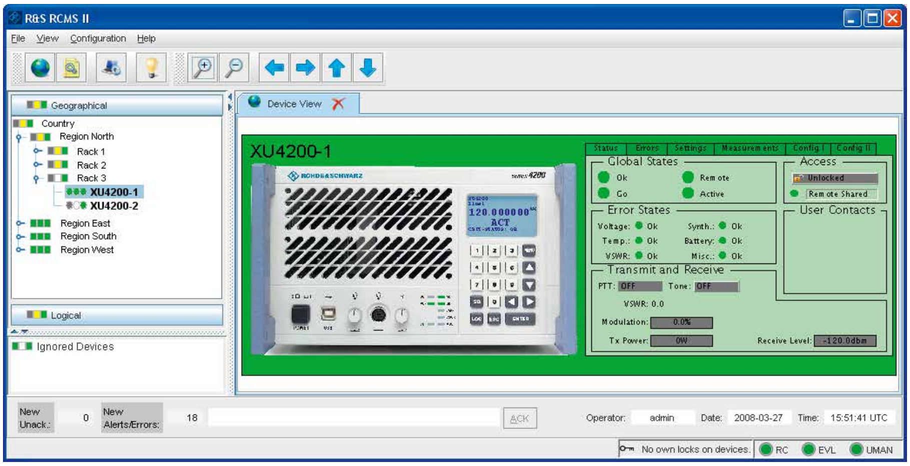
Although air traffic controllers have a complete overview of flight movements in their airspace on their radar screen, they have no visual feedback about which aircraft is making a radio call. Not unless this information is supplied by direction finders and superimposed on the radar image. This visual information prevents confusion and misunderstandings – especially when the airspace is full and the radar screen is packed with a myriad of symbols. Direction finders also ensure unambiguity and clarity when aircraft have similar call signs. Convinced of the value of this extra safety feature, the Hungarian air navigation service provider HungaroControl invested in a direction finding network and bought CERTIUM® LOCATE, a positioning solution with networked ATC direction finders.

Direction finding allows a calling aircraft to be identified and marked on the radar image.

HungaroControl manages Hungarian airspace and, on behalf of NATO, the upper Kosovo airspace. With around three-quarters of a million aircraft movements to be monitored per year, HungaroControl has so much to do that it is happy to take advantage of any technical assistance. Which is why R&S®DF-ATC-S direction finders are being set up at seven locations and networked via a location server (also supplied by Rohde & Schwarz) that calculates aircraft positions from the DF data. The server transfers this information to HungaroControl's MATIAS air traffic management system, which merges the information with the data from the radar and other systems. The system is scheduled to be installed and ready for operation by the end of 2021.

DFS CONTROLS ITS NETWORK WITH CERTIUM® MANAGEMENT

Deutsche Flugsicherung GmbH (DFS), the air navigation service provider responsible for German airspace, operates a nationwide network of around 100 radio stations with more than 4000 Rohde & Schwarz radios for ATC voice communications. In the past, this fleet of radio equipment could be managed centrally but with limited functionality, which no longer met the growing requirements of DFS. When deciding on a new remote control and monitoring solution, it made sense to consider CERTIUM® MANAGEMENT, whose R&S®RCMS II software core not only optimally integrates the Rohde & Schwarz radios and voice communications system but also manages all third-party devices, e.g. network switches that support the simple network management protocol (SNMP). Now that the management tool has been completely rolled out, DFS has its system components conveniently under control.



Every DFS radio in Germany – like the R&S®Series 4200 transceiver shown here – can be centrally monitored and configured using the R&S®RCMS II software.

6G IN SIGHT

Channel measurements for future mobile communications

Understanding the propagation properties of electromagnetic waves in a millimeterwave radio channel is essential for the development of future standards such as 6G. Accordingly, a time domain channel sounder for the 300 GHz band has been developed in cooperation with two Fraunhofer institutes and used in initial research projects.

From 5G to 6G

Setting up nationwide 5G networks and the successive provision of all designated options in the FR1 and FR2 frequency bands will keep the industry busy for many years. Meanwhile research is focusing on the fundamentals for the next generation: 6G [1] [2].

Some candidate technologies for 6G, such as new waveforms as alternatives to OFDM or full duplex operation, were previously discussed for 5G but not included in the standard. 6G research is also focusing on new network topologies, ultra-massive MIMO, visible light communications (VLC), quantum communications (for inherently secure communications) and the application of machine learning to network control and optimization.

On the way to the terahertz spectrum

Whereas 5G pioneered the use of millimeterwave frequencies with large bandwidths to enable the transmission rates necessary for demanding real-time applications such as wireless factory automation, the nascent 6G technology is aiming at significantly higher transmission rates and lower latencies.

Large contiguous frequency ranges with bandwidths of several GHz are only available in the subterahertz and terahertz range, i.e. above 100 GHz (Fig. 1). Extensive parts of the D band (110 GHz to 170 GHz) have already been designated for future communications services. Last year's ITU World Radio Conference (WRC 19) added more bands between 275 GHz and 450 GHz. Initially, however, research efforts for 6G are concentrating on the D and H bands (Fig. 1).

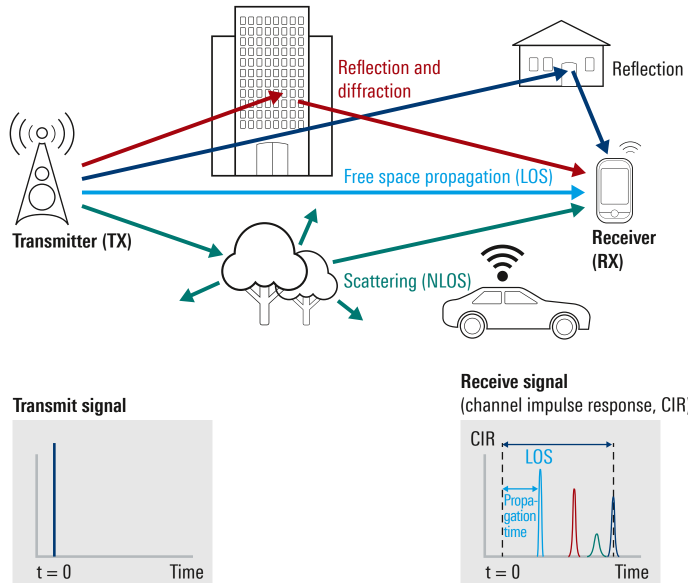


Fig. 2: Operating principle of channel sounding. The channel impulse response (CIR) is measured by emitting an electromagnetic "ping" at the frequency of interest and capturing all returning signal components.

Channel models as the basis for utilizing new frequency ranges

Before a new communications standard can be developed, the propagation properties in the designated frequency band must be understood and characterized. Then channel models can be derived to enable system-level simulations of the new standard.

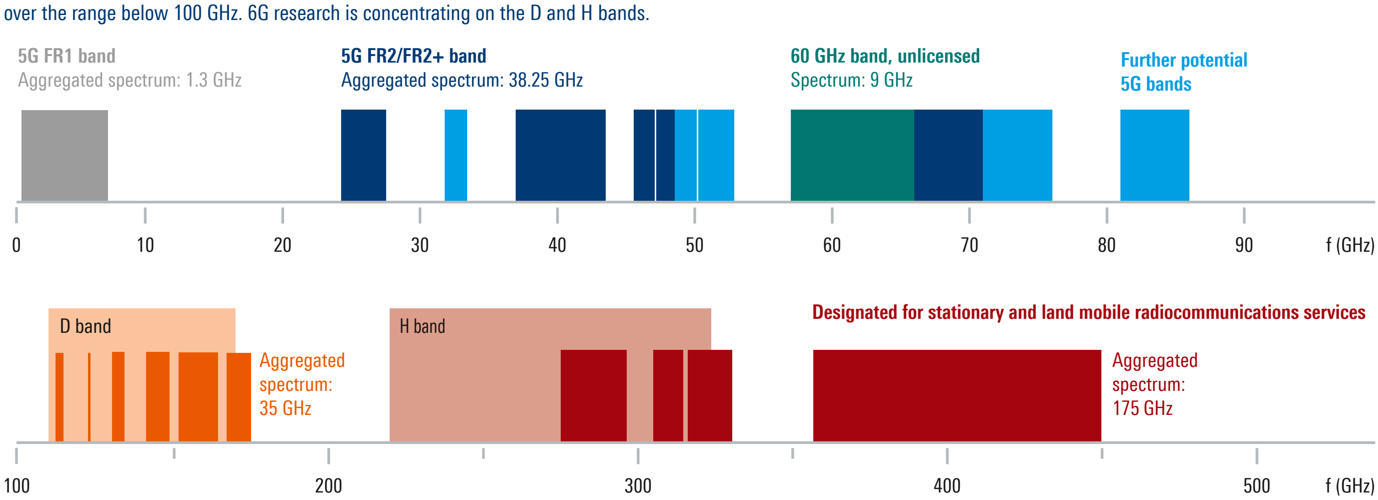
This requires that the underlying measurement data correctly reproduces the investigated environment. Geometry based stochastic channel models (GSCM) such as 3GPP TR 38.901 [3], which is valid up to 100 GHz, are based on a large number of such channel measurements in different environment scenarios.

Up to 4G, channel model development and specification by 3GPP was limited to the frequency range below 6 GHz and quasi-static environments. Dynamic scenarios and other types of environment scenarios corresponding to new use cases, such as automotive, high speed trains and industrial environments, became relevant with 5G, and the frequency range was extended to the millimeterwave region. The resulting channel models, however, cannot simply be extended to the range above 100 GHz where 6G is intended to operate. Even more than in the millimeterwave range, propagation in this frequency range is strongly influenced by human bodies, vehicles, and environmental conditions such as rain.

From channel sounding to channels models

Channel measurements by channel sounding deliver an image of the propagation properties of

Fig. 1: Spectrum of frequency bands available for mobile communications. The 5G bands are distributed over the range below 100 GHz. 6G research is concentrating on the D and H bands.



electromagnetic waves at a particular frequency. The term "channel sounding" stems from sonar technology, where short acoustic pulses are sent out from a ship or submarine and the reflections are recorded in the time domain. This provides a viable image of the surroundings. With sonar, the transmitter and receiver are in the same place; with channel sounding for electromagnetic waves, the transmitter and receiver are spatially separated. A short modulated signal with excellent autocorrelation properties serves as a "ping" whose impulse response is recorded. The measurement is therefore a propagation time measurement. It includes both the direct propagation components (line of sight, LOS) and all reflection and scattering components (non line of sight, NLOS) from objects in the environment (Fig. 2). The channel model parameters and their values can be derived and determined from the results.

As a rule, objects are only "physically visible" to electromagnetic waves and act as reflectors or scatterers when they are at least as large as the wavelength of the incident wave. This means that at higher frequencies such as 30 GHz, objects with dimensions in the centimeter range act as reflectors.

Collaborative research

Rohde & Schwarz has been acquiring experience in channel sounding projects for years. For example, it has been investigating the frequency range up to 150 GHz together with the Japanese network operator NTT DOCOMO, and the results were presented in late 2018. In 2019, the focal point of a 3GPP research initiative was the development of new 5G channel models in industrial scenarios such as production environments. To support the 3GPP, Rohde & Schwarz carried out measurements in its Memmingen and Teisnach plants, not only in the 28 GHz and 66 GHz millimeterwave frequency bands but also in the 3.7 GHz band designated for private campus networks [4]. In collaboration with the Fraunhofer Heinrich Hertz Institute (HHI) and NTT DOCOMO, the results were submitted for the 3GPP meeting in Xian (China) in the second quarter of 2019.

Presently the focus is on channels at significantly higher frequencies. The team now includes another research heavyweight from the Fraunhofer cosmos: the Fraunhofer Institute for Applied Solid State Physics (IAF). In a collaborative effort, the team has developed a joint research setup that enables signal generation and analysis in the range of 270 GHz to 320 GHz with a bandwidth of 2 GHz [5]. The signal can be used to perform channel measurements and can be modulated with novel waveforms for transmission experiments.

HHI is responsible for signal processing, transmitter-receiver synchronization and system integration. The millimeterwave transmit

Test setup

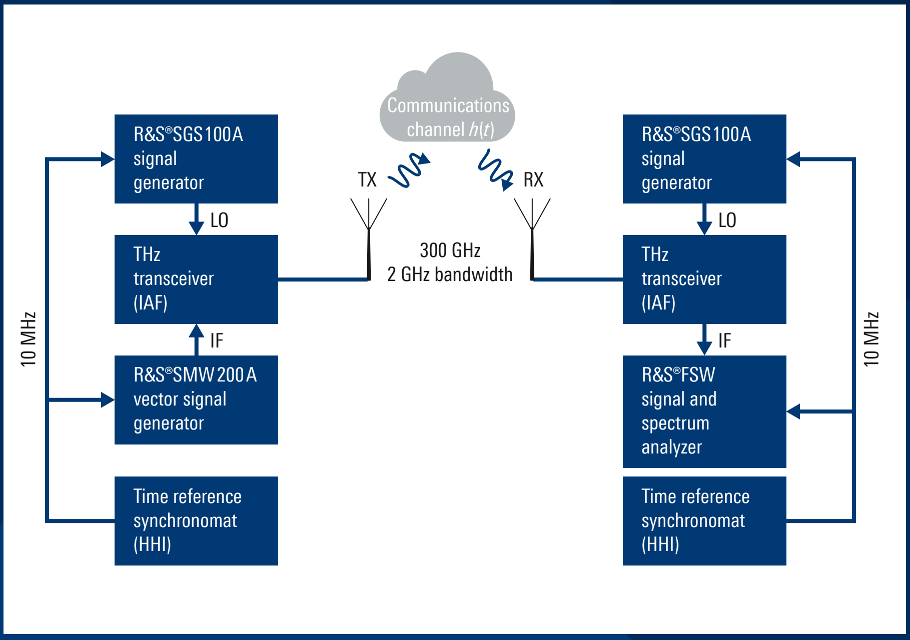


Fig. 3: Block diagram of the 300 GHz channel sounding system. On the transmit end, an R&S®SMW200A signal generator generates a "ping sequence" with a bandwidth of 2 GHz (suitable for autocorrelation) at an intermediate frequency. The terahertz transceiver from Fraunhofer IAF raises this to the wanted transmit frequency, with an R&S®SGS100A acting as a local oscillator. On the receive end, the signal is processed in the reverse order, but with an R&S®FSW analyzer at the end of the chain. The details are described in [5].

and receive modules come from IAF. Rohde & Schwarz is contributing its T&M and wireless technology expertise and providing the instruments needed for signal generation and analysis. Figs. 3 and 4 show the test setup.

Initial measurements at 300 GHz with this measuring system demonstrate its high dynamic range, which is unparalleled in this frequency range (Fig. 5). In collaboration with Fraunhofer HHI and NTT DOCOMO, further measurements in various environment scenarios are in preparation to systematically characterize this subterahertz frequency range.

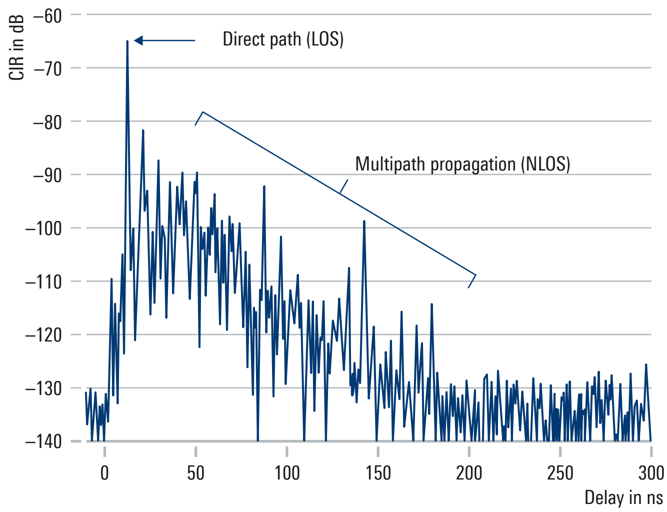


Fig. 5: Channel impulse response (CIR) at 300 GHz in an indoor environment with multiple reflections. The distance between the transmitter and the receiver was approximately 4 m. The pronounced shoulder with many reflections is typical for an indoor environment. An electromagnetic wave travels approximately 30 cm in 1 ns.

Summary

Even though 6G will probably only be introduced in about eight to ten years, research is already underway on its fundamental aspects. The development of subterahertz communications as envisaged for 6G is only possible with a good understanding of wave propagation properties in this as yet insufficiently researched frequency range. Rohde & Schwarz is collaborating with research organizations and industry partners on projects that aim to close these knowledge gaps. This will give the company valuable insights into the requirements for T&M equipment that the mobile communications industry will need in a few years.

Dr. Taro Eichler

References

[1] "5G Evolution and 6G", NTT DOCOMO, Inc., white paper, January 2020.

[2] "Key drivers and research challenges for 6G ubiquitous wireless intelligence (white paper)", 6G flagship research program, University of Oulu, Finland, 2019.

[3] 3rd Generation Partnership Project (3GPP), "3GPP TR 38.901 (V16.0.0): Study on channel model for frequencies from 0.5 to 100 GHz", October 2019.

[4] "Measurement and Characterization of an Indoor Industrial Environment at 3.7 and 28 GHz", to be published at EuCAP2020, https://arxiv.org/abs/2004.11561.

[5] "THz Channel Sounding: Design and Validation of a High Performance Channel Sounder at 300 GHz", to be published at IEEE WCNC2020, https://arxiv.org/abs/2001.06703

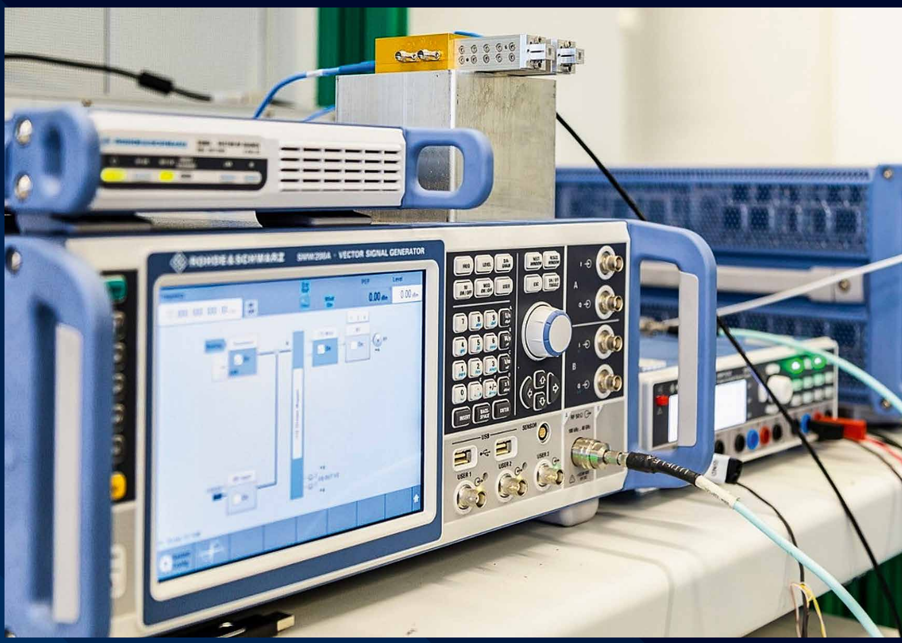


Fig. 4: Test setup for channel measurements at 300 GHz with the R&S®SMW 200A vector signal generator, the R&S®SGS 100A signal generator and the R&S®FSW 43 signal and spectrum analyzer. A transceiver with an integrated horn antenna is shown at the top of the picture. The setup can be used for channel sounding for channel characterization and for transmission experiments with new waveforms.

I SPY WITH MY AI

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Mobile network operators need to test the stability and performance of their networks in order to ensure good service. Due to the enormous amounts of data involved, this is hardly possible with manual methods. Artificial intelligence comes to the rescue.

