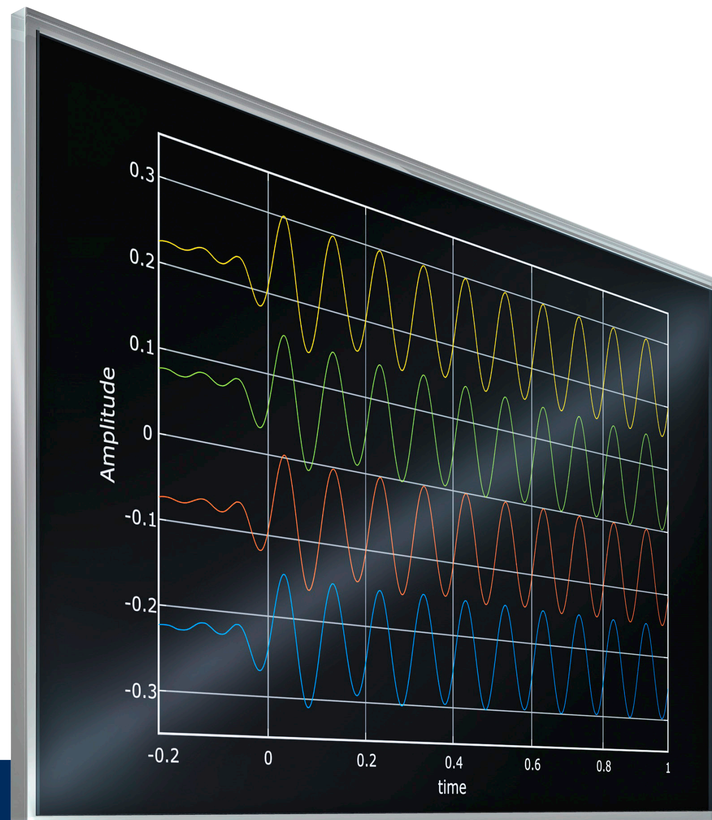
RELIABLE AND FLEXIBLE SIMULATION OF ANGLE OF ARRIVAL (AoA)

Phase-coherent multi-instrument setups with R&S®SMW200A



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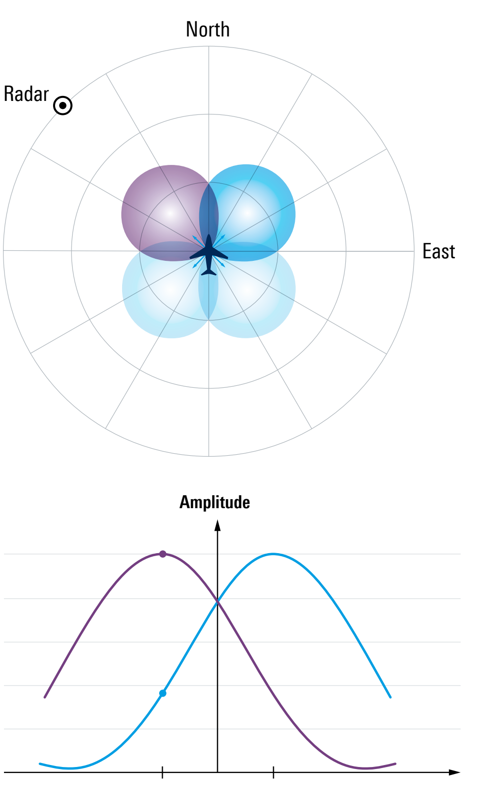
THE APPLICATION

Radar warning equipment is installed in all types of airborne platforms such as airplanes and helicopters, and in naval or ground based platforms. This equipment protects the platforms and all personnel operating the platform such as pilots and naval staff, etc. The purpose of the radar warning equipment is to detect, measure and identify radar signals and to provide a warning to the crew so that available countermeasures can be taken or maneuvers carried out.

