THREAT SIMULATION AND VERIFICATION FOR RADAR WARNING RECEIVER TESTING

Products:

- ► R&S® SMW200A Vector signal generator
- ► R&S® Pulse Sequencer Software
- ► R&S® FSW Signal and Spectrum Analyzer
- ► R&S® FSW-K6 Pulse measurements

Walter Schulte | 1USOPS | Version 1E | 11.2020

ROHDE&SCHWARZ

Make ideas real

Contents

1 Introduction

This application note belongs to a series of application notes which explains how to test EW receivers at RF in the lab with commercial, off-the-shelf signal generators and software. The series will cover all relevant use cases. This application note will discuss threat simulation and verification. Further application notes will address calibration and verification of multi-channel setups for simulation of angle of arrival [1], generation of radar signals in a hardware in the loop (HIL) environment with PDW Streaming [2], and automated threat creation and sequencing [3].

Optimizing EW simulation realism in lab testing ensures that an EW receiver is ready for flight testing which can cost millions of dollars per hour and must be scheduled months in advance. Lab testing, therefore, reduces cost and schedule risk by ensuring that the EW receiver passes flight testing the first time.

Lab testing must be done with a progression in test complexity in order to determine whether test failures come from the receiver under test or the test stimulus. As test complexity increases, so does the test realism but so do the difficulties in troubleshooting failures and verifying scenarios. For example, the simplest type of test simulates only one mode of one emitter at a time and sequences through all modes of all emitters stored in the look-up table on the EW receiver. Any failures at this stage are easily traced to either the test stimulus or EW receiver. Longer, more complicated scenarios can then be created using combinations of the same emitters for multi-emitter testing with power scaling for range, motion and antenna scan effects and angle-of-arrival (AoA). This application note covers single emitter and multi-emitter testing and verification without angle-of-arrival simulation using pre-calculated scenarios created using Rohde & Schwarz Pulse Sequencer software. We will begin with a brief discussion of RWR function and signal generation for EW testing to explain the motivation for increasing levels of test complexity and realism. We will use a radar warning receiver (RWR) as a proxy for a generic EW receiver in this application note series.

1.1 RWR Function and Signal Generation for EW Test

RWRs are designed with numerous trade-offs affecting the ability to intercept, sort and identify the pulses of enemy radars called "threats". For example, sensitivity can be traded-off for instantaneous bandwidth to give greater probability of intercept of closer threats at diverse frequencies at the expense of intercepting threats further away. Different angle-of-arrival methods trade-off accuracy for bandwidth and speed. Since the effects of the trade-offs are measured in testing, the signal generators used to simulate threats at RF must have better simulation fidelity than the specifications of the receiver. Simulation fidelity can be described in at least three different ways.

The first is the basic RF performance of the simulation at RF which depends on the RF performance of the signal generators used to simulate threats. The signal generator should generally have better performance than the RWR being tested. Specifically, the signal generator should have better spurious free dynamic range, image, and LO feedthrough performance than the spurious performance of the RWR because the RWR will attempt to classify all spurious signals. The signal generator must also be able to produce lower power levels than the sensitivity of the RWR to ensure that the RWR can detect threats and their scans at the expected range. Simulating other threat parameters such as modulation-on-pulse, frequency diversity and antenna scans requires the generator to have at least one baseband generator with adequate bandwidth and resolution (effective bits).

The second way RWR performance is measured is in its ability to sort and track multiple threats at the same time, or at least one threat in the presence of other pulses. This requires more signal generation resources and the ability to qualify the simulations which are often built from single-emitter scenarios. Some signal generators, such as the SMW200A vector signal generator, can have multiple baseband entities to add pulse density and threat density at RF without increasing the number of signal generators in the scenario.

Finally, we must discuss simulating the physical location of emitters since RWRs use angle-of-arrival (AoA) measurements as a primary sorting parameter and this must be simulated at RF as well. This brings us to the third way simulation fidelity is described: AoA simulation performance, which is the accuracy of AoA simulation using amplitude, phase, and time offsets between synchronized generators after a calibration. Simply put, the signal generators should have better AoA simulation performance than the SUT. How much better depends on the required uncertainty in the simulation. This is discussed further in subsequent application notes in this series.

2 Mission Data File Testing

The simplest form of testing is called "mission data file testing." Mission data files are software look up tables that contain information about the emitters the receiver must identify by their waveform parameters and antenna pattern and scan. The parameters include frequency, pulse width, pulse repetition interval, modulation on pulse. Testing the receiver's mission data file requires emulating each mode and beam of the emitters in the file at RF with power scaling due to range, antenna pattern and scan. This type of testing verifies whether an EW receiver can identify all modes and beams of an emitter and whether the emitter can be tracked through these changes.

The key to this form of testing is to reproduce the parameters in the mission data file accurately. The emitters must be simulated at RF with high spurious-free dynamic range (SFDR), low harmonics, and high frequency accuracy and stability. Timing parameters such as pulse width and pulse repetition interval must be accurate and stable. Modulation-on-pulse is often required, and this requires a signal generator with adequate bandwidth and spectral purity to reproduce the modulation. Closely related to SFDR requirements is amplitude resolution to simulate the antenna beam pattern with sidelobes and the antenna scan. Simulating an antenna scan using an IQ waveform segment for each pulse with a power offset can consume a large amount of memory, so a signal generator that plays pulse descriptor words (PDWs) greatly streamlines emitter mode and beam creation in MDF testing. This is because PDWs are digitally-parameterized descriptions of output RF pulses that are described in tens of bytes while arbitrary waveforms are full signals at baseband which consume tens of kilobytes or megabytes, one for each pulse in an antenna scan.

The Pulse Sequencer software enables both manual and automated threat creation and sequencing. Libraries of pulses, sequences, antenna scans and patterns can be combined into different threats and sequenced using "Emitters (Collection)" or "Localized Emitters" scenarios. The figure below shows radar modes sequenced over time using the Pulse Sequencer Software in an "Emitters (Collection)" scenario.
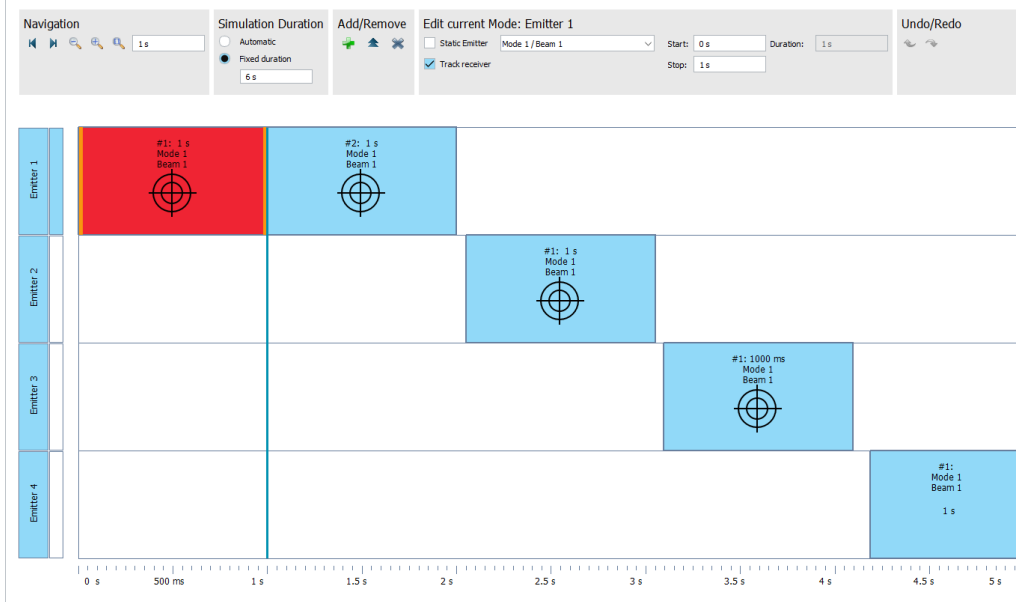
Figure 1 - Mode Sequencing with "Emitters (Collection)" or "Localized Emitters" scenario

