SATELLITE PAYLOAD AND COMPONENTS TESTING

With instruments from Rohde & Schwarz

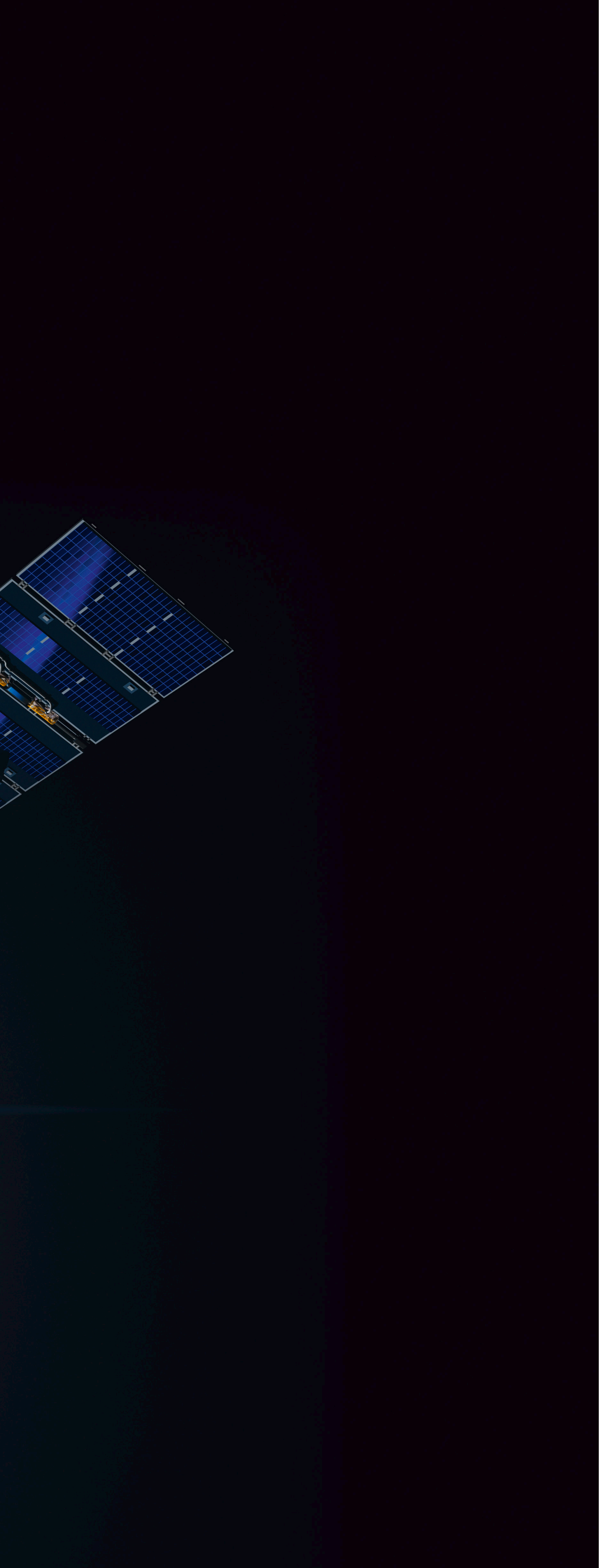
Application Brochure
Version 02.00

ROHDE & SCHWARZ

Make ideas real

Application Brochure | Version 02.00

ROHDE & SCHWARZ HELPS ENGINEERS DEVELOP AND TEST SATELLITE TRANSPONDERS, MODULES AND COMPONENTS BY PROVIDING THE TEST AND MEASUREMENT SOLUTIONS THAT THE SATELLITE MARKET NEEDS.



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A PARADIGM CHANGE IN TEST PHILOSOPHY

Satellite communications systems must cover a diverse set of user requirements in direct broadcast, wireless communications and remote sensing applications for both commercial and government systems. These systems must operate reliably around the clock with multi-decade system longevity. They must be thoroughly tested to ensure a quality of service over the life cycle of the satellite.

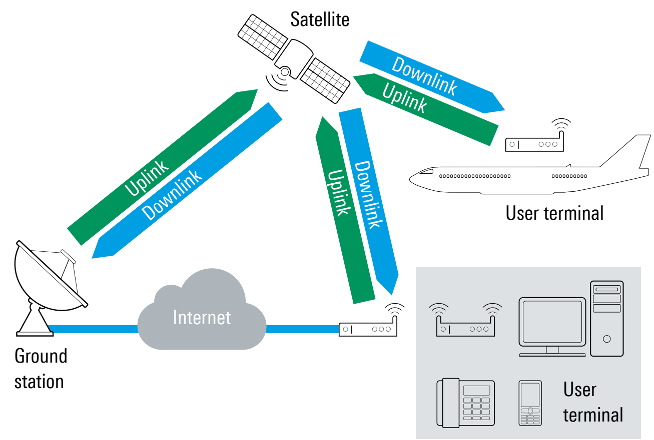
Today's satellite systems need to be future-ready to be fully compatible with both existing cellular networks and emerging wireless technologies. The technology evolution from bent-pipe or digital transparent payloads to digital regenerative payloads to increase system capacity and flexibility are increasing testing complexity. Regenerative transponders include additional functions such as digital signal demodulation, baseband signal processing and switching and signal modulation.

Satellite companies need to thoroughly test RF communications systems and components to ensure 24/7 operation with a high quality of service. On the other hand, satellite equipment manufactures need to reduce test time and cost while the total number of uplink and downlink beams is increasing. One digital stream of data on the uplink corresponds to multiple streams on the downlink.

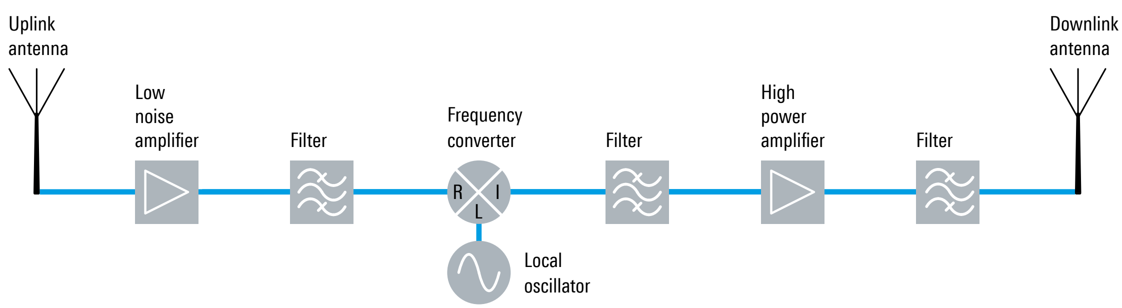
These challenges require straightforward, fast and reproducible test and measurement solutions that provide high measurement performance and repeatability.

Rohde & Schwarz offers innovative RF and millimeterwave measurement solutions to help customers successfully design, develop and test satellite payloads, payload subsystems and components. These solutions meet customer needs in terms of performance, cost and schedule. RF test and measurement solutions for the most critical satellite payload and components measurements are introduced in the next sections.

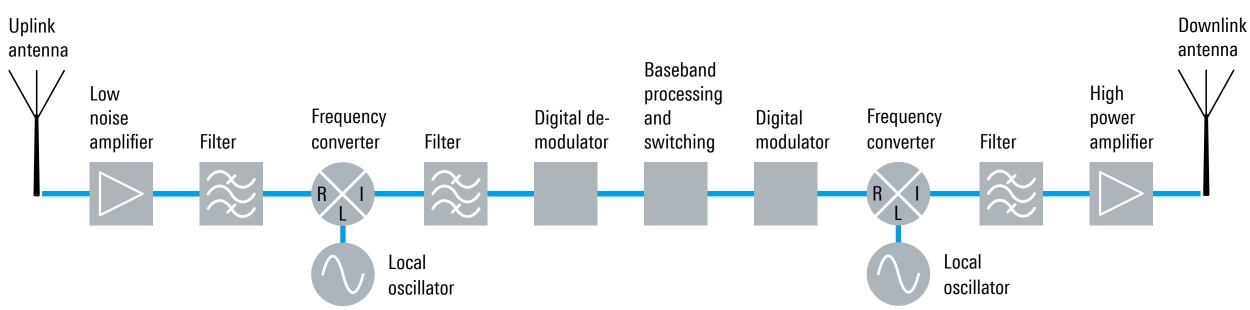
Satellite communications network components



High-level system components of a bent-pipe satellite payload channel (e.g. filters, amplifiers, frequency converters)



High-level system components of a regenerative payload channel



GROUP DELAY MEASUREMENTS

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

Group delay measurements in transponder modules and frequency converters with spectrum analyzers and signal generators

The R&S®FSW spectrum analyzer and R&S®SMW200A signal generators can be used to measure absolute and relative group delay on satellite transponders, frequency converters and other components in a fast and straightforward way. In the multi-carrier group delay measurement approach, the signal generator transmits a multi-carrier continuous wave signal as the stimulus. The number of tones and the separation between them (aperture) can be changed to meet the requirements of the device under test. The R&S®FSW spectrum analyzer performs these measurements in two steps:

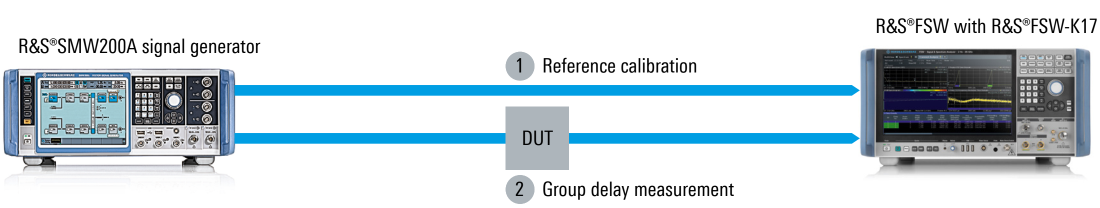
First step – reference calibration

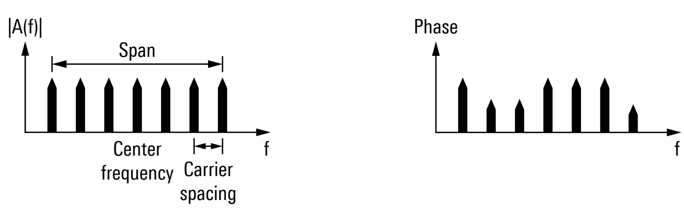
The generator is connected directly to the analyzer, which determines the reference phase and amplitude of the individual carriers.

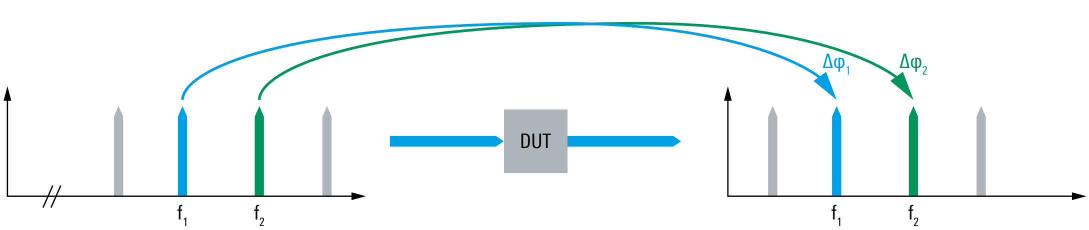
Second step – group delay and gain measurement

The DUT is connected and the analyzer precisely determines the group delay over the entire carrier frequency range from the phase difference between the reference signal and the multicarrier signal measured at the output of the DUT.

