Realistic simulation of radar pulses and complex radar scenarios

Development lab work often requires time-consuming implementation of customized test solutions. Any automation will noticeably increase productivity. That is exactly what the R&S®Pulse Sequencer software in combination with a vector signal generator does for development and testing of radar components and receivers.

Pulsed signals are required for a number of tests in radar engineering – for components such as amplifiers or entire devices such as receivers. Since there are no standardized test specifications, test engineers have had to invest a lot of time in programming all the signals. The R&S®Pulse Sequencer software minimizes this effort. Users can subject DUTs to realistic signal scenarios and make optimizations as needed.

Scenarios for all requirements

The R&S®Pulse Sequencer software includes numerous preconfigured scenarios. The user only has to set scenario-specific parameters:

▮ Simple pulse sequences made up of pulse groups with complex single pulses and the associated deterministic interpulse modulation
▮ 2D and 3D scenarios in which the generated signal is not only a result of single pulses with defined amplitude and interpulse modulation, but also of effects caused by rotating transmit and receive antennas and their polarization as well as the position of the transmitter and receiver in three-dimensional space.

I/Q signals and measured antenna patterns can also be used by importing them into the software.

The 3D visualization and realtime preview of configured signals makes it easier for the user to quickly become familiar with the software and make full use of its performance range. After

configuration, the signals are automatically transmitted to a vector signal generator, where they are replayed.

Definition of single pulses and sequences

Depending on the application, the envelope and possibly the modulation on pulse (MOP) of pulses must be defined and their sequence specified. In the simplest case, the sequence consists of the pulse and a pulse pause. The R&S®Pulse Sequencer software can define all details of the pulses and embed them in a sequence, e.g. via the pulse repetition rate. The tree structure shown in Fig. 1 shows all the simulation components that can be used to set up a scenario.

All essential pulse parameters are defined in the Pulse menu (Fig. 2, top): edges and pulse width as well as all other envelope characteristics such as overshoot, pulse droop and ripple. Numerous modulation types such as linear frequency modulation (chirp), amplitude, frequency, phase and vector modulation are predefined. This comprehensive set can be expanded as needed via the software's open plug-in interface. The interface can also be used to add customer-specific inter-pulse modulation, for example.

The preconfigured single pulses can be embedded in a sequence. The user only has to define what should happen from pulse to pulse. Interpulse modulation is used to define such sequences for testing during development or for
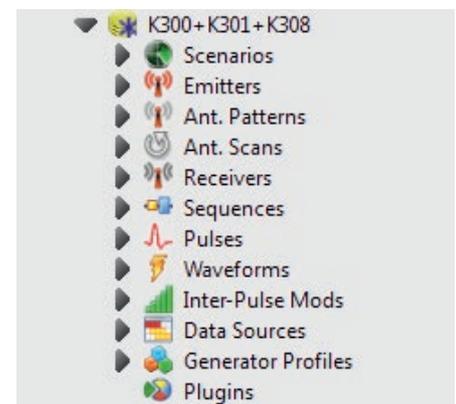

Fig. 1: Tree with simulation components

Testing the channel change function of WLAN routers

Some weather radars operate in the 5 GHz band, which WLAN devices are also allowed to use. To ensure that a WLAN router does not interfere with the weather radar, the router must use dynamic frequency selection (DFS) to automatically change channels when it receives such radar pulses. Regulatory authorities have defined numerous radar profiles that must be used to test all WLAN stations.