Network testing in the 5G era

With the advent of the fifth generation of mobile communications, network testers are confronted with a novel situation. Many aspects of 5G – diverse frequency bands, network operators' different rollout programs, the breadth of applications such as IoT, conventional mobile communications, traffic networking, etc. – lead to highly differentiated networks and test data. Analyzing this data in the usual aggregated form quickly leads to distorted results and incorrect interpretations. Artificial intelligence offers a good solution to this dilemma. Algorithm based methods only reflect specific theories. These may not be ideal, but the data itself is reliable. AI methods, such as pattern recognition, are able to evaluate data sets without preconceptions and discover relationships that would remain hidden to human analysts.

Big data needs AI

The term "artificial intelligence" has been bandied about a lot in recent years, often without a clear definition of what it means, and with no differentiation between systems that are able to learn (a characteristic of AI) and systems that are simply based on complex algorithms. The term "machine learning" is a bit more specific. Here the goal is to automatically derive general rules from a large volume of data. After completion of the learning process, yes/no decisions can be made based on multidimensional dependencies or features. The decision rules are learned by approximating between real data points rather than being formulated by human experts. This method requires very large data volumes and an intensive training phase. But in the application phase, it is able to correctly interpret new measurement data almost spontaneously.

Supervised and unsupervised learning

Machine learning can be roughly divided into two types: supervised and unsupervised.

The goal of supervised learning is to find statistical relationships between the data and events or predefined labels in order to generate estimations for unknown inputs. A widely used application is object recognition, in which the presence and position of a particular object in an image (e.g. "A cat is/is not present in the picture") is determined through multi-stage interpretation of patterns (edges, colored areas, etc.). For training, the learning software is presented with images labeled by humans and works out characteristics that allow decisions to be made. These rules are concealed in the neural network of the AI system rather than being formulated in algorithms. An example of non-visual pattern recognition is the determination of the call stability score (CSS) for network tests (described below).

Unsupervised learning works without labels. The algorithms have to independently recognize patterns or multidimensional data aggregates in order to derive usable conclusions from them, for example with the aim of measuring differences between new and known data points. A typical task for unsupervised learning is anomaly detection, which identifies unusual data without the support of experts.

Rohde & Schwarz opts for AI methods

Rohde & Schwarz uses AI methods for applications such as simplifying the optimization of mobile networks or improving the assessment of qualitative differences between providers. The Data Intelligence Lab established in 2018 tackles these issues and supports Rohde & Schwarz R&D departments with data based analysis methods. These approaches are especially promising for testing mobile networks where particularly large amounts of data are generated, so that manual analysis and rule formulation are no longer practical. Machine learning makes it possible to use the information hidden in large data sets, for example to derive new assessment metrics. An example is the call stability score.

Call stability score: a new assessment metric for reliable communications

A suddenly dropped phone call is an annoying experience. That is why mobile network

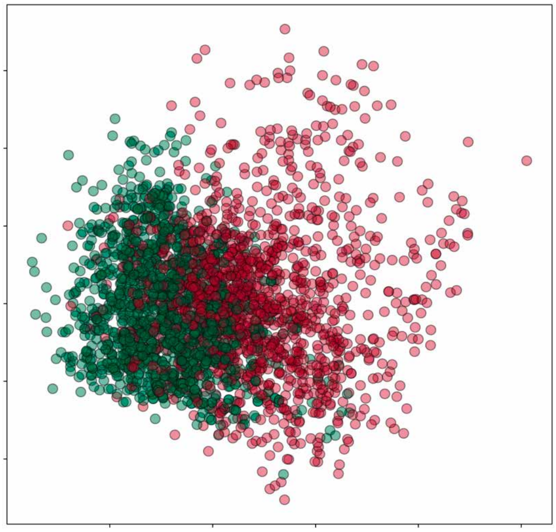


Fig. 1: Two-dimensional projection of multidimensional transmission conditions. Green dots represent successfully completed calls; red dots represent dropped calls.

operators have been testing voice quality and connection stability for many years. The most popular statistic is the call drop rate (CDR). But since the number of dropped calls is very low in mature networks, it is necessary to make a large number of calls in order to obtain a statistically significant value. Consequently, drive test campaigns are long and expensive.

Therefore, Rohde & Schwarz uses a method to replace the binary call status (either successfully completed or dropped) by a finely graduated analog value. This is done by creating a statistical AI-generated model that links the transmission conditions with the call status.

The CSS derived from the model allows the reliability of the mobile connection to be measured over the entire call duration and classified based

R&S®SmartAnalytics analysis platform

Fig. 3: Display of a network optimization scenario using the R&S®SmartAnalytics analysis software's call stability score. Average CSS values are shown on the upper left, arranged by region. On the upper right, especially low scores are marked for later analysis. The exact values are listed in the table with additional information (shown here are sample results for demo purposes). ▷

Fig. 2: Data analytics made easy. R&S®SmartAnalytics enables provider comparisons and network optimizations using AI-generated estimations.

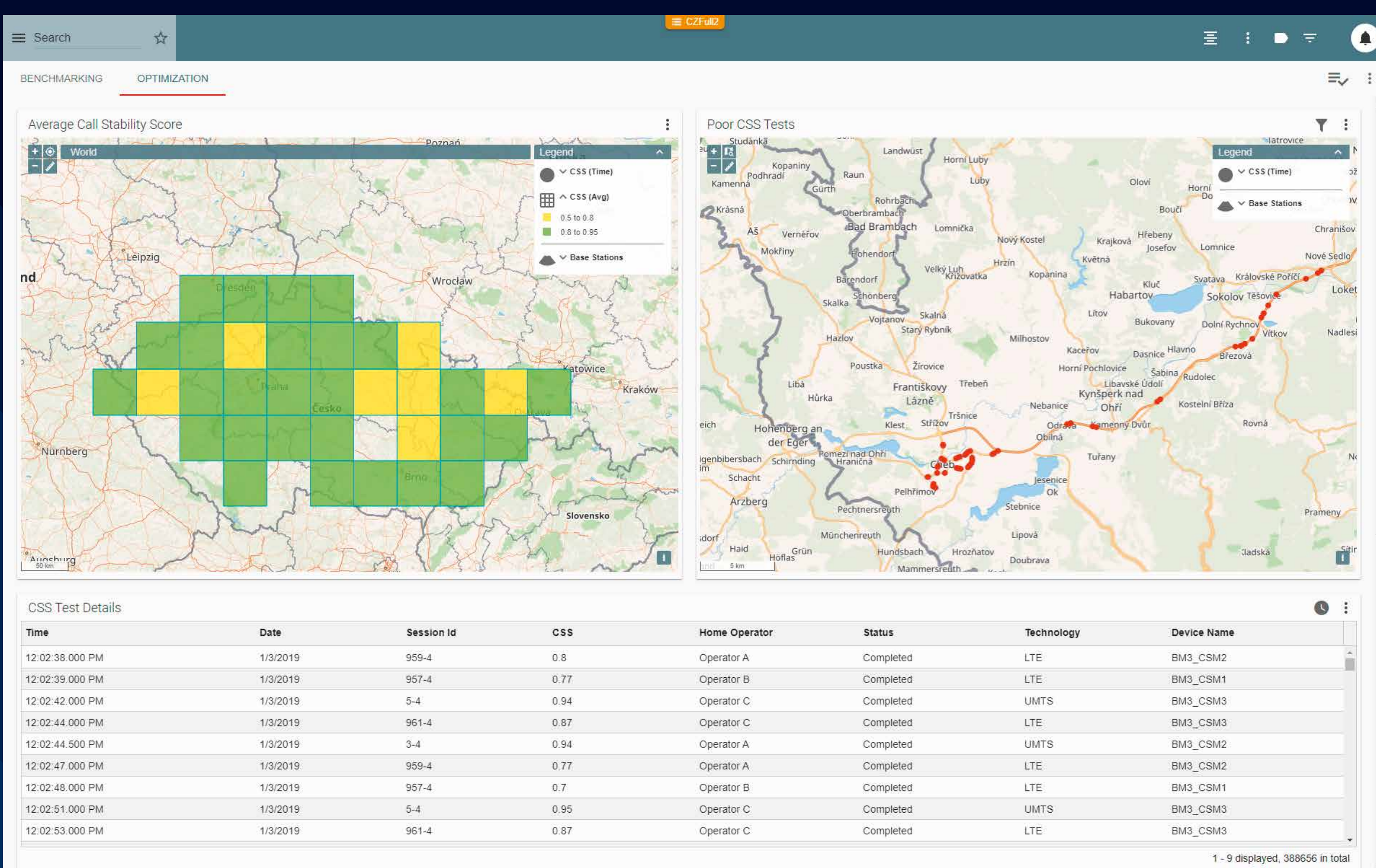
on quality (Fig. 1). The diagnostic also includes unstable calls that were successfully completed but the data proves they were not far away from being dropped. In conventional CDR statistics, those unstable calls would be assessed positively as successful calls, distorting the network quality assessment.

The CSS value is based on information gathered from millions of test calls and incorporated in the model during the learning process. The assessment is conclusive right from the first call. The network call quality is registered more accurately and with less test effort.

In practice, every nine seconds of a call, measurement data is sent to the statistical model as a time series. The model assesses the data based on the learned rules and outputs a number between 0 and 1. The higher the number, the lower the likelihood of a drop occurring in that nine-second interval.

The CSS measurement is part of the R&S®SmartAnalytics analysis platform (see text box). Another AI-driven function in this software suite is anomaly detection using unsupervised learning. In both cases, the use of artificial intelligence leads to results that are not possible with conventional means. AI methods will be used more and more in the future to maximize exploitation of the information content of measurement data.

Dr. Alexandros Andre Chaaraoui



SAFELY NAVIGATING ON ROADS

Vehicles see the world through sensors.
A new test system sharpens their vision.

Without highly advanced sensors, autonomous driving is only a dream. But sensor development is making rapid progress. Radar sensors can now deliver image-like resolution, but only if they are calibrated. A compact test system from Rohde & Schwarz accomplishes this very quickly.

ADAS increases road safety

The EU has a relatively good record when it comes to traffic safety. Nevertheless, according to a publication of the European Parliament, there are still more than 25,000 fatalities every year on roads in the EU, and another 135,000 persons suffer severe injuries. The socioeconomic consequences alone are estimated at EUR 120 billion annually.

These figures could be reduced by improving the safety systems in vehicles. Advanced driver assistance systems (ADAS), such as blind spot warning and braking assistants, have been state of the art for many years. In February 2019, forty countries under the leadership of Japan and the European Union agreed to require new passenger vehicles and light commercial vehicles to be equipped with automatic emergency braking (AEB) systems from 2022 onward. In addition, the European New Car Assessment Program (NCAP) evaluates vehicles on the basis of safety features to increase user awareness and push ADAS deployment by vehicle manufacturers.

Radar is essential for autonomy

Even without legislative requirements, the ADAS development trend is being explicitly promoted because autonomous vehicles (the ultimate goal of all development efforts) are otherwise simply not feasible. The sensor frontend, which is intended to replace the driver's eyes and ears, is making especially rapid progress. Vehicles at autonomy levels 4 and 5 will presumably make use of an extensive sensor set consisting of cameras, ultrasonic sensors, lidar and radar sensors. Along with functional aspects, the costs of these components are decisive for their use. Lidar sensors, which are based on laser technology, are lagging a bit behind radar sensors and are still relatively expensive. They feature higher spatial resolution capability, but their reliance on optical systems impairs their capability under poor weather conditions. Radars are not bothered by this, and since their performance has improved dramatically in recent years and they are relatively low-cost, they form the backbone of current ADAS.

The latest 77 GHz/79 GHz radar sensors have bandwidths of up to 4 GHz, compared to 200 MHz with traditional 24 GHz sensors. The higher frequency band allows smaller antennas while significantly improving resolution capability and accuracy. The increasingly high levels of sensor integration are another contributing factor. The radar-on-chip (RoC) module from Uhnder (Fig. 4), which combines all analog and digital frontend and backend components on a single chip, leads the development trend.

Tricky test conditions

R&D, optimization, validation and calibration of automotive radar sensors must be be subjected to accurate tests because road safety is directly dependent on precision. In addition to measuring the RF parameters, target simulation must be used to evaluate whether a sensor can determine the positions and speeds of objects in its field of view (FoV) within the required resolution.

This is a demanding task due to the high frequency band and the need to make measurements under far-field conditions in order to achieve accurate results. The Fraunhofer formula shows that measuring a 77 GHz radar with a 15 cm aperture requires a target distance of at least 11.5 meters (Fig. 1) to obtain the necessary electromagnetic field uniformity (quiet zone, Fig. 2). The industry is striving for higher and higher angular resolution, so the trend is to integrate more antennas per module, leading to the deployment of antenna arrays with larger apertures. Aperture sizes of more than 20 cm are not unusual, especially in the prototype phase. Far-field test chambers are impractical for these conditions, so near-field to far-field transformation methods can be used instead. These lead to compact antenna test ranges (CATR) that are small enough to easily fit in relatively small labs and are especially beneficial in production environments (Fig. 3).

Radar sensors are in the category of automotive devices that have to be individually tested. Each and every sensor has to be verified, both for safety reasons and because the RF features make individual calibration necessary. This

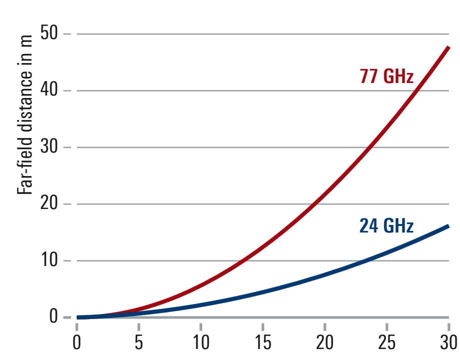


Fig. 1: The large far-field distance of a 77 GHz automotive radar compels T&M manufacturers to come up with innovative solutions to keep measurement setups compact.

is done by simulating a target with a known position, size and speed. The gain, phase and coupling of the antenna path are calibrated for this target, which means that unique calibration data is assigned to them and stored in the module.

The industry is independently trying to do everything necessary to make radars reliable, and now the competent standardization bodies are also tackling this issue. For example, the European Telecommunications Standards

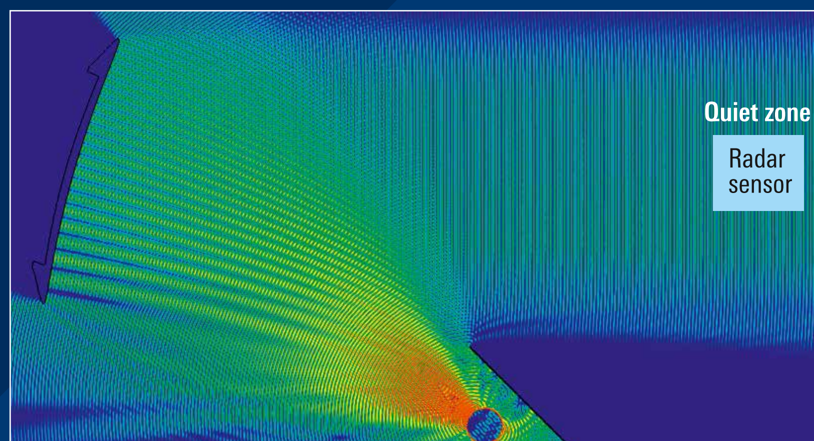


Fig. 2: The precision parabolic reflector in the test chamber transforms the spherical near-field waves from the feed antenna into planar far-field waves, resulting in a quiet zone with a diameter of 30 cm at the positioner location where the radar under test is placed.

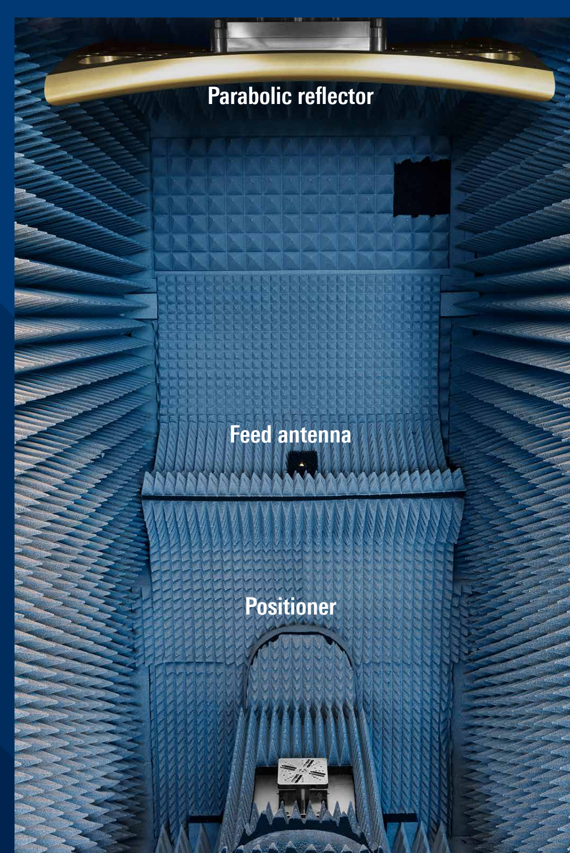


Fig. 3: The test solution for automotive radar sensors, consisting of the R&S®ATS1500C shielded test chamber and the R&S®AREG100A radar echo generator. For operation, the remotely controlled echo generator is mounted on the rear wall of the chamber.

Institute (ETSI) has published automotive radar standards that are applicable within the EU and specify measurements under far-field conditions. Given the importance of radars for future road traffic, similar standards can be expected for other regions.

Precise tests in a very small space

Rohde & Schwarz is the first company to develop a comprehensive solution for testing automotive radar sensors. It consists of the R&S®ATS1500C test chamber with a footprint of only 1.3 m^2 and the R&S®AREG100A radar echo generator (Fig. 3).

The echo generator simulates up to four targets with customer-specific distance, speed and size. The chamber's 3D positioner features high positioning speed and an angular resolution of 0.03°. Specifically developed for radar applications, it automatically varies the angle of incidence (in azimuth and elevation) of the echo hitting the radar sensor. It can maintain a constant polarization orientation between the radar and the measuring system. This avoids the motion-dependent errors that occur with simple positioning systems.

Fig. 4: It is hard to believe that this small chip is a complete multi-channel radar with all signal processing circuitry. All that is missing are the antennas.

Like all devices that transmit and receive signals, radar sensors must be certified in line with the legal regulations for EMI. The limit values in Europe are specified by the Radio Equipment Directive (RED) and the associated ETSI standards. The FCC has issued similar standards for the USA. The R&S®AREG100A allows test equipment such as signal generators and signal analyzers to be connected to the IF input to fully process the relevant test cases. Key parameters such as occupied bandwidth, chirp linearity and chip duration can be measured at the same time.

A new generation of automotive radars

Uhnder, a high-tech startup based in Austin, Texas, has developed a revolutionary imaging radar system and integrated it into a radar-on-chip (RoC) module the size of a fingernail (Fig. 4). Unlike conventional automotive radars, the Uhnder RoC works with digital code modulation (DCM) instead of FMCW chirps with analog modulation (see page 25).

The RoC is also unique because it is the first to combine the analog frontend, baseband processing, digital frontend, digital backend, memory and interfaces on a single CMOS chip. Two CPUs and two DSPs handle digital signal processing. The baseband section alone has a processing capacity of 20 teraOPS. All that computational power is needed to make a complete radar system with an antenna array consisting of 12 transmit antennas and 16 receive antennas. The RoC creates 192 virtual transceivers by utilizing the code diversity of the signals. All this results in a variety of advantages, including extreme compactness, very low power consumption, high processing power and unprecedented spatial resolution.

The Uhnder RoC is classified as a 4D radar because it provides azimuth, elevation, distance and velocity values for each target. Thanks to the high spatial resolution, an Uhnder RoC based sensor can be used to obtain a detailed environment model that is comparable to optical sensors (Fig. 5).