Group delay measurements with R&S®SMW-K61 and R&S®FSW-K17 multicarrier group delay measurement application







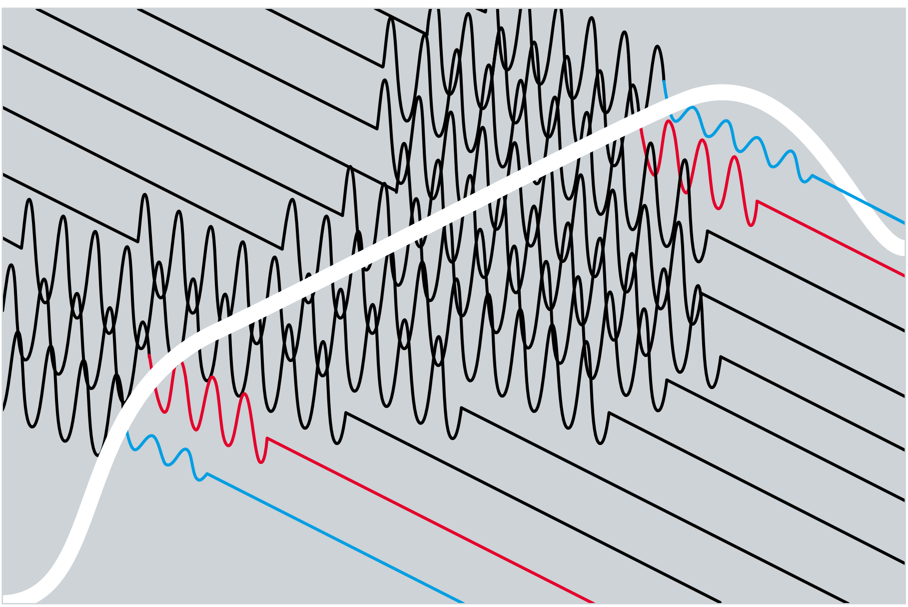
Group delay $\tau = \frac{-1}{360°} \cdot \frac{\Delta\varphi}{\Delta f}$

Frequency shift $\Delta f = f_1 - f_2$

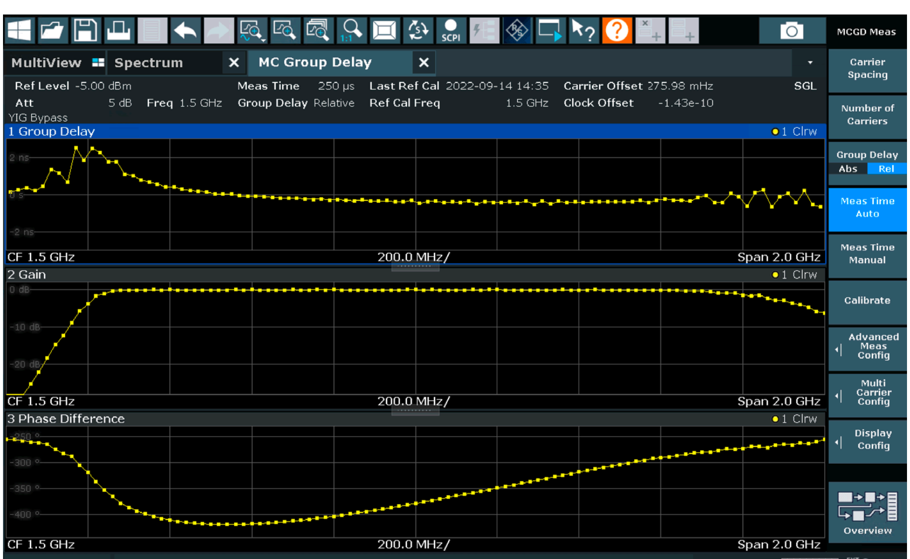
Phase shift $\Delta\varphi = (\varphi_{1\,out} - \varphi_{2\,out}) - (\varphi_{1\,in} - \varphi_{2\,in})$

The multi-carrier approach offers the following advantages

- It is possible to measure absolute and relative group delay on wideband signals within milliseconds
- Signal averaging and smoothing improve the carrier-to-noise ratio to obtain valid results for high signal path losses
- Automatic compensation of Doppler effects for in-orbit measurements
- The relative group delay of frequency converters can be characterized with 1 ns measurement accuracy; no reference mixer or golden device is required
- 300 ps measurement accuracy for relative group delay in non-frequency-translating measurements
- Internal flexible generation of multi-carrier continuous wave (MCCW) signals and modulated signals; spacing and number of carriers can be configured on the R&S®SMW200A vector signal generator
- Deembedding function corrects the frequency response of cables and fixtures in the measurement setup
- Wideband signals with a low signal-to-noise ratio (SNR) can be measured with the R&S®FSW-K17S option that improves SNR and measurement speeds by analyzing subspans of the overall signal



Group delay on a bandpass filter. This figure shows how a bandpass filter adds more group delay at the band edges. In satellite communications systems, the relative group delay of the frequency converter or the transponder channels is critical when it comes to determining the amount of distortion at the band edges of each channel.



Relative group delay measurement on a bandpass filter.

Using vector network analyzers (VNA) to measure group delay on frequency converters without LO access

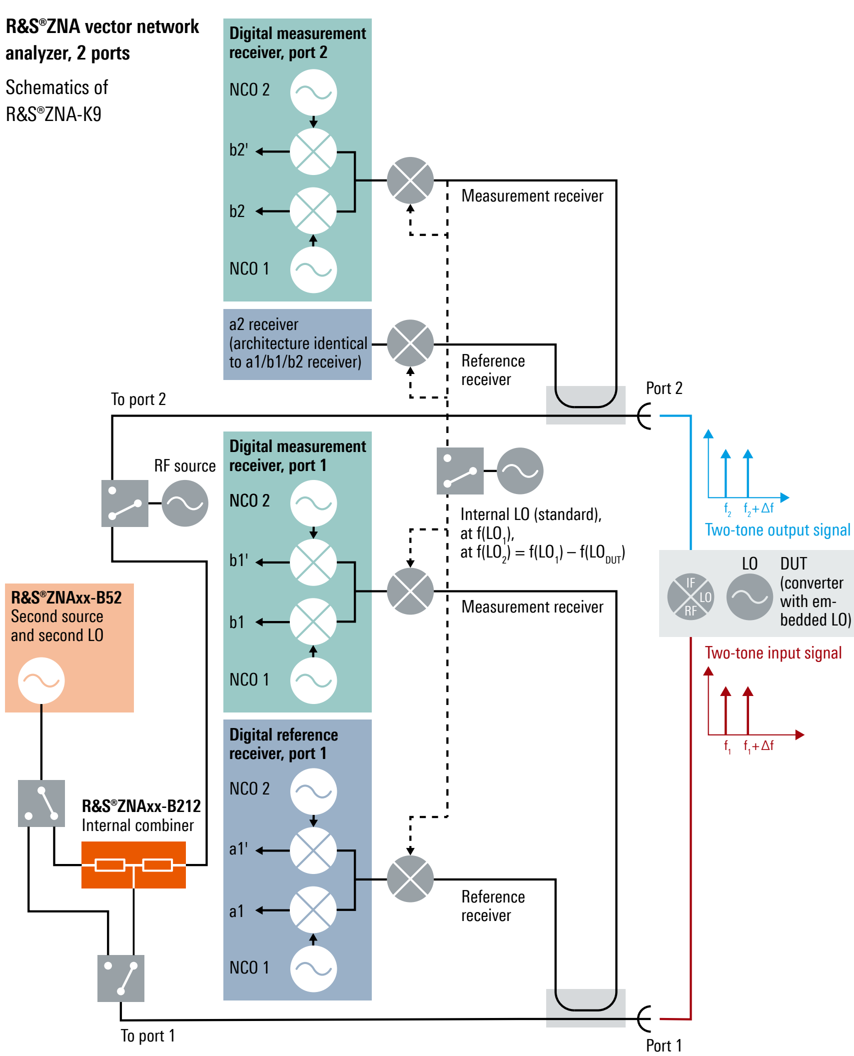
Normally, group delay and relative phase measurements on frequency converting devices without LO access are only possible if the DUT has a highly stable internal LO. Phase and frequency deviations due to drift or noise considerably limit the accuracy and applicability of available methods. The two-tone technique from Rohde & Schwarz overcomes all these limitations.

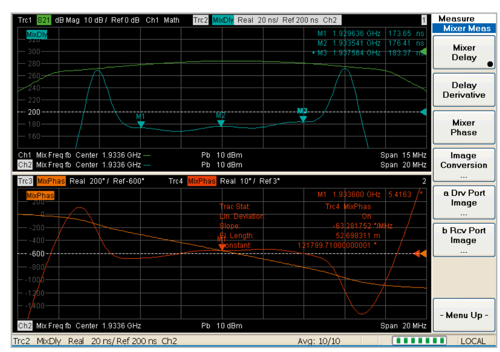
By using a two-tone stimulus signal, the R&S®ZNA vector network analyzer can measure the phase difference between two signals, at the input and then at the output of the DUT. Comparable to the classic S-parameter technique, the group delay is calculated from the phase difference and the frequency offset. The frequency offset Δf between the two signals is the aperture. To measure the phase between two signals with different frequencies, Rohde & Schwarz has developed a unique frontend for the R&S®ZNA. For calibration, only an unknown through mixer is required. This method is ideal for frequency converting DUTs with unstable LOs since the frequency and phase deviations of the DUT's internal LO can be in the range of the IF bandwidth (i.e. up to several MHz).

The new internal combiner simplifies measurement setups and the two signals no longer require an external connection. A two-port R&S®ZNA can now measure embedded LO converter group delay and intermodulation with an optional second source. Two independent LOs for the internal receivers allow RF/IF to be measured simultaneously with mixers. Measurement speeds are now twice that of a single LO, while trace noise is also reduced in conversion loss and group delay measurements.

In addition to group delay, the R&S®ZNA also calculates the relative phase and deviation from linear phase by integrating the group delay.

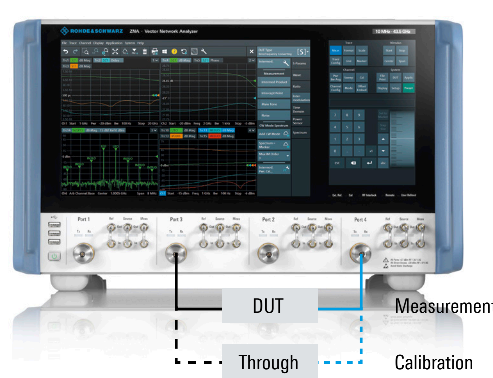
Test setup with network analyzer





Simultaneous display of measurement results:

- Conversion loss (green)
- Group delay (blue)
- Relative phase (orange)
- Deviation from linear phase (red)



Comparison of test setups for spectrum analyzer and network analyzer group delay measurements

Spectrum analyzer and signal generator	Vector network analyzer
Instruments	
► R&S®FSW signal and spectrum analyzer with R&S®FSW-K17 option ► R&S®SMW200A vector signal generator with R&S®SMW-K61 option	► R&S®ZNA vector network analyzer with R&S®ZNA-K9, R&S®ZNA-K4, R&S®ZNAx-B52 and R&S®ZNAx-B212 options (x = 26/43/50/67)
Measuring principle	
► Multi-carrier signal from vector signal generator ► Phase shift/difference between carriers is measured, then GD is calculated based on those phase shift measurements	► Two-tone signal from R&S®ZNA ► Phase between carriers measured in reference and measurement receivers
Benefits	
► Fast measurements with a single shot ► Compensates for Doppler effect in in-orbit measurements ► Special option for measuring wideband signals with low SNR	► High single-carrier power level with two-tone signal (compared to multi-carrier CW stimulation) ► High dynamic range and power range ► Entire VNA frequency range usable ► Comprehensive DUT characterization ► Reliable measurements despite distinct embedded LO drift
Recommendation	
► Best for testing on complete payload	► Best for testing at component level

LINEARITY AND GAIN TRANSFER MEASUREMENTS

RF engineers working with satellite communications systems need to characterize satellite transponders or components such as power amplifiers and frequency converters. Typical measurements include gain compression, AM/AM, AM/PM and distortion NPR/ACLR.