A special DFS version of the R&S®Pulse Sequencer software (R&S®SMx-K350) is available. This version comes with radar profiles that comply with international standards. Used together with a vector signal generator, it can perform all required tests – a convenient plug&play solution that also supports report generation for analyzing the test results.
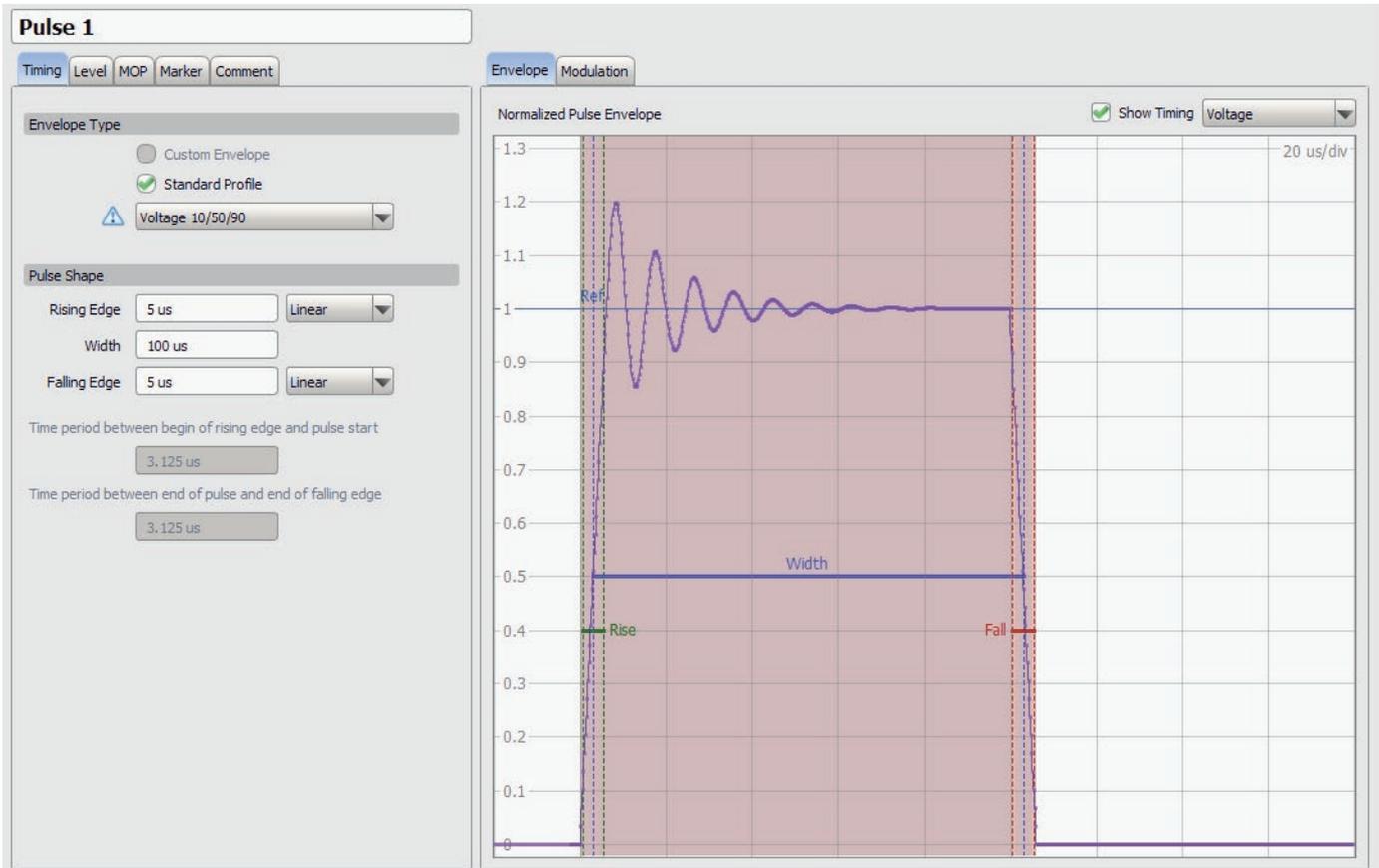
Pulse 1