Win-win cooperation

Sensors based on the Uhnder RoC require precise calibration to realize their full potential, and the test solution from Rohde & Schwarz is the answer to this task. The two companies have been cooperating closely for a good while to optimize their products. This has enabled Uhnder to not only improve the sensitivity and accuracy of its sensors, but also develop a fast production-ready calibration algorithm that helps its customers (the sensor manufacturers) perform verification at the end of the production line. And Rohde & Schwarz has gained insight on how to further improve its test chambers. In a joint demo at CES 2020 in Las Vegas, the partners showed how a radar sensor based on the Uhnder RoC could be calibrated in less than a minute. Fig. 6 illustrates the process.

Summary

Radar sensors are the most import source of information about the vehicle environment. Advanced imaging sensors (4D imaging radars) already provide sufficiently high resolution to allow complex environment models to be generated from the data and used as the basis for making vehicle driving decisions. The sensors, which use ever larger antenna arrays and MIMO transceivers, achieve this performance only after precise calibration, which must be performed for each unit on the production line. The compact test system developed by Rohde & Schwarz, which consists of a shielded test chamber and a radar target simulator, allows even the latest generation of complex sensors to be calibrated in less than a minute. The 30 cm diameter quiet zone in the chamber, where far-field conditions prevail, provides enough space for large-aperture sensors, making it suitable for future sensor generations.

Rong Chen Leng; Ralf Reuter

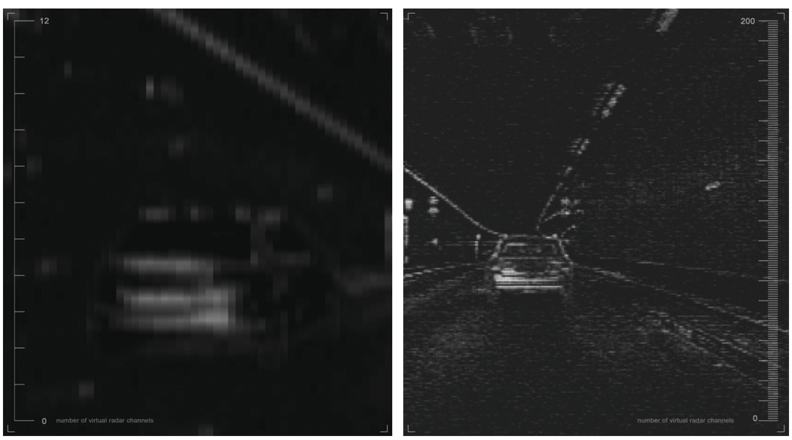


Fig. 5: This simulation gives an impression of the difference between an imaging radar and a conventional automotive radar. Its resolution is so high that it can detect and separate objects that are close together, such as a pedestrian next to a cyclist, and process their individual 4D coordinates.

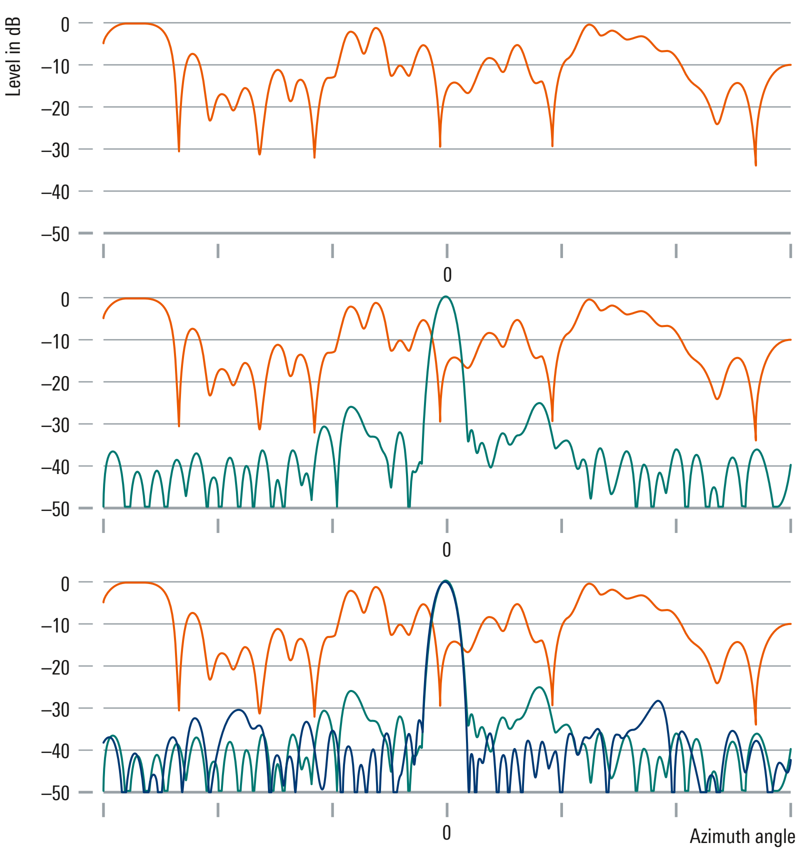


Fig. 6: Calibration of a sensor based on the Uhnder RoC in the R&S®ATS1500C test chamber with the R&S®AREG100A radar echo generator.

Top: The uncalibrated sensor does not detect the target.

Middle: The first calibration step takes place with the sensor stationary and directly facing the target (center axis oriented to the target). This calibration compensates for individual antenna differences in terms of phase and amplitude due to different path lengths. Now the target is clearly distinguishable with a peak to side lobe ratio (PSLR) of 25 dB. The sidelobes are due to the cross-coupling of the antennas.

Bottom: In the second step, the azimuth angle between the sensor's central axis and the target is varied from –45° to +45° by continuously rotating the positioner. This allows correction for cross-coupling, resulting in a 10 dB improvement in the PSLR. This sweep calibration takes less than 25 seconds. At the end, the sensor is calibrated.

BANDWIDTH HUNGRY

FMCW radar: simple principle, sophisticated T&M solution

FMCW radars are extremely wideband at the analog transmitting and receiving ends. Until recently, the up to 4 GHz analysis bandwidths necessary for their validation were only available in oscilloscopes. Now they are also available in the R&S®FSW signal and spectrum analyzer.

Unlike the Uhnder RoC (described in the article starting on page 20), which was the first automotive radar to use digitally modulated signals, frequency modulated continuous wave (FMCW) radars are state of the art. Only the carrier frequency is varied in interruption-free, typically sawtooth or triangular sweeps. A sweep period is called a chirp. Depending on the given requirement, individual ramps with different frequency change rates (chirp rates) can be played out one after the other. This makes it possible to optimize the radar in terms of range resolution, radial velocity resolution and working range. For generating signals, a voltage-controlled oscillator (VCO) is modulated and the output signal is brought to the desired bandwidth and into the desired band using multipliers and frequency converters (Fig. 1).

The signal received by the sensor exhibits a frequency offset (proportional to the target distance) to the momentary transmit frequency, which has moved up a bit on the sweep ramp during the signal delay. If the relative velocities of the transmitter and receiver differ, there is also a Doppler shift (Fig. 2). The transmit and receive signals are mixed to a relatively low intermediate frequency that can be directly sampled.

The advantage of this method is the very inexpensive components. No wideband ADCs or DACs are needed. And thanks to the extremely low data rates, the digital signal processing requirements are not so demanding. But the requirements on analog components at the transmitting end are all the more stringent. Deviations from the linearity of the FM ramps lead directly to a poorer signal-to-noise ratio (which means objects might be overlooked) or to phantom signals (simulation of objects that are not really there).

Demand for wideband signal analysis

Since higher bandwidths are associated with higher range resolution, FMCW radars are designed to be as wideband as possible at the analog transmitting

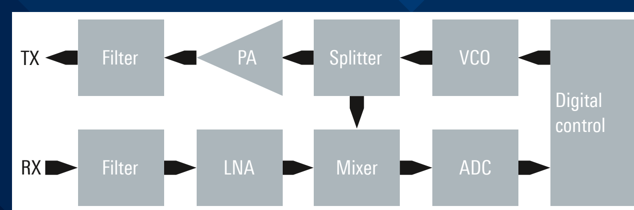


Fig. 1: Simplified block diagram of an FMCW radar. The received signal is mixed with the signal being transmitted. Only the resulting, relatively narrowband beat frequency is digitized and analyzed.

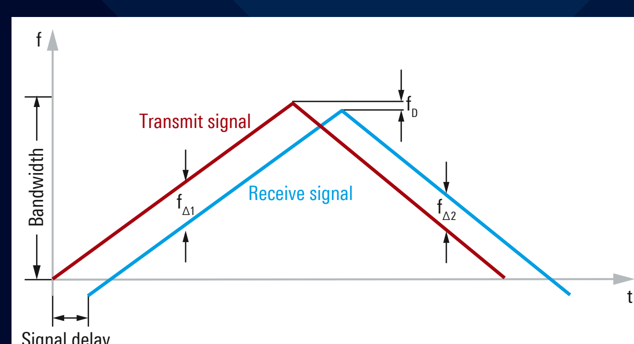


Fig. 2: FMCW signal with triangular modulation. To simply determine the distance, either a rising or falling edge would suffice (sawtooth); in both cases the target distance is proportional to the frequency difference f_Δ, but distorted by the Doppler frequency f_D when the radar and target are moving relative to each other. The graphic shows the case where an object is moving away. If you want to determine the relative velocity based on the Doppler frequency and also eliminate the Doppler distance error, you need both edges. In that case, the Doppler frequency is half the difference of the frequency differences $f_{\Delta 1}$ and $f_{\Delta 2}$. To achieve the desired precision, high requirements are placed on the linearity of the edges – and consequently on the measuring equipment used during radar development.

and receiving ends. In the E band (76 GHz to 77 GHz or 77 GHz to 81 GHz), up to 4 GHz of contiguous spectrum is available, resulting in a range resolution of about 7 cm. In research and development, as well as during validation, the complete signal must be known over the entire modulation bandwidth. Until recently, only oscilloscopes offered the necessary analysis bandwidths of up to 4 GHz.

Validating conformity with ETSI, FCC, etc., requires not only signal analysis but also spectral measurements using a spectrum analyzer in order to detect spurious emissions and measure the occupied bandwidth. The R&S®FSW signal and spectrum analyzer combines these two functions.

The new R&S®FSW-B4001, -B6001 and -B8001 bandwidth options equip the instrument with analysis bandwidths of 4,4 GHz, 6.4 GHz and 8.3 GHz, respectively. These bandwidths are unique in signal and spectrum analysis. The advantage over a combination solution with an oscilloscope (for wideband IF sampling) is clear: a single instrument analyzes all frequency ranges of interest and digitizes them with a high dynamic range. This applies to signals modulated on an intermediate frequency, to the transmit signal in the E band and to the low-frequency receive signal mixed with the transmit signal. The top-of-the-line model, the R&S®FSW85, additionally provides a very high-quality spectrum analyzer that covers the range from 2 Hz to 85 GHz in a single sweep and features an internal attenuator, preselection and image suppression (Fig. 3).

Customized measurement application

The signal data recorded by the R&S®FSW in wideband is initially available in digital format. All of the signal information, i.e. level and phase or frequency, is contained within the analysis bandwidth, acquisition period and dynamic range.

Rohde & Schwarz provides different measurement applications for analyzing this information. The R&S®FSW-K60 transient analysis option with its R&S®FSW-K60c chirp analysis extension is specifically designed for the FMCW signals used in automotive radar. The software selectively searches for FM transients in the acquisition memory, recognizes and catalogs them and displays them in a table with their key parameters (Fig. 4). Individual chirps in the acquisition memory can be selectively chosen and analyzed. Statistical analysis across a large number of acquisitions is also possible.

Fig. 3: The R&S®FSW85 covers the entire spectrum in a single sweep with preselection from 2 Hz to 85 GHz. The 4 GHz radar signal in the E band at 79 GHz is clearly visible.

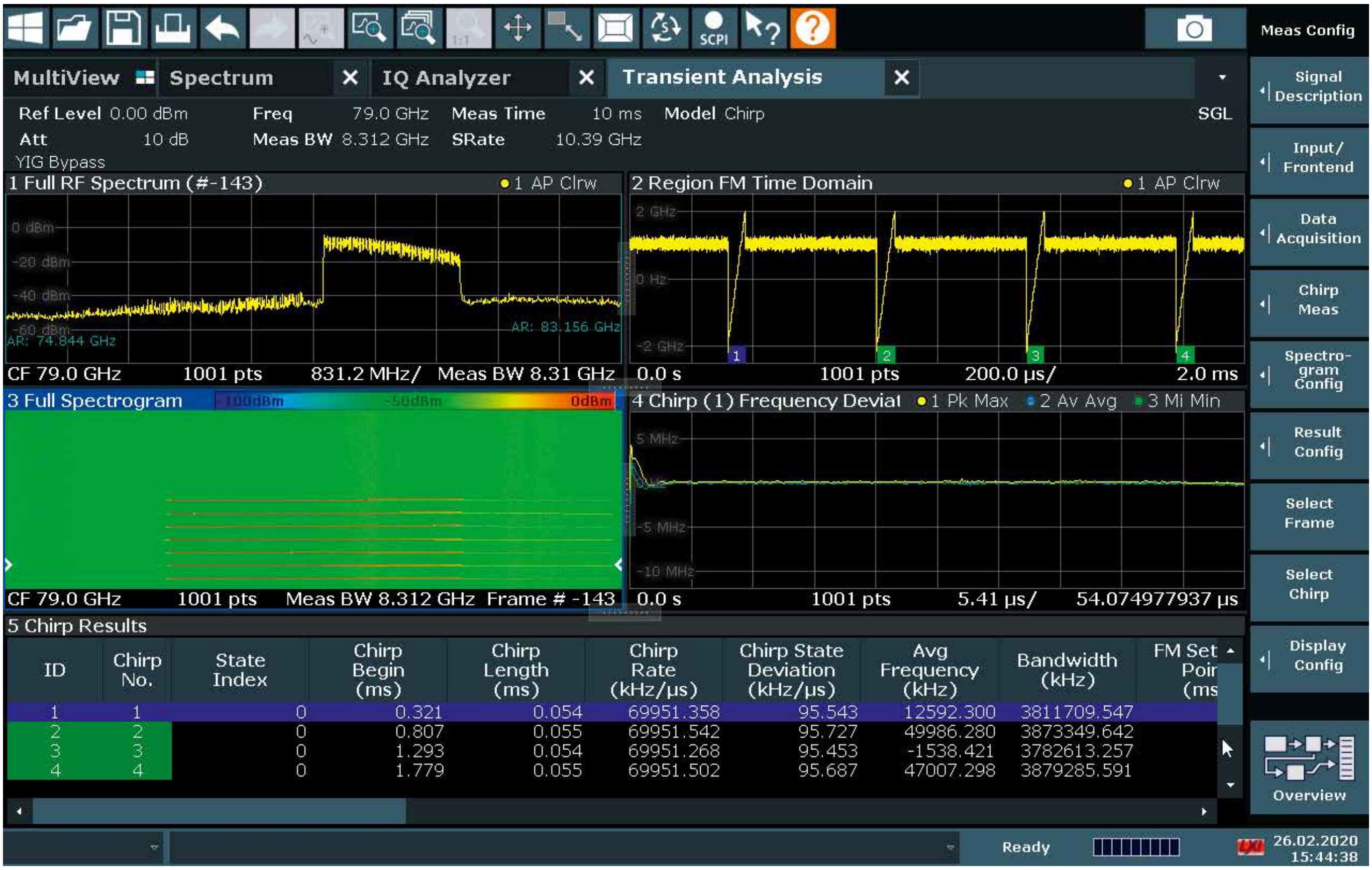


Fig. 4: The R&S®FSW-K60 transient analysis software option extended by the R&S®FSW-K60c chirp analysis option provides all key parameters of an FMCW signal on one screen.

Key parameters are the chirp length, chirp rate and the settling time. Nonlinearities in the frequency modulation, i.e. in the time domain, as well as frequency deviations from the ideal frequency are calculated, graphically displayed and statistically evaluated.

Ready for what the future brings

With the trend toward higher signal bandwidths and the ever growing number of radar sensors installed in vehicles, interference problems are increasing: radar sensors receive signals from neighboring vehicles, which limits their functionality and can even cause connected driver assistance systems to make wrong decisions. Additional frequency bands and waveforms can solve these problems. Regulatory authorities are therefore considering releasing frequencies beyond 100 GHz for automotive radars, e.g. the 134 GHz to 141 GHz band. Within the 7 GHz available here, a 4 GHz sensor could hop to an interference-free frequency subrange when interference occurs.

Technologies such as software defined radar make it possible to use entirely different waveforms, for instance the orthogonal frequency division multiplexing (OFDM) modulation used with LTE and 5G. Using different types of modulation on the individual transceiver channels would allow the MIMO multi-antenna technology to be used even more effectively, as demonstrated by Uhnder with its RoC. And individual parameters could be modulated onto the separate radar signals, allowing the receive signal to be clearly identified.

With up to 8.3 GHz analysis bandwidth and a large number of measurement applications, the R&S®FSW is ready for whatever direction technology takes.

Martin Schmähling

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BRINGING THE TEST LAB TO YOUR HOME OFFICE

Many employees have to work at home due to the corona pandemic. This is rarely an option for engineers who need constant access to test equipment. However, there are workarounds.

Remote control of test equipment has been standard practice in labs and system houses for many decades. Nowadays even low-cost devices have the necessary interfaces, at least as options. Top-end devices often have built-in web servers, allowing them to be operated remotely from any browser. All that is needed is the IP address, and the device must be accessible online. For remote unattended measurement stations with a static setup, remote access and operation is already common practice. In all cases, it is important to have effective access protection with authentication mechanisms. This is not a problem in a protected lab environment, where remote control capability is often used for convenience to avoid having to constantly go back and forth between the workplace and a test lab located elsewhere. What these scenarios have in common is that they are one-off special solutions that have to be reconfigured for each application. For those who want to take a broader approach to remote control of test equipment and make it a workable standard practice, a cloud based solution is an obvious approach.

Collaborative measurement via the cloud

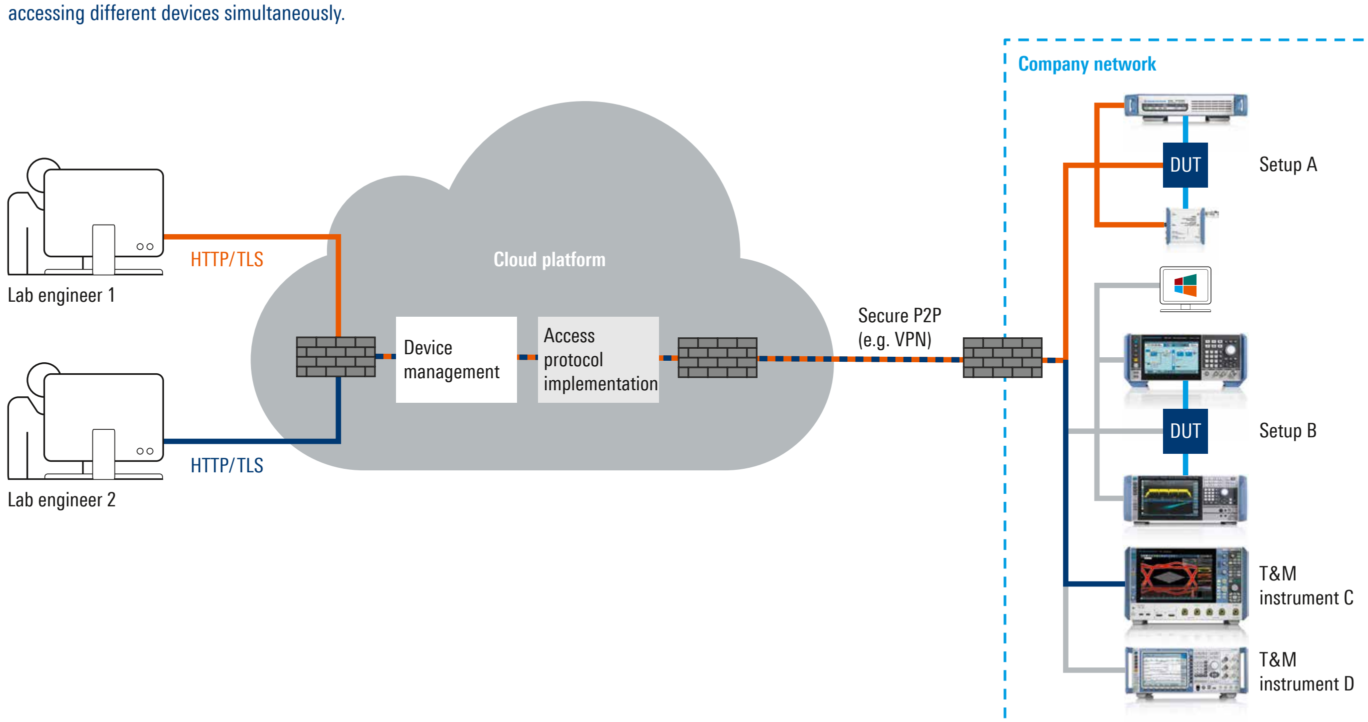
Everything as a service (EaaS) is the latest trend, and it is becoming more and more popular. Users of such services, most of which are based on cloud technology, save on capital expenditures because they do not have to maintain the underlying infrastructure and only pay for the services they actually use. In addition, these services are usually highly scalable, so users can count on the required capacity being available. A prerequisite for moving a service to the cloud is that it can be virtualized. At a virtual sales counter, the user simply books a service based on type, time, scope and quality. The cloud management system allocates the necessary resources.