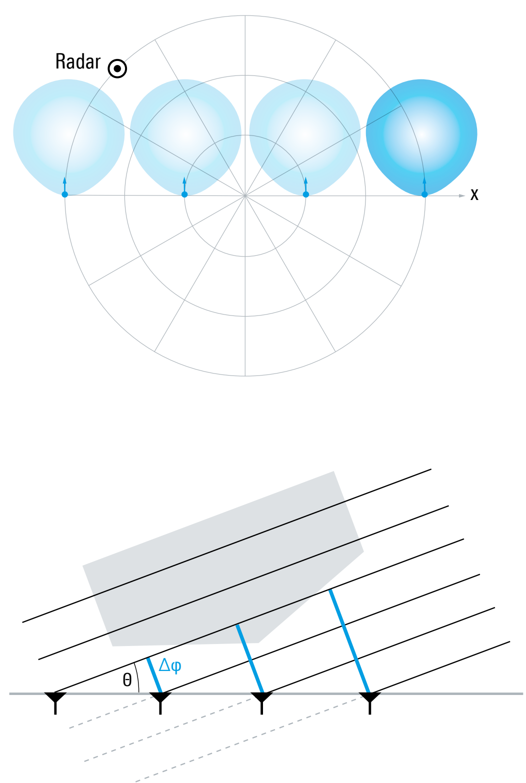
It is also mandatory to have direction finding (DF) capabilities to identify the angle of arrival (AoA) of a signal. For DF purposes, platforms have multiple antennas installed at different positions. After downconversion to an intermediate frequency (IF), the received signals are fed to a multichannel radar warning receiver and processed in a central computer that evaluates the amplitude, phase and time difference between the individual received signals. Typical DF techniques are amplitude comparison (amplitude monopulse) and interferometry.

Amplitude monopulse technique with four antennas



Usually two out of four antennas receive signals with adequate power levels. A radar with a bearing of 0° creates the same power level in each receive path. A radar with a bearing of –45° creates an higher power level in the receive path with the antenna in purple than in the receive path with the antenna in blue.

Interferometry technique with four antennas



The signal is received with multiple antennas that have the same boresight direction. The AoA can be derived from the relative phase difference (blue lines) between the individual antennas. In this example, a flat phase front is assumed.

YOUR CHALLENGE

For electronic warfare (EW) engineers, it is highly desirable that they have a simulator in their hands that can provide test signals for simulating the AoA. This is necessary from the very beginning of the design phase. However, often this is not the case and engineers face the following problems:

- Early verification of DF accuracy and the system concept is often delayed to later design phases due to lack of basic simulators
- Limited amplitude and phase stability of multichannel RF simulators
- Poor simulator performance leads to inaccurate simulation of AoA
- Only expensive and inflexible customized simulators with long lead times are available
- Complex or homemade software tools for scenario definition
- Multivendor solutions that are inconvenient to use

OUR SOLUTION

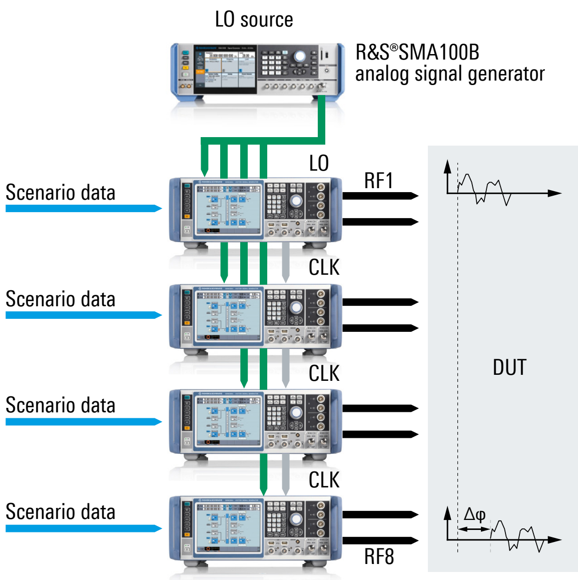
EW engineers can use multiple coupled R&S®SMW200A vector signal generators to simulate the AoA of radar signals. Sharing the local oscillator signal and the clock signal between multiple instruments ensures stable and repeatable simulation of relative amplitude, phase and time offsets between the RF ports. After calibration, the system provides a defined reference plane and simulation software can configure the relative amplitudes, phases or time offsets between the RF ports as defined by the desired scenario. This solution is ready to verify the performance of equipment that measures the AoA.