Linearity and gain transfer measurements with vector signal generators and spectrum analyzers

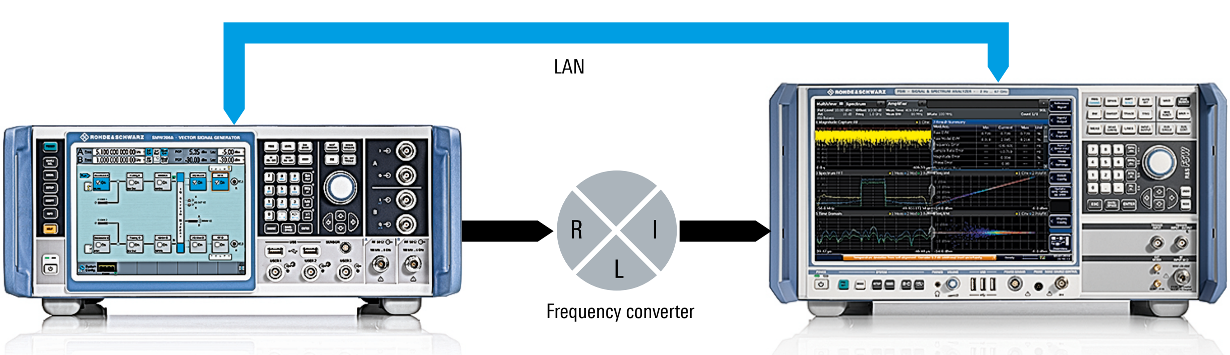
A combination of the R&S®SMW200A vector signal generator and the R&S®FSW vector signal analyzer equipped with the R&S®FSW-K18 option characterizes the DUT using real-world modulation and analysis.

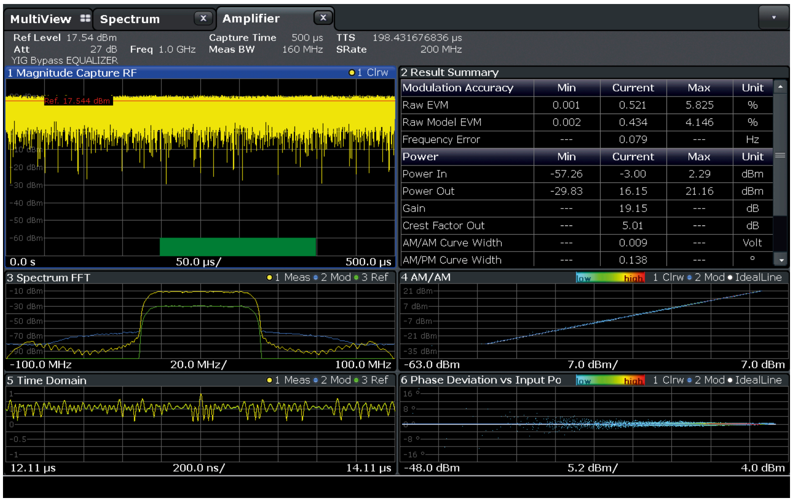
The R&S®FSW-K18 controls the R&S®SMW200A and therefore knows the reference signal that is applied to the DUT. The results are derived with a single measurement that synchronizes the reference signal and the signal transmitted by the DUT.

The main advantages of this measurement approach are:

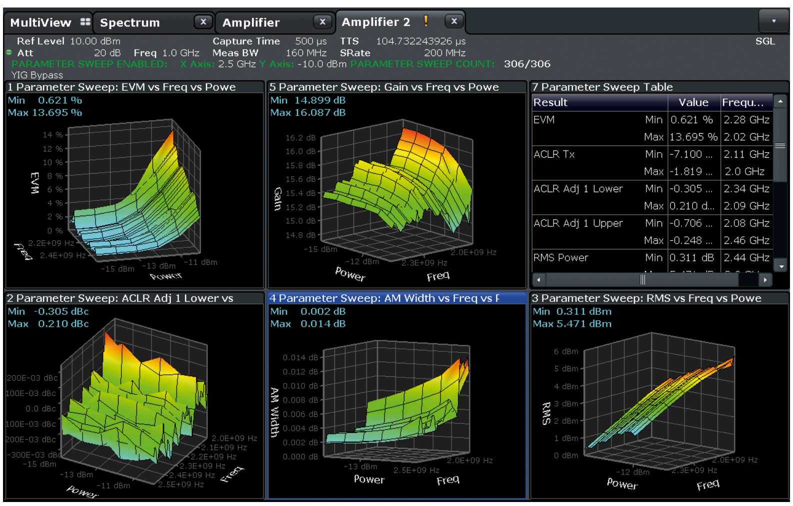
- Allows the device to be tested using both CW power sweep as a reference signal or a digitally modulated signal (with the bandwidth and crest factor for the intended application) to determine how the DUT will perform under real-world conditions
- Analysis bandwidth of up to 8.3 GHz enables measurement of amplified signals with wide bandwidths
- Direct digital predistortion (direct DPD) compensates memory effects and helps to get the best possible performance out of the DUT (R&S®FSW-K18D option)
- R&S®FSW-K18M allows users to directly derive and export memory polynomial coefficients for high performance DPD. The Hammerstein model is also included in R&S®FSW-K18M for real-time memory DPD with Rohde & Schwarz signal generators
- Polynomial/model-based DPD methods are supported with R&S®FSW-K18 and R&S®SMW-K541
- Parameter sweep provides 3D plots to quickly find the DUT's optimum operating point

Compact setup for characterizing two-port devices (e.g. amplifiers, frequency converters, transponders) with R&S®SMW-K541 and R&S®FSW-K18

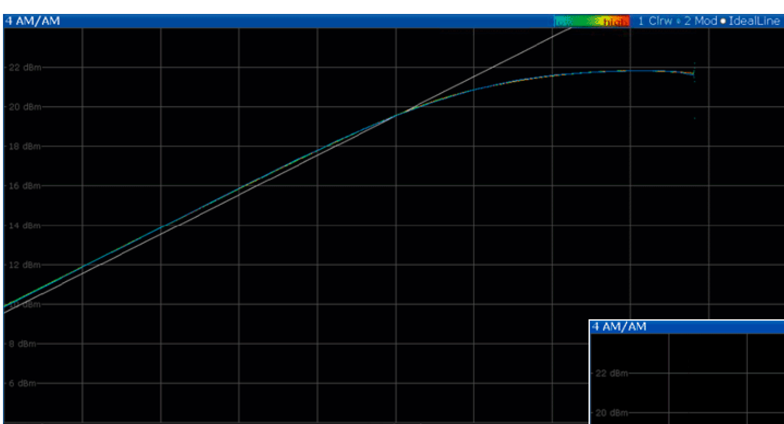


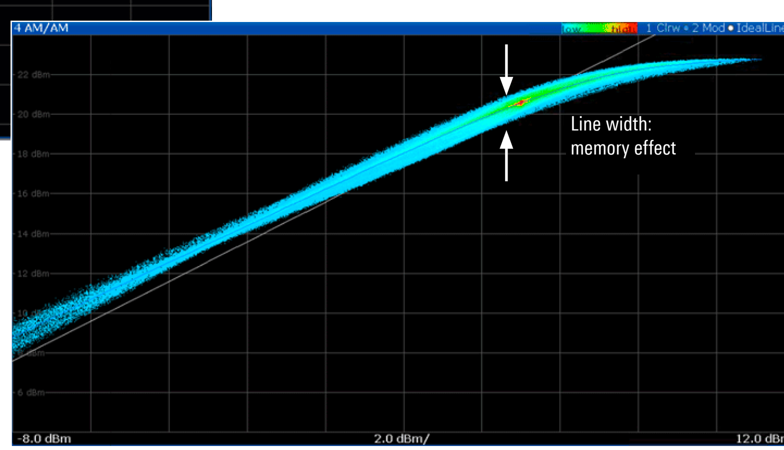


Complete characterization of two-port devices with one measurement.



3D plots (power/EVM/frequency) help you quickly identify the DUT's optimum operating point.





Gain transfer curve measurement (AM/AM) of an amplifier. For the curve above, a CW ramp sweep of the R&S®SMW200A digital baseband has been used as the stimulus. As expected, the AM/AM curve is a line. The curve on the right has been measured using a digitally modulated signal generated by the R&S®SMW200A. The AM/AM is a cloud-like curve; the line width is due to amplifier memory effects.

NOISE POWER RATIO (NPR)

Noise power ratio is an important standard RF payload test. NPR measurements are used to test the linearity of a RF transponder and simulate a Gaussian noise-like distribution of a multi-channel communications payload.

NPR measurements in transponders and components

NPR provides a measure of the intermodulation and noise floor of an RF output chain. The stimulus signal sent by the R&S®SMW200A signal generator can consist of multiple CW carriers with a notch. The deeper the notch at the output of the transponder or components, the fewer intermodulation products the device under test produces.

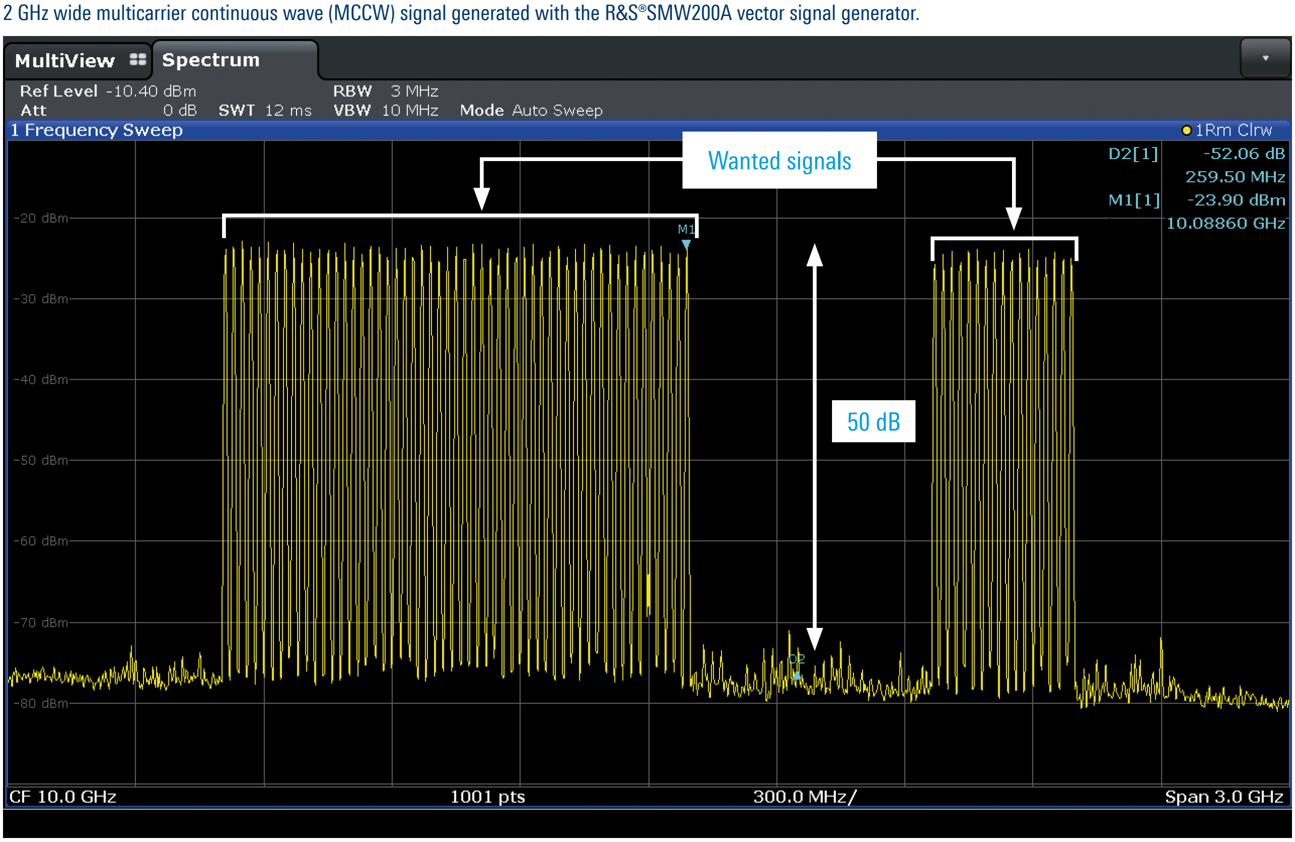
The R&S®SMW200A vector signal generator equipped with R&S®SMW-K61 option can be used to generate a multi-carrier continuous wave (MCCW) signal to simulate a wideband signal. A group of CW tones can be turned off to generate a notch with steep edges and maximum on/off ratio of around 50 dB. Users can vary the position and width of the notch using a control menu. The R&S®FSW signal and spectrum analyzer measures the resulting notch depth after going through the DUT with a dedicated measurement function.