Such systems, which are typically offered by large cloud operators for various tasks, can also be set up on a smaller scale for test and measurement services. These differ from typical software as a service (SaaS) solutions with regard to the type of service and the resources. A company that wants to virtually pool all or a part of its T&M equipment to make it accessible companywide from any location only has a limited number of each type of T&M instrument in its portfolio, and unlike a server, each instrument can only be used for one measurement task at a time. Scalability is not the main consideration here. However, collaboration and remote access are increasingly important and necessary – now more than ever.

Fig. 1 shows the basic structure of a T&M equipment cloud. The cloud operator has reserved a set of instruments for cloud access and formed instrument groups for frequently used setups. Virtual operation of a T&M cloud is not fully possible because most instruments need a physically connected device under test (DUT). A helpful soul on site has to provide the connection. In many cases, the cloud users will do this step themselves whenever possible, and then carry out their analyses remotely. In extreme cases, instruments and users are in different countries or even different continents, for example in a collaborative development project. Then each user will have to find a workable solution based on the situation and task.

Access is possible via any web browser. TLS encryption on the web ensures a secure connection with the cloud. Typical for the cloud, the system includes a device management service that prevents multiple use of devices and enables times to be reserved. You can book individual devices or preconfigured device groups, which are managed via a local control computer that is also used to exchange data with the setup, e.g. to upload waveforms or script files. With devices that support access via the RDP or VNC remote desktop protocols, an access protocol translation service sets up the connection. Then the data stream flows from the cloud platform through a dedicated point-to-point communications channel, for instance a secure VPN tunnel, to the remotely controlled hardware.

Fig. 1: A T&M equipment cloud like the one Rohde & Schwarz operates for its own purposes and that could also be set up for customers. The devices and device groups can be used from any location. In this example, two users are accessing different devices simultaneously.



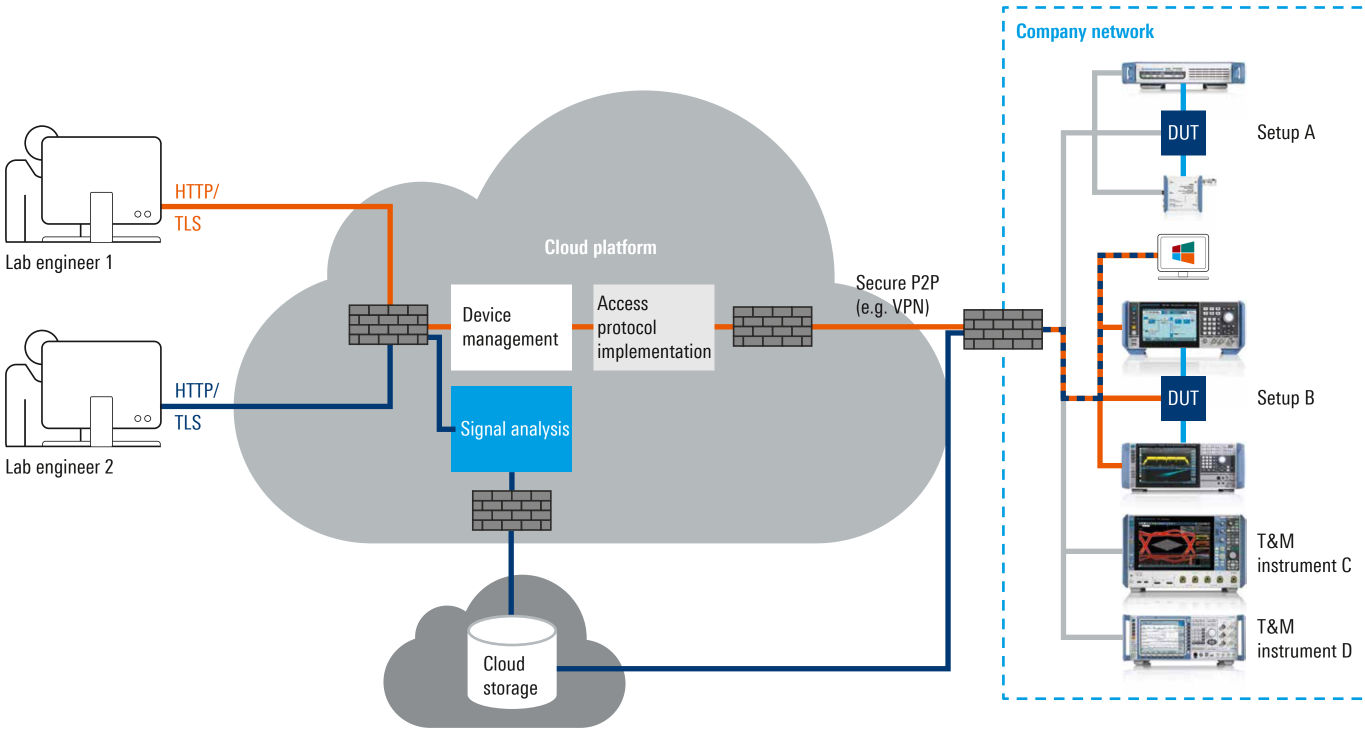
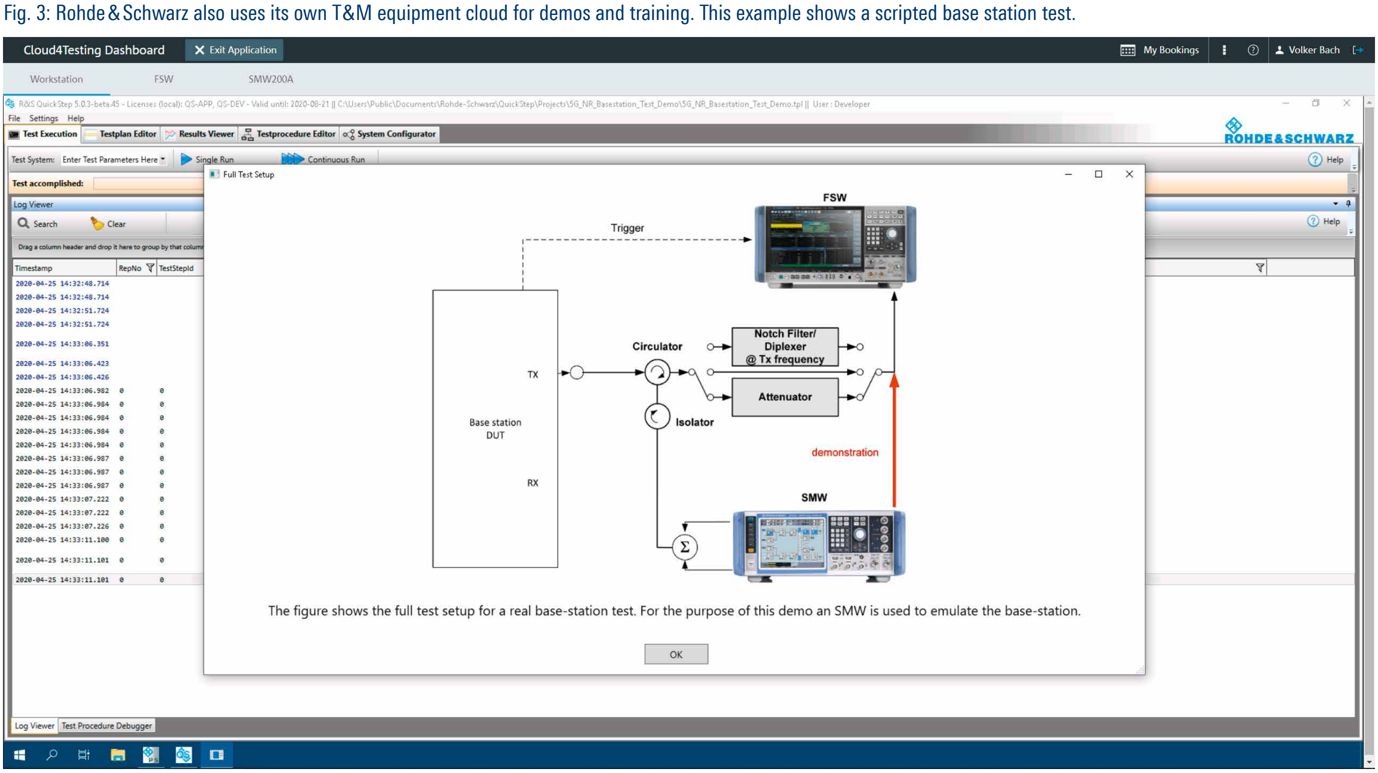


Fig. 2: Adding a data analysis path to the setup in Fig. 1. Measurement data collection at the instrument location and data analysis can be decoupled and performed by different persons. Rohde & Schwarz offers this sort of analysis cloud for public use at www.rohde-schwarz.com/cloud4testing.

Fig. 3: Rohde & Schwarz also uses its own T&M equipment cloud for demos and training. This example shows a scripted base station test.



In order to extend the possibilities for measurements based on the division of labor, a cloud storage component can be added to the Fig. 1 setup (Fig. 2). This also makes it possible to separate the collection and analysis of measurement data. For example, one engineer can execute the measurements and send the data to cloud storage, while a second engineer performs the software based analysis at a convenient time from any location.

R&S®Cloud4Testing

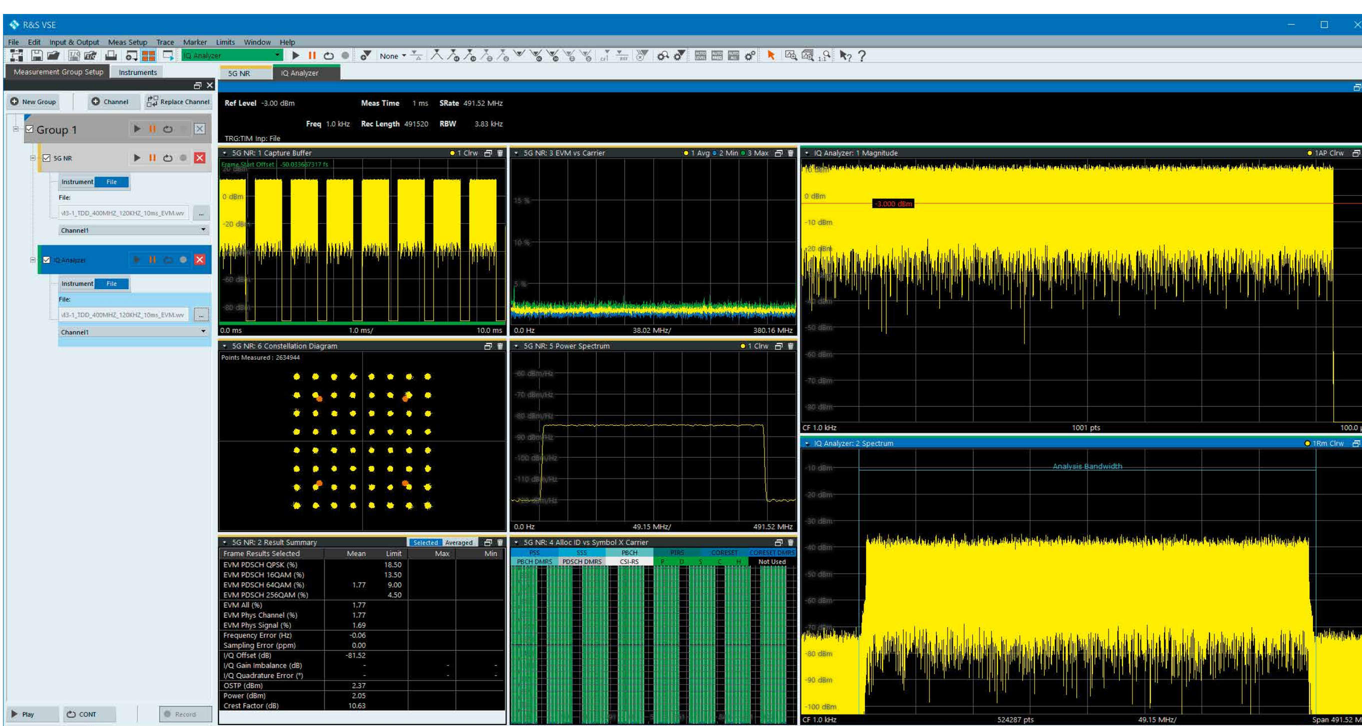
This use case – cloud based measurement data analysis – is supported by the new R&S®Cloud4Testing SaaS that is available to the public as a paid service at www.rohde-schwarz.com/cloud4testing (all products are also available as free trials). The service currently offers analysis packages for various mobile communications standards, as well as general transient and pulse analysis packages (Figs. 3 and 4). Other packages are in preparation.

The "large" cloud solution for instrument access is worth considering for companies that want to make some or all of their T&M equipment conveniently available online for collaborative work, customer demos, training courses, better resource utilization and other reasons. As a reliable partner, Rohde & Schwarz can assist in the custom implementation of this kind of cloud, if desired with connection to a cloud storage system as shown in Fig. 2.

Rapid progress is being made in the virtualization of our work environments. A T&M cloud is fully aligned to this trend and can prove to be a valuable or even indispensable tool, even in non-pandemic times.

Sascha Laumann

Fig. 4: Various packages for mobile network analysis, pulse analysis and general signal analysis can be accessed on the R&S®Cloud4Testing SaaS.



JACK OF ALL TRADES

Economy vector signal generator for a wide variety of tasks

The R&S®SMCV100B is the first commercial multistandard platform for automotive, broadcast, navigation and wireless applications. It is fully software configurable and ideal for numerous applications from the lab to production – in all situations where different technologies come together.

The base configuration of the vector signal generator (Fig. 1) covers the output frequency range from 4 kHz to 3 GHz with an RF bandwidth of 60 MHz and output power from –110 dBm to +15 dBm. A 64 Msample ARB generator is included in this configuration. At the maximum configuration level, the upper frequency limit is 7.125 GHz, the RF bandwidth is 240 MHz and the maximum output power is +25 dBm. In this configuration, the R&S®SMCV100B also covers 5G NR applications in the extended FR1 frequency range.

The high-performance, Linux based platform is completely extensible using software options. All options are present in the device firmware and can be activated with option keys as needed. No additional hardware is necessary. The options include frequency and bandwidth extensions, higher RF output power, larger memory depth for the ARB generator, and phase noise reduction to less than –125 dBc (20 kHz offset) at 1 GHz (Fig. 2).

The R&S®SMCV100B uses an RF DAC for signal generation, allowing I/Q modulation and RF signal generation to be performed in the digital domain. This results in very good values for I/Q imbalance, carrier/sideband suppression and EVM. The RF DAC directly generates the output signal for frequencies up to 2.5 GHz. For higher frequencies, the signal goes through a mixer stage before it is output.

Like other signal generators in the portfolio, the R&S®SMCV100B can be provided with precalculated signals via the R&S®WinIQSIM2 PC software. This simulation software supports all common wireless standards, including those for IoT. It can also generate non-cellular signals such as Wi-Fi (802.11xx) and many more. In total, more than 30 standards are available in combination with the R&S®SMCV100B. The custom digital modulation option allows user-defined signals to be loaded into the instrument and output by the internal arbitrary waveform generator.

For Go/NoGo tests, the generator can output GPS, GLONASS, Galileo and BeiDou signals of a single navigation satellite. Predefined, time-limited

Fig. 1: The R&S®SMCV100B vector signal generator for automotive, broadcast, navigation and diverse mobile communications applications.

I/Q sequences can be output for functional tests with fixed satellite positions, for example in production.

In the base configuration, the memory depth of the ARB generator is 64 Msamples. It can be extended to as much as 1 Gsample using keycodes. If this is not enough, waveform streaming can be used to play back I/Q signal scenarios with RF bandwidths up to 56 MHz from the internal SSD or USB storage media. Via the digital I/Q interface, data can also be fed to the R&S®SMCV100B from external devices such as the R&S®IQW I/Q data recorder.

FPGA based real-time coders for broadcast standards used worldwide are available. The R&S®SMCV100B supports analog and digital audio standards as well as second and third generation digital terrestrial and satellite based television standards. This is the first economy platform that supports ATSC 3.0 in addition to the DVB-T2 and DVB-S2X standards.

A wideband internal noise generator is available for receiver tests where a defined C/N ratio is required.

The generator is housed in a half-width 19" box for space-saving rack mounting. Its compact dimensions and cooling concept make it ideal for bench use. The exhaust air is vented at the rear with a low fan noise level of 52 dB(A).

Ralph Kirchhoff

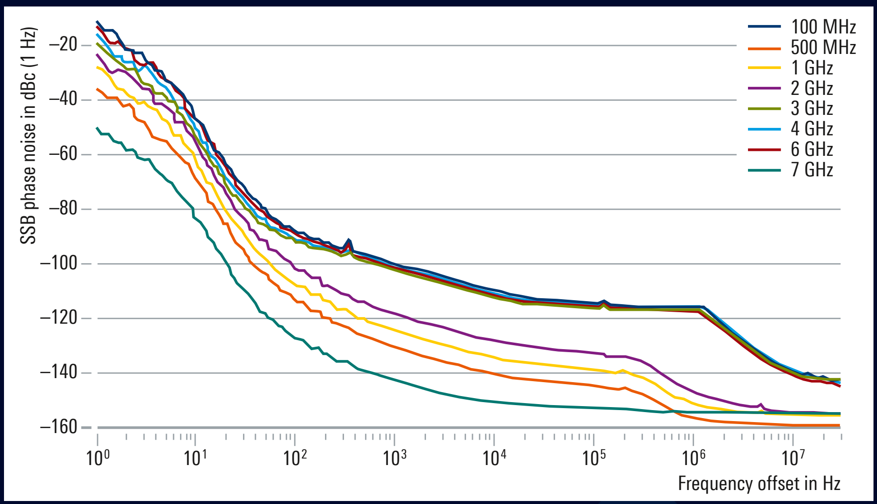
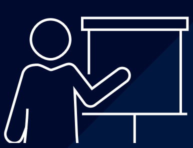


Fig. 2: Measured SSB phase noise at different carrier frequencies (with the R&S®SMCVB-K709 option for low phase noise).

APPLICATIONS

The many available standards and its broad functionality make the R&S®SMCV100B ideal for a large number of applications.



Research and education

In university labs, schools, etc.

Broadband market

General purpose generator in labs

Mobile communications market

Signals for communications standards such as 5G, LTE, IoT and Wi-Fi in line with the various versions of IEEE 802.11, Bluetooth™ and other standards

Broadcast and consumer device industry

Manufacturing and testing of broadcast receivers, set-top boxes, TV receivers, etc.

Automotive industry

Production, end-of-line testing of car radios, entertainment and navigation systems and many other products

Electronics production

Manufacturing of various products with constantly changing requirements regarding modulation types, system bandwidths, etc.