Now, engineers have a perfect multichannel RF simulator based on the R&S®SMW200A vector signal generator with the following benefits:

- Stable multichannel RF hardware for repeatable scenarios
- Calibrated reference plane between the RF ports and signal coherency with the Rohde & Schwarz calibration solution
- Small setup size allowing scalable setups with two, four, six, eight or more ports on an engineer's benchtop
- Commercial off-the-shelf (COTS) test and measurement equipment
- Worldwide Rohde & Schwarz customer service and support
- No risk of failure from the beginning of the design phase
- Vector signal generator supports all kinds of conventional or I/Q modulated baseband signals
- Stream scenario data via pulse descriptor words (PDW) to R&S®SMW200A
- Uploading of precalculated scenario data from R&S®Pulse Sequencer software to the R&S®SMW200A
- Automated calibration software

REFERENCE SOLUTION

Reference solution with eight RF ports



Reference solution with eight RF ports for eight phase-coherent, time-aligned and synchronized RF signals up to 20 GHz. For optimized performance, the R&S®SMA100B analog signal generator provides an ultraclean LO signal in a star configuration.

Compact and modular design

The two-path R&S®SMW200A vector signal generator is the core building block for multichannel setups. Simply distribute the local oscillator (LO) signal and the clock (CLK) signals to another instrument to build up a phase-coherent multichannel RF simulator. The advanced clock distribution concept ensures highly synchronized basebands and RF signals at the RF output ports. With two RF paths up to 20 GHz per instrument, the setup is compact and fits on an engineer's benchtop. The simulator is easily scalable to the number of receive ports of the DUT. A simulator with eight RF ports is only 16 height units and easily fits into a small rack or on an engineer's desk.

The R&S®SMW200A state-of-the art vector signal generator is also suitable for standalone use. This approach gives engineers the advantage of test case flexibility. They can use the instrument throughout different projects and therefore save costs. It also reduces the variety of different signal sources in the lab.

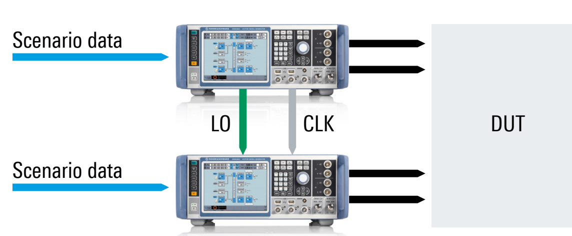
Precise coupling

Both the LO and the advanced clock coupling ensure long-term signal stability and signal repeatability. For best performance, the R&S®SMA100B provides the ultraclean LO signal to a splitter. Equal-length cables distribute it to the LO input port of each vector signal generator in a star configuration. This ensures highly symmetric LO signals.

One instrument, two RF ports

One box, two RF paths up to 20 GHz RF frequency, up to 2 GHz internal I/Q modulation bandwidth. Use both paths independently or share a common LO for phase-coherent operation with outstanding internal LO and clock coupling. The R&S®SMW200A combines powerful hardware with compact design.

Ultracompact four channel setup up to 20 GHz



Basic setup with two coupled R&S®SMW200A. It provides four phase-coherent RF paths in an ultracompact form factor of only eight height units. It allows high portability for use at varying locations.