Timing | Level | MOP | Marker | Comment

Envelope | Modulation

Envelope Type

○ Custom Envelope
● Standard Profile
⚠ Voltage 10/50/90 ▼

Pulse Shape

Rising Edge | 5 us | Linear ▼
Width | 100 us
Falling Edge | 5 us | Linear ▼

Time period between begin of rising edge and pulse start
3.125 us

Time period between end of pulse and end of falling edge
3.125 us

Normalized Pulse Envelope   ✓ Show Timing Voltage ▼
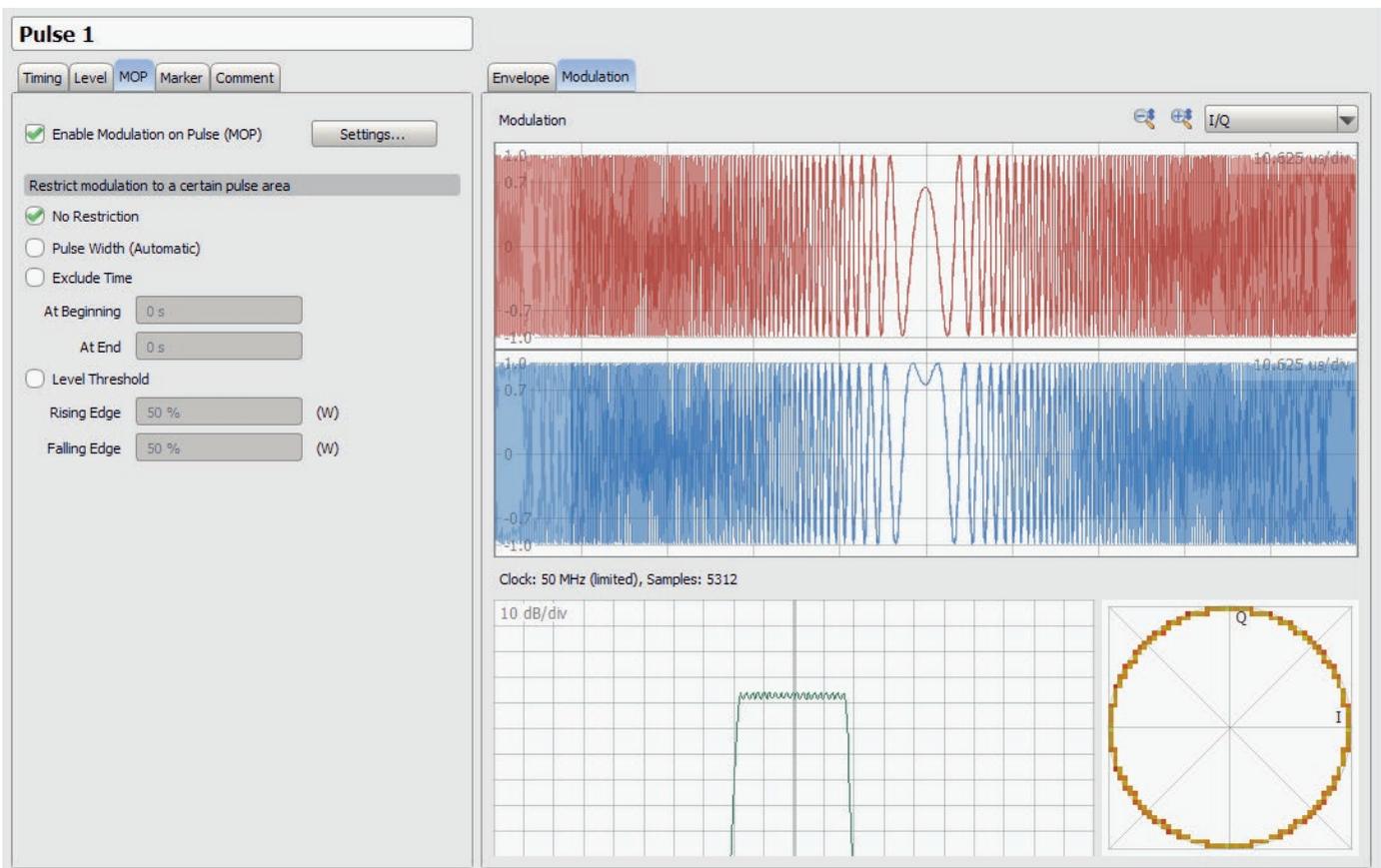
20 us/div

Ref

Width

Rise   Fall

Fig. 2: Top: menu for defining a single pulse with a preview of the envelopes, here with overshoot. Bottom: linear frequency modulation settings with a preview of the baseband signal and spectrum.

Pulse 1

Timing | Level | MOP | Marker | Comment

Envelope | Modulation

✓ Enable Modulation on Pulse (MOP)   Settings...