The R&S®SMW200A can also generate AWGN or a modulated signal with notches instead of an MCCW signal. Notched modulated signals enable the simulation of real world conditions for a DUT.

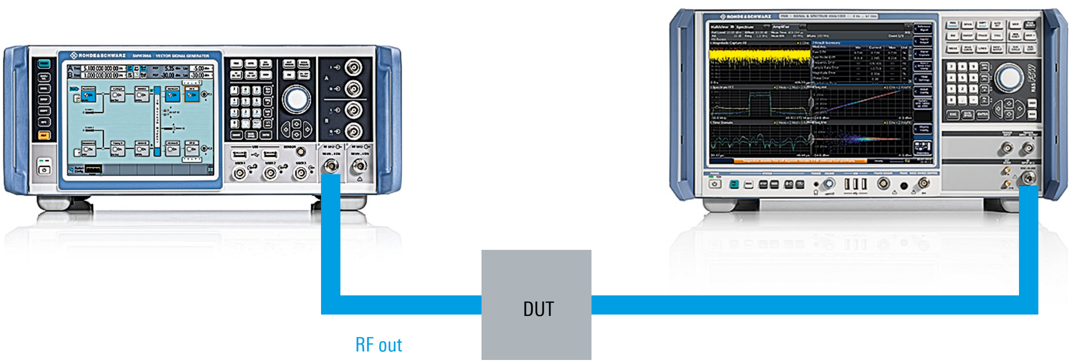
The advantages of this measurement method are:

- No previous calibration is needed to measure NPR notch depth up to 50 dB using flat signals over a 2 GHz bandwidth
- The test signal is easy to create and modify
- Easy read out of the results on the R&S®FSW analyzer

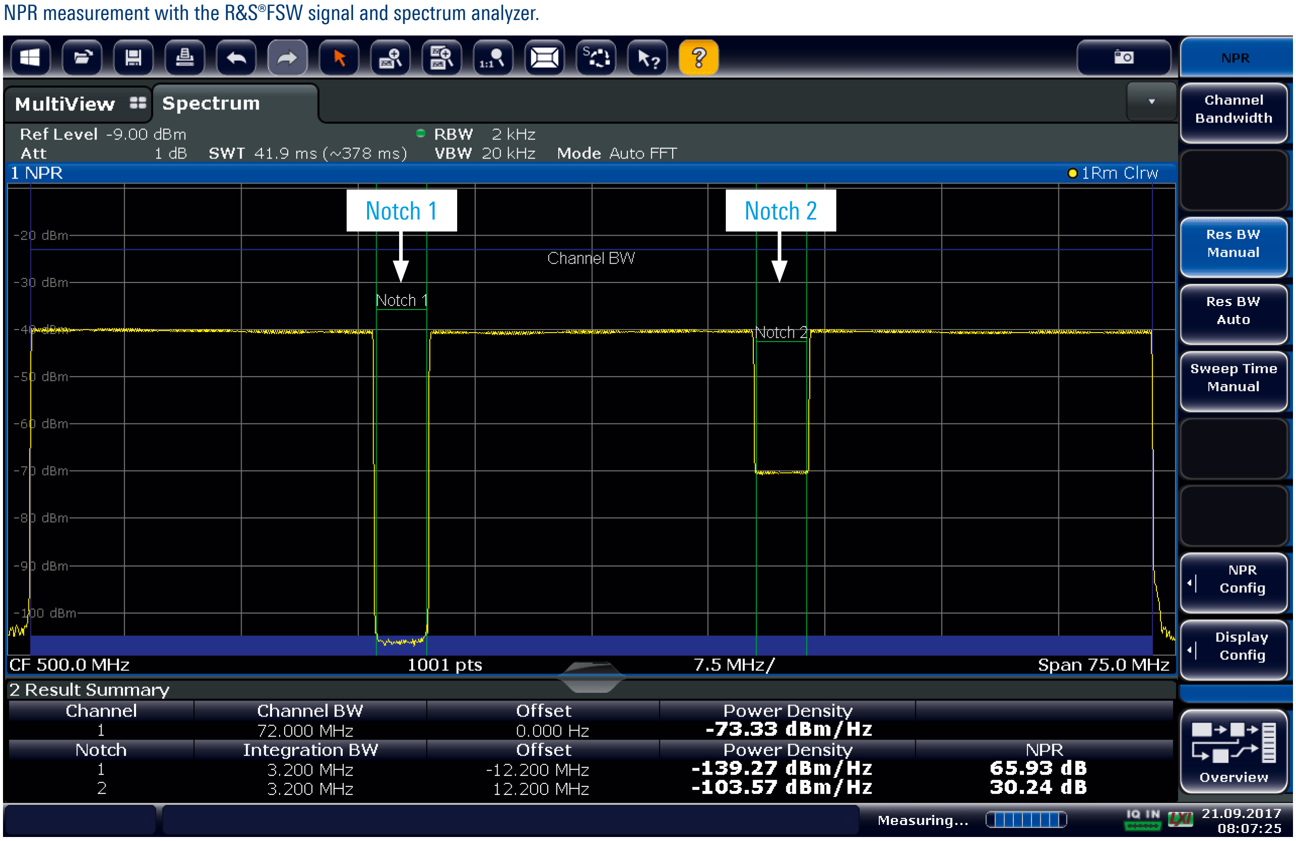
2 GHz wide multicarrier continuous wave (MCCW) signal generated with the R&S®SMW200A vector signal generator.



NPR measurements with R&S®SMW-K61 and R&S®FSW



NPR measurement with the R&S®FSW signal and spectrum analyzer.



SIGNAL QUALITY MEASUREMENTS

Modulation accuracy and bit error rate (BER) measurements are necessary to verify the quality of satellite links during satellite integration as well as during in-orbit operation.

Modulation accuracy and BER measurements often involve analyzing the power and digital demodulation characteristics of carriers transmitted from an in-orbit satellite or a ground station at different frequencies. The error vector magnitude (EVM) is a key parameter in determining the quality of the regenerated signal inside the transponder.

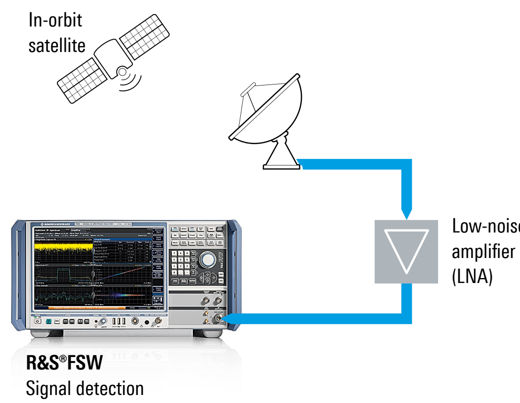
Parameters such as EVM, BER, signal amplitude and phase are easy to monitor with the R&S®FSW-K70 vector signal analysis (VSA) option. The R&S®FSW-K70 VSA option determines the quality of the signal transmitted and/or received by the satellite by comparing it with an ideal reference signal. The R&S®FSW-K70 option calculates the reference signal from the signal transmitted by the DUT and the user settings such as modulation type and symbol rate.

The vector signal analyzer in the FSW-K70 option enables users to:

- Analyze digitally modulated single carrier signals with up to 8.3 GHz signal analysis bandwidth
- Analyze modulation
- Use predefined standard-specific settings for DVB-S2(X), DVB-S2X Annex E, DVB-RCS2
- Measure BER

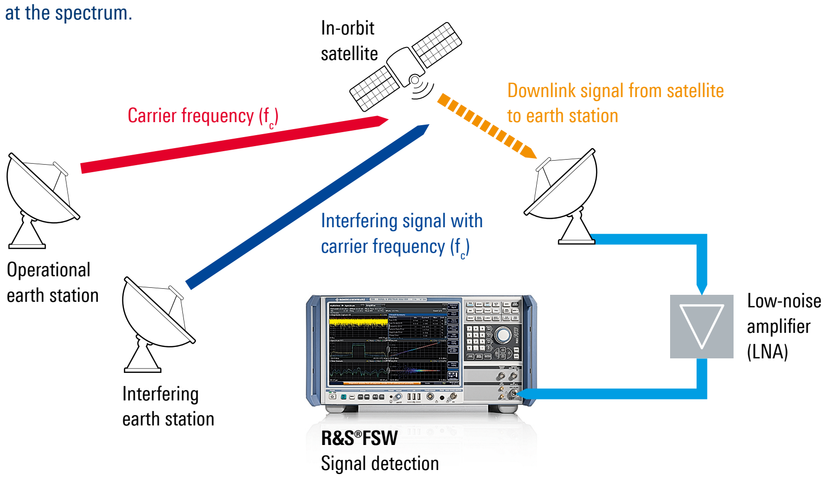
In-orbit satellite carrier monitoring

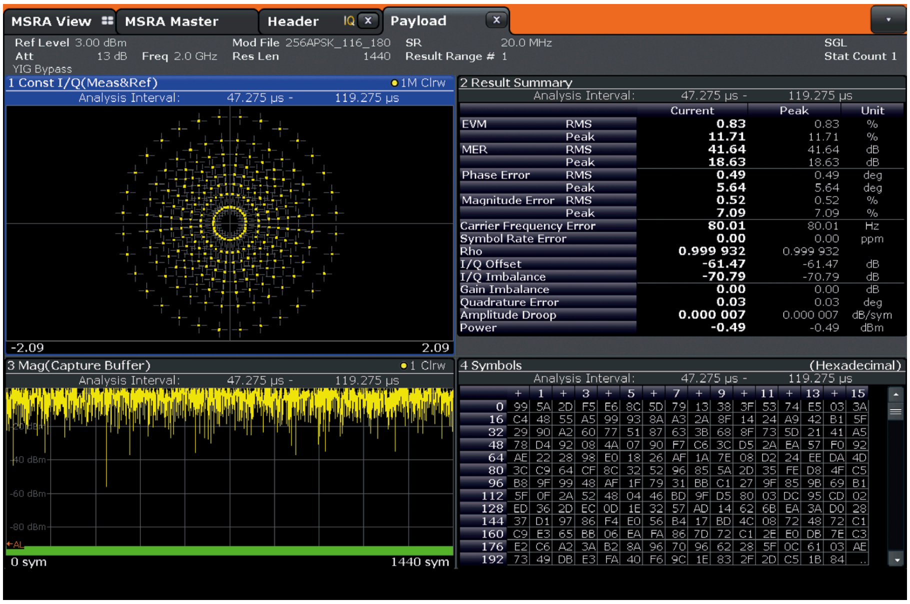
Satellites can be quickly and accurately monitored using the setup shown in the figure. Depending on the ground station configuration and frequency band used, spectrum analyzers with different frequency ranges are available.



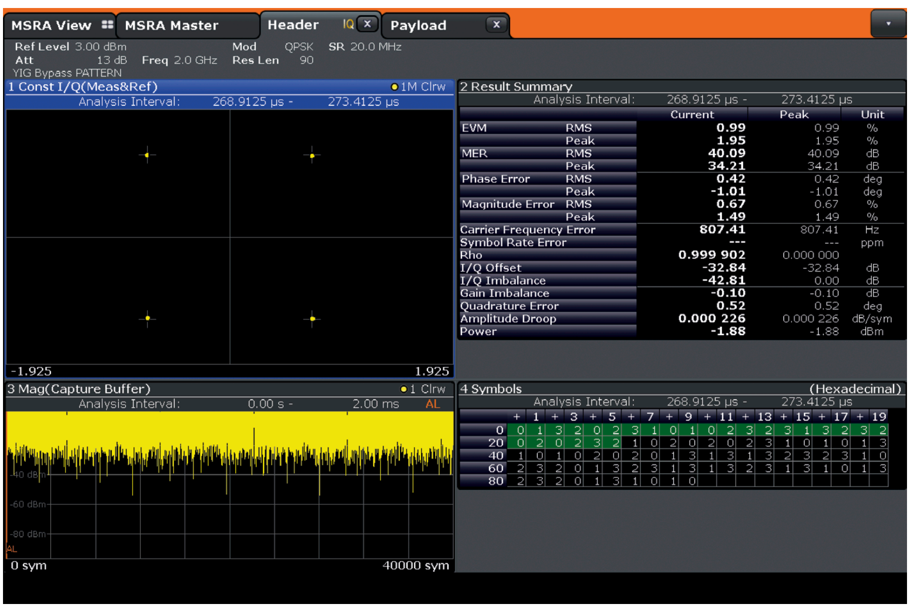
Troubleshooting interference in satellite links: carrier-in-carrier measurement

The carrier-in-carrier measurement is an example of how the VSA application helps to analyze and troubleshoot interference in satellite links: for example a wireless communications signal interfering with a signal transmitted by an operational ground station or when satellite ground stations interfere with one another. In this situation, the interferer and the victim work in the same frequency band and have the same modulation characteristics. Therefore, the quality of the wanted signal deteriorates but no interferer can be immediately detected when looking at the spectrum.