PRODUCT PERFORMANCE

Agile frequency switching

Within 2 GHz internal I/Q modulation bandwidth, the R&S®SMW200A vector signal generator is capable of super-fast frequency hopping. The R&S®SMW200A vector signal generator achieves agile frequency switching within its wideband baseband by quickly varying baseband offset frequencies. It can generate unmodulated pulsed signals or pulses with modulation on pulse. The signal can originate from the R&S®Pulse Sequencer software or from external simulators that stream the signal as pulse descriptor words (PDW) to the R&S®SMW200A. The R&S®SMW200A can achieve a pulse rate of up to 12 MPDW/s for PDW streaming or more than 19 MPDW/s for frequency agile switching if used with the R&S®Pulse Sequencer software.

Excellent phase repeatability performance

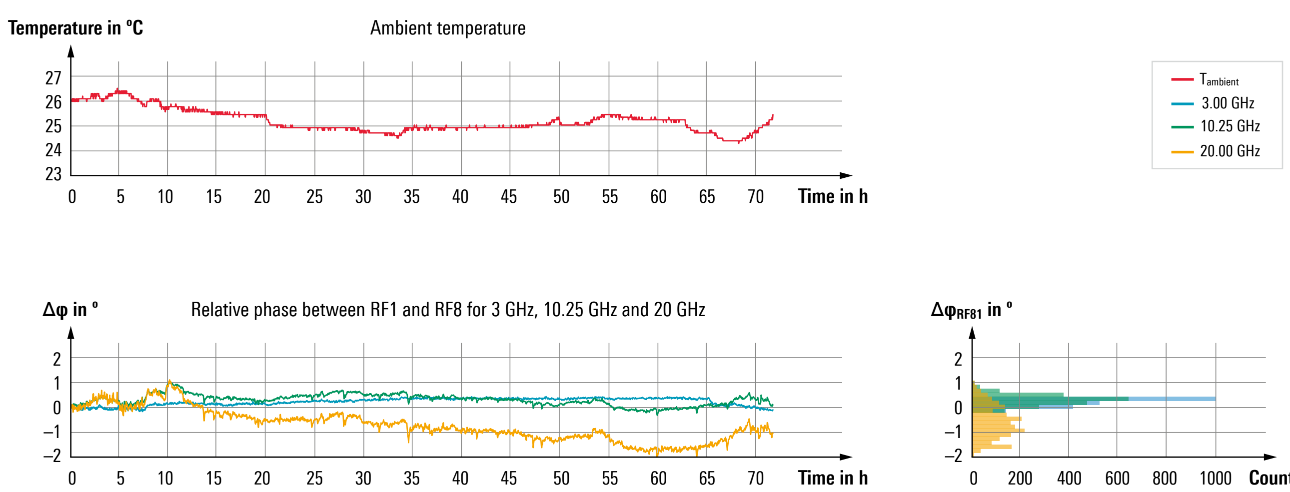
The R&S®SMW200A achieves frequency switching by changing baseband offset frequencies (e.g. from 10 GHz to 10.25 GHz) or by changing the carrier frequency (e.g. from 3 GHz to 20 GHz) for a band change.

Repeatability of relative phase between RF ports especially when switching frequencies back and forth is the key performance indicator for multichannel RF simulators. Multiple coupled R&S®SMW200A can provide four, six, eight ore more phase-coherent RF output signals. They show excellent performance of that key performance indicator and are an ideal solution for simulating multiple phase-coherent signals. The histogram in the figure below indicates the deviation from the initial phase difference. A narrow distribution means excellent repeatability of the phase difference. To obtain the histogram below, the software switched the frequencies according to the pattern shown in the figure „Measuring the performance – frequency changing pattern“ on page 6.

Long-term stability

It is highly desirable that multichannel RF systems have stable RF hardware. This allows long time intervals before recalibration is needed because signals are not biased by long-term drifts. Highly stable RF hardware requires stable ambient temperature. The plot below shows a measurement in a typical air-conditioned lab environment over 72 hours. The phase difference varies only 1.5° for a 10.25 GHz microwave signal.