Restrict modulation to a certain pulse area

● No Restriction
○ Pulse Width (Automatic)
○ Exclude Time
At Beginning | 0 s
At End | 0 s
○ Level Threshold
Rising Edge | 50 % | (W)
Falling Edge | 50 % | (W)

Modulation   I/Q ▼

10.625 us/div

10.625 us/div

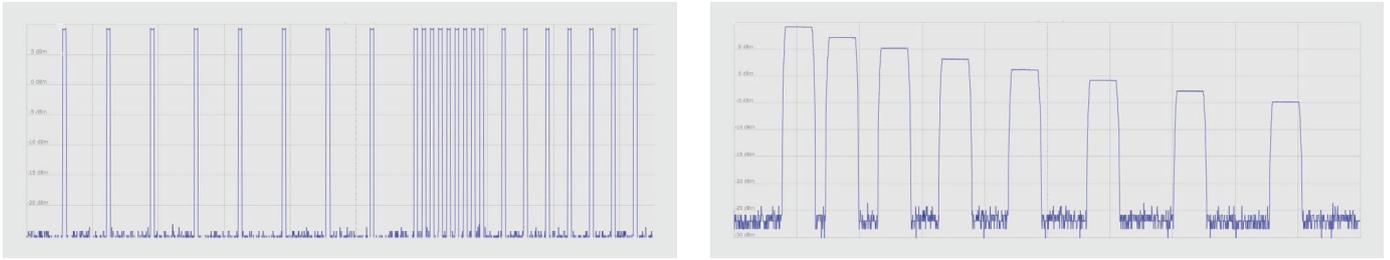Clock: 50 MHz (limited), Samples: 5312

10 dB/div

Q

I

Fig. 3: Left: interpulse modulation with three bursts. The pulse pause changes from burst to burst. Right: interpulse modulation can vary several parameters simultaneously, e. g. pulse pauses and pulse peak power.

verification of receivers or systems. In the simplest case, the user only has to define a pulse pause. The pulse pause, frequency hops, pulse levels, etc. can be modified from pulse to pulse according to definable rules.

The pulse repetition rate plays a major role for radars. Radars must operate with low pulse repetition rates so that their detection range is large enough to detect distant objects. However, high rates are required to measure the often high speed of detected objects. In order to reconcile these and other requirements, radars use a number of operating modes that are selected based on the detection task.

Fig. 3 (left) shows an example with three bursts of eight pulses each. The pulse repetition rate changes from low, to high, to an average value in the last burst. The interpulse modulation can affect several pulse parameters simultaneously, e. g. it can increase the pause from pulse to pulse while

simultaneously reducing the level by 2.5 dB (Fig. 3, right).

Frequency agile radars use hopping with a changing center frequency to make them more resistant to jamming and being detected. This frequency agility can be simulated via interpulse modulation of the offset frequency. Fig. 4 shows a generated, linear frequency-modulated signal that changes its center frequency from pulse to pulse.

Receiver tests with realistic signal waveforms

In order to test receivers under realistic conditions, all influence quantities have to be taken into consideration. This includes not only pulse parameters, modulation formats and interpulse modulation, which describe the actual signal, but also system-specific influences. Radars are usually equipped with rotating antennas to transmit and / or receive signals directionally, for example. Receivers for monitoring

the electromagnetic spectrum can be connected to moving or static, stationary antennas. A signal from a specific direction often only briefly reaches the receiver. The absolute receive level depends on the transmit power, the gain of the transmit and receive antennas as well as the frequency-dependent free-space loss. Additional losses occur when the transmit and receive antennas have a different polarization or when the antennas are not aligned exactly to each other. In addition, transmitters and receivers in three-dimensional space can have different elevations above sea level and different attitudes, which are defined by roll, pitch and yaw angles. The received power is reduced when the boresight directions of the transmit and receive antennas are not directly facing each other due to different attitude angles.