"Localized Emitters" scenarios, shown below, enable emitters to be placed on a map with moving platforms and power scaling according to emitter modes, kinematics and time. Emitter modes can be sequenced as shown above.
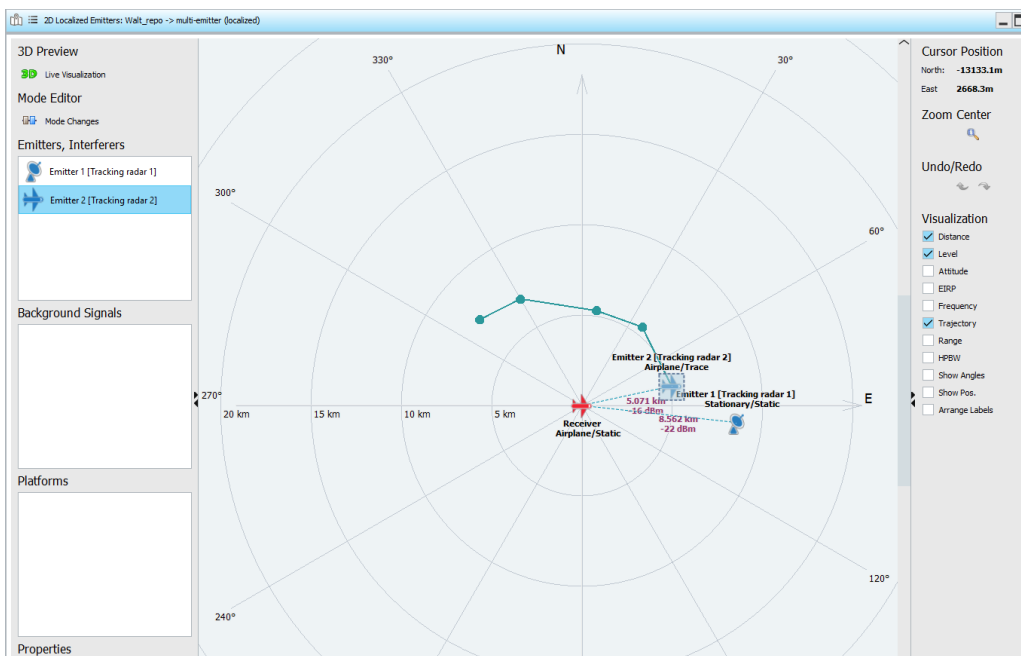
Figure 2 - "Localized Emitters" scenario with two emitters with their trajectories and a receiver (red airplane in the middle) on a map.

2.1 Automated Threat Creation and Sequencing

Since mission data files can have hundreds or thousands of entries, it is best to automate threat creation and simulation. This is accomplished by importing threat parameters from an intelligence database or a spreadsheet to the simulation software using a software tool. This is explained in another application note "Automated Threat Creation and Emitter Sequencing for Mission Data File Testing." [3]

2.2 Threat Verification

2.2.1 Real-time, in-situ threat verification

When an EW receiver fails to identify an emitter during "single-emitter" mission data file testing, the test engineer must determine whether the mission data file (MDF) and operational flight program (OFP) are at fault or the simulated emitter. This can be done by measuring simulation parameters during MDF testing by splitting the output of the SMW200A vector signal generator into the FSW signal and spectrum analyzer running the K6 Pulse Measurement application. A single trigger line from the User 1 output of the SMW200A to the Trigger 1 input of the FSW allows segmented capture of pulses on the K6 application using the pulse markers of the simulated emitter.
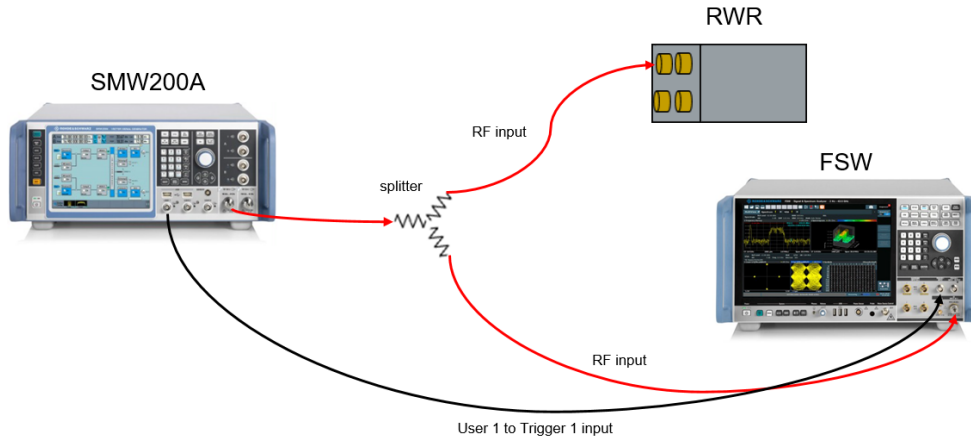
Figure 3 - Simultaneous test and emitter validation

2.2.2 Measure cable loss with NRP sensors

Measurement can be further improved by correcting for the loss through the 3 dB splitter with a power sensor by connecting the control cable from an NRP power sensor (e.g. NRP-Z81 or NRPxxS) to the 'Sensor' port on the SMW200A and replace the DUT with the power sensor. Follow the instructions in the Pulse Sequencer help on Compensating Path Loss.

Figure 4 - Source power correction with NRP power sensor

Rohde & Schwarz | Application Note Threat Simulation and verification for radar warning receiver testing

2.2.3   Generate and measure pulsed signals

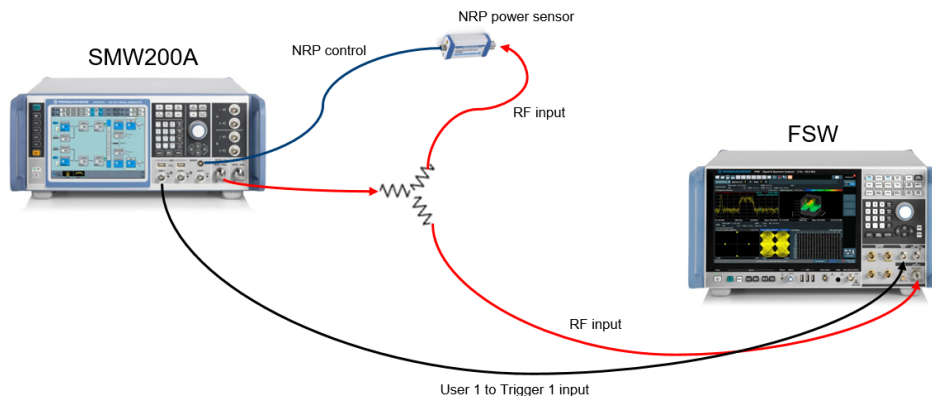The following section describes how to generate pulsed radar signals and how to measure them with the FSW signal and spectrum analyzer. Often it is a good approach to use markers along with the generated RF signal. Markers can be used as trigger inputs into the FSW measurement application. Configure the SMW200A to output a marker for each pulse using the Pulse Sequencer application at the "Pulse" level of the Repository Tree. Set the "Gate" pulse marker for each pulse (compare Figure 5). This will be used to trigger the measurement on the Pulse Measurement application in the FSW K6.
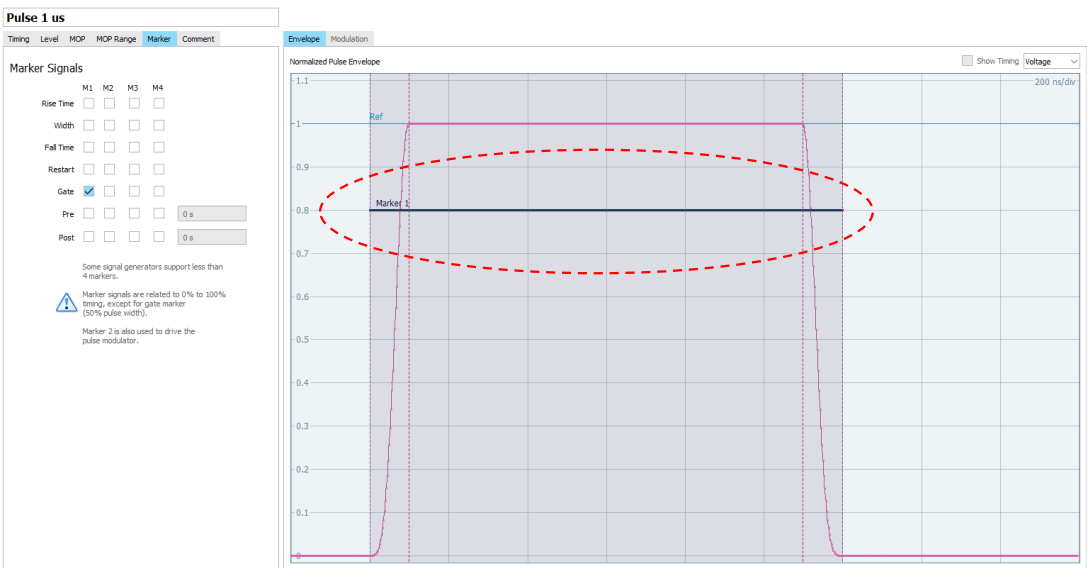
Figure 5 - Preview of pulse together with configured pulse markers relative to pulse width

The markers need to enabled in the sequence (compare Figure 6).
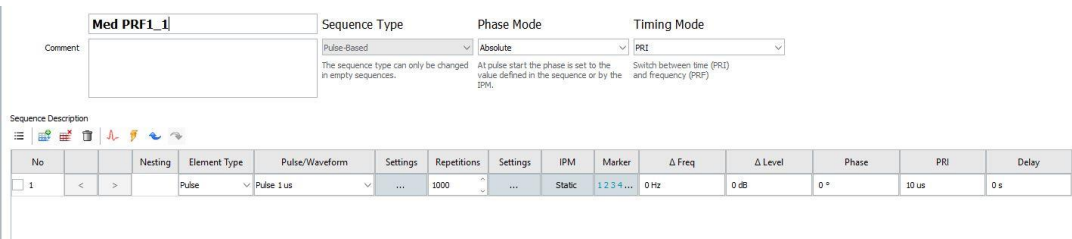
Figure 6 - Pulse markers enabled at the sequence level

Finally, enable the markers in the scenario. On the Repository Tree, Select > Scenario > Signal Calculation > Config > Config > Marker Signals". Enable sequence and waveform markers and marker 1, which was set at the "Pulse" level (compare Figure 7).