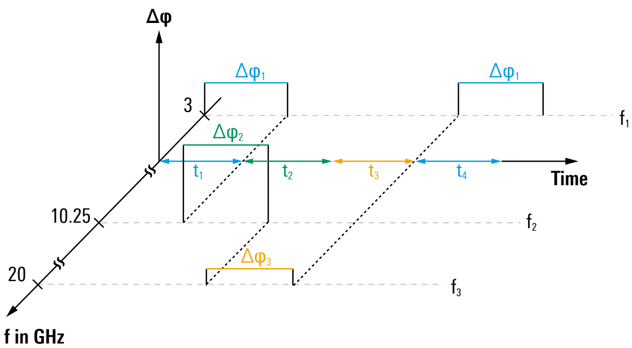
Phase repeatability and stability of switching frequencies for a setup with eight RF ports



The plot shows an example for phase repeatability performance at 3 GHz ($f_{carrier}$ = 4 GHz, $f_{BB-offset}$ = –1 GHz), 10.25 GHz ($f_{carrier}$ = 10 GHz, $f_{BB-offset}$ = 250 MHz) and 20 GHz ($f_{carrier}$ = 19 GHz, $f_{BB-offset}$ = 1 GHz) when changing the frequency according to the pattern shown on the next page. The histogram shows the deviation of the phase difference from the initial value over 72 hours. As the phase difference between two RF ports is very repeatable when switching frequencies (e.g. from 10 GHz to 10.25 GHz), the phase difference is also extremely stable and does not drift.

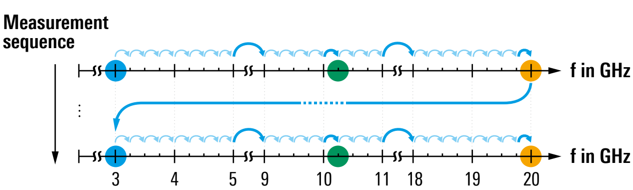
MEASUREMENT PROCEDURE

Desired hardware performance



Ideally, the RF hardware does not impair the configured phase difference between RF ports. The phase difference versus time and temperature should remain stable when switching the frequency back and forth. In this example, the phase difference between two ports in the time interval t_4 is the same as the phase difference in time interval t_1 after the frequency switching cycle from f_1 to f_2 to f_3 to f_1. Only then does the phase difference measured between two ports really reflect the value defined by PDWs or by a scenario calculated by the R&S®Pulse Sequencer software.

Measuring the performance – frequency changing pattern



With a vector signal generator, one can achieve different output frequencies by varying the baseband offset frequency with a fixed carrier frequency or by varying the carrier frequency alone. In the example shown on the left, the carrier frequencies were selected at 4 GHz, 10 GHz and 19 GHz. The baseband offset frequencies were successively varied from –1 GHz to +1 GHz in 250 MHz steps so that the measurement covered the frequency bands from 3 GHz to 5 GHz, from 9 GHz to 11 GHz and from 18 GHz to 20 GHz in 250 MHz steps. The performance plot „Phase repeatability and stability of switching frequencies for a setup with eight RF ports“ on page 5 shows the results for phase stability and repeatability between the RF ports for 3 GHz, 10.25 GHz and 20 GHz versus time.

AUTOMATED RF PORTS ALIGNMENT

Calibrate and simulate precise AoA
Realistic AoA simulations require both phase-coherent synchronization for the RF ports along with precise initial timing, amplitude and phase calibration. RF ports alignment software automatically supports such multi-port signal generator system calibrations. Without a calibration of the entire test setup, the AoA for the receiver inputs cannot be generated with the required precision.