In order to simulate these kinds of complex scenarios, the R&S®Pulse Sequencer software includes a simulator in which all the above-mentioned

Fig. 4: interpulse modulation that changes the center frequency from pulse to pulse based on a list.
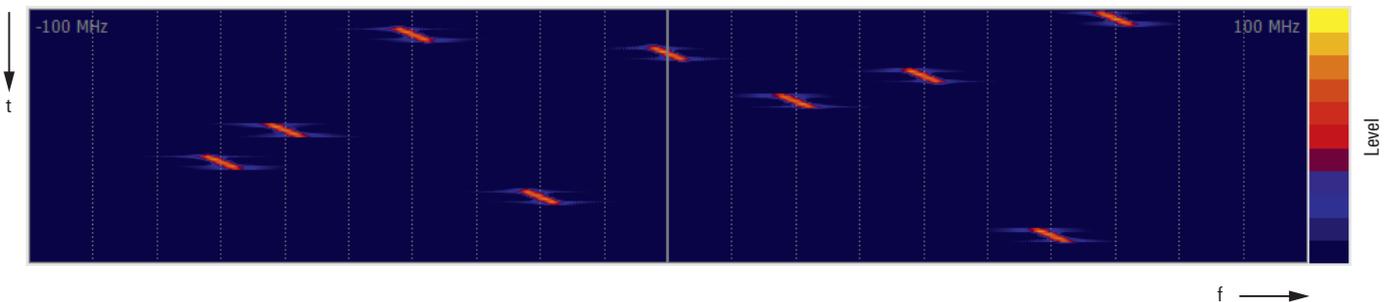
effects as well as the transmit signal can be configured. Numerous pre-defined simulation components such as antenna patterns and scan types are included in the software. Complex patterns of phased array antennas are quickly calculated when the user enters the spatial distribution of the individual radiator elements and the desired side-lobe suppression. All antenna patterns can be assigned a polarization. It is even possible to define unwanted rear leak-age. The configured antenna patterns are visualized in a 3D view, including the angle offset to the normal position and the polarization (Fig. 5).

The R&S®Pulse Sequencer software automatically calculates the time-dependent receive level according to the defined scenario. The level no longer has to be manually determined, a time-consuming process. Lab results can easily be correlated with the results of real field tests.
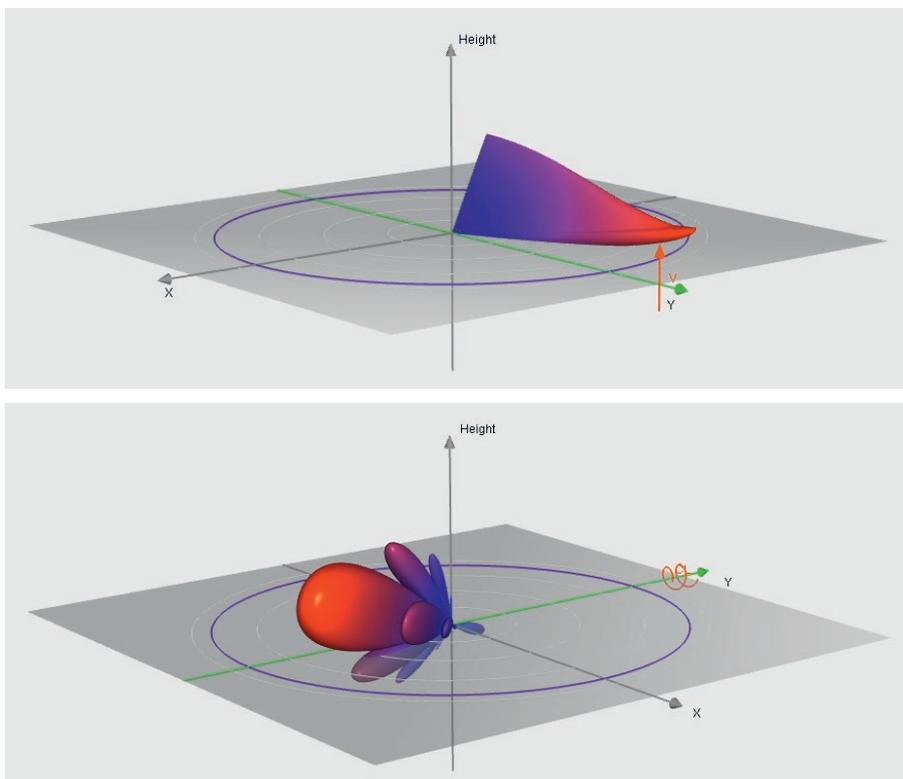
Complex 3D scenarios