POWER SOURCE MANAGEMENT

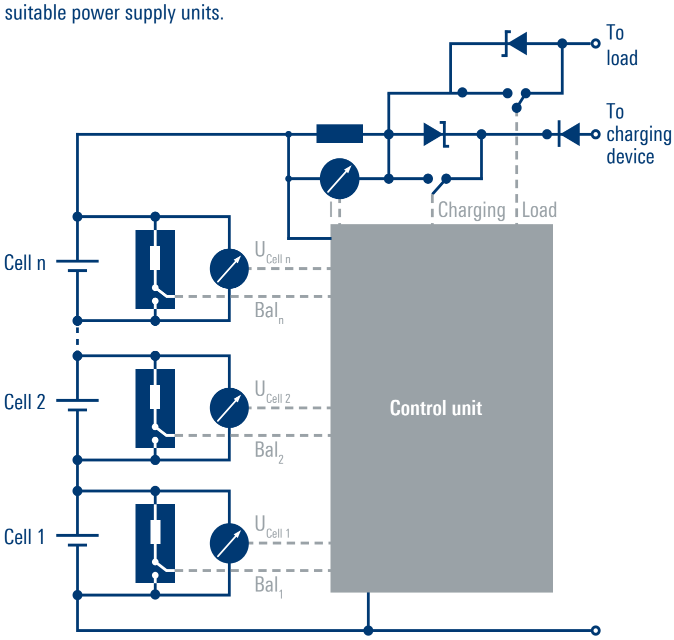
Testing battery management systems with the R&S®NGL200 and R&S®NGM200 power supplies

Ever since the lithium-ion battery became an inexpensive mass-produced article, virtually the only devices still connected by cable are stationary devices; rechargeable batteries are now standard. Single-cell batteries suffice for operating small devices such as toothbrushes and smartphones. Batteries for devices with a higher power requirement consist of a series circuit of cells. These cell groups must be actively managed. This is taken care of by battery management systems (BMS), which control charging and discharging.

The tasks of a BMS include the following:

- Determining the state of charge (SoC) of individual cells
- Determining the overall SoC, also known as fuel gauging
- Monitoring the integrity (state of health, SoH) of individual cells
- Maximizing battery life by optimally charging the individual cells
- Early detection and avoidance of dangerous situations, such as overheating or even igniting cells

Fig. 1: Setup of a multicell current supply with integrated battery management system. During development of the management system, the cells are simulated using suitable power supply units.



Since the cells are in a series circuit, the charge and discharge current for all cells is initially the same. But over a large number of charge and discharge cycles, slight production and aging differences can result in the cells having different SoCs, which will decrease the battery's usable capacity and life. This is why BMSs monitor the voltages of the individual cells and balance the SoC within the cells.

A distinction is made between passive and active balancing. During the charging process, passive balancing uses load resistors to drain charge from the cells with the highest SoC until they have the same charge as the rest of the cells. Active balancing can also work while the cells are discharging, and uses switching regulators to move charge from the highest charged cells to the lowest charged cells.

Fig. 1 shows a block diagram of a battery management system.

Since battery management systems play a crucial role in the safety and life of batteries, their development requires special attention. It is important to test their behavior in all operating states and error cases that can be expected. To do this effectively, it must be possible to simulate the behavior of individual cells as accurately as possible. Controllable power supplies with integrated voltage and current measurement functions are used for this purpose.

Cell behavior is primarily characterized by the open-circuit voltage and the internal impedance as a function of the SoC. The current must be measured and the voltage set as a function of the current. For low to medium powers, the power supplies can directly simulate this using the integrated battery simulation. For very high powers, software simulates the actual charge and discharge currents, and only the equalizing currents flow into the power supplies.

One basic requirement on power supplies for this application is two-quadrant operation, where the power supply has to give off energy to simulate the battery discharge but must be able to receive energy for the charging process by reversing the current flow. Another requirement is setting the output voltage as a function of the simulated battery's SoC and of the present flow of the current. To do this, the power supply must have a current measurement function. To realistically simulate a cell's internal impedance, it has to be possible to measure the current as well as set the voltage with sufficiently short latencies.

Besides two-quadrant operation and short setting times, the R&S®NGL200 and R&S®NGM200 power supplies also offer a highly accurate current and voltage measurement function and are therefore ideal for testing battery management systems. The individual channels are isolated from the protective conductor and designed for a relative voltage of up to 250 V, which is sufficient for a series circuit of approx. 50 lithium-ion cells. In the two-channel version (R&S®NGL202 and R&S®NGM202), the power supplies allow a space-saving setup even for simulating a large number of cells (Fig. 2).

Compared with the R&S®NGL200, not only does the R&S®NGM200 offer increased measurement accuracy for voltage and current by switching the measurement range and more accurate simulation of the internal impedance, it also comes with an option for directly simulating battery cells. The sequencing of the cell voltage and internal impedance as a function of the SoC can be defined using text files. For the most common battery systems, such definitions are included ex factory. In addition, the R&S®NGM200 can record the measured voltage and current sequences for a detailed analysis with up to 500,000 values per second.

Thomas Lechner

Fig. 2: Battery management systems for up to 16 cells can be tested using eight R&S®NGM202 power supplies.

BMS system tests

- Cell balancing test by setting differing cell voltages
- Fuel gauging test over multiple charge and discharge cycles
- BMS behavior with cell over- and undervoltage
- Simulation of cell failures
- BMS behavior with overtemperature of battery cells
- Simulation of different aging of cells
- Testing the detection of charging device and load
- Testing switch-off devices by simulating malfunctions in the charging device (overvoltage) and load (increased current consumption and short circuit)

Benefits of the R&S®NGL200 and R&S®NGM200 in testing battery management systems

- Easy scalability
- Simple setup thanks to 19" rackmounting and rear panel cabling
- Flexibility by combining universal power supplies with specific application software
- Direct simulation of internal impedance
- Integrated battery simulation (R&S®NGM200)
- Logging and fast logging (R&S®NGM200) for highly accurate current and voltage measurements with high time resolution

EFFICIENCY BOOST FOR EVERY LAB

The R&S®NGP800 DC power supply series can simultaneously power up to four DUTs.

Standard lab power supplies with up to 100 W output power are increasingly reaching their limits with the requirements of today's circuits. The new R&S®NGP800 power supply series (Fig. 1) is future-proof. The range of applications goes far beyond consumer goods. These power supplies can be used in medical engineering, industrial and A&D applications and in automotive electronics, for example for developing and testing 48 V vehicle components. Their flexibility, functionality, protection functions and connectivity make them ideal for versatile deployment in R&D, in test and production environments, in quality assurance, in service and in training.

Fig. 1: The R&S®NGP800 DC power supply series consists of five models with 400 W or 800 W total output power. The large touchscreen shows everything at a glance (here an overview of all channels).

The large touchscreen, numerous convenience features and compact format make them a practical, universal lab bench tool. Thanks to short command processing times, a variety of remote control interfaces and rackmounting capability, they are equally suitable for integration into automated test systems and production lines.

Maximum flexibility

The R&S®NGP800 power supplies deliver up to 800 W. Each of the two or four outputs can provide up to 200 W, with a maximum of 64 V or 20 A, depending on the model. Thanks to the FlexPower technology, they have a significantly larger operating range than standard power supplies with the same output power. The rated power of 200 W per channel is available over a large and continuously adjustable range of voltage and current settings. Fig. 2 shows the operating range for channels with 32 V/20 A and 64 V/10 A. When operated in parallel or series, they can provide voltages up to 250 V or currents up to 80 A (Fig. 3).

All channels are galvanically isolated, so they can be operated and loaded completely independently of each other. The output button enables simultaneous operation of all channels or selected channels.

Maximum functionality

Well-conceived functions make everyday measurement tasks very efficient. For example, inrush currents can be precisely controlled with the ramp function, and different power-up sequences can be configured using the individually adjustable output delays. The QuickArb arbitrary function supports dropout tests and simulation of realistic power supply scenarios. Integrated voltage and current measurements and internally calculated power values enable quick analysis directly on the unit (Fig. 4). All values can be logged for repeatable test setups and detailed examination later on. Remote sensing ensures a constant supply voltage at the load, and the user button can be configured with a frequently used action.

Maximum safety

In keeping with their high power, the R&S®NGP800 series features extensive protection functions, including overcurrent, overvoltage and overpower protection. These functions protect DUTs from too high voltages and currents, and they are especially essential for limit testing. The tripping behavior and sensitivity of the electronic fuse can be individually set for each channel; the Fuse Link function couples the fuses of multiple channels. Safety limits prestrict the power supply to values that are not dangerous for the DUT.

Maximum connectivity

The large selection of remote control interfaces supports a wide variety of application areas. All models are delivered with USB and LAN ports; WLAN and IEEE-488 interfaces are available as options.

Trigger conditions can be programmed with the digital I/O ports and used, for example, to synchronize several devices.

Using external control voltages from 0 V to 5 V to control the output voltages and currents enables very short setting times.

Anja Fenske

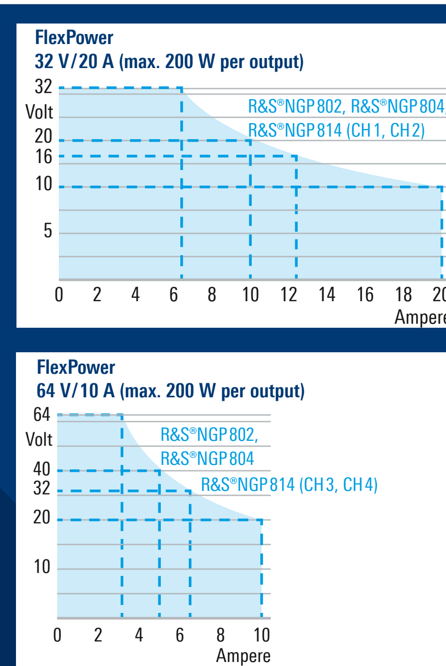


Fig. 2: Thanks to the FlexPower technology, the 200 W output power is available for a wide range of voltage and current settings.

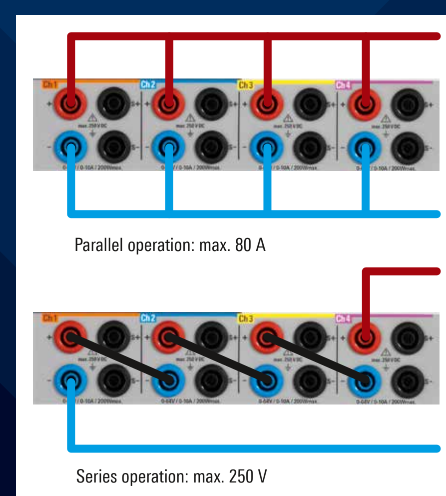


Fig. 3: Up to 80 A or 250 V when operated in parallel or series.

Fig. 4: Real-time statistics for power, voltage and current enable quick assessment without additional software.

LONG LIVE THE KING

Ultrawideband signal analysis

With its 85 GHz sweep range and 2 GHz analysis bandwidth, the R&S®FSW signal and spectrum analyzer was already the king of wideband. New analysis bandwidths up to 8.3 GHz cement its position.

The trend toward higher signal bandwidths continues in virtually all high frequency applications. Bandwidths of 4 GHz or more are no longer utopic. They are already standard practice in radar and communications technology. But up until now, signal analysis technology for these wideband systems has been more of a workaround than a user-friendly, single-box solution. The A/D converters needed to sample the modulated range were only available in oscilloscopes. Consequently, previous solutions used a signal and spectrum analyzer as a wideband downconverter to feed the signals to an oscilloscope. The Rohde & Schwarz setup consisted of the R&S®FSW signal and spectrum analyzer and an R&S®RTO oscilloscope. Users had to accept the disadvantages of more instruments and limited performance.

With the launch of new options for the R&S®FSW signal and spectrum analyzer to extend the internal signal analysis bandwidth to 4.4 GHz, 6.4 GHz and 8.3 GHz, this type of improvisation is no longer necessary. One-box signal processing in the R&S®FSW enables users to take advantage of the analyzer's unequaled dynamic range and sensitivity, its precision and its EVM performance up to very large modulation bandwidths. A variety of applications benefit from this.

In **radar technology**, wider bandwidths lead to better range resolution for object detection. Since the range resolution improves in proportion to the signal bandwidth, current automotive radar systems operate with bandwidths of 4 GHz or more in the millimeterwave bands (see the articles starting on page 20). A&D radars change frequency and modulation from one pulse to the next over a wide frequency range. This helps reduce the probability of intercept by enemy reconnaissance and avoid interference – for example from jammers intended to reduce the sensitivity of enemy radars or render them completely blind. This is done using wideband noise-like signals or frequency agile signals. When developing and verifying both radar systems and radar jammer systems, wideband acquisition makes it possible to analyze frequency hops in detail while examining different radar systems operating at different frequencies.

In **communications technology**, bandwidths are increasing with every new technology generation to enable ever higher data throughput. The 802.11ay standard for Wi-Fi supports channel bonding, which leads to signals with bandwidths greater than 8 GHz.* Suitable wideband T&M equipment is also needed for upcoming gigabit communications in the E band and subterahertz bands. For digital predistortion, which is used to correct nonlinearities of amplifiers, it is necessary to analyze not only the user channel but also its adjacent channels. In the case of an 800 MHz multicarrier 5G NR signal, this would require an analysis bandwidth of up to 4 GHz.

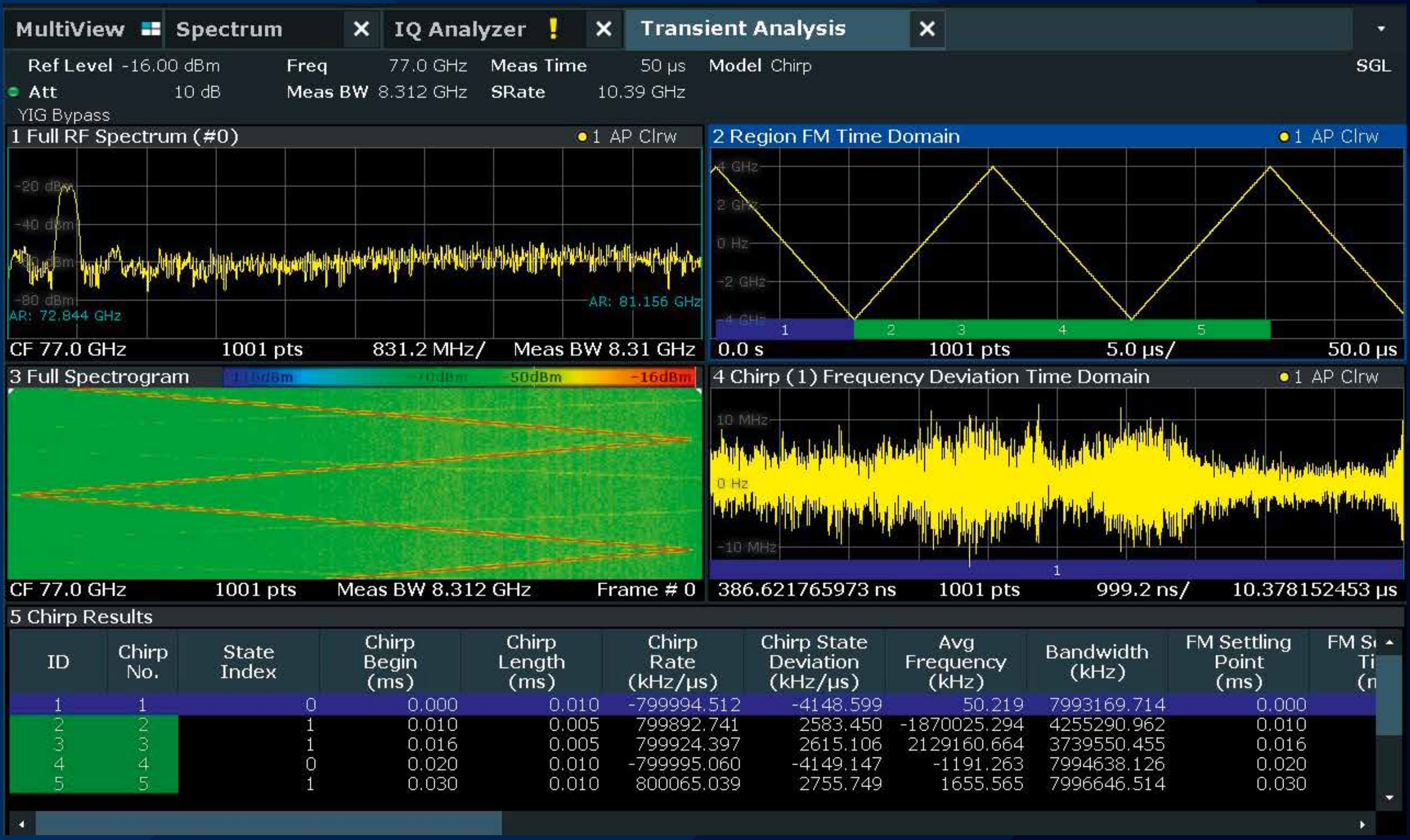
Similar to the radar and communications industries, future **satellite systems** will operate with higher frequencies and wider bandwidths. Signal bandwidths are expected to increase to 3 GHz or 5 GHz at frequencies up to 90 GHz, e.g. for high throughput satellites designed to support terabit connectivity.

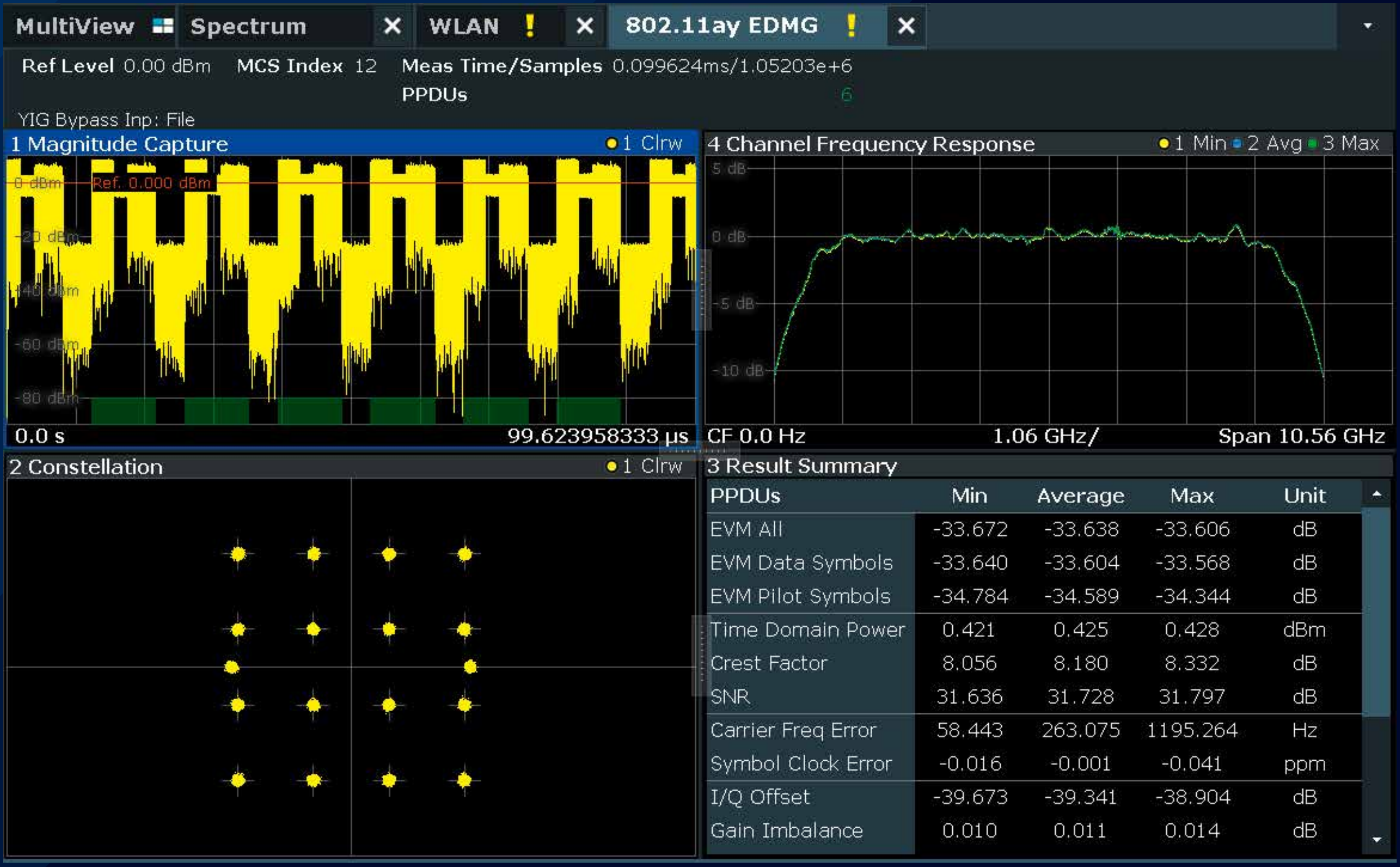
Melanie Mauersberger; Werner Dürport

* WLAN 802.11ay: up to 176 Gbit/s over the air. NEWS (2019) No. 221, pages 26 to 27.