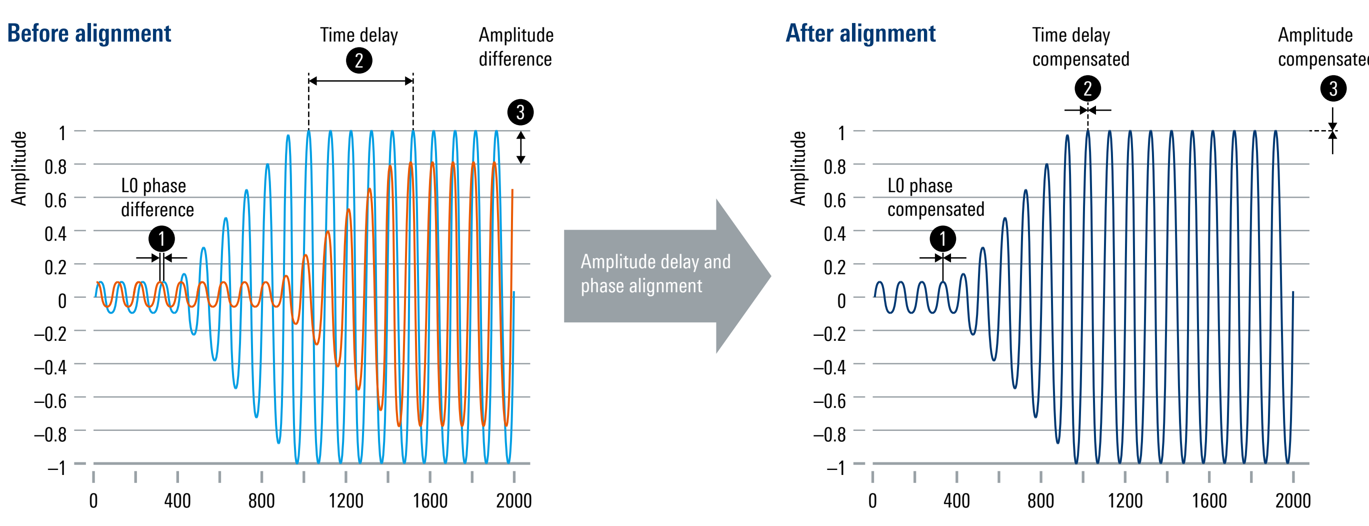
Calibration at the reference plane
Since the AoA is calculated based on relative differences between the receiver RF ports, relative deviations between the RF ports are also measured for calibration. The port alignment reference plane on the receiver serves as the calibration plane (see block diagram below). Special test signals help automatically record deviations, calculate correction data and load these into the signal generators. Applying the correction data ensures precise and reproducible AoA simulations over the entire test period.

User friendly GUI
The clear graphic depiction of the instruments and cabling in the software GUI ensures a quick and error-free setup.

Guided stepwise alignment of RF ports
- Step 1: Define and prepare setup
- Step 2: Define calibration parameters in ports alignment software
- Step 3: Start automatic calibration
- Step 4: Perform your AoA tests

Features and benefits
- Step-by-step user guide for simple and reliable operation
- Scalable for all test systems with two RF ports or more
- Support of all receiver types (TDOA, amplitude based or interferometry)
- Time savings thanks to automated calibration
- State-of-the-art network analyzers from Rohde & Schwarz ensure accurate results

Signals before and after alignment of RF ports



The two diagrams show two sample signals and their amplitude, phase and time relationships relative to time. The deviations of the signals (blue, red) from one another are clearly depicted. The right diagram shows the signals after alignment. The two signals here are calibrated and equivalent.

FEATURES AND BENEFITS

Multi-instrument setups

One R&S®SMW200A instrument can have two RF ports up to 20 GHz or one RF path up to 44 GHz. Two-path instruments or multiple coupled R&S®SMW200A vector signal generators are the perfect choice for generating phase-coherent signals. Two-port instruments can couple the RF ports phase-coherently or operate them as independent signal sources. Thanks to the advanced clock distribution and LO coupling mechanism, the relative phase between multiple RF ports remains stable not just for hours, but for days. This makes the R&S®SMW200A the ideal solution for simulating the AoA with single or multiple emitter signals.