The R&S®Pulse Sequencer software can also be used to simulate complex 3D scenarios for receiver tests as shown in Fig. 6. Fig. 7 shows the receiver (red) at the center of the coordinate system. Its antenna, which has a defined pattern, uses raster scanning to scan a specific solid sector. The transmitter (blue) has a circularly rotating antenna that also has a defined antenna pattern. The level at the receive antenna port changes due to the raster-like search movements of the receive antenna. The software can simulate the time-dependent influ-ences of either the transmit and receive antenna alone and also the combina-tion of all effects, including the impact of position and polarization losses on the absolute receive level (Fig. 8). It can be clearly seen in the bottom fig-ure that the transmit signal is weighted with influence of the receiver's scanning antenna. The absolute level at the out-put of the receive antenna is now deter-mined based on the free-space loss, antenna gains and transmit power, and

Fig. 5: Top: antenna pattern with vertical polarization. Bottom: with mainlobe, sidelobes and rear leakage.
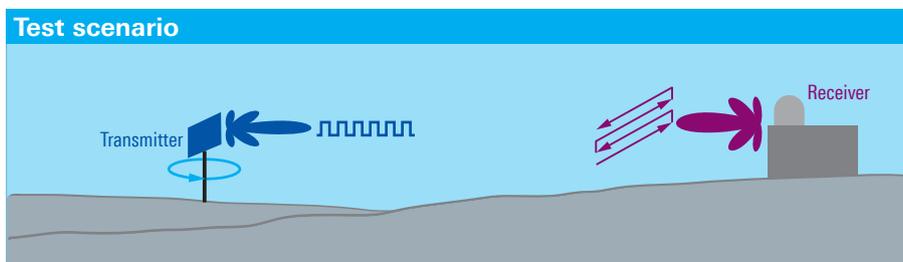

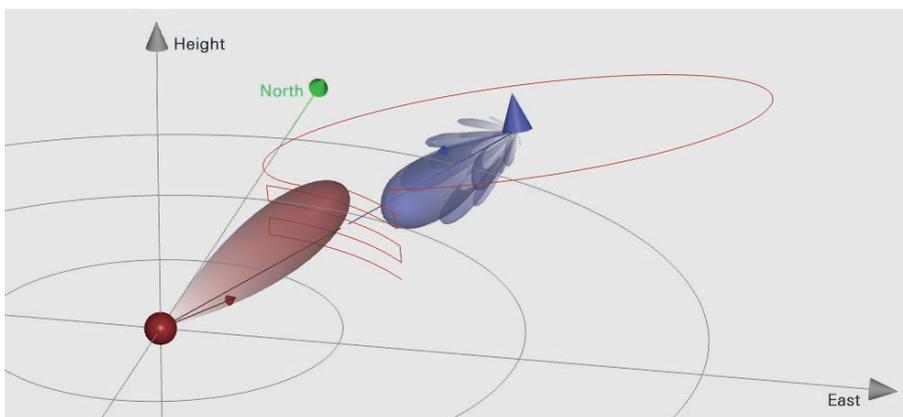Fig. 6: Challenging receiver and transmitter test scenario