Fig. 1: In radar technology, more bandwidth means better range resolution. That is a few centimeters at 8 GHz as in this chirp.

Fig. 2: The channel bonding supported in the IEEE 802.11 ay standard for Wi-Fi can lead to data bandwidths greater than 8 GHz, which necessitates correspondingly wideband analyzers.


MultiView
Spectrum
IQ Analyzer
Transient Analysis
Ref Level -16.00 dBm
Freq 77.0 GHz
Meas Time 50 µs
Model Chirp
SGL
Att 10 dB
Meas BW 8.312 GHz
SRate 10.39 GHz
YIG Bypass
1 Full RF Spectrum (#0)
1 AP Clrw
CF 77.0 GHz
1001 pts
831.2 MHz/
Meas BW 8.31 GHz
2 Region FM Time Domain
1 AP Clrw
0.0 s
1001 pts
5.0 µs/
50.0 µs
3 Full Spectrogram
-16dBm
CF 77.0 GHz
1001 pts
Meas BW 8.312 GHz
Frame # 0
4 Chirp (1) Frequency Deviation Time Domain
1 AP Clrw
386.621765973 ns
1001 pts
999.2 ns/
10.378152453 µs
5 Chirp Results
ID | Chirp No. | State Index | Chirp Begin (ms) | Chirp Length (ms) | Chirp Rate (kHz/µs) | Chirp State Deviation (kHz/µs) | Avg Frequency (kHz) | Bandwidth (kHz) | FM Settling Point (ms)
1 | 1 | 0 | 0.000 | 0.010 | -799994.512 | -4148.599 | 50.219 | 7993169.714 | 0.000
2 | 2 | 1 | 0.010 | 0.005 | 799892.741 | 2583.450 | -1870025.294 | 4255290.962 | 0.010
3 | 3 | 1 | 0.016 | 0.005 | 799924.397 | 2615.106 | 2129160.664 | 3739550.455 | 0.016
4 | 4 | 0 | 0.020 | 0.010 | -799995.060 | -4149.147 | -1191.263 | 7994638.126 | 0.020
5 | 5 | 1 | 0.030 | 0.010 | 800065.039 | 2755.749 | 1655.565 | 7996646.514 | 0.030


MultiView
Spectrum
WLAN
802.11ay EDMG
Ref Level 0.00 dBm
MCS Index 12
Meas Time/Samples 0.099624ms/1.05203e+6
PPDUs 6
YIG Bypass Inp: File
1 Magnitude Capture
1 Clrw
Ref. 0.000 dBm
0.0 s
99.623958333 µs
4 Channel Frequency Response
1 Min 2 Avg 3 Max
CF 0.0 Hz
1.06 GHz/
Span 10.56 GHz
2 Constellation
1 Clrw
3 Result Summary
PPDUs | Min | Average | Max | Unit
EVM All | -33.672 | -33.638 | -33.606 | dB
EVM Data Symbols | -33.640 | -33.604 | -33.568 | dB
EVM Pilot Symbols | -34.784 | -34.589 | -34.344 | dB
Time Domain Power | 0.421 | 0.425 | 0.428 | dBm
Crest Factor | 8.056 | 8.180 | 8.332 | dB
SNR | 31.636 | 31.728 | 31.797 | dB
Carrier Freq Error | 58.443 | 263.075 | 1195.264 | Hz
Symbol Clock Error | -0.016 | -0.001 | -0.041 | ppm
I/Q Offset | -39.673 | -39.341 | -38.904 | dB
Gain Imbalance | 0.010 | 0.011 | 0.014 | dB

VECTOR MIXER MEASUREMENTS IN THE TERAHERTZ RANGE

Thanks to a novel test method, the R&S®ZNA vector network analyzer now provides full vector correction of frequency converters and mixers up into the terahertz range.

Frequencies above 67 GHz and up into the terahertz range are increasingly gaining in importance for commercial applications. To ensure correct data transmission and achieve low bit error rates (BER), the systems and modules used in a transmission channel must have a constant frequency response and a linear phase response. Instead of the phase response, the group delay or the deviation of the frequency response from linear phase is usually measured.

Up- and downconverters play a crucial role at these high frequencies, since the performance of these key components decisively impacts the transmission quality of the overall system. Although measuring the magnitude, phase and group delay on coaxial converters in the lower gigahertz range is today standard in Rohde & Schwarz network analyzers, these measurements continue to be a challenge in the mmWave and terahertz ranges.

Mixer measurements above 67 GHz – previously in terms of magnitude only

Up- and downconverters typically convert waveguide frequency bands to the coaxial baseband below 10 GHz using a harmonic mixer. The straightforward user interface of the R&S®ZNA makes it easy to configure test setups with up to four identical or two different mmWave converters from the R&S®ZCxxx series, which covers frequency bands from 50 GHz to 1100 GHz.

Users can set frequencies and power levels in the R&S®ZNA mixer menu (Fig. 1). With up to five phase coherent sources, the R&S®ZNA can provide all the necessary signals, i.e. the RF and LO signals for the frequency converter(s) and the LO signal for the mixer to be characterized.

At frequencies above 67 GHz, the conversion loss of mixers and converters could previously only be determined by means of scalar, i.e. magnitude, measurements. Power calibration was performed with both a coaxial and a waveguide power meter on the IF and the RF end. While accuracy can be enhanced by additionally performing one-port correction to remove mismatch errors at the test ports, this approach does not provide full calibration.

Vector mixer measurements for the first time up into the terahertz range

The R&S®ZNA now offers the unknown through, open, short and match (UOSM) calibration for precise phase and group delay measurements on frequency converters. In combination with the phase coherent

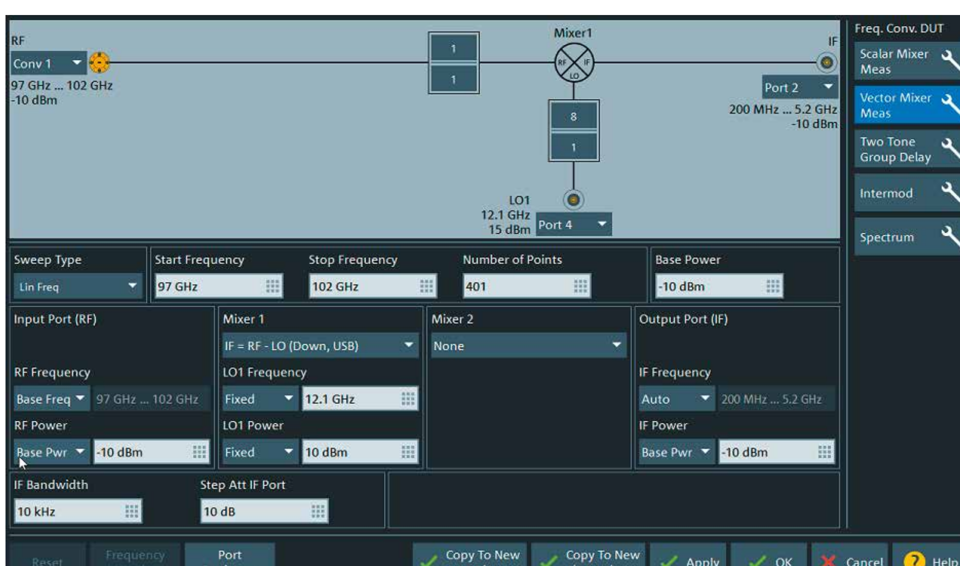


Fig. 1: User interface for configuring mixer measurements. In this example, the mixer under test is configured for downconverting of the frequency band from 97 GHz to 102 GHz to the baseband from 200 MHz to 5.2 GHz, using the 8th harmonic of 12.1 GHz of its LO signal.

sources of the R&S®ZNA, this feature enables calibration and measurement of the phase, group delay and magnitude of the conversion loss of mixers and converters up into the terahertz range.

UOSM is a full two-port calibration method that provides system error correction, taking into account port mismatch. The frequency-converting UOSM calibration requires no more than a coaxial and a waveguide calibration kit. As a through connection, a reciprocal mixer is used, whose conversion loss in terms of magnitude and relative phase is unknown but identical in both directions, i.e. for up- and down-conversion. Passive mixers without an isolator, including harmonic mixers, are generally reciprocal to a large extent, especially in terms of their group delay and relative phase. Mismatch at the mixer's RF and IF ports and losses of a few decibels have no impact on the measurement. If the DUT itself is a passive mixer without an isolator in the RF or IF path, it can also be used as an unknown through.

After UOSM calibration, the R&S®ZNA measures all four S-parameters of the mixer or converter under test (Fig. 2). It displays the magnitude, phase, deviation from linear phase and group delay of the conversion loss of the mixer or converter (Fig. 3).

As can be expected from a passive mixer, the group delay in this example is virtually constant. The low residual ripple of 200 ps peak to peak reflects the measurement accuracy achieved with coaxial mixer measurements in the lower gigahertz range.

Thilo Bednorz; Andreas Henkel

Measurements now up to 1100 GHz

The new R&S®ZC750 and R&S®ZC1100 mmWave converters extend the frequency range of the R&S®ZNA vector network analyzer up to 750 GHz and 1.1 THz. They offer unprecedented output power of typ. –18 dBm (R&S®ZC750) and typ. –25 dBm (R&S®ZC1100), allowing better compensation of losses in the test setup, such as losses occurring in probes for on-wafer measurements. Like all converters of the R&S®ZCxxx series, the new converters are automatically detected and configured and can be assigned to the desired test port(s) in the analyzer's configuration window. The R&S®ZCxxx converters are ideal for use in component design, antenna and material characterization, and other applications.

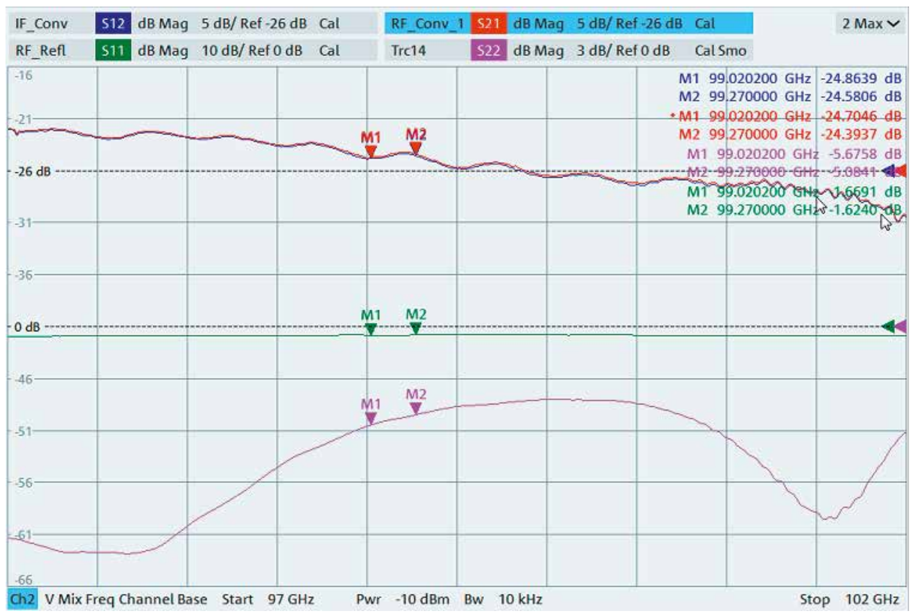
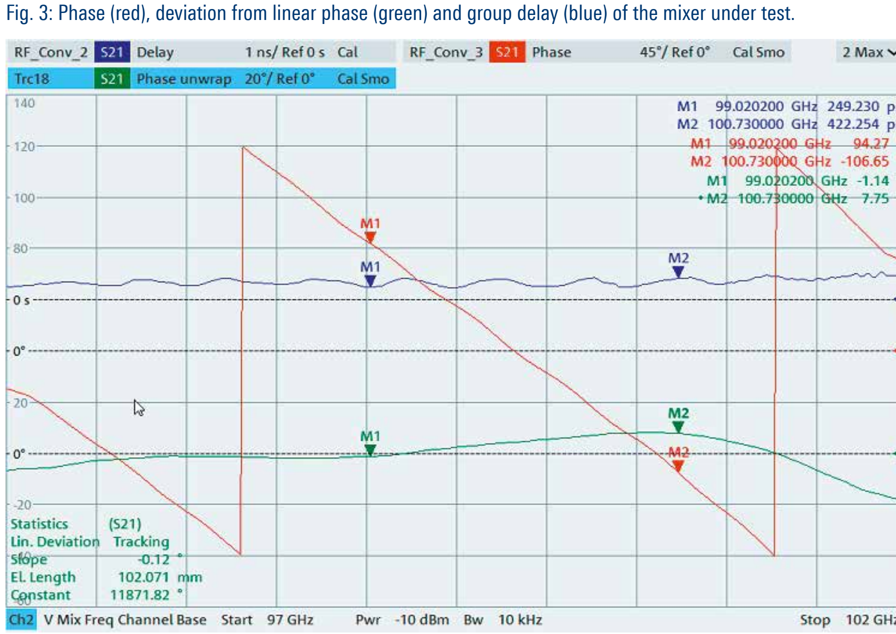


Fig. 2: Transmission (red, blue) and RF and IF port matching (green, violet) after UOSM calibration.

Fig. 3: Phase (red), deviation from linear phase (green) and group delay (blue) of the mixer under test.



JITTER SPLITTER

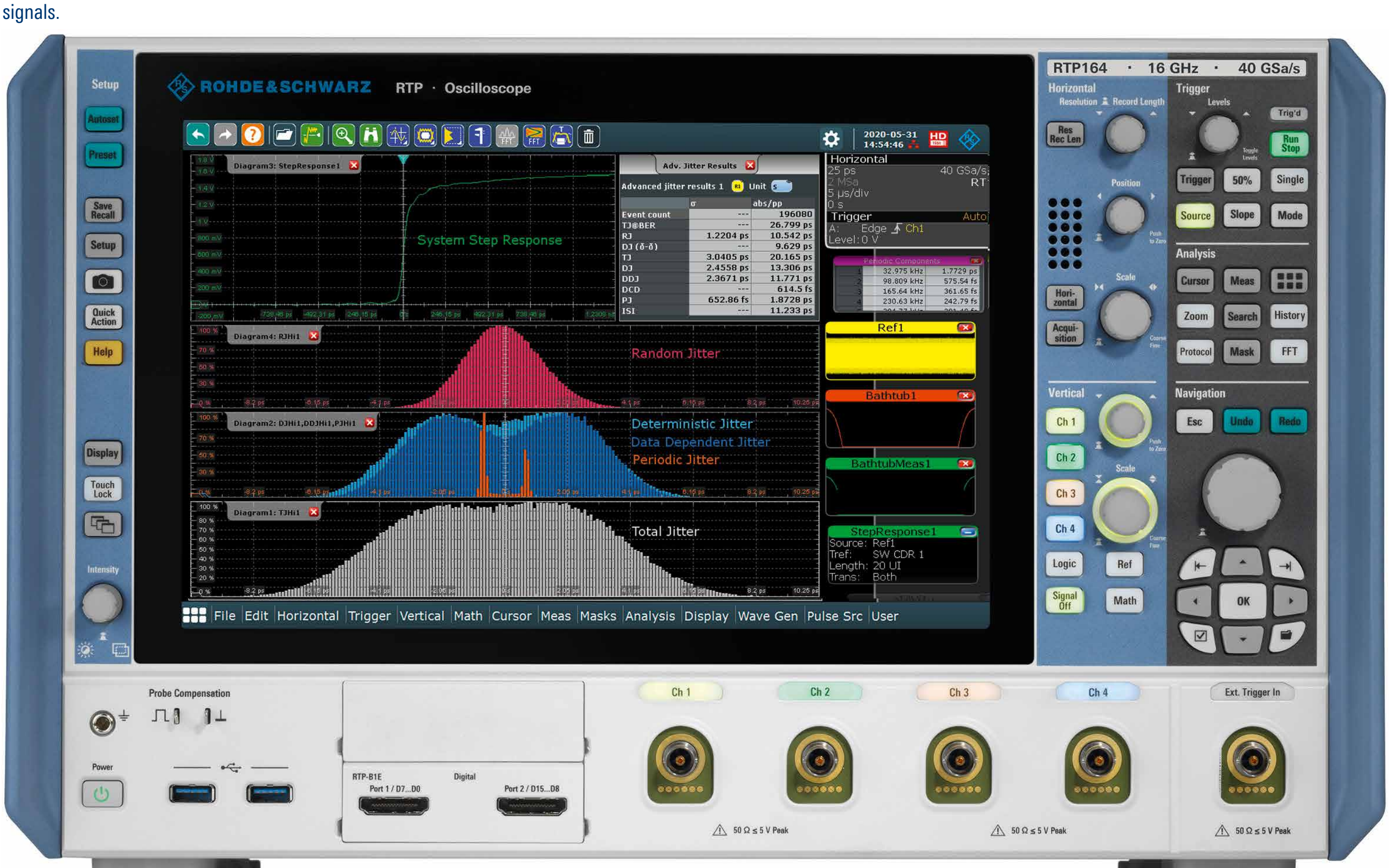
Comprehensive jitter analysis at the push of a button

A new signal model based algorithm from Rohde & Schwarz precisely separates jitter components, giving developers deep insights during debugging and characterization of high speed signal transmissions in electronic circuits.

Characterizing the jitter budget

The rising data rates and shrinking voltage levels on digital interfaces, the complexity and density of advanced designs, and the cost pressure on board material, connectors and components are driving the need for jitter component analysis. One way to characterize the total jitter of an interface is to measure the bit error rate (BER). According to the specifications, fast interfaces such as USB or PCI Express typically have a target BER of 10^{-12}. This means that only one incorrectly transmitted bit is allowed for every sequence of 10^{12} bits. However, validating the total jitter with a BER tester is very time consuming and does not provide any details about the individual jitter components.

Oscilloscopes are unsuitable for direct BER measurements due to their limited acquisition memory. A straightforward measurement of the total jitter for a certain BER is impossible, as illustrated in the following example. The waveform acquisition time for a test pattern with 10^{12} bits is 200 seconds at a data rate of 5 Gbit/s. With a sampling rate of 20 Gsample/s,



An R&S®RTO or R&S®RTP (shown here) oscilloscope with the R&S®RTO/RTP-K133 advanced jitter analysis option helps users characterize and debug DUTs with high speed data interfaces or fast clock signals.

an acquisition memory of 4 Tsample would be required. Today's oscilloscopes do not have such a deep acquisition memory.

In the early 2000s, a smart solution to this dilemma was found: the invention of jitter separation (also known as jitter decomposition) and the subsequent estimation of the total jitter. The idea behind this approach is that the total jitter consists of deterministic components and random components. The deterministic jitter is bounded, while the random jitter is unbounded and therefore its peak-to-peak values scale with the BER. Fig. 1 shows these jitter components in the BER bathtub curve. The open eye area for data sampling by the receiver is the difference between the unit interval (UI) and the total jitter (TJ).