After configuration of all pulse parameters and markers, the signal generator in use has to be linked to the Pulse Sequencer Software. Then the signal generation can be started and the final waveform can be loaded and generated with the signal generator. In this case a SMW200A vector signal generator is used.
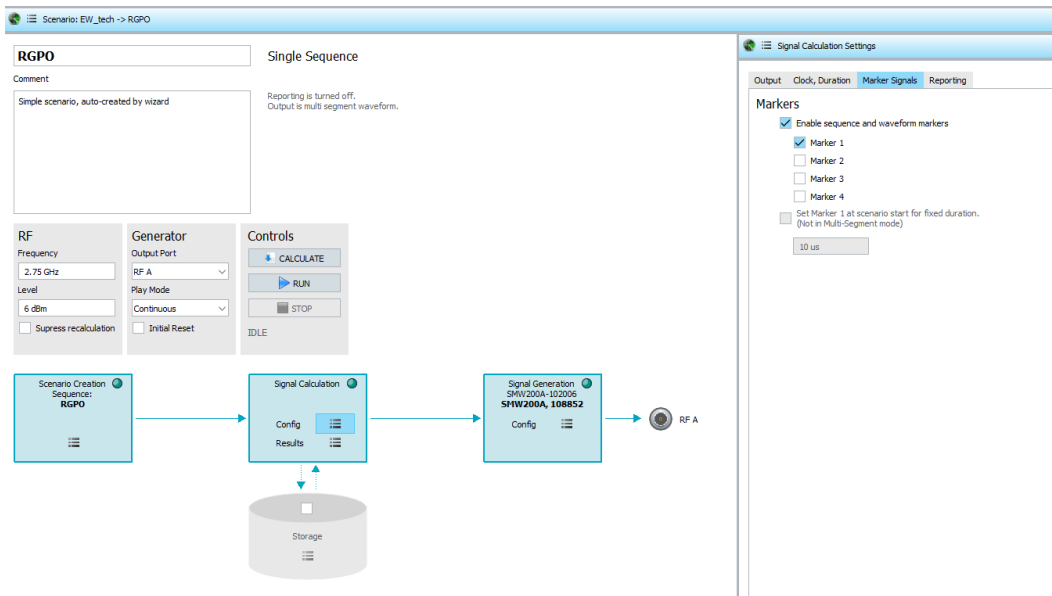
Figure 7 - Markers enabled at the scenario level

In order to trigger on the pulse marker, the FSW pulse measurement application must be configured beforehand. When the scenario runs, a marker will be output with each pulse through the User 1 port on the SMW200A to the Trigger 1 Input on the FSW.   Configure the segmented capture under the "Trigger" menu on the FSW:
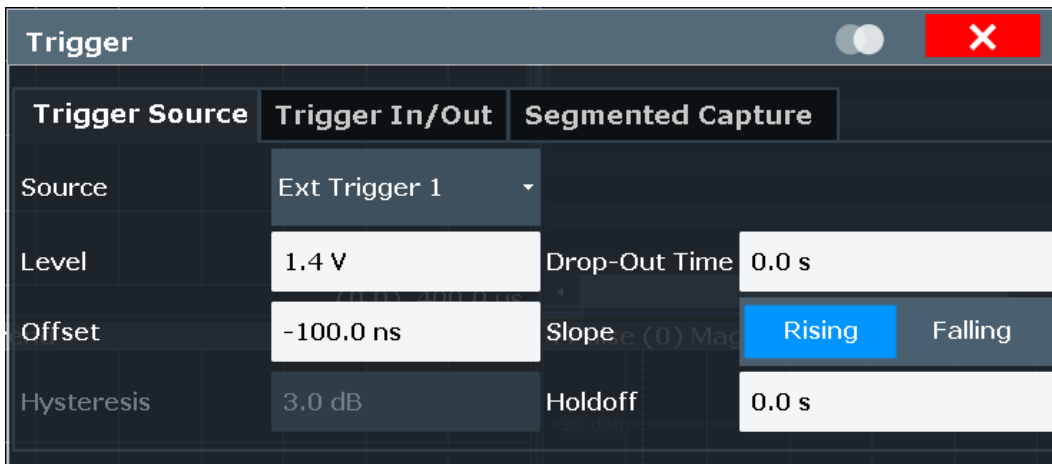
Figure 8 - Trigger settings on the analyzer for threat verification

Use -100 ns of pre-trigger offset to ensure that the entire pulse is captured, including the rise time. Set the segment length to be slightly longer than the longest pulse to be measured, accounting for the pre-trigger offset. Generally, the segment length should be the sum of the pre-trigger offset, the longest pulse width, and an additional 100 ns. In this case the widest pulse is 1 µs, though analyzer settings limit the pulse

segment width to greater than 2 µs. 200 pulses will be captured.

Figure 9 - Segmented capture settings on the analyzer. Segment lengths are determined by the pulse width of the threat to be analyzed. The number of events is the number of pulses to be analyzed.

Finally, the pulse detection settings must be set. If an emitter is using an antenna scan, the detection threshold must be quite low relative to a peak or absolute threshold but still far-enough from the noise floor so that noise is not detected as a pulse in cases where triggering with a marker from the source as in this case. In cases where no markers are available, the IF trigger level and pulse detection level must be equivalent and quite low if using an antenna scan.
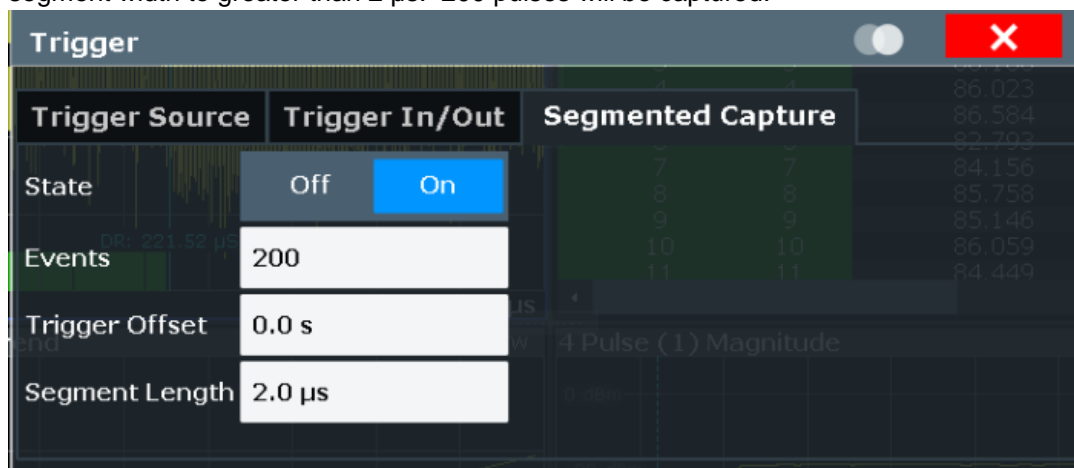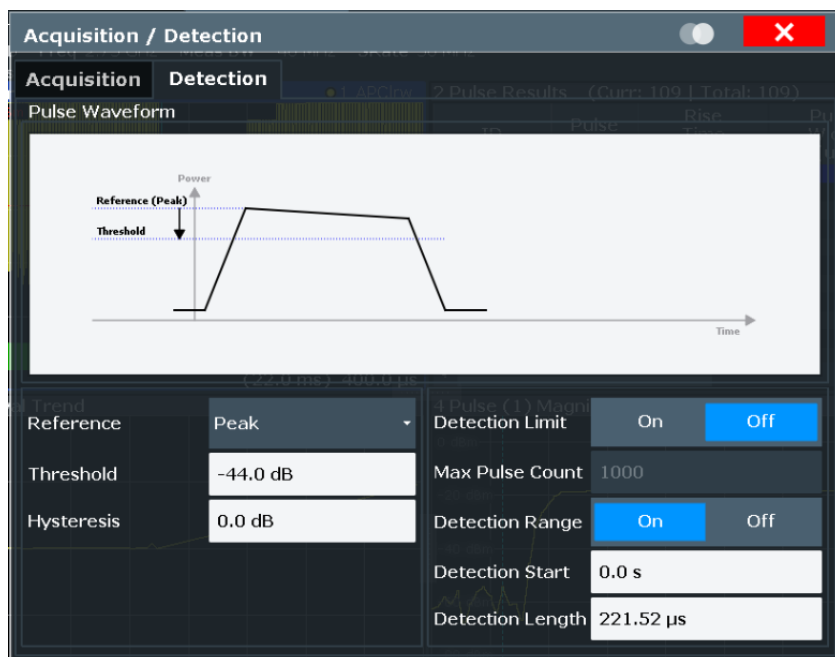

Figure 10 - Pulse detection settings determine whether a pulse captured in a segment or acquisition period is detected as a pulse.