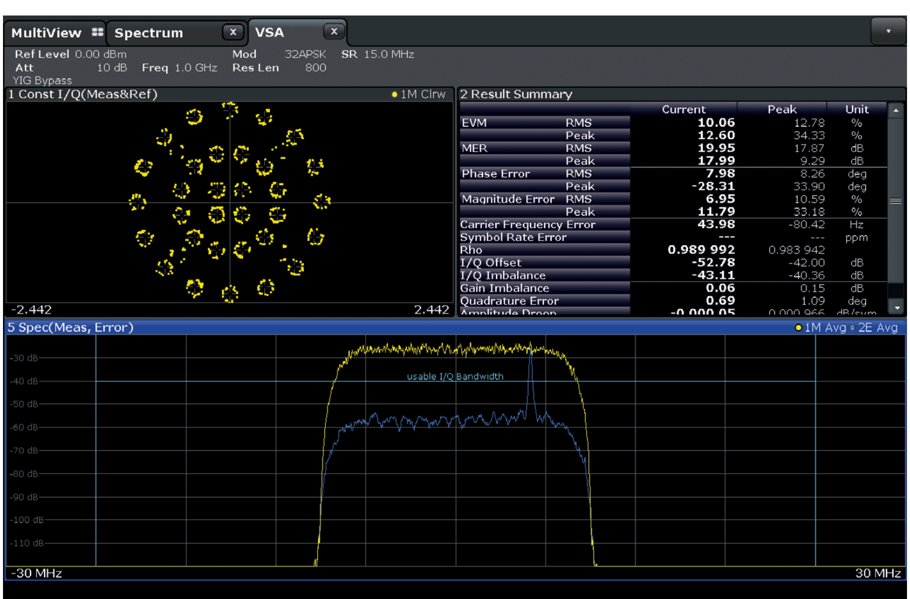




DVB-S2X signals use different modulation schemes for the payload and the header sections of the frame. The different modulations can be analyzed using the R&S®FSW multi-standard radio analyzer (MSRA) mode and the R&S®FSW-K70 option. With this configuration, the R&S®FSW demodulates the header and payload data of the DVB-S2X signal based on the same I/Q data and displays the performance parameters, constellation diagrams, etc. in separate windows. In this case, the payload uses 256APSK modulation and the header and pilot section a more robust QPSK modulation. This screenshot shows the payload tab.



The scenario is the same as in the screenshot above. This screenshot shows the header tab.



This screenshot shows an example of an interference scenario. The wanted signal is a DVB-S2 32APSK modulated signal with a 15 Msymbol/s sample rate. The interfering GSM signal has a –20 dB/5 MHz level/frequency offset with respect to the wanted signal. The result summary shows that the wanted signal has an increased EVM. The error spectrum (blue) shows a higher error level where the interfering GSM signal is located in spectrum.

OFDM SIGNAL GENERATION AND ANALYSIS

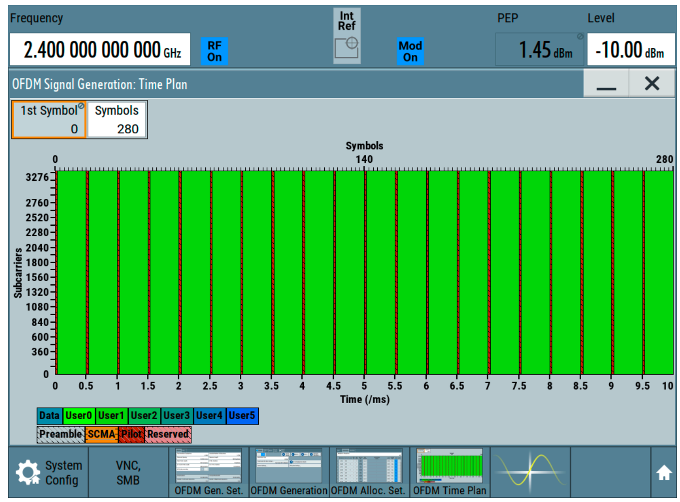
Develop, test and measure custom OFDM signals, precisely tailored to any application requirement.

OFDM signal generation

Many modern communications standards use orthogonal frequency division multiplexing (OFDM) as their underlying modulation. The R&S®SMW-K114 OFDM signal generation option is ideal for generating custom OFDM based waveforms.

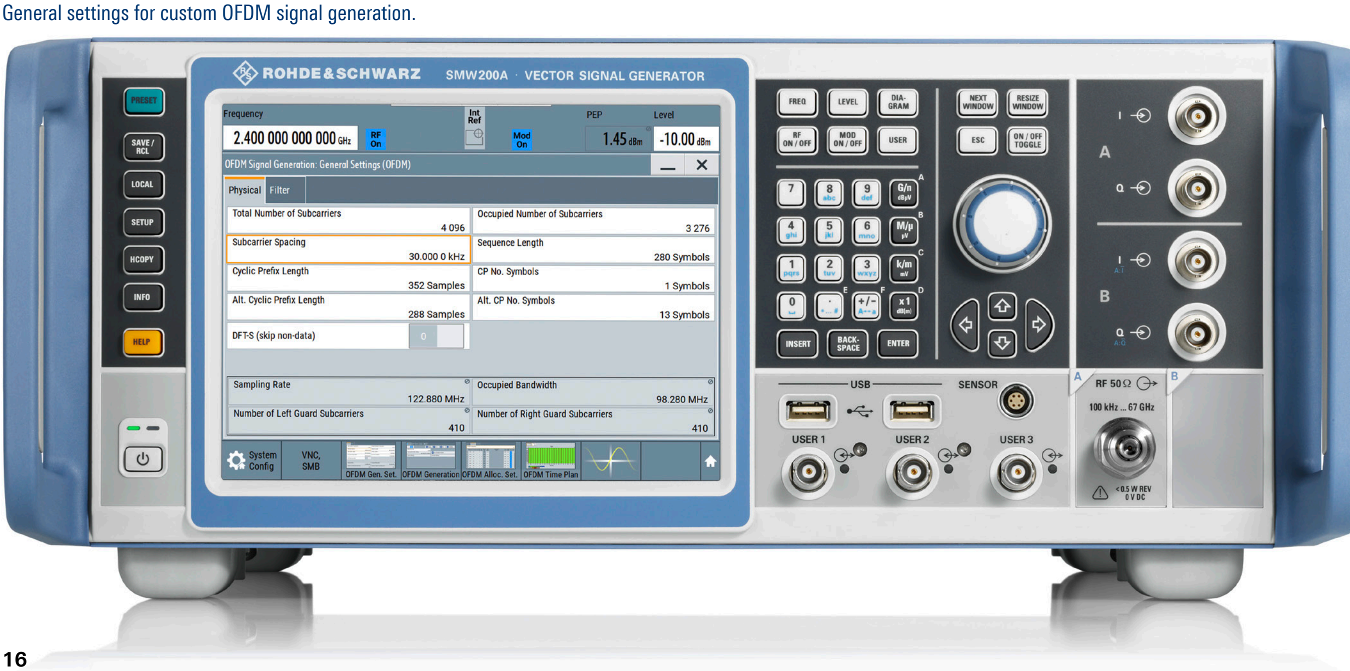
The R&S®SMW-K114 OFDM signal generation option supports up to two different cyclic prefix (CP) lengths per signal, and discrete Fourier transform spread OFDM (DFT-s OFDM) on data allocations. It also allows the completely flexible allocation of pilot and data using BPSK, QPSK and QAM modulations up to 256 for pseudo random noise or pre-defined data sequences, as well as user-defined custom I/Q sequences.

R&S®SMW-K114 also supports the generation of filtered OFDM (f-OFDM), universal filtered multi-carrier (UFMC), filter band multi-carrier (FBMC) and generalized frequency division multiplexing (GFDM) signals. Custom signal filtering, as well as the placement of notches in the OFDM signal for NPR measurements are also possible with the option.



Preview of the allocation time plan.

General settings for custom OFDM signal generation.

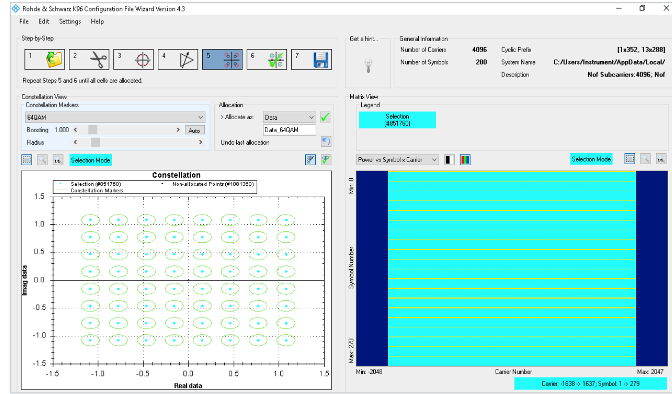


OFDM signal analysis

The R&S®FSW-K96 OFDM signal analysis option enables the R&S®FSW signal and spectrum analyzer to demodulate and analyze custom OFDM and DFT-s-OFDM (SC-FDMA) signals with a known FFT size and cyclic prefix (CP). Synchronization can be done with either the CP or a preamble sequence (training sequence).

Even complex OFDM based communications standards can be analyzed with the R&S®FSW-K96 option. However, the real selling point is freedom it allows during configuration and the setting of measurement parameters.

The configuration file defining the signal and allocation structure can be exported directly from the R&S®SMW-K114 OFDM signal generation option for a quick and simple start.



Configuration file definition made easy using the built-in file wizard.

User-definable OFDM parameters include:

- Sampling rate, FFT size, capture time, result length
- Cyclic prefix length: two different cyclic prefix lengths are supported per signal configuration
- Preamble structure
- Pilot and data carriers
- Fixed constellation points per pilot sample
- Different modulation formats for data carriers
- Symbol ID and bitstream result
- Burst recognition
- Channel estimation and equalization using phase, timing and level tracking
- Cyclic delay shift
- FFT shift
- Transform precoding

Analyzing a custom OFDM signal with 100 MHz occupied bandwidth.

SPURIOUS MEASUREMENTS

Searching for spurious emissions with spectrum analyzers is an essential measurement when designing, verifying and manufacturing RF and microwave devices.

Transmitter and receiver devices in satellite applications have to fulfill very stringent spurious emissions limits. This implies searching for very low level spurs over a wide frequency range. In general, a narrow resolution bandwidth (RBW) is required to make the measurements with high sensitivity. The tradeoff is a much longer measurement time. Even when working with fast spectrum analyzers with FFT filters, a spur search may take several hours or even days.

A new spurious search algorithm automates and speeds up spurious measurements.