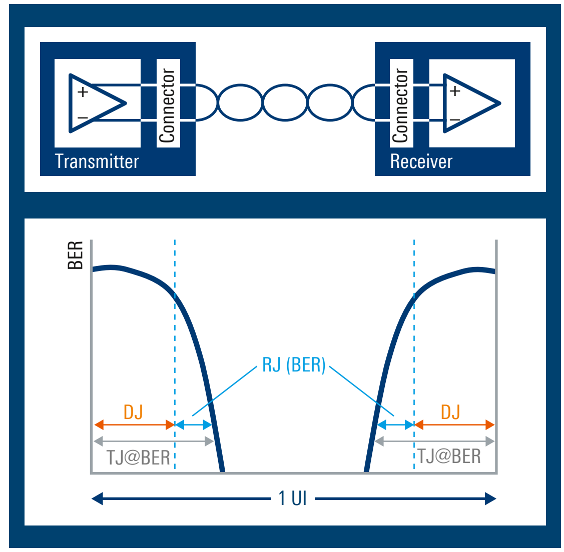


Fig. 1: Shows the bit error rate of a digital transmission system as well as the dominating jitter components that sum up to the total jitter (TJ) in the unit interval (UI): deterministic jitter (DJ) and random jitter (RJ).

Jitter components and their causes

Deterministic jitter can be broken down into several components: data dependent jitter, periodic jitter and other bounded uncorrelated jitter components (Fig. 2). Understanding the dominating jitter components in a signal enables developers to take suitable measures to optimize the design.

Jitter components have various causes:

- **Random jitter (RJ)** depends on factors such as the quality of the reference clock oscillator or the thermal noise of semiconductor components
- **Periodic jitter (PJ)** is typically caused by interferers from switched-mode power supplies or oscillators, or is a sign of PLL stability issues
- **Intersymbol interference (ISI)** is mainly related to transmission losses and limited bandwidth of circuits and signal transmission paths, including reflections caused by impedance mismatches
- **Duty cycle distortion**, which is the other part of data dependent jitter, indicates rise/fall time mismatches of the signal edges or offset errors in the transmitter or receiver
- **Bounded uncorrelated jitter** is typically caused by crosstalk from adjacent signal traces

These examples show that jitter decomposition is an important first step for localizing design problems and achieving cost-effective solutions.

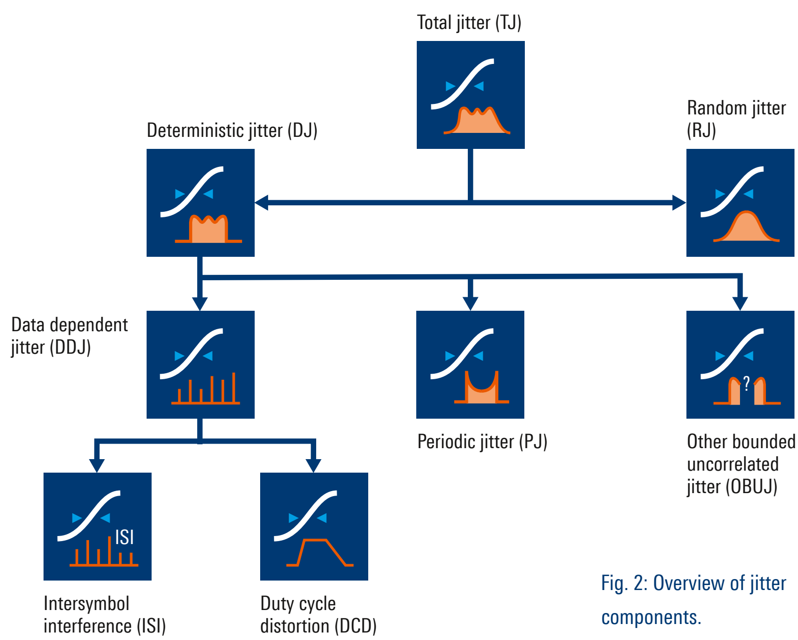


Fig. 2: Overview of jitter components.

New algorithm for jitter decomposition

The approaches and algorithms for jitter decomposition have evolved over the last 20 years. The initial methods such as tail fitting for determining random jitter and the dual Dirac model for estimating deterministic jitter, are still being used and are included in certain interface specifications. The conventional method to further break down the deterministic jitter reduces the input signal information from the sampling points of an analog waveform to a set of time interval error (TIE) measurements (Fig. 3).

The new jitter decomposition algorithm from Rohde & Schwarz uses an analytical approach. It is based on a parametric signal model that fully characterizes the behavior of the transmission path under test (Fig. 3). The main advantage of this method is that it utilizes the complete waveform characteristic, including the vertical and horizontal components. This leads to more accurate and more consistent measurement results, even for relatively short signal sequences.

The core element of the signal model is the step response that describes the data dependent characteristics of the signal. The model also includes the periodic and random error terms:

Step response

Input signal

$$\boldsymbol{y} = \boldsymbol{A} \cdot \begin{bmatrix} \hat{\boldsymbol{h}}_{\mathrm{sr}} \\ \hat{y}_{-\infty} \\ \hat{\boldsymbol{p}}_{\mathrm{v}} \end{bmatrix} + \boldsymbol{\epsilon}$$

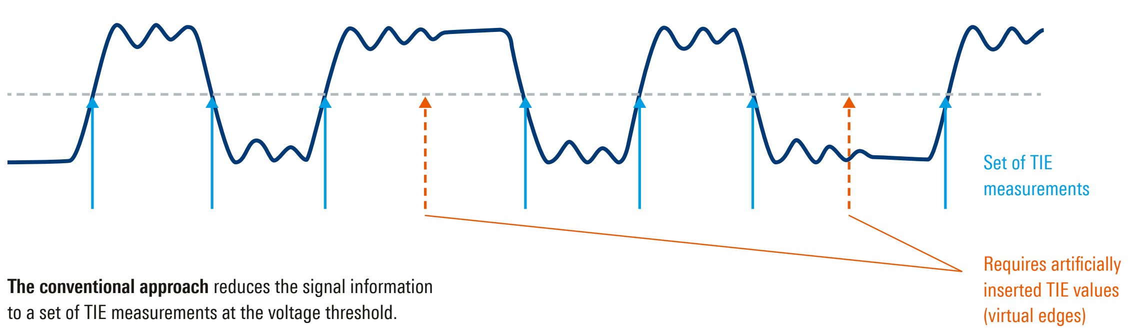
Random error

Perdiodic components

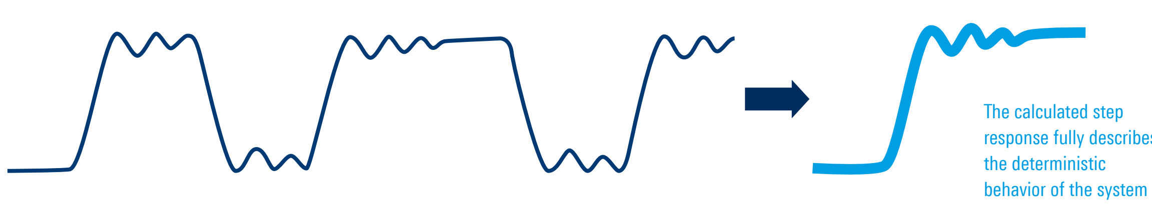
Fig. 4: The linearized signal model from Rohde & Schwarz fully describes the signal characteristic.

During the decomposition process, a least square (LS) estimator compares the input signal to the signal model and iteratively calculates the parameters of the signal model. Then, based on the input signal's bit sequence, the algorithm reconstructs synthetic signal sequences for the individual deterministic jitter components (Fig. 5). In the next step, the random jitter is calculated from the difference between the input signal and the data dependent and periodic synthetic signal sequences.

Fig. 3: Comparison of the conventional TIE based approach to jitter decomposition and the innovative Rohde & Schwarz method based on a signal model.



The conventional approach reduces the signal information to a set of TIE measurements at the voltage threshold.



The Rohde & Schwarz algorithm calculates the step response, which fully characterizes the deterministic behavior of the transmission path. The parametric signal model contains all signal information for accurate and reliable jitter decomposition.

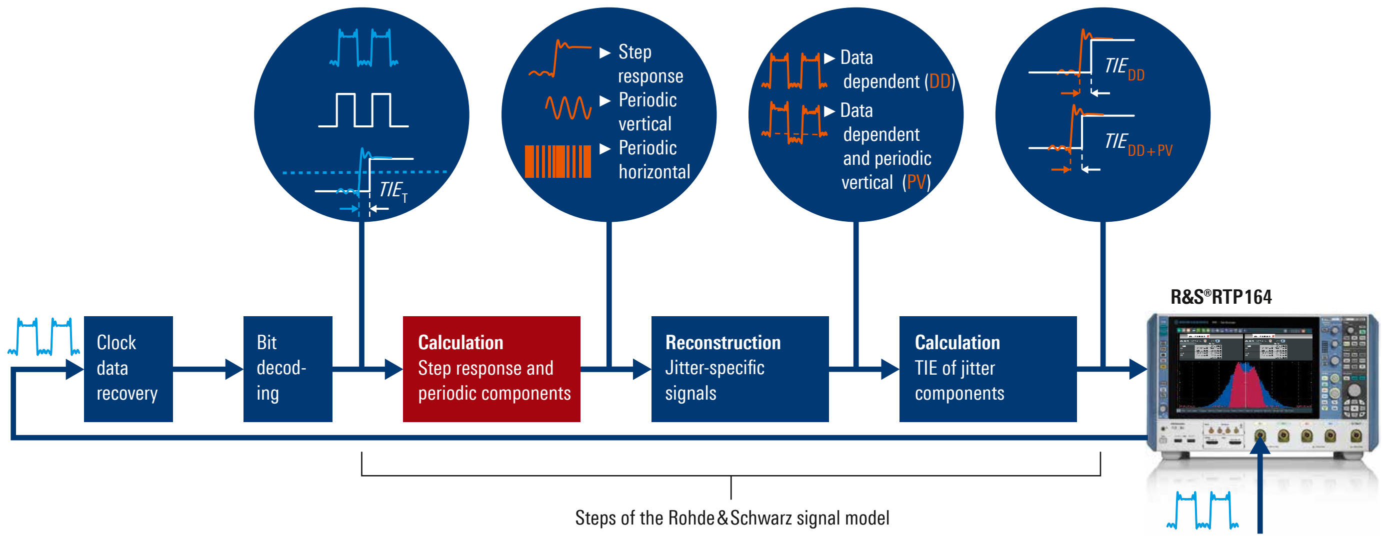


Fig. 5: Jitter decomposition using the Rohde&Schwarz method. The step response is the basis for calculating the deterministic jitter components. In a final step, the random jitter and OBUJ are determined.

Deep insight into the jitter characteristic

The characteristic step response that results from the jitter composition calculation is new and very useful for debugging and optimizing designs (Fig. 6). Previously the step response could only be measured with time domain transmissometry (TDT) or with a vector network analyzer. The step response says a lot about the characteristics of the transmission path. For instance: the rise time is related to the bandwidth, overshoots or a damped response provide information about the frequency response characteristics, and dips indicate reflections due to mismatches.

The algorithm provides information about all common jitter components. Users can analyze the various components as numerical values or examine them in histograms, track curves or spectrum views. BER bathtub curves and eye diagrams support in-depth analysis.

The Rohde&Schwarz signal model differentiates between the horizontal and vertical direction of periodic jitter components (Fig. 7). The direction provides useful information about whether periodic jitter components originate from amplitude modulation or frequency modulation. The spectrum of the horizontal periodic jitter components is available for analysis.

Quick start for analysis or custom setup in three steps

The new decomposition algorithm is integrated into the R&S®RTO/RTP-K133 advanced jitter analysis option for the R&S®RTO and R&S®RTP oscilloscopes. The **quick start** function is the

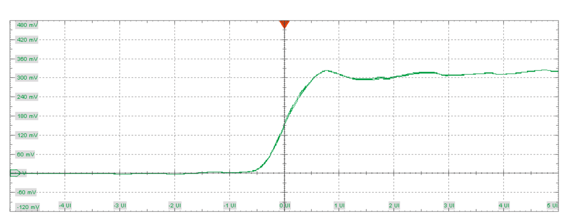
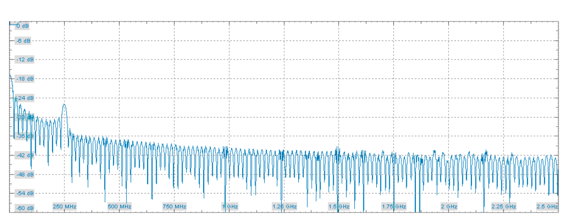


Fig. 6: The calculated step response time is helpful for understanding the data dependent channel characteristic.



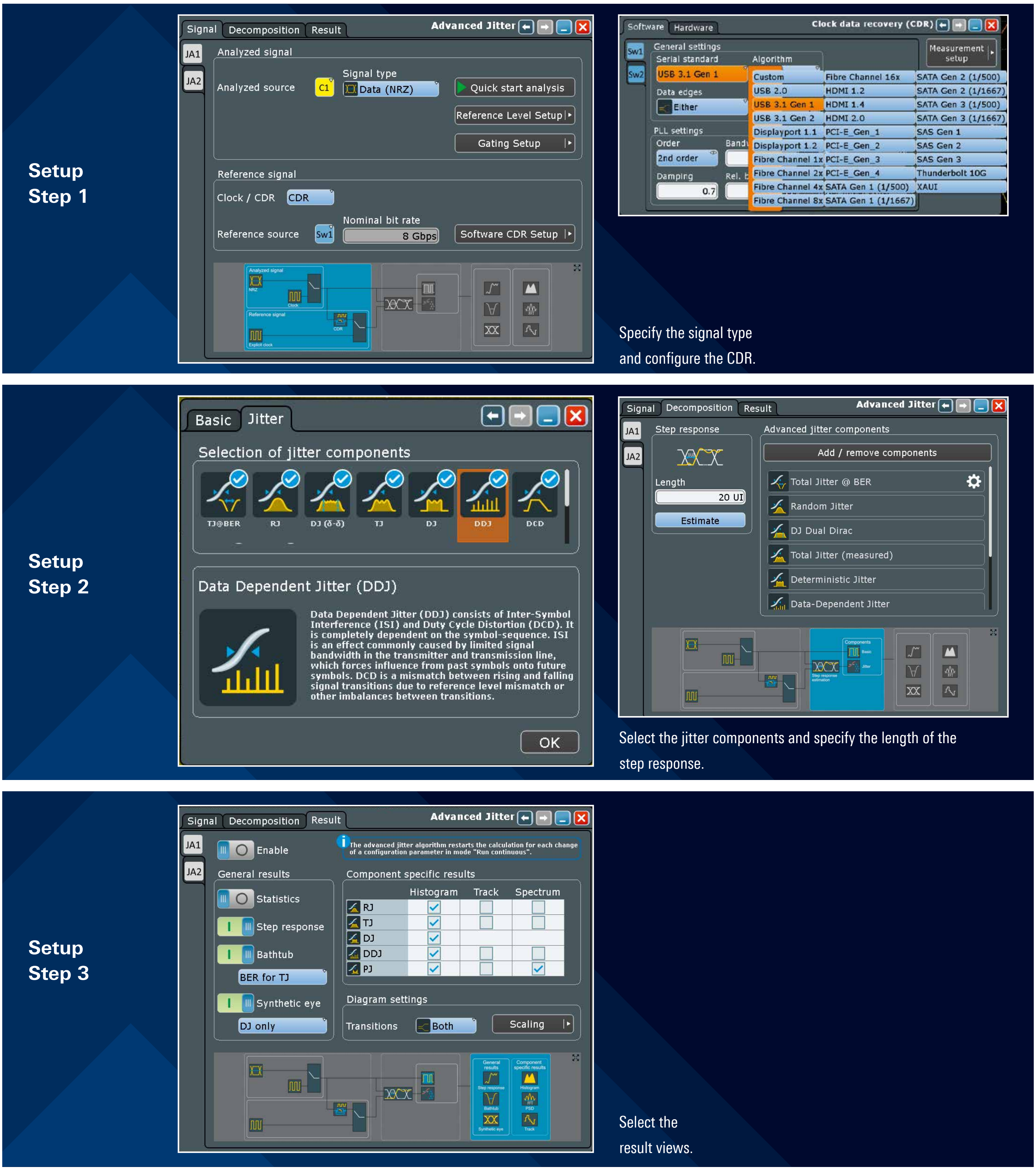
Periodic components 1 C1

	Frequency	Value	Direction
1	89.999 MHz	70.857 mUI	Horizontal
2	180.01 MHz	37.75 mUI	Horizontal
3	2.9773 MHz	18.763 mUI	Horizontal
4	1.8713 MHz	18.544 mUI	Horizontal
5	2.3468 MHz	12.683 mUI	Horizontal
6	90 MHz	264.85 mV	Vertical
7	124.61 MHz	4.4961 mV	Vertical
8	127.83 MHz	2.0532 mV	Vertical
9	83.436 MHz	1.9033 mV	Vertical
10	97.921 MHz	1.8791 mV	Vertical

Fig. 7: Display of the power spectrum density (PSD) of the horizontal periodic jitter components and differentiation between the horizontal and vertical direction.

easiest route to fast jitter results. It automatically performs predefined setups, calculates a default set of jitter components and displays the corresponding results in preselected views. Users can adjust the setup and the result display at any time.

Fig. 8: Custom configuration of jitter measurement in just three steps.



As an alternative to quick start, users can **custom configure** a setup in just three steps (Fig. 8). The first step is to select the signal source and type and define the clock data recovery (CDR). A selection menu for the DUT technology (e.g. USB 3.1 Gen 1) simplifies the CDR setup.

The second step is to configure the parameters for decomposition. This consists of selecting the jitter components of interest and defining the step response length for processing. A longer length uncovers more details, such as far away reflections, but it requires more computation time.

The final step is configuring the result display. For the jitter components, the user can choose between the histogram, track and spectrum views. The step response, the bathtub curve and the synthetic eye diagram are available for in-depth analysis.

Now the user simply has to press the Enable button to start the jitter decomposition process. Fig. 9 shows an example of the different result views. The R&S®SmartGrid function allows users to arrange the screen to their preference by simply dragging and dropping diagrams and tables.

Summary

The new jitter decomposition algorithm calculates the step response, which fully characterizes the deterministic behavior of the transmission path. Users benefit from more accurate measurement results – even for relatively short signal sequences. The in-depth results give developers deep insights for validating and debugging DUTs with high speed data interfaces or fast clock signals.

Guido Schulze

A comprehensive white paper on the described jitter analysis method can be downloaded from the company website (search term: Designcon2020).