This can be quite challenging because using enough bandwidth to accurately measure the pulse shape also raises the equivalent noise bandwidth of the analyzer given by 10 log (kTB) dB

In a 1 Hz bandwidth, the equivalent noise power at T = 290 K is -174 dBm. The bandwidth of the analyzer adds another 10log(B/1 Hz) dB. In a 40 MHz analysis bandwidth, which allows the accurate measurement of many pulse shapes, another 76 dB must be added to the noise power for an equivalent noise power of -98 dBm. The noise figure and sensitivity of the analyzer must be added to the equivalent noise bandwidth to give a decent approximation of the final sensitivity. The noise figure of the analyzer at 2.75 GHz can be computed from the displayed average noise level (DANL) on the data sheet by subtracting the equivalent noise in a 1 Hz bandwidth (-174 dBm) from the DANL. The FSW data sheet, with the wide analysis

Rohde & Schwarz | Application Note Threat Simulation and verification for radar warning receiver testing

bandwidth options, gives a DANL of -154 dBm normalized to a 1 Hz bandwidth which gives noise figure of 20 dB: -154 dBm + 174 dBm. Further, I am using 15 dB attenuation. The final sensitivity calculation becomes:

Equivalent noise power (-98 dBm) + noise figure (20 dB) + attenuation (15 dB) = -63 dBm

In reality, the displayed noise floor on the analyzer will be higher due to different detector settings, load match of the generator, and output noise of the generator. This doesn't leave much dynamic range to analyze the entire antenna scan nor detect every pulse. Measuring the emitter at greater power levels does not always help if it requires more input attenuation from the analyzer.

In the case of the emitter below, the amplitude did not change by more than 10 dB so the analyzer was able to trigger on all the pulses and capture all of them. This can be confirmed using the "Pulse Results" table (top right) and the "Pulse Magnitude" (bottom right) display. After a single sweep, each pulse in the table can be selected and displayed in the "Pulse Magnitude" display to visually confirm that it was captured. The data from the "Pulse Results" table can be retrieved by a piece of custom software for further automated analysis if necessary. Finally, amplitude and timing trends can be analyzed and compared using the "Magnitude Capture" and "Trends" windows on the left. This is particularly helpful for analyzing antenna scans and jamming techniques, and can also be automated:
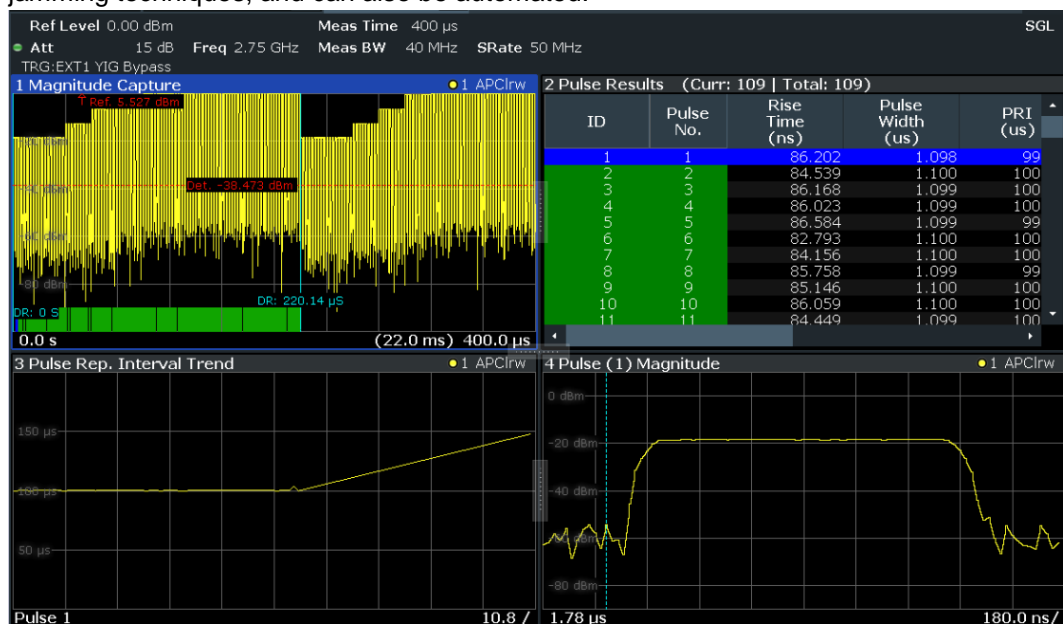

Figure 11 - Segmented pulse capture showing pulse detection threshold (red line, top left) and detections (top right). Individual pulses are viewed using the cursor to highlight a pulse in the table on the top right to view the individual pulse on the bottom right. Trends such as change of repetition interval (bottom left) can also be displayed.

3 Multi-Emitter Simulation

Multi-emitter simulation is performed to determine if an RWR can track one or more emitters with increasing levels of pulse density to emulate a real threat environment and electronic order of battle (EOB). Adamy [4] defines EOB as "the number and types of electronic systems arrayed against you" and it changes with time. For example, a strike aircraft approaching a coastline will first be illuminated by acquisition radars in L-S band. As it nears its objective, it may be illuminated by both the acquisition radar but also by one or more tracking and fire control radars at X-band. The latter will use much higher pulse repetition frequencies (PRFs) resulting in greater pulse density. Often, the pulses from different emitters will overlap in time, which is called "pulse coincidence" or "time coincidence" or "pulse-on-pulse." This is especially true when emulating tracking and fire control radars which alternate between medium and high PRFs to resolve range and Doppler ambiguities from medium and short-range targets. Multi-emitter simulation can be done with

"Emitters (Collection)," or "Localized Emitters" scenarios. "Emitter Collections" replays emitters collected and stored in a list.   "Localized Emitters" allow the users to place emitters on a 3D map, define emitter trajectories and preview the configured scenario with powerful animation features which makes them better for simulating EOB.

A typical threat environment with three emitters is shown in the following figure.
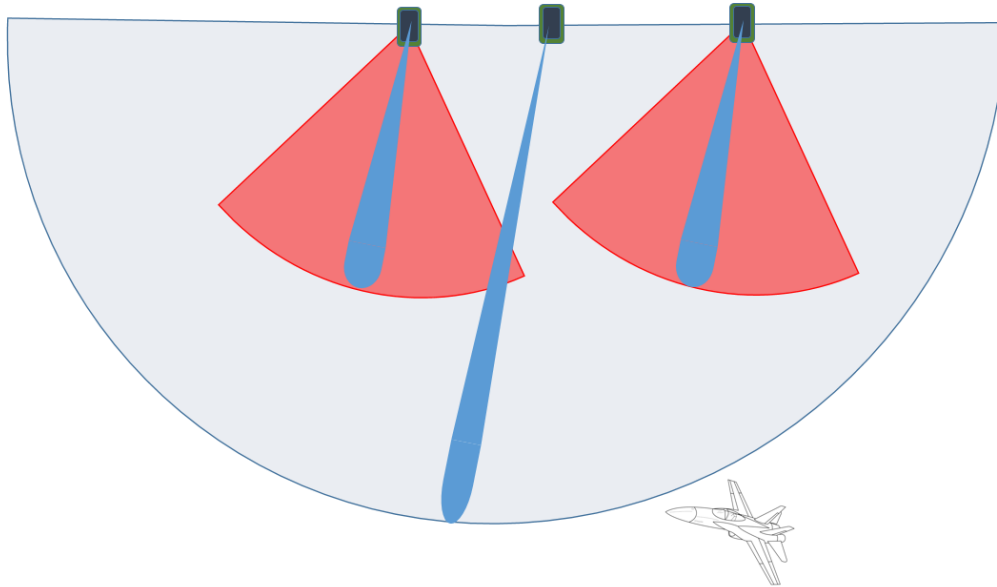
Figure 12 - Air defense system with two tracking radars in X-band (left and right) and one acquisition radar in C-band (middle). The pulse density will be greater at X-band because two radars are using medium and high PRF while the pulse density at C-band will be lower because one radar is using low and medium PRF. Notice the overlapping radar fields-of-view.

3.1 Simulating multiple emitters with pulse dropping

When using legacy signal generators, the number of emitters that can be simulated at the same time depends on the signal generators used in the simulation. This is because they play only one pulse at a time, corresponding to an SMW200A with one digital baseband entity and one RF output. A second or third pulse at the same time cannot be considered. However, for the sake of this discussion, we will assume that only one legacy signal generator is used for multi-emitter simulation. In this case, multiple emitters are played by ranking them and playing the highest priority emitter and dropping the lower priority emitters that overlap in the time domain. This is an accepted approach in the industry but of course gives up some real-world effects of overlapping pulses that can easily occur in high density multi emitter scenarios.