Radar simulator

The R&S®SMW200A vector signal generator together with the R&S®Pulse Sequencer software is a powerful off-the-shelf radar simulator. It can generate a wide range of radar scenarios. For the first time, one radar software package helps to define all the radar test cases that are necessary in the lab for the entire product development cycle. Test cases extend from simple pulse scenarios to moving emitter or multiple emitter scenarios. The software supports single or multiple coupled instruments for simulating the AoA. 3D previews and live graphical visualization of configured signals allow engineers to quickly familiarize themselves with.

The R&S®SMW200A vector signal generator can also take on the role of an agile signal source that generates EW environments within its baseband bandwidth of 2 GHz. It generates I/Q modulated pulsed signals, agile signals with fast switching and classic pulsed signals from streamed PDWs. The R&S®SMW200A receives the streamed PDWs from the user's radar signal simulator via LAN.

The simulator can also stream multiple streams to coherently coupled R&S®SMW200A for simulating the AoA.

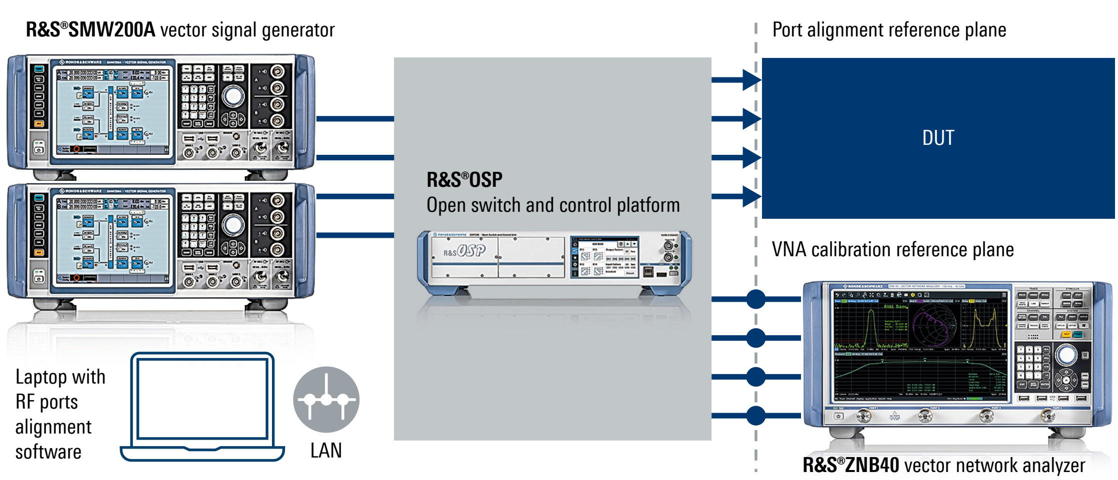
Ready for calibration

Excellent repeatability and reliable long-term stability make it possible to set up calibration to achieve a defined reference plane (amplitude, phase and time) between the RF output ports. A calibration tool only needs to compensate stable but fixed offsets of phase, amplitude and time between the RF ports. The port alignment software together with the R&S®SMW-K545 automated RF port alignment option is an excellent solution for this task. It runs predefined and optimized calibration routines for the R&S®SMW200A. Users can conveniently define the RF frequencies, used bandwidth and level range for calibration. The software together with a network analyzer determines the correction coefficients automatically for all RF ports. This solution saves time and costs. The user can focus on test execution instead of coding calibration routines.

Flexible use of investment

Thanks to the flexibility of the software defined R&S®SMW200A vector signal generator, engineers can configure the signal source by software to tailor it to their specific application. Engineers can share the signal source among different applications from simple vector signal generation to high-end radar simulation and profit from the outstanding RF performance. This reduces costs and gives users flexibility. As the RF hardware is based on commercial off-the-shelf vector signal generators, users can benefit from fast delivery times and worldwide service support. The R&S®SMW200A vector signal generator is the perfect instrument, especially for labs with changing requirements.

Typical RWR test setup with ports alignment



Test setup for a four channel radar warning receiver (DUT), suitable for TDOA, amplitude-based or interferometry receivers.