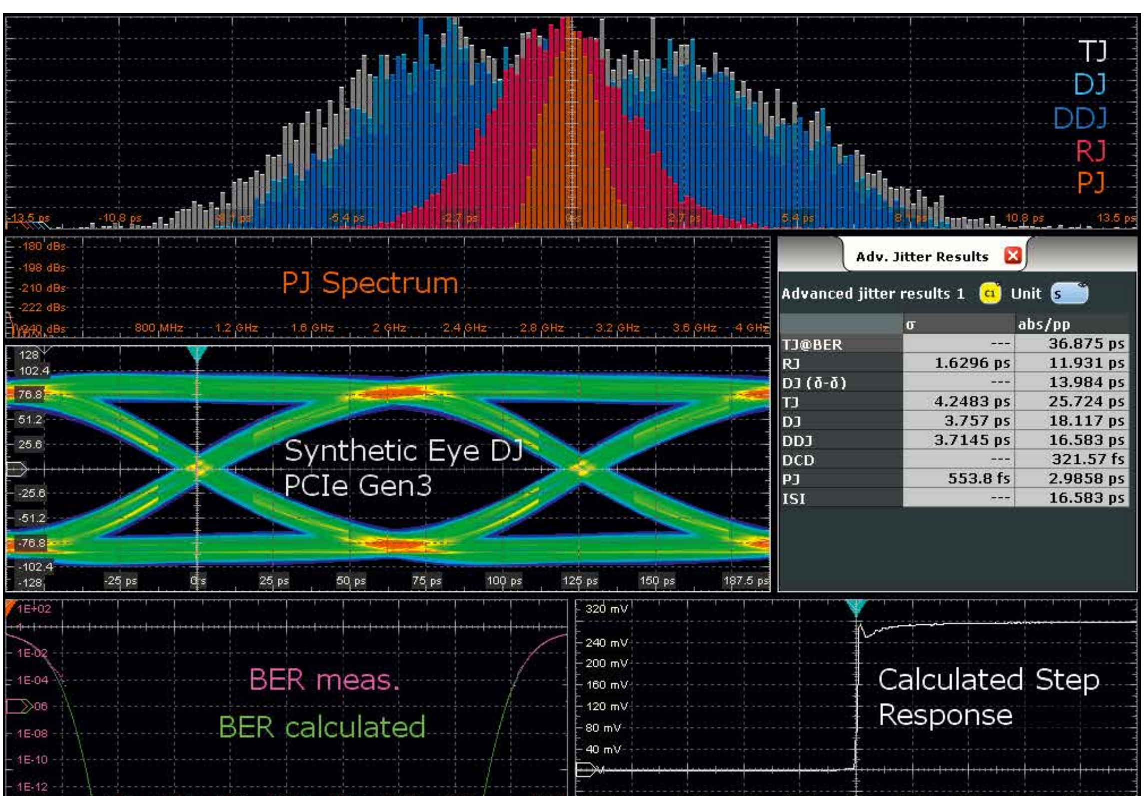


Fig. 9: Result display for jitter decomposition of a PCIe Gen3 signal using the R&S®RTP oscilloscope with the R&S®RTP-K133 advanced jitter analysis option: step response, histogram of the individual jitter components, jitter spectrum, synthetic eye diagram and BER bathtub curve.

FASTER SWITCHING

External triggers control switching processes more precisely and make them up to 1000 times faster when solid-state relays are used.

For most control tasks, switching times in the millisecond range or longer are sufficient. But when testing RF scenarios where fast switching of e.g. antennas or IC connections is necessary, it makes sense to use external triggers to control switching processes for significantly faster switching and more exact timing.

In the development and production of new technologies such as 5G and in radar technology, very short, exact switching times are sometimes required. This is not possible with relays controlled by LAN or USB due to long transmission times. LAN control also suffers from the uncertainty of network latencies, so it is only possible to achieve switching times in the millisecond range – even with very fast solid-state relays.

Fast, reproducible switching can only be achieved using application-specific control or a triggerable switch unit. The R&S®OSP fulfills this requirement with the new R&S®OSP-K100 trigger option. It combines the advantages of a universal switch unit (e.g. easy configuration and a large selection of switch modules) with the fast, exact switching of hardware based control.

Trigger interface

Every second generation R&S®OSP (Fig. 1), i.e. R&S®OSP220/230/320, comes with external connectors and internal FPGA logic that prepare it for external triggering of switching operations. The units have two female BNC connectors with corresponding status LEDs on the front panel. The R&S®OSP320 also has a male D-Sub connector with a trigger interface on the rear panel. The triggers can be configured and activated either remotely by SCPI commands or manually via the touchscreen or a keyboard and monitor.

Trigger types

Four different trigger types are available (Fig. 2). Depending on the trigger type, up to 16 paths can be controlled. A path can consist of just one switching relay or a number of switchable elements located in different modules or even in other R&S®OSP units of a primary/secondary system or in optionally connected R&S®OSP satellite boxes. This creates a virtually unlimited variety of applications.

Sequential triggering enables switching sequences with up to 16 paths, like a step switch. The sequence can be reset at any time with an external reset signal. In addressing mode, the R&S®OSP320 can address up to 16 paths in any desired order (see Fig. 2).

Fig. 1: The trigger menu shows the minimum trigger interval possible with the given path configuration.

Trigger switching times

The time between the external trigger signal and the 90 % level of the output switching level (trigger switching time) is:

- approximately 2 µs with digital output channels
- between 2 µs and 10 µs with solid-state relays (SSR)
- between 10 ms and 20 ms with electromechanical relays

A trigger switching time of 2 µs allows digital outputs and solid-state relays to be switched up to 1000 times faster than with a software command via LAN, with corresponding repeatability. The delay due to LAN communications (approx. 1 ms to 2 ms), is less significant with the relatively long switching times of electromechanical relays (several milliseconds). However, precise hardware-controlled switching and path addressing via digital control channels of other devices also has advantages when electromechanical relays are used.

Faster than data sheet specs

The data sheet for the R&S®OSP specifies trigger intervals for the unit and the relays. It can be possible to achieve even shorter trigger intervals with electromechanical relays, as can be seen in the oscilloscope measurement in Fig. 3. In this example, the measured switching time of an electromechanical changeover relay (SPDT) was 3.8 ms instead of the specified 15 ms.

Similar improvements are also possible with SSRs by using part of the internal delay time for early retriggering, which makes it possible to achieve 10 % to 20 % shorter trigger intervals or higher trigger rates. Such optimizations are the responsibility of the user.

Reading trigger intervals on the display

Determining trigger intervals with switch paths consisting of several different relays is time-consuming and complicated. To spare users the effort of this calculation, the R&S®OSP trigger menu shows the minimum trigger interval based on the data sheet values of all relays involved and taking into account the internal delays (Fig. 1). This allows users to optimize paths and avoid timing problems.

Triggerable R&S®OSP modules

Nearly all standard R&S®OSP modules are triggerable (see data sheets for details). Exceptions are application-specific system modules without provision for external triggering and modules equipped with relays having internal control sequences.

Gert Heuer; Michael Kunert; Franz Rauscher; Werner Rohde; Cornelius Söll

Trigger type	Number of paths	Interfaces	Function
Single	1	BNC A	The trigger can only activate one path; then the trigger mode is deactivated
Toggle	2	BNC B	Switches back and forth between two paths
Sequenced	3 to 16	BNC A, B	Sequential switching from path 0 to path n (n = 2 to 15). A reset starts the sequence again with path 0
Addressed (only R&S®OSP 320)	Up to 16	D-Sub	The R&S®OSP 320 has additional address lines to directly control paths 0 to 15

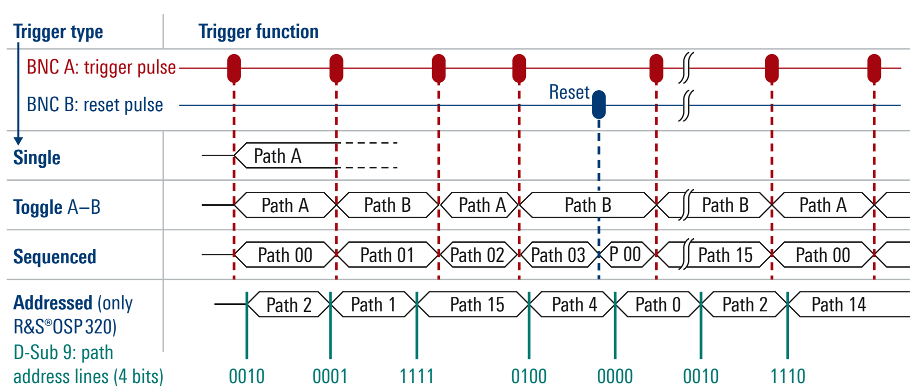


Fig. 2: The various trigger types and functions.

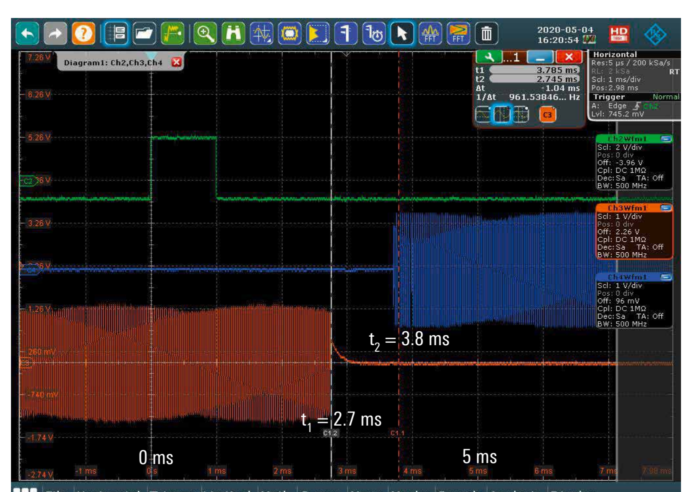


Fig. 3: Measured switching time between the trigger (green) and switching the relay outputs (brown and blue) of a changeover relay (SPDT). Measurements on relays sometimes show significantly shorter switching times than the times specified in the data sheet.

BEST PRACTICE FOR MANAGING SCHOOL WI-FI

One goal, many paths. The increasing digitalization of education is making reliable school Wi-Fi essential for teaching. A look at current practices reveals that authorities and schools have very different methods of keeping their networks operational.

Thanks to the multi-billion euro support program DigitalPakt Schule (Digital Pact for Schools) that was established in 2019 by the German federal and state governments to drive digitalization in German schools, many schools will have blanket Wi-Fi coverage for the first time. The motivation behind the program is clear: fast, powerful and stable wireless networks are needed to enable flexible use of a laptop or tablet, efficient use of educational apps and fast access to the school server.

Professional Wi-Fi is far from straightforward, however. It requires maintenance, updates and troubleshooting. Those in charge need to consider who will manage the new network infrastructure. This article examines four best practice examples of LANCOM Systems customers and the approaches that have been successful for authorities and schools.

Self-managed, controller based Wi-Fi

In February 2020, the school authority in Helmstedt, Germany, was the first in Lower Saxony to receive support from the DigitalPakt Schule program. Since then, LANCOM Wi-Fi access points in the town's five elementary schools have been providing blanket Wi-Fi coverage. The town's IT administration manages the networks via a Wi-Fi controller and is responsible for operating and expanding the networks. Immo Ulbricht, Helmstedt's Head of Telecommunications and IT, is an avowed LANCOM user: “For us, it was clear that the Wi-Fi products for our schools had to come from LANCOM. LANCOM has always delivered in terms of performance and reliability, and the portfolio provides everything we need.”

IT service provider manages networks via Wi-Fi controllers

The Archdiocese of Paderborn in Germany also uses a controller based concept for managing its 19 schools in North Rhine-Westphalia, and is supported by an IT service provider that manages around 1000 LANCOM access points and 19 Wi-Fi controllers. “From configuration to monitoring and troubleshooting, we perform the standard administrative tasks of an IT department,” explains Steffen Schnorbus, CEO of Schnorbus-IT. The support team can access all school networks from a central location via the Wi-Fi controller, and take fast and targeted action when required. Kai von Holtz, IT Coordinator for schools and universities at the General Vicariate of the Archdiocese of Paderborn, sees wireless technology as a key educational tool: “Wi-Fi helps schools put their media concepts into practice and enables modern teaching methods.”

Cloud-managed Wi-Fi saves time

Instead of a standard controller based network, school authorities are increasingly using cloud-managed Wi-Fi. One example is the James Krüss School in Heligoland, Germany, whose network was set up in the fall of 2018. At the heart of the network is the LANCOM Management Cloud (LMC), which uses smart technology to simplify time-consuming tasks such as installing firmware updates and rolling out new networks. The Heligoland municipality manages the network for the primary and secondary school. The LMC has proved invaluable for the school authorities: “We don’t just manage the school network from a central location via the cloud; we can also use it to map all other networks that use LANCOM hardware,” explains Tobias Wutschke, Heligoland’s IT Manager. The town hall and library network is also managed via the cloud. “We have mapped all the networks in one management instance,” says Wutschke. “This is a convenient solution that gives us a clear overview. The cloud solution saves us a lot of time and, as administrators, we can manage the network without needing to be on site. We can remotely install hardware updates within a few minutes. In the past, this would have taken much longer.”

School manages own network in the cloud

The Wi-Fi of the Viktoria School in Aachen, Germany, is also managed in the cloud. In this case, however, the school manages its own network. IT teacher Guido Hinz manages the wireless network for pupils and teachers. He is very impressed with the LMC: “This is an excellent solution for us. We always have an overview of the availability and location of networks, and whether areas with heavy network traffic need to be optimized. We can quickly and easily modify and expand networks.” The LMC saves Hinz a lot of time. If he had to configure each individual access point, managing the entire Wi-Fi would be a much bigger challenge.

Educational benefits are key

As you can see, school Wi-Fi takes many different forms. The individual requirements of the schools and school authorities dictate which type of network management is most suitable. A reliable wireless network helps schools provide what matters most: educational benefits. A stable Wi-Fi connection, performance that meets the school’s requirements, a highly responsive technical support team and the right management concept are vital for schools and school authorities.

André Faßbender

Helmstedt has digital media on the curriculum starting in elementary school.

© Archdiocese of Paderborn

Like all 19 schools in the Archdiocese of Paderborn, the St. Michael secondary school uses LANCOM Wi-Fi technology.

SHORTWAVE FOR LONG DISTANCE

Even in the age of fiber optics, satellite links and mobile connections, there is still a need for shortwave radio. New antennas and tuning units make it easier than ever to build high-performance systems.

Shortwave connections do not require any infrastructure, and communications is free aside from the one-time investment in the equipment. Major progress has been made in the development of secure, high-performance transmission methods, so shortwave transmission is still a valuable information medium, especially for public authorities and military users.

However, optimal transmission conditions are required to fully exploit the potential of this medium. Antennas play a key role. Losses at the antenna cannot be compensated elsewhere in the transmission path. Today's wideband transmission methods need the best possible signal-to-noise ratio, and that means optimized antennas. In addition to developing transceivers, Rohde & Schwarz has always been active in the development of high-performance, low-loss HF antennas. The latest result of these efforts is the R&S®HX002Hx series, which together with new antenna tuning units (ATU) and an innovative control and power supply unit is raising the HF air interface to a new level.

Compact antenna solutions

The shortwave bands, with frequencies between 1.5 MHz and 30 MHz, are based on long wavelengths up to more than 100 m. Depending on the antenna type, the necessary antenna dimensions can be just as large, resulting in high costs for the antenna itself and even more for the necessary installation space. In tight spaces, such as on ships or in urban environments, it might not even be possible to use them.

This can be remedied by compact tunable dipole structures that feature high efficiency. For example, the R&S®HX002H0 1 kW solution and the R&S®HX002H3 150 W system (Figs. 1 and 2) offer outstanding HF performance despite their very compact dimensions of approximately 10 m × 5 m and provide 360-degree coverage for short, medium and long distances. A special version for ship deployment, the R&S®HX002H3M, can manage with antenna elements that are 50 % shorter, making it easier to install in the usually cramped superstructures of naval ships. All models feature single-mast mounting and a single coax cable connection to the junction unit.

Fig. 1: The R&S®HX002H0 1 kW solution integrates the antenna and the tuning unit in an ultracompact unit.

Fig. 2: The R&S®HX002H3 150 W unit, consisting of an antenna and ATU, is very small for an HF unit.

Fig. 3: The R&S®FK002H0 1 kW antenna tuning unit can be operated at the base of various antennas.

Alternative wideband solutions in the form of resistor-damped dipoles (implemented as a loaded dipole, terminated folded dipole, inverted V, delta antenna, etc.), on the other hand, have barely acceptable gain even with significantly larger dimensions and are mainly used in special applications such as tactical deployment. These types are not part of the current portfolio.

High-performance tuning units

The new antenna tuning units and antenna/tuning unit combination solutions are available in two power classes: 150 W and 1 kW (Fig. 3). They offer superior tuning characteristics over the entire HF frequency range and can be used to tune a wide variety of antennas, including electrically very short antennas, delivering high efficiency without internal damping.

HF antennas are sensitive to their environment. For optimal results, the antenna environment has to be taken into account when tuning. A smart algorithm allows the new ATUs to include site factors during tuning to consistently achieve a VSWR of less than 1.3. The necessary internal circuitry with low-loss capacitors and air-core coils is learned and stored for each tuned frequency during a one-time up-front learning phase. So when a frequency change occurs during later operation, the right compensation components can be quickly switched on without further fine tuning. If no command is received from the transceiver, the antenna/ATU can detect the frequency change itself.

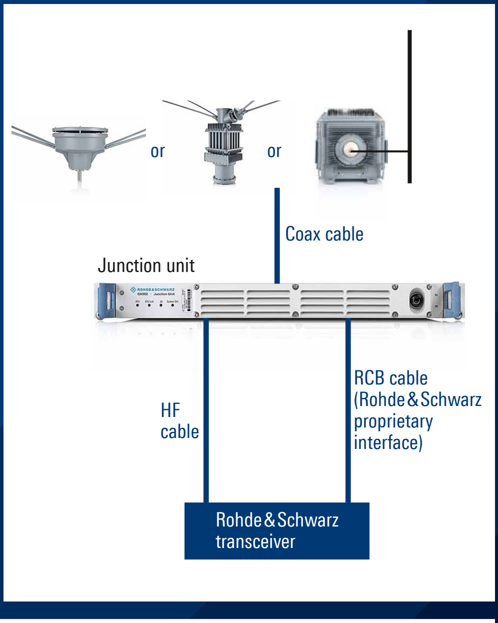
Easy connection

All ATUs and antennas with integrated ATUs are powered and controlled by an R&S®GX002 junction unit (Fig. 4). The unit fits seamlessly into the operating concept of the latest shortwave transceiver generation. It is also ideal for use in legacy applications with older Rohde & Schwarz

Fig. 4: The R&S®GX002 universal junction unit powers the antenna and the tuning unit, passes on the HF signal, and manages data exchange between the transceiver and tuning unit.

transceivers and with transceivers from other manufacturers thanks to its universal interfaces, including LAN and optical ports. And separating the antenna/ATU from the control unit allows different forms of integration into a high-level communications system. Depending on the configuration, different levels of functionality can be achieved that range from simple frequency switching with basic commands to support for state-of-the-art transmission methods. Fig. 5 shows two possible alternatives.

Klaus Fischer



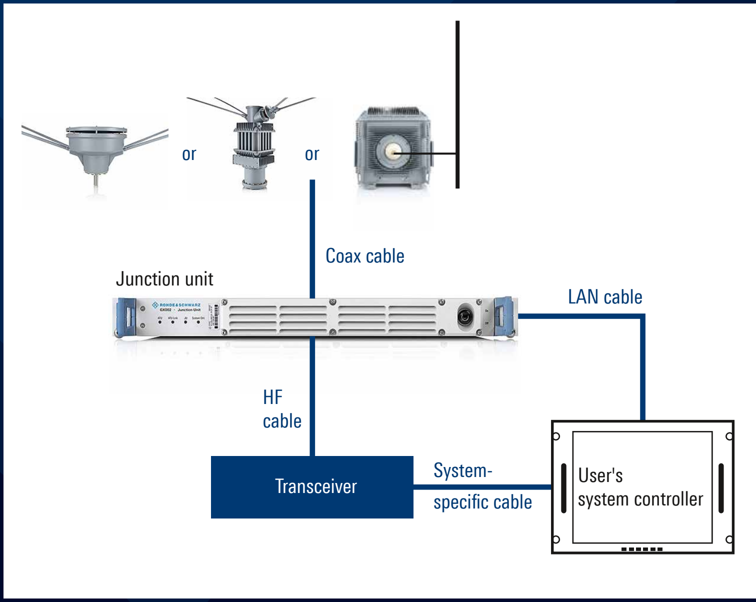


Fig. 5: Basic setup with a state-of-the-art Rohde & Schwarz transceiver (top) and with system components from other manufacturers (bottom). The junction unit not only offers diverse system configuration options, only one coax cable is needed to connect to the antenna/ATU. The cable carries the HF signal, the control signals and the DC supply voltage. This saves money, simplifies system integration and increases operational reliability.