Figure 13 shows an example of how pulse dropping works with an example of three emitters whose pulses partly overlap.

Figure 13 - The video pulse train of three interleaved emitters at X-band played out of one signal generator. Three pulses are dropped from the lowest-priority emitter (red) while two pulses are dropped from emitter 2 (green) because none are time-coincident with the pulses of emitter 1 (blue). No pulse-on-pulse can be created because only one signal generator is used.

Since the signal generator drops none of the highest priority emitter (blue pulses) and the RWR should be able to track it through its mode changes since the simulation fidelity of this emitter should be very high. The RWR will track lower priority emitters (e.g. the red pulses) with less accuracy as some pulsed were dropped.

The EW test engineer determines the priority of the emitter in the simulation software. Typically, the software will use an interleaver to determine which pulses are played either for scenarios computed and streamed in real-time or for pre-computed scenarios.

The R&S Pulse Sequencer software pre-computes scenarios and loads them onto a configured signal generator enabling the user to display interleaving results both graphically as shown in Figure 14 and in tables as shown in Figure 15.

Name	Prio	Total 288191	Dropped 88192	Dropped % 30.6	Density (pps) 199999 pps
Emitter 4	3	100000	0	0	100000
Emitter 5	4	21524	21524	100	0
Emitter 6	5	166667	66668	40	99999

Pulses: 288191, Playtime: 1 s, Interleaved: 199999, Dropped: 88192 (30.6%), Density: 199999 pps

Figure 14 - Graphical result of the interleaving process giving the percentage of dropped pulses for one generator where emitter 4 has the highest within the interleaving group.

Navigation
⏮ ◀ ▶ ⏭   Start position 0 s

Cursor position 0 s

Display
Group baseband 4 ▼
Filter All   ▼

Range
1 s   87954 visible / 87954 total

Table Graphics Histogram Statistics

	Signal	TOA	Level	PW	Freq	Phase	Type	MOP	Param	Marker
154	Emitter 6	0.000 912 000 0...	-54.05 dB	1 us	300 MHz	0.00	Real time	UNMOD		0000
155	Emitter 5	0.000 920 000 0...	0.00 dB	1 us	-300 MHz	0.00	Real time	UNMOD		0000
156	Emitter 5	0.000 930 000 0...	0.00 dB	1 us	-300 MHz	0.00	Real time	UNMOD		0000
157	Emitter 6	0.000 930 000 0...	-54.05 dB	1 us	300 MHz	0.00	Real time	UNMOD		0000
158	Emitter 5	0.000 940 000 0...	0.00 dB	1 us	-300 MHz	0.00	Real time	UNMOD		0000
159	Emitter 6	0.000 942 000 0...	-54.05 dB	1 us	300 MHz	0.00	Real time	UNMOD		0000
160	Emitter 5	0.000 950 000 0...	0.00 dB	1 us	-300 MHz	0.00	Real time	UNMOD		0000
161	Emitter 5	0.000 960 000 0...	0.00 dB	1 us	-300 MHz	0.00	Real time	UNMOD		0000
162	Emitter 6	0.000 960 000 0...	-54.05 dB	1 us	300 MHz	0.00	Real time	UNMOD		0000
163	Emitter 5	0.000 970 000 0...	0.00 dB	1 us	-300 MHz	0.00	Real time	UNMOD		0000
164	Emitter 6	0.000 972 000 0...	-54.05 dB	1 us	300 MHz	0.00	Real time	UNMOD		0000
165	Emitter 5	0.000 980 000 0...	0.00 dB	1 us	-300 MHz	0.00	Real time	UNMOD		0000
166	Emitter 5	0.000 990 000 0...	0.00 dB	1 us	-300 MHz	0.00	Real time	UNMOD		0000
167	Emitter 6	0.000 990 000 0...	-54.05 dB	1 us	300 MHz	0.00	Real time	UNMOD		0000
168	Emitter 5	0.001 000 000 0...	0.00 dB	1 us	-300 MHz	0.00	Real time	UNMOD		0000
169	Emitter 6	0.001 002 000 0...	-54.05 dB	1 us	300 MHz	0.00	Real time	UNMOD		0000
170	Emitter 5	0.001 010 000 0...	0.00 dB	1 us	-300 MHz	0.00	Real time	UNMOD		0000
171	Emitter 5	0.001 020 000 0...	0.00 dB	1 us	-300 MHz	0.00	Real time	UNMOD		0000
172	Emitter 6	0.001 020 000 0...	-54.05 dB	1 us	300 MHz	0.00	Real time	UNMOD		0000

Figure 15 - Tabular representation of dropped pulses shown in Figure 14.

3.2 Methods of scenario debugging

3.2.1 Log Files

If the RWR fails to sort, identify, and track the highest priority threat in a multi-emitter simulation with pulse-dropping, the fault must be traced to the simulation or the RWR. A simple and effective preliminary verification tool is Pulse Sequencer log file created for each emitter in the multi-emitter simulation. This can be compared to the PDWs and track files generated by the RWR itself. These log files are enabled under the "Reporting" tab in the "Signal Calculation Settings" of the Pulse Sequencer Software. The log files should show that the power, PRF, pulse width and modulation-on-pulse (MOP) were generated as expected, as well as the simulated emitter and DUT azimuth and elevation.

3.2.2 Using the animation and visualization features of Pulse Sequencer

The power level of the simulation is often the culprit when simulating threats with antenna patterns and scans. For example, this threat uses a "cosecant squared" antenna pattern resulting in no power at the SUT if the SUT is positioned on the ground as shown in Figure 16.
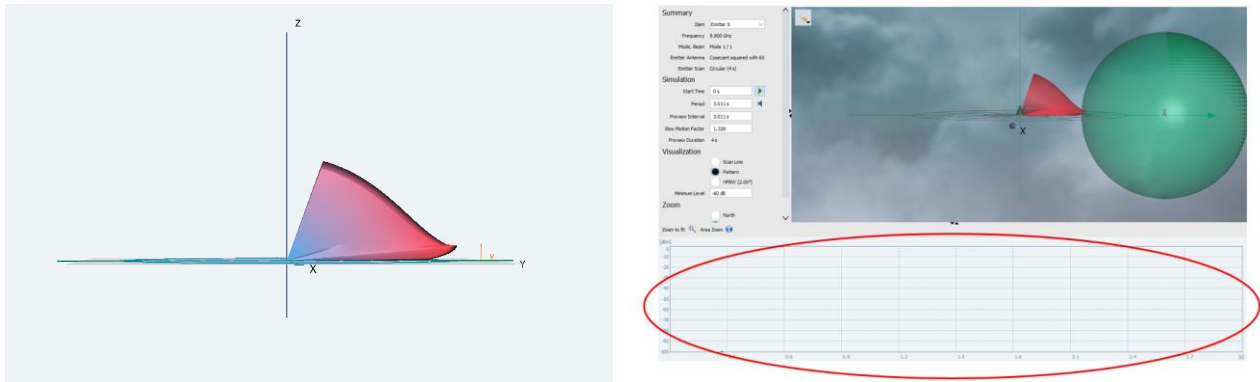
Figure 16 (Left) Acquisition radar using a cosecant squared antenna pattern. (Right) Preview of the threat beam and scan, SUT antenna pattern (green) and power level at the SUT (circled in red). No power is sent to the SUT for this threat since the SUT is below the antenna pattern of the threat. This is due to the antenna pattern shape of the cosecant antenna. This issue can be resolved by using the threat in a "Localized Emitters" scenario and increasing the SUT altitude
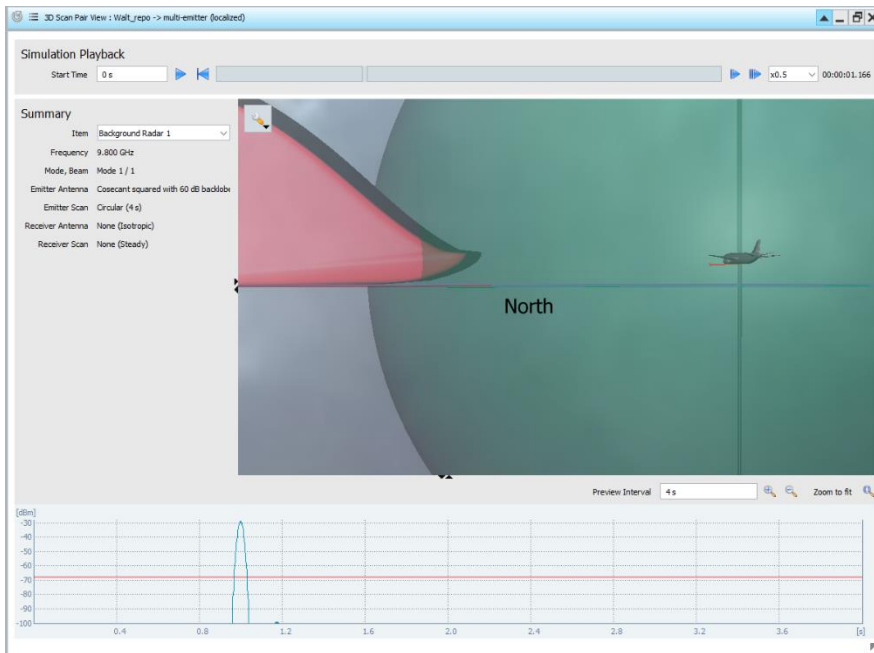

Figure 17 - Zoomed view of the same emitter used in a "Localized Emitters" scenario with the SUT platform (center) elevated to 2000 m altitude. Notice the main lobe flash at 1 second that was not visible in the previous scenario (Figure 16).