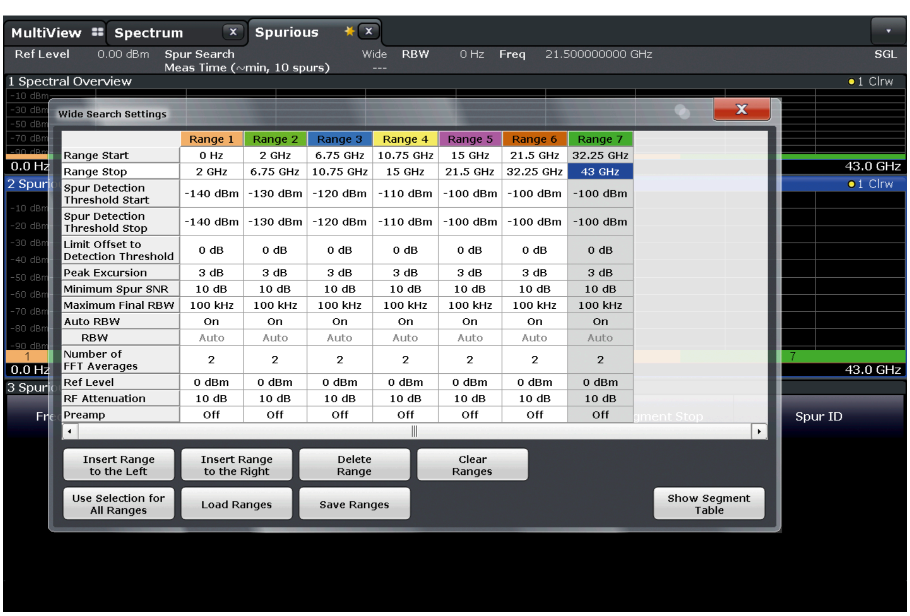
The R&S®FSW-K50 spurious measurement application detects and identifies spurs using an innovative three-step approach. An initial fast sweep is used to determine the optimum RBW. A second sweep is performed to detect possible spurs. A final high-speed search around each known spur frequency determines whether the peak is a real spur, a noise artifact or an internal analyzer spur. In the last step, the RBW can be further reduced to satisfy signal-to-noise requirements.

Measurement process within the R&S®FSW-K50 spurious measurements application

Spectral overview and noise floor estimation
- Estimated measurement time
- Segment table with best fit RBWs

Spur detection
- Pass/fail spurious detection limit
- Preliminary spurious table

Spot search
- Pass/fail
- Final spurious table
- RBW optimized if needed



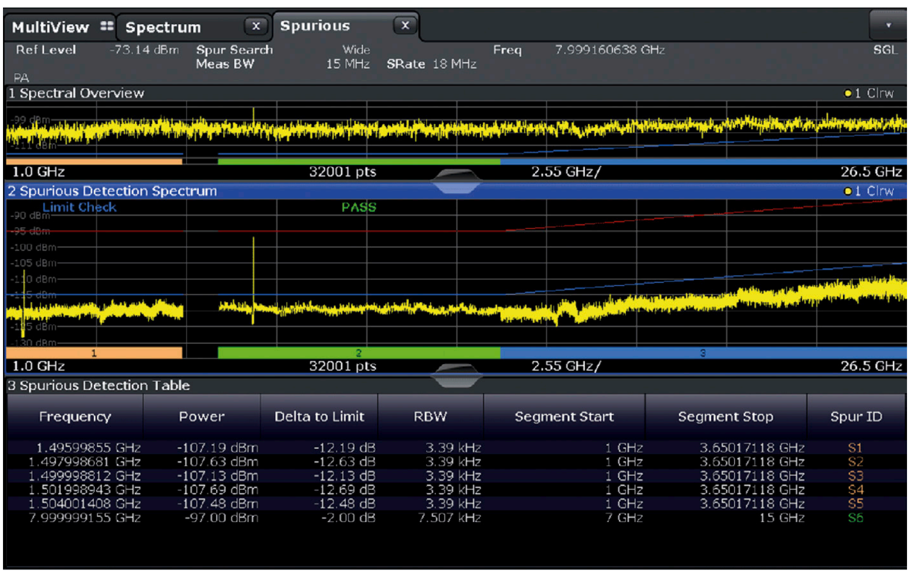
	Range 1	Range 2	Range 3	Range 4	Range 5	Range 6	Range 7
Range Start	0 Hz	2 GHz	6.75 GHz	10.75 GHz	15 GHz	21.5 GHz	32.25 GHz
Range Stop	2 GHz	6.75 GHz	10.75 GHz	15 GHz	21.5 GHz	32.25 GHz	43 GHz
Spur Detection Threshold Start	-140 dBm	-130 dBm	-120 dBm	-110 dBm	-100 dBm	-100 dBm	-100 dBm
Spur Detection Threshold Stop	-140 dBm	-130 dBm	-120 dBm	-110 dBm	-100 dBm	-100 dBm	-100 dBm
Limit Offset to Detection Threshold	0 dB	0 dB	0 dB	0 dB	0 dB	0 dB	0 dB
Peak Excursion	3 dB	3 dB	3 dB	3 dB	3 dB	3 dB	3 dB
Minimum Spur SNR	10 dB	10 dB	10 dB	10 dB	10 dB	10 dB	10 dB
Maximum Final RBW	100 kHz	100 kHz	100 kHz	100 kHz	100 kHz	100 kHz	100 kHz
Auto RBW	On	On	On	On	On	On	On
RBW	Auto	Auto	Auto	Auto	Auto	Auto	Auto
Number of FFT Averages	2	2	2	2	2	2	2
Ref Level	0 dBm	0 dBm	0 dBm	0 dBm	0 dBm	0 dBm	0 dBm
RF Attenuation	10 dB	10 dB	10 dB	10 dB	10 dB	10 dB	10 dB
Preamp	Off	Off	Off	Off	Off	Off	Off

Measurement settings for a wide spurious search. Configurable parameters for each frequency range under investigation.

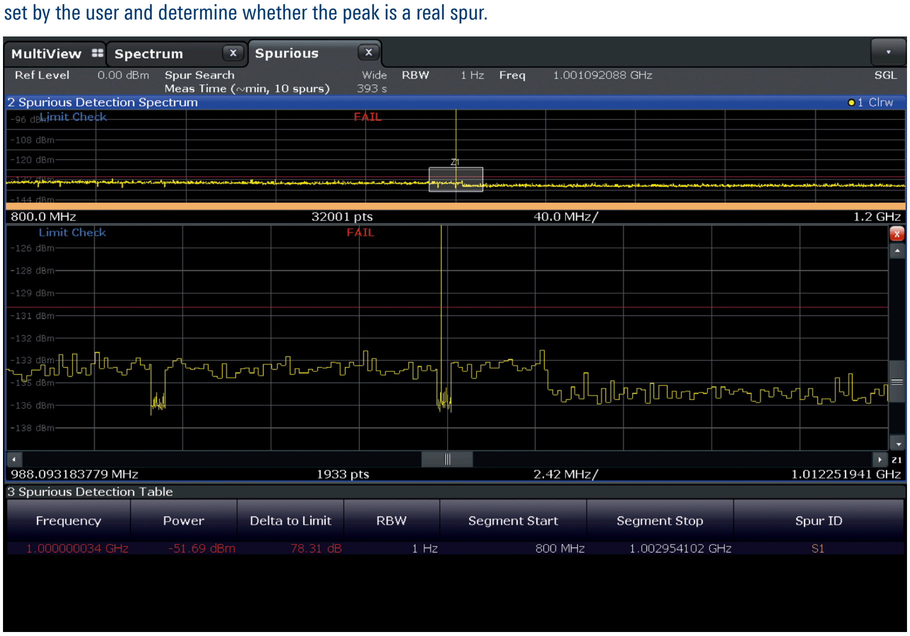
The R&S®FSW-K50 offers many advantages compared with traditional spurious measurement applications:

- Spurious searches that are around 30 times faster than existing spectrum analyzer spurious searches, especially at low RBWs
- RBW automatically calculated based on the maximum allowed spur level and required signal-to-noise ratio (SNR)
- Two different measurement modes: a wide search measurement for unknown spurious scenarios and a directed search measurement at specific frequencies

Spurious measurement application results screen.



Zoom of a spot search. The RBW around the spur is reduced to lower the noise floor and fulfill the SNR requirement set by the user and determine whether the peak is a real spur.

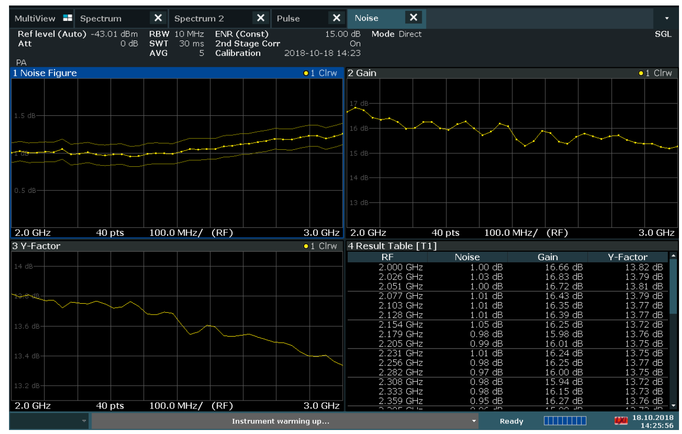


NOISE FIGURE AND GAIN MEASUREMENTS USING THE R&S®FS-SNS

The R&S®FS-SNS smart noise source enables simple and accurate noise figure and gain measurements by automatically loading necessary setup parameters and taking environmental temperatures into account. Measurement uncertainty is automatically calculated and displayed on the result screen.

R&S®FS-SNS smart noise source key facts

- Frequency range up to 18 GHz, 26.5 GHz, 40 GHz, 55 GHz or 67 GHz
- Supported by the R&S®FSW, R&S®FSV3000, R&S®FSVA3000, R&S®FPL1000 signal and spectrum analyzers, the R&S®FSWP phase noise analyzer and VCO tester and the R&S®ZNL vector network analyzer
- Automatic loading of the ENR table
- ENR uncertainty and reflection coefficients table for automatic uncertainty calculation
- Automatic temperature readout for improved accuracy



Noise figure and gain measurement with R&S®FSx-K30 application firmware. In addition to the result table and the noise figure traces, the calculated gain and Y factor uncertainty can also be displayed.

Noise figure and gain measurements with a spectrum analyzer

An excess noise ratio (ENR) source with a well-defined (white) noise for the DUT input is needed for noise figure and gain measurements with a spectrum analyzer. The Y factor is the ratio of noise power at the DUT output with and without this added noise. This is used to calculate the noise contributed by the DUT, its noise figure and gain.

Although output signal characteristics for a noise source in the specified frequency range approximates white noise, there is still a slight frequency response and temperature dependency. To eliminate this deviation from ideal behavior, noise sources come with written tables indicating the ENR behavior of the noise source based on frequency and temperature. The correction values must be manually transferred to the noise figure measurement software. The R&S®FS-SNS smart noise source eliminates the time consuming and error prone step by including electronic ENR and environmental temperature tables in the spectrum analyzer calculations.

R&S®FS-SNS smart noise source is connected to the analyzer with a 7-pin cable as a power supply and control interface. An adapter cable is supplied for instruments without the necessary connector. When connected to a spectrum analyzer with the R&S®FSx-K30 noise figure measurement firmware, the instrument automatically sets all the parameters.

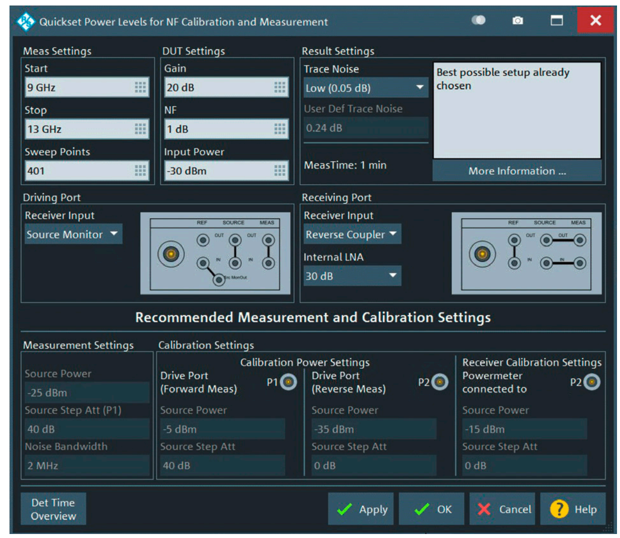
R&S®FS-SNS for simple and accurate noise figure and gain measurements.