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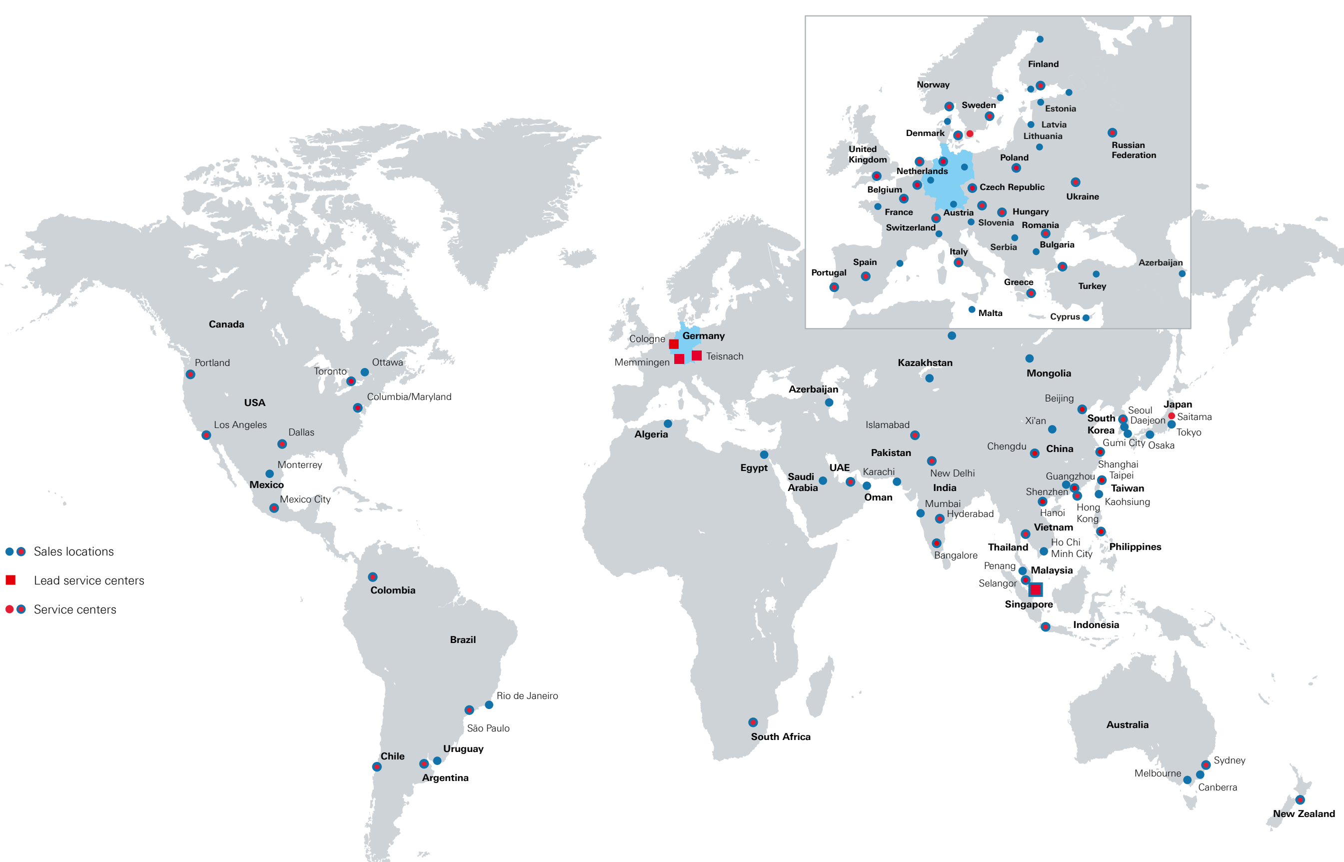

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Reliable and flexible simulation of angle of arrival (AoA)
Data without tolerance limits is not binding | Subject to change

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