3.2.3   Measurements with FSW signal and spectrum analyzer

The signal can be measured at RF using a signal analyzer with a pulse measurement application such as the R&S FSW as explained before. Generally, this is possible only if the emitters use different center frequencies and the analysis bandwidth of the signal analyzer can be narrowed around the pulse spectrum of the threat being analyzed to avoid spectral leakage from other emitters.
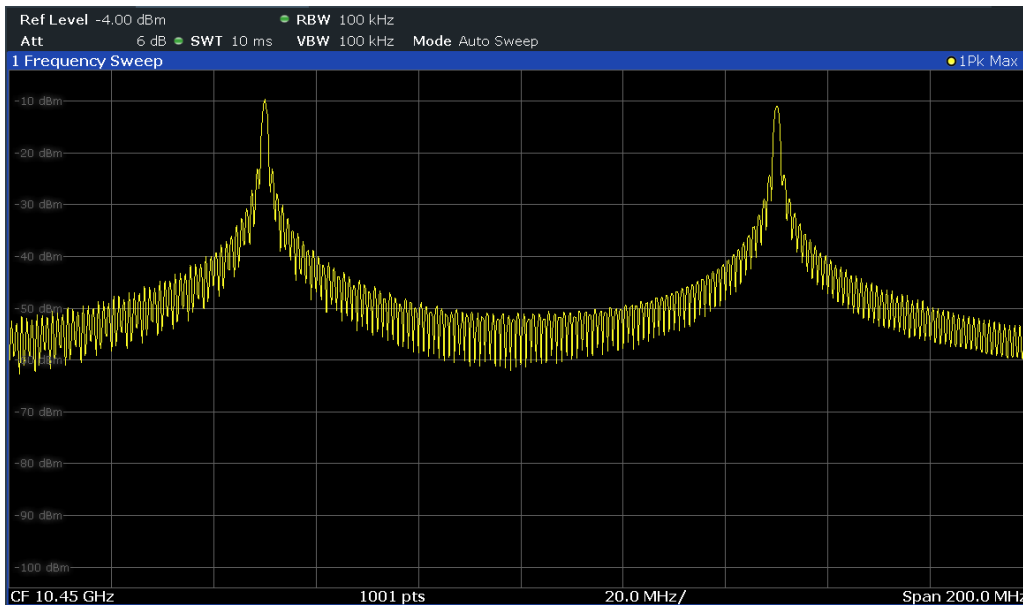
Figure 18 - Multi-emitter simulation with two emitters separated by 100 MHz

3.3 Minimizing pulse dropping in multi-emitter simulation

Though the number of available signal generators is always a constraint in multi-emitter simulation, it is necessary to test with enough signal generators to achieve the required pulse density to ensure RWR function and performance. RWRs are designed to de-interleave and sort millions of pulses per second and track multiple emitters at the same time. Testing this performance at RF requires creating pulse-on-pulse due to overlapping emitters and dropping as few pulses as possible so that emitters are simulated as accurately as possible. This traditionally required more signal generators, one for each time-coincident pulse.
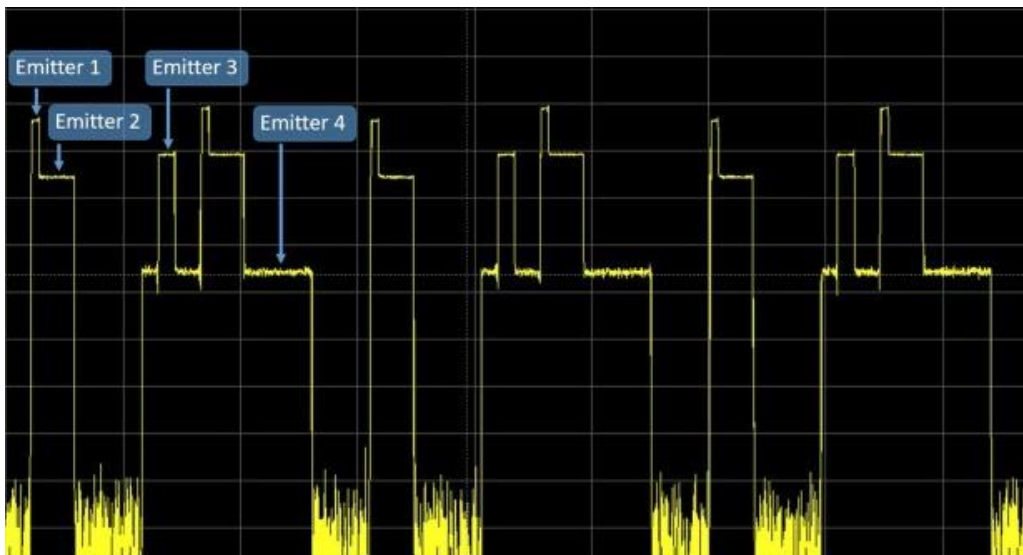

Figure 19 - Time-coincident pulses (pulse-on-pulse) from four emitters, generated with one R&S®SMW200A.

The SMW200A provides a cost-effective alternative by enabling up to 6 independent pulse streams which are supplied to up to 6 internal baseband generators. The combined outputs from the baseband generators are then mapped to up to two RF output ports. This baseband system allows 6 pulses at the same time out of one RF port. A dual channel SMW with two RF ports (e.g. 2 x 20 GHz) allows either 6 pulses at the same

Rohde & Schwarz | Application Note Threat Simulation and verification for radar warning receiver testing

time at one RF port A or RF port B or 3 pulses at the same time at RF port A and 3 pulses at the same time at RF port B

Generating pulse-on-pulse scenarios is available when using the Pulse Sequencer software and also when using the SMW together with an external customer radar simulator in a PDW streaming application. When using PDW streaming, a maximum PDW rate of 12 MPDW/sec out of one RF port is possible. The following figure shows this principle.
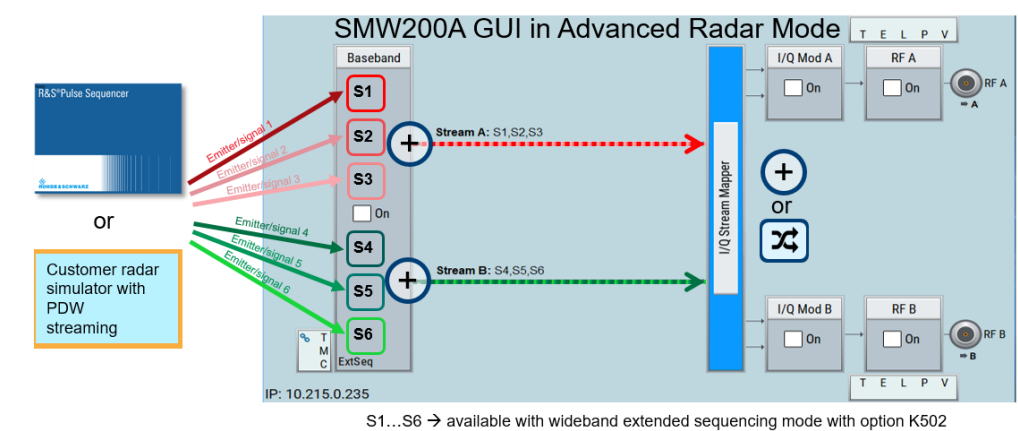

Figure 20 - SMW200A user interface showing control of 6 digital baseband generators for independent emitter creation within the 2 GHz I/Q modulation bandwidth.

The Pulse Sequencer software allows the user to assign emitters via drag-and-drop to available output RF ports at the "Scenario" level of the "Repository Tree". In this example, we assume we have an SMW200A with 4 baseband entities (instead of 6 that would be possible), enabling up to 4 emitters out of one RF port or splitting 4 emitters between two RF ports. The I/Q stream mapper combines the emitters at baseband synchronously and maps them to the RF port. No pulses will be dropped in this case.

Figure 21 - SMW200A with 4 baseband modules allowing four pulses at the same time out of one RF port or two pulses per RF port at the same time out of two RF ports.

In cases where there are more emitters than basebands, emitters can be assigned to interleaving groups and given a priority within the interleaving group. For example, you can prioritize emitters within a group while playing simultaneous emitters of the same priority from other groups to create reliable and repeatable pulse-on-pulse simulations. It also makes visualization of the interleaving easier.