Fig. 7: Transmitter (blue) with vertically rotating antenna and receiver (red) whose antenna uses raster scanning to scan a solid sector.
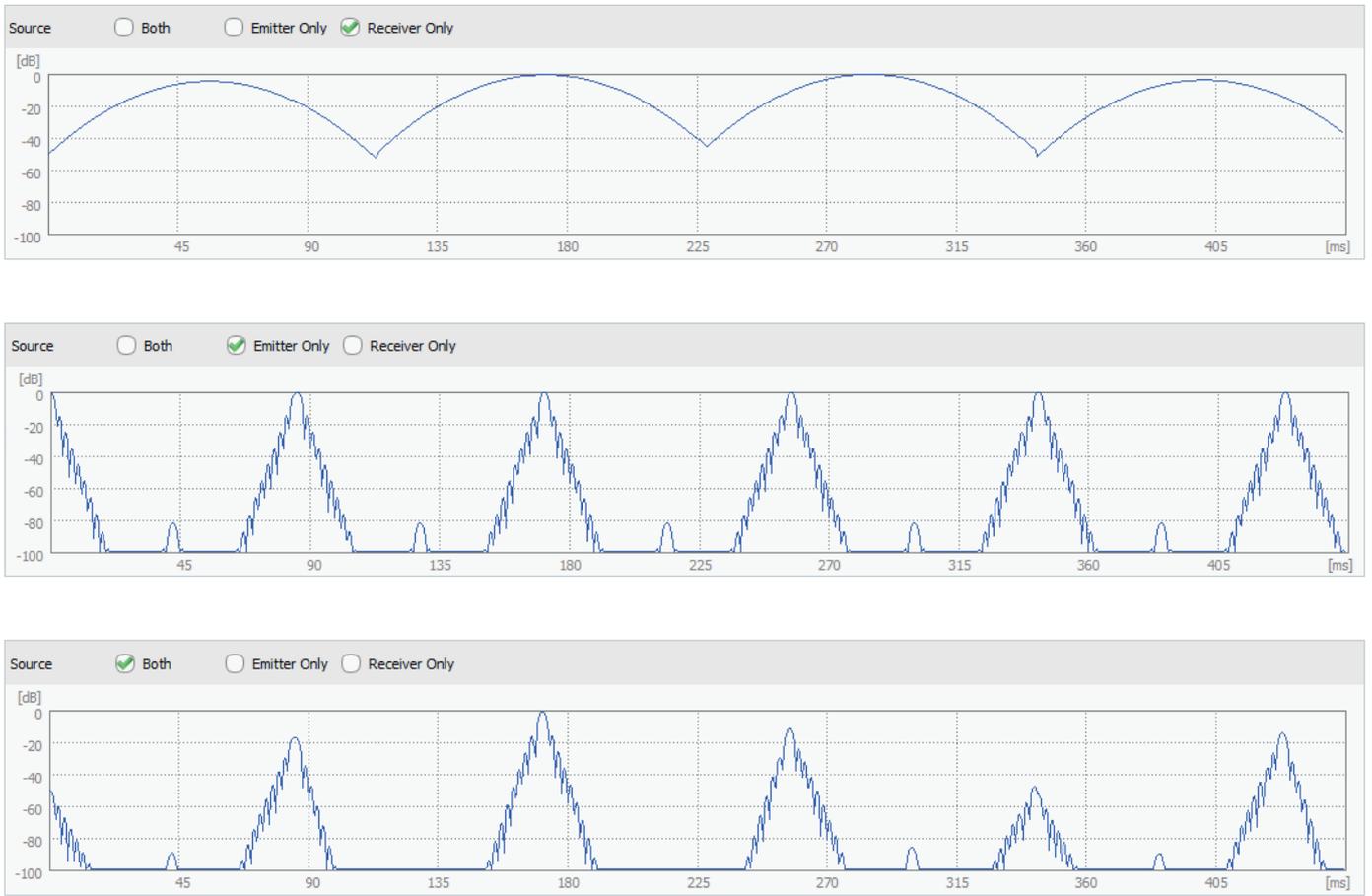
Fig. 8: Top: receive level fluctuation due to the movement of the receive antenna. Center: contribution of transmitter antenna rotation to the time-dependent receive level. Bottom: total of all contributions to the time-dependent receive level, including position and polarization losses.

calculated automatically using the normalized level curve shown in the bottom figure. Once everything has been set as desired, the signal is transmitted to a vector signal generator and replayed there. This makes it possible to test whether or not the receiver can clearly recognize and classify a transmitter's signal.

Testing multichannel receivers

Receivers with multiple channels are used in direction finders to determine the angle of arrival of a signal. When testing these kinds of receivers, the R&S®Pulse Sequencer software offers the option of positioning a transmitter that transmits a defined signal in a polar coordinate system (Fig. 9, left). The user

can position the individual antennas of the receiver's antenna configuration as desired (Fig. 9, right). All parameters