NOISE FIGURE MEASUREMENTS OF AMPLIFIERS AND MIXERS

The R&S®ZNA-K30 option can analyze noise figures for amplifiers, converters and T/R modules. Hardware options can be added to further improve this function and stimulate high gain amplifiers with very low levels and accurately measure low gain/low noise figure LNAs.

Single connection device characterization

Instead of a noise source to determine a noise figure, the R&S®ZNA directly measures absolute noise power on the source and receive sides, providing the signal-to-noise ratios at the DUT input and output. Absolute power level calibration and system error correction are applied. Instrument calibration with a manual calibration kit, a calibration unit and a power sensor requires no extra equipment and an external noise source is unnecessary. The convenient calibrate all function can cover the entire setup. The DUT (amplifier, converter, T/R module) needs to be connected only once for full device characterization, including (conversion) gain/loss, intermodulation distortion, compression and group delay. The GUI displays the hardware components in the measurement path as graphic elements und helps configure all the details. Users can see all relevant settings at a glance.



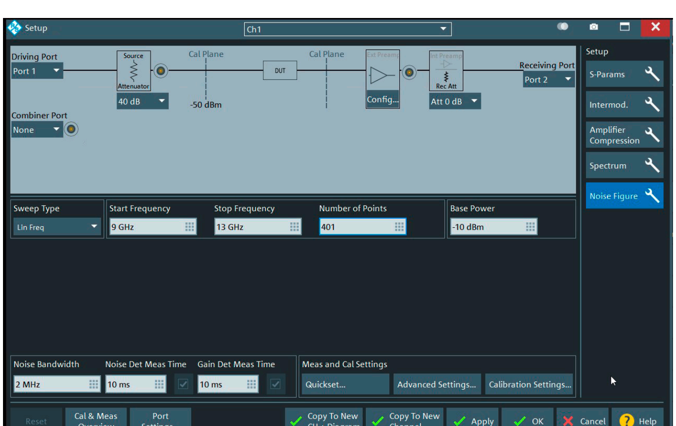
Interactive and semi-automatic configuration of optimal test parameters and R&S®ZNA hardware in the Quickset dialog

Calibration features and settings

The potential for increased uncertainty from very low stimulus power and high measurement power may conflict with test accuracy requirements, especially with high gain converters. The main GUI includes essential parameters guiding users easily to the best settings for manual configuration. Correction algorithms used in system error correction provide accurate and reliable results.

Quickset – the fast and intuitive way to optimal settings

The powerful Quickset dialog is a valuable addition to the main configuration GUI: it interactively guides users to the optimal setup, based on the estimated DUT characteristics such as the approximate noise figure and gain along with the desired noise figure trace noise. The R&S®ZNA calculates parameters such as the measurement time and source power and displays the recommended optimum hardware configuration.



GUI for easy noise figure measurement configurations.

TESTING IN THERMAL VACUUM CHAMBERS

Satellite payload qualification requires performance testing using a thermal vacuum chamber (TVAC) to simulate the environment and temperature extremes of space.

Commercial off-the-shelf test and measurement equipment is not capable of working under TVAC conditions. Spectrum analyzers, vector network analyzers, signal generators, etc. have to remain outside the TVAC and require long cables to interface to the DUT inside the chamber.

Cables, adapters and switches in the test setup will drift as the temperature changes in the TVAC. The calibration performed in the chamber at a different temperature is no longer valid. After moving cables and changing temperatures, regular recalibration is necessary to ensure accurate measurements. The calibration procedure inside the TVAC is especially challenging because the operator cannot access inside the chamber when the vacuum is applied.

Rohde & Schwarz has developed calibration accessories to help maintain accurate measurements on the uplink and downlink reference plane. One is an inline calibration module to enable a calibration update inside the TVAC after cabling and temperature changes and another is a power meter to monitor the uplink and downlink power at the test coupler.

The R&S®ZN-Z33 inline calibration unit is designed to operate inside the TVAC.

Vector network analyzer multiport calibration in TVAC

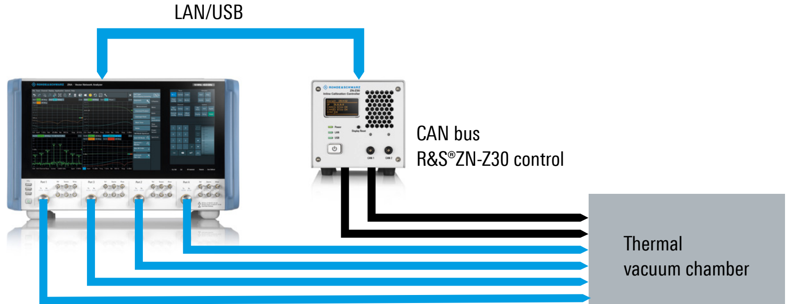
The R&S®ZN-Z33 (model .03) automatic calibration units are designed to operate inside the TVAC and are permanently connected between the test setup cables and the DUT, which allows recalibration whenever necessary.

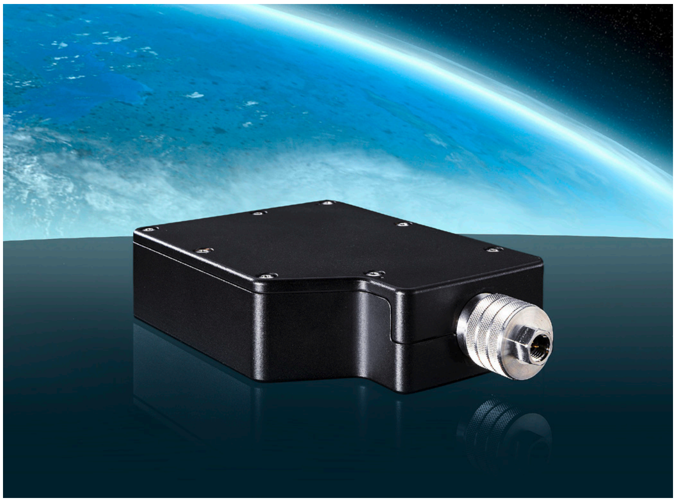
A basic (multiport) calibration with through connections is only needed once for environmental conditions. For temperature runs under vacuum conditions, the inline calibration units support remote controlled re-calibration with the DUT in place.

The R&S®ZN-Z33 automatic calibration units are connected to the R&S®ZN-Z30 controller via a CAN bus. Control of the R&S®ZN-Z30 CAN bus network and R&S®ZN-Z32 and R&S®ZN-Z33 calibration units is integrated in the firmware.

Measurement setup

The control of the R&S®ZN-Z30 CAN bus network and of the R&S®ZN-Z32 and R&S®ZN-Z33 calibration units is integrated in the R&S®SMARTerCal concept of the R&S®ZNA for seamless remote control calibration and in situ re-calibration. The inline R&S®ZN-Z33 calibration unit operates up to 40 GHz and can also be TVAC compatible.





Special R&S®NRP33SN-V/R&S®NRP67SN-V three-path diode power sensor for use in a TVAC environment.

They are automatically detected for easy integration in the user interface.

A single controller supports up to 48 inline calibration modules, making it ideal for multiport DUTs. Distances up to 20 m are possible. The setup enables simple plug & play configuration. The extended feature range enables correction for auxiliary components such as adapters and splitters and enables mixer measurements.

The main advantages of this solution are:

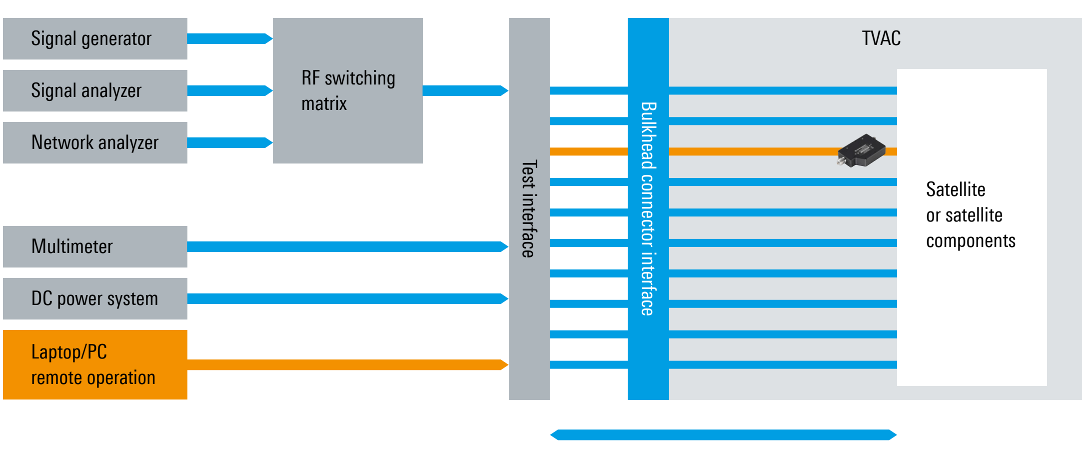
- The R&S®ZN-Z33 automatic calibration unit is characterized over the temperature range from –30 °C and +80 °C in the factory to work in vacuum conditions
- The R&S®ZN-Z33 has low insertion loss (typ.1.5 dB at 1 GHz, 5 dB at 40 GHz) and high effective directivity (typ. 38 dB between 700 MHz and 20 GHz)
- Compact setup for multiport testing: one R&S®ZN-Z30 controller supports up to 48 calibration units
- Flatness power calibration (included in R&S®SMARTerCal) is possible during base calibration
- Plug & play configuration
- Accurate stimulation power even in TVAC
- Correct for auxiliary components, (de-)embedding
- Converter testing

Power measurements

General power measurements inside the TVAC (under TVAC conditions) are possible with Rohde & Schwarz TVAC power test heads. The R&S®NRP33SN-V and R&S®NRP67SN-V power sensors have been especially designed for TVACs and comply with the European Space Agency (ESA) norms. R&S®NRP33SN-V and R&S®NRP67SN-V power sensors cover the satellite communications frequency range up to 33 GHz and 67 GHz for fast, highly accurate power measurements over a dynamic range of up to 93 dB, independent of signal bandwidth and modulation type. The power sensors can be easily controlled from outside the chamber via a power over Ethernet LAN connection.

The measurement setup and calibration procedure can be simplified by connecting the sensors directly to the input or output of the satellite inside the chamber, eliminating the need for long RF cables while improving measurement accuracy by measuring close to the DUT. Rohde & Schwarz TVAC cables, special LAN feedthroughs from the inside to the outside of the chamber, are made of vacuum friendly materials that have been baked long enough to eliminate VOC and other contaminants.

The Rohde & Schwarz calibration unit and power sensor are connected directly to the payload in the TVAC



DIGITAL INTERFACE TESTING

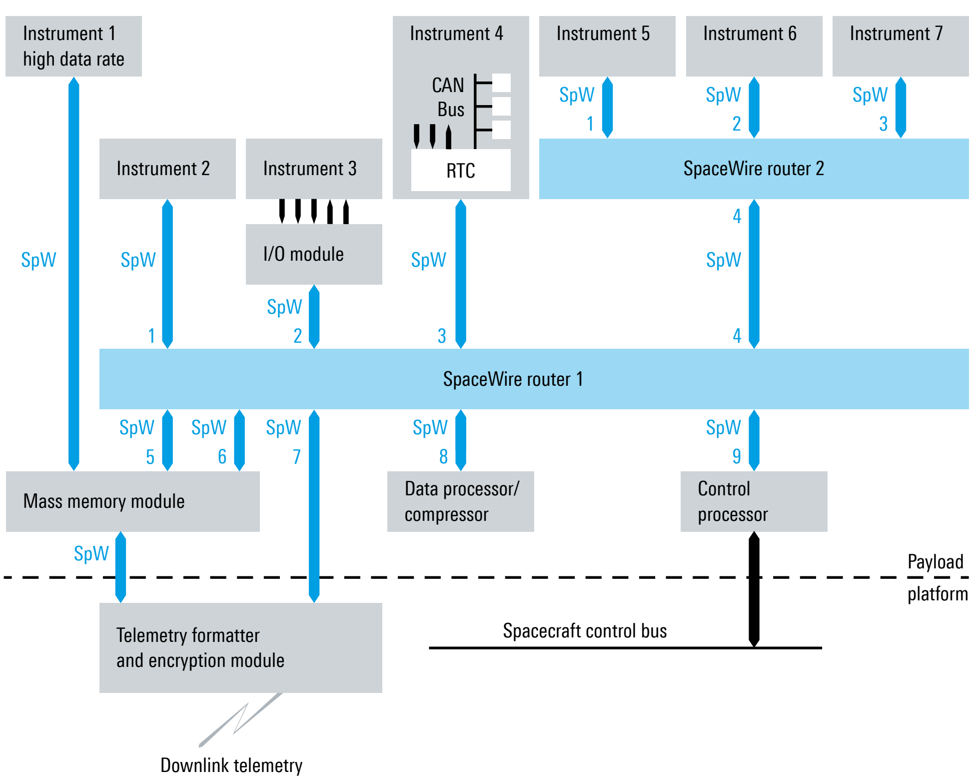
The data communications between different systems and components within a satellite is crucial for a mission and has to be ensured under all conditions.