Alias Name	Emitter type	Frequency	Freq. Offset	Scan delay	Enable	Time Offset	Prio [0=Highest]	Level Offset	Interleaving Group
Emitter 1	Tracking radar 1_a	10.5 GHz	0 Hz	0 s	✓	0 s	0	0 dB	Group 1
Emitter 2	Tracking radar 2_a	9.5 GHz	0 Hz	0 s	✓	0 s	1	0 dB	Group 2
Emitter 3	Fire Control 1_ant	10 GHz	0 Hz	0 s	✓	0 s	2	0 dB	Group 3
Emitter 4	Fire Control 2_ant	10.1 GHz	0 Hz	0 s	✓	0 s	3	0 dB	Group 4
Emitter 5	Background Radar	9.8 GHz	0 Hz	0 s	✓	0 s	4	0 dB	Group 4
Emitter 6	Background Radar	10.4 GHz	0 Hz	0 s	✓	0 s	5	0 dB	Group 4

Figure 22 - Six emitters interleaved using four interleaving groups which will each be automatically assigned to a baseband generator to minimize pulse dropping

Rohde & Schwarz | Application Note Threat Simulation and verification for radar warning receiver testing

Each interleaving group can then be assigned to an RF port and the software automatically distributes them to a baseband generator. One interleaving group occupies a baseband generator. Figure 23 and Figure 24 depict the 4 interleaving groups first shown in Figure 14. Each interleaving group is assigned to an RF channel by the user and to a baseband generator by the software in the background. Since there are four baseband generators, the highest priority emitter in each of the four groups will be played with no dropped pulses. The first 3 groups contain one emitter. The fourth group contains 3 emitters and pulses will be dropped from the lower-priority emitters in this group.
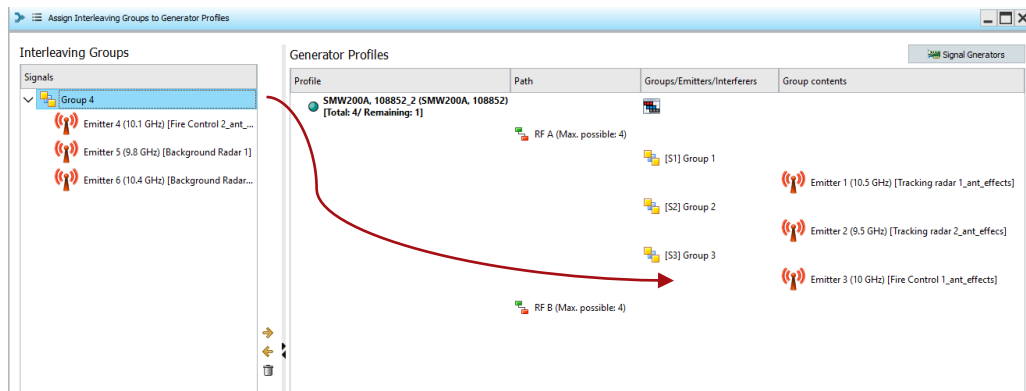

Figure 23 - Four interleaving groups assigned to one SMW200A RF path (RF A).

.

Figure 24 - Interleaving groups from Figure 23. Group 4 contains three emitters at three frequencies.

3.4 Verification of multi-emitter scenarios with pulse-on-pulse

3.4.1 Visualize precomputed scenarios

Longer scenarios should be visualized before playback at RF. The Pulse Sequencer Software provides tools and previews for that purpose both before and after the signal calculation. The sections above explain the use of the signal previews. Figure 25 (below) depicts the results of signal calculation for interleaving group 4.
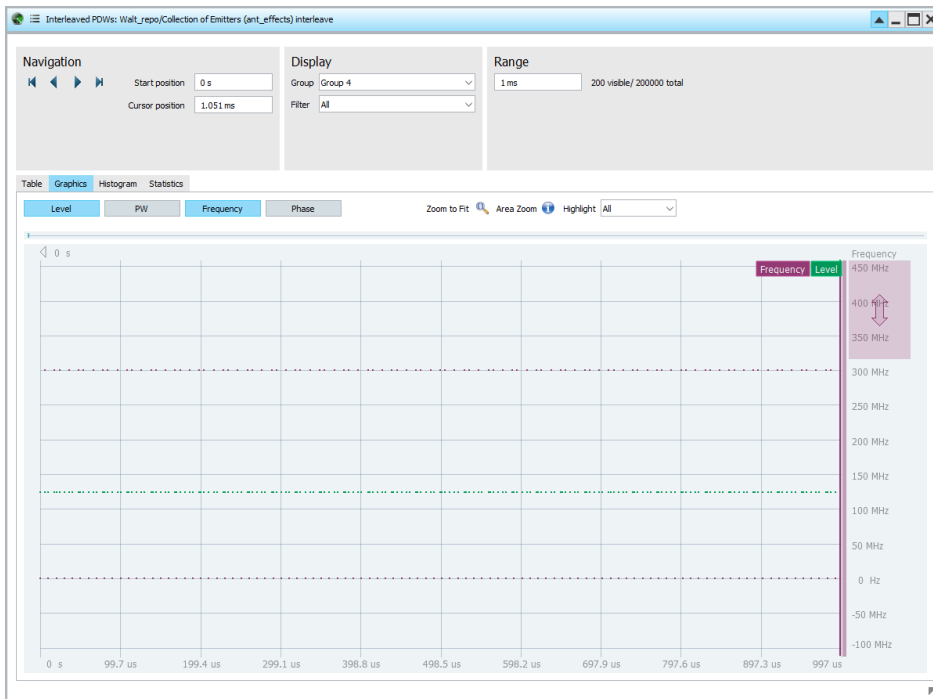
Figure 25 - Signal preview showing the power and frequency of the three emitters (emitters 3, 4, and 5) in interleaving group 4. Notice that only two of the three frequencies appear. This is due to the fact that all pulses from emitter 5 are dropped as explained in Figure 16.

The signal calculation shows a missing emitter (emitter 5) in group 4 as was explained in Figure 14, Figure 15, and Figure 16. The solution was to re-compute the scenario as a "Localized Emitters" scenario and elevate the SUT.

Mistakes in scenario programming happen even with diligent pre-verification of the scenario using Pulse Sequencer's visualization tools. Consequently, verification at RF is still necessary, even if individual emitters were validated at RF in MDF testing as explained in Section 2.2, Threat Verification. It can be tedious to re-run the entire simulation to verify each emitter, so it is best to compute and re-run only the portion(s) of the scenario where the DUT failed using more signal analyzers to validate the individual emitters in pulse-on-pulse conditions.

3.4.2   Measure the individual emitters with separate signal analyzers

This can be done by splitting the RF output into the DUT port into multiple signal analyzers set on the center frequency of each emitter. This can accelerate the process as long as amplitude corrections are used in each signal analyzer to compensate for splitter insertion losses.
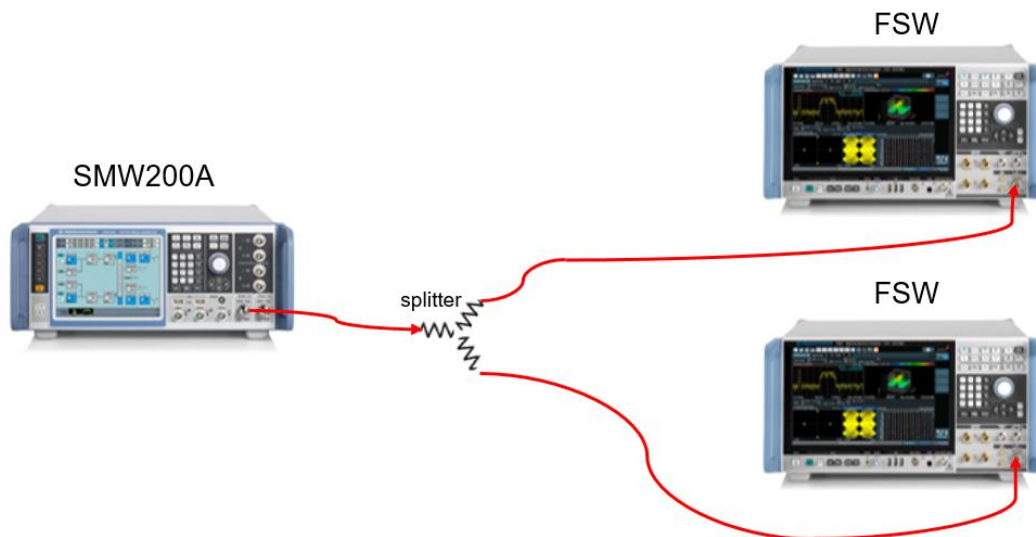
Figure 26 - Multi-emitter verification after SUT test failure with replacement of the SUT by another FSW signal analyzer.