used to simulate a single-channel receiver antenna are also available here.
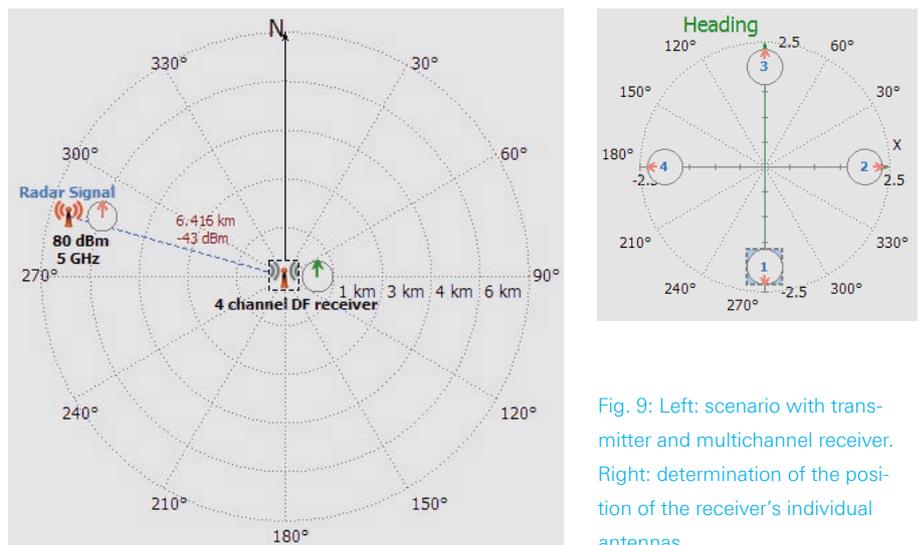

Fig. 9: Left: scenario with transmitter and multichannel receiver. Right: determination of the position of the receiver's individual antennas.

The software automatically calculates the correct receive signal for each of the multichannel receiver's inputs, taking into account all configured parameters. A diagram helps the user assign the calculated signals to the RF outputs of the vector signal generators and shows the cabling required for the test setup (Fig. 10).

An R&S®SMW200A vector signal generator with two paths is ideal because all receiver channels must be simulated simultaneously. For testing receivers with four channels, a four-channel test setup can be configured by adding two R&S®SGS100A and two R&S®SGU100A generators (Fig. 11).

Summary

The new R&S®Pulse Sequencer software, together with appropriate software options and vector signal generators, is a powerful signal simulator for numerous aerospace and defense applications. Applications range from simple test cases for component testing to complex test cases that simulate real-world 3D scenarios for testing single or multichannel receivers. The software is available for all Rohde & Schwarz vector signal generators, which cover the frequency range up to 40 GHz. Thanks to the modular, flexible concept, the number of channels can be selected based on the application.

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Fig. 10: Top: assignment of four signals to the RF paths of the R&S®SMW200A vector signal generator that has been upgraded to a four-channel setup by adding two R&S®SGS100A generators. Bottom: the required cabling.
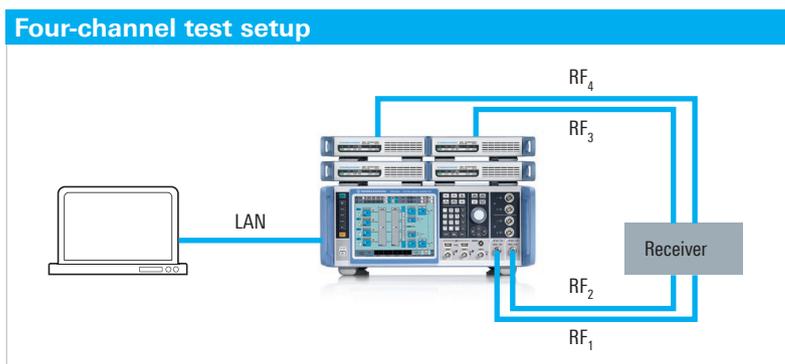
Four-channel test setup

Fig. 11: Four-channel test setup up to 20 GHz in only six height units, consisting of the R&S®SMW200A vector signal generator, two R&S®SGS100A and two R&S®SGU100A generators.

The R&S®Pulse Sequencer software is available as a free download, e.g. at

https://www.rohde-schwarz.com/software/smw200a/

It can be used together with the R&S®SMx-K300 / SMx-K301/ SMx-K350 or SMW-K308 options for the R&S®SMW200A, R&S®SMBV100A and R&S®SGT100A vector signal generators. Options subject to charge are only required when the signals need to be replayed on vector signal generators.