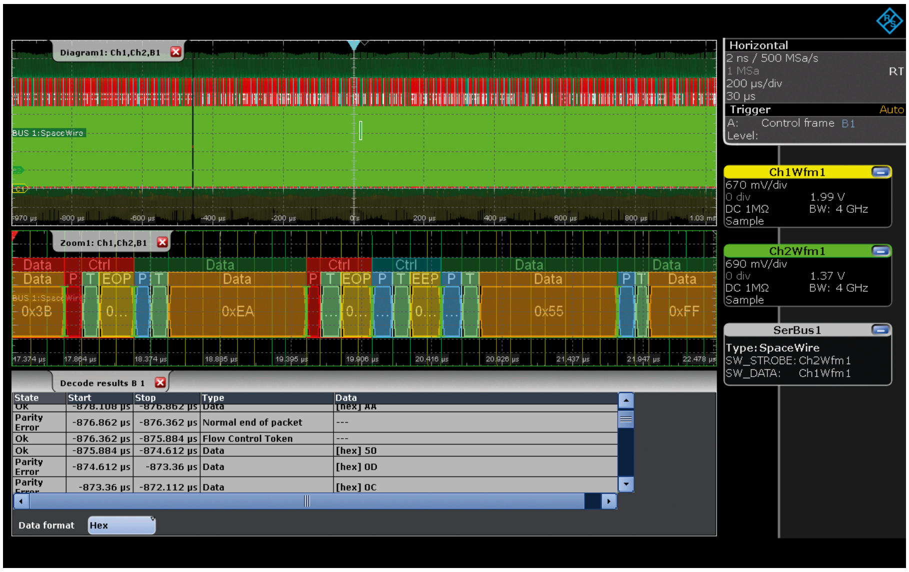
The different instruments and modules within the payload and between the payload and the satellite platform are interconnected via digital data and communications bus systems. State-of-the-art systems use protocols such as SpaceWire for this task.

The R&S®RTP and R&S®RTO6 oscilloscopes easily decode and debug the different bus standards, offering a wide range of functions to verify the performance of a DUT:
- Trigger and decode options for standardized and proprietary bus systems such as SpaceWire and 8b/10b-based SpaceFibre
- A unique time and frequency zone trigger
- Easy correlation between different events simplifies system troubleshooting
- Excellent signal fidelity with up to 16-bit vertical resolution
- Compact format with fully integrated multi-domain test solution including frequency, protocol and logic analysis functionality
- Integrated arbitrary waveform and pattern generator for device control and stimulus

SpaceWire architecture

Two SpaceWire routers are used to provide connectivity between the different instruments and modules in the satellite.

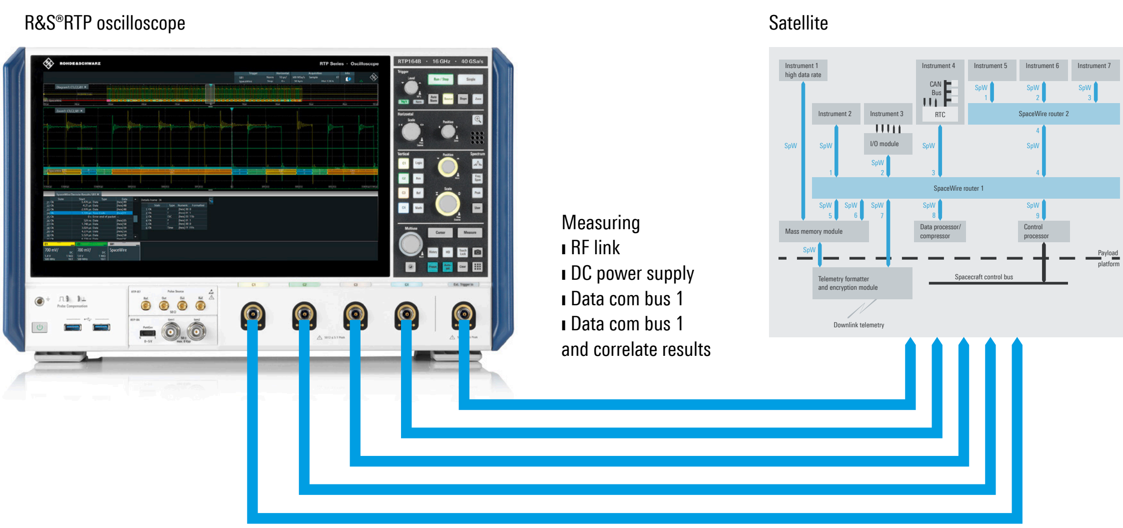




Equipped with the R&S®RTP-K65 option, the R&S®RTP easily decodes and debugs the SpaceWire serial protocol.

Debug test setup with a four-channel R&S®RTP oscilloscope

Each R&S®RTP channel measures a different domain (RF link, DC power supply, datacom buses) and correlates the measurement results.



Selection of commonly used trigger and decode options for digital interface testing on satellites								
Option	**Serial standard**	**Application**	**Decode**	**Decode table**	**Trigger**	**Label support**	**Symbolic T&D**	**Search**
R&S®RTP-K1	I²C/SPI	Embedded	●	●	●	●		●
R&S®RTP-K2	UART/RS-232/422/485	Embedded	●	●	●			
R&S®RTP-K3	CAN/LIN (CAN-dbc)	Automotive, industrial	●	●	●	●	●	●
R&S®RTP-K6	MIL-STD-1553	Aerospace	●	●	●	●		●
R&S®RTP-K7	ARINC 429	Aerospace	●	●	●	●		●
R&S®RTP-K9	CAN-FD (CAN-dbc)	Automotive	●	●	●	●	●	●
R&S®RTP-K50	Manchester, NRZ	Configurable	●	●	●			
R&S®RTP-K52	8b10b	Embedded	●	●	●			●
R&S®RTP-K65	SpaceWire	Aerospace	●	●	●	●		●

RF MEASUREMENTS ON PAYLOAD COMPONENTS

WITH THE R&S®ZNA VECTOR NETWORK ANALYZER

R&S®ZNA key features

- Extremely high sensitivity
- Unparalleled measurement speed
- Frequency range up to 67 GHz
- Up to eight independent receivers
- Four internal, phase coherent sources
- Two internal LO sources
- Four pulse generators and four pulse modulators
- Internal combiner
- Comprehensive trigger and synchronization capabilities

MIXER/CONVERTER MEASUREMENT

- Conversion loss
- Input/output matching
- RF/LO crosstalk
- Compression/intermodulation
- Group delay
- Noise figure
- Phase measurements without reference mixers

ANTENNA MEASUREMENT

- Matching
- Antenna characterization
- RCS measurements
- Direct IF access with 1 GHz bandwidth
- Comprehensive trigger and synchronization capabilities
- Supports mmW measurements up to 1100 GHz
- Reverse frequency sweep

R&S®ZNA

VECTOR NETWORK ANALYZER

AMPLIFIER MEASUREMENT

- Delay, gain
- Input/output matching
- Intermodulation
- Compression
- Noise figure
- Harmonic distortion
- Pulsed measurements
- Absolute power

FILTER MEASUREMENT

- Passband and stopband attenuation
- Ripples
- Steepness
- Delay
- Matching
- Bandwidth
- Q-factor
- TDR tuning

WITH THE R&S®SMW200A VECTOR SIGNAL GENERATOR

R&S®SMW200A key features

- Frequency range up to 67 GHz
- Up to 2 GHz I/Q modulation bandwidth (in RF) with internal baseband
- 4 GHz signal bandwith available with R&S®SMW-K555 bandwidth extension
- Optional second RF path up to 44 GHz

WITH THE R&S®FSW SIGNAL AND SPECTRUM ANALYZER

R&S®FSW key features

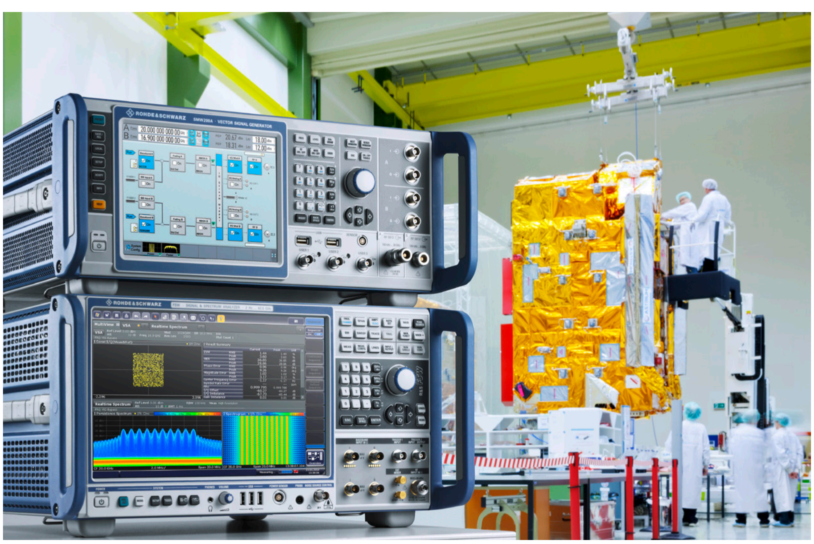
- Frequency range up to 90 GHz and up to 500 GHz with external harmonic mixers
- Up to 8.3 GHz internal analysis bandwidth
- 800 MHz real-time analysis bandwidth

AMPLIFIERS (R&S®SMW200A AND R&S®FSW)

- Gain and gain compression
- AM/AM, AM/PM, compression
- Modeling and digital predistortion
- EVM
- In/out power, ACLR, NPR
- Noise figure
- Frequency response measurement and correction
- Group delay, intermodulation

MIXERS/FREQUENCY CONVERTERS (R&S®SMW200A AND R&S®FSW)

- Conversion loss
- Compression
- AM/AM, AM/PM
- Spurious
- Noise figure
- Frequency response measurement and correction
- Group delay



R&S®SMW200A

SIGNAL GENERATOR

R&S®FSW

SIGNAL AND SPECTRUM ANALYZER

FILTERS (R&S®SMW200A AND R&S®FSW)

- Passband and stopband attenuation
- Magnitude and phase
- Frequency response measurement and correction
- Group delay

OSCILLATORS/SYNTHESIZERS (R&S®FSW)

- Phase noise
- Spurious
- Output power

Service that adds value
- ▶ Worldwide
- ▶ Local and personalized
- ▶ Customized and flexible
- ▶ Uncompromising quality
- ▶ Long-term dependability

Rohde & Schwarz
The Rohde & Schwarz technology group is among the trailblazers when it comes to paving the way for a safer and connected world with its leading solutions in test & measurement, technology systems and networks & cybersecurity. Founded more than 85 years ago, the group is a reliable partner for industry and government customers around the globe. The independent company is headquartered in Munich, Germany and has an extensive sales and service network with locations in more than 70 countries.

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Sustainable product design
- ▶ Environmental compatibility and eco-footprint
- ▶ Energy efficiency and low emissions
- ▶ Longevity and optimized total cost of ownership

Certified Quality Management
ISO 9001

Certified Environmental Management
ISO 14001

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PD 5215.2120.92 | Version 02.00 | September 2022 (ch)
Satellite payload and components testing
Data without tolerance limits is not binding | Subject to change

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