3.4.3 Using the IF magnitude trigger

In multi-emitter simulation, it may be impossible to trigger a measurement on a marker from the signal generator that corresponds to the threat to be measured. Marker outputs from the signal generator are limited. Marker settings in the simulation software may not enable a unique marker output for each threat. Toggling marker settings and re-computing scenarios takes time. Instead, it may be better to trigger on the IF magnitude (power level) of the threat to be measured, assuming the threat uses a different center frequency than other time-coincident threats. Setting the IF magnitude trigger is a matter of trial-and-error depending on the antenna scan of the threat and the kinematics of the simulation. It is best to configure both the trigger and detection settings during the part of the scenario where the mainlobe flash of the emitter is incident on the DUT. After that, IF trigger level, attenuation, and detection settings can be optimized to ensure that pulses from the emitter's sidelobes are measured.

Task: Analysis of a single emitter within a multi emitter scenario using IF magnitude trigger in a FSW signal and spectrum analyzer. Let's consider this emitter (emitter 1 in the list of figure 29) illuminating the receiver under test with a narrow beam and a raster scan.
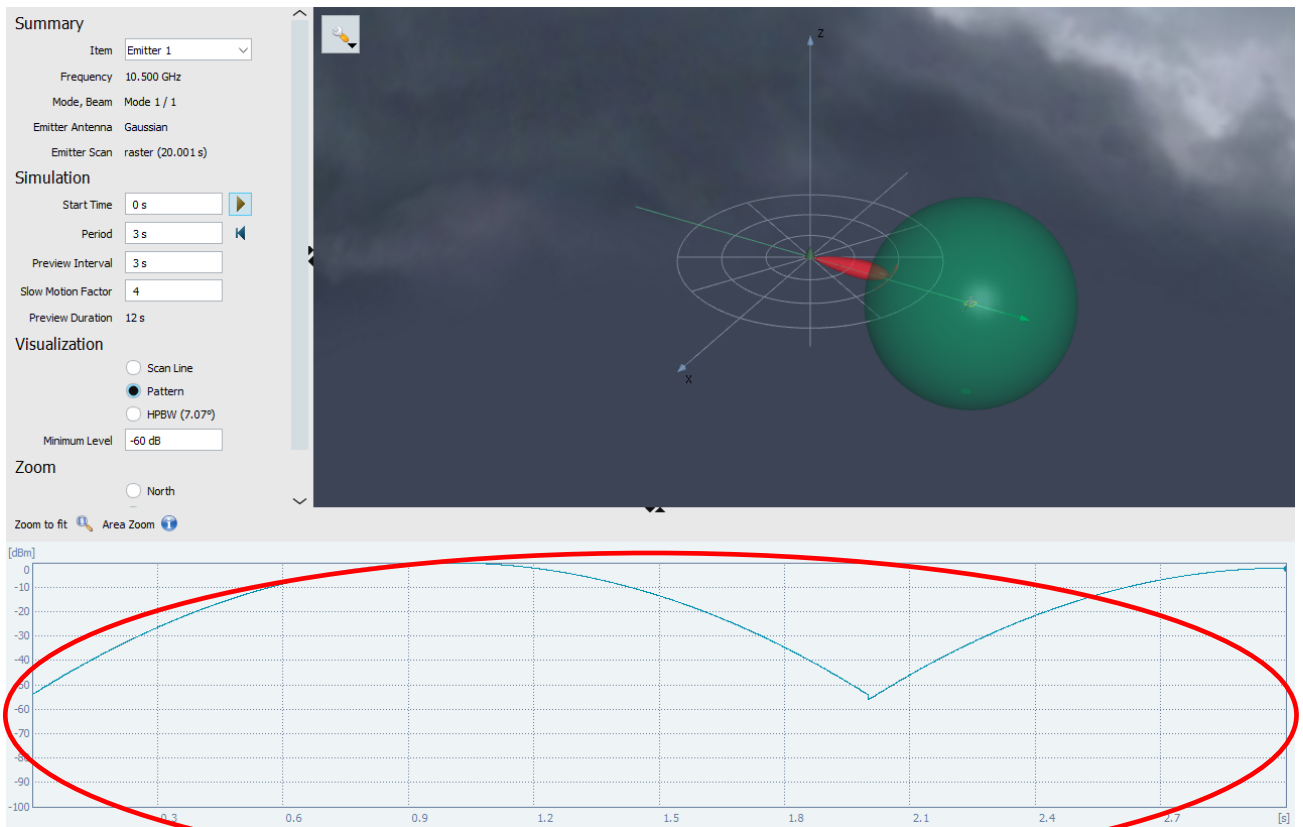
Figure 27 - Graphical representation of a single emitter in a scenario with a total of 6 emitters and enabled with pulse-on-pulse. Notice the expected power at the SUT circled in red.

The total emitter scenario consists of 6 emitters as defined in the table below.

No	Alias Name	Emitter type	Frequency	Freq. Offset	Scan delay	Edit Emitter type	Absolute Level	Modes|Beams|Attit
1	Emitter 1	Tracking radar 1_ant_effects	10.5 GHz	0 Hz	0 s	...	0 dBm	...
2	Emitter 2	Tracking radar 2_ant_effecs	9.5 GHz	0 Hz	0 s	...	0 dBm	...
3	Emitter 3	Fire Control 1_ant_effects	10 GHz	0 Hz	0 s	...	0 dBm	...
4	Emitter 4	Fire Control 2_ant_effects	10.1 GHz	0 Hz	0 s	...	0 dBm	...
5	Emitter 5	Background Radar 1	9.8 GHz	0 Hz	0 s	...	0 dBm	...
6	Emitter 6	Background Radar 2	10.4 GHz	0 Hz	0 s	...	0 dBm	...

Figure 28 - Emitters and their center frequencies.

All center frequencies have an offset from the others by at least 100 MHz and the threat waveforms use no modulation-on-pulse, so we can use an analysis bandwidth of 40 MHz and measure only the first emitter at 10.5 GHz.

In order to trigger on that emitter, configure IF power triggers and detection settings during the mainlobe flash (around second 0.9) where the power from the threat is the greatest. As the emitter uses a medium PRF, the PRI analysis is more accurate without segmented capture. The IF magnitude trigger is set above the noise floor and above any spectral leakage from other emitters. Pulse detection can be set at the same level using an absolute detection setting.
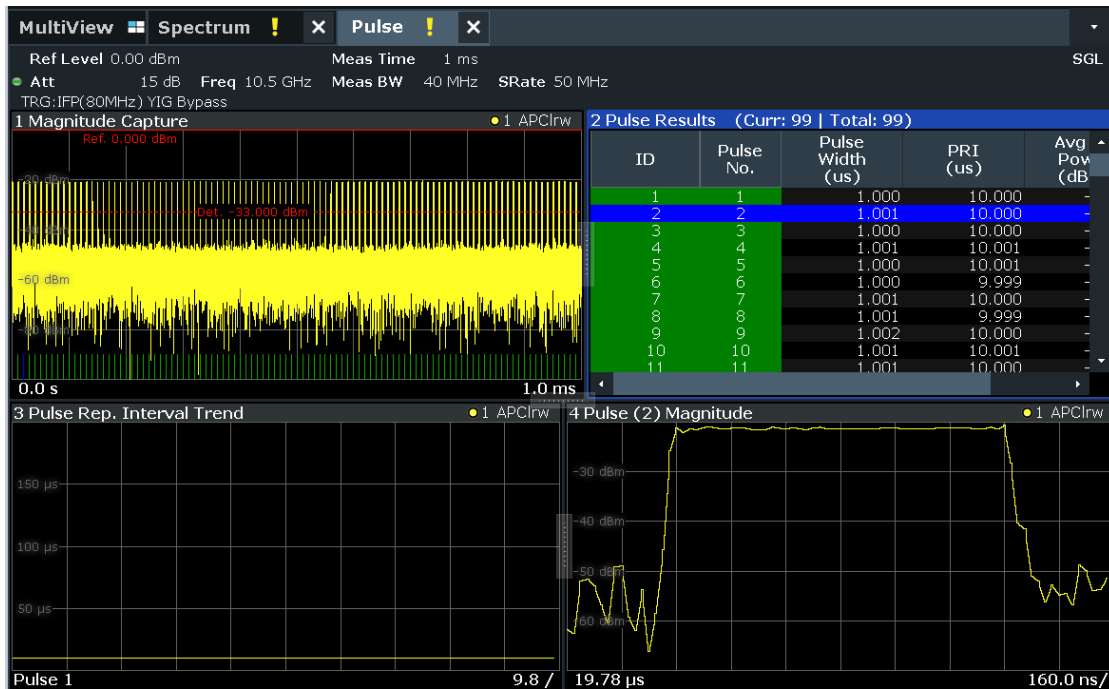
Figure 29 - Pulse analysis of emitter 1 at 10.5 GHz. Notice that the measurement bandwidth is narrowed to prevent spectral leakage from other emitters and reduce effective noise bandwidth.

In this example, the timing parameters are measured without interference of adjacent emitters because of the bandwidth of the analyzer. This becomes more difficult as emitters become closer in frequency due to the leakage of adjacent pulsed spectra.

4 Conclusion

In this application note, we learned how to create EW scenarios of single emitters for mission data file testing and multiple emitters with pulse-on-pulse using the Rohde & Schwarz Pulse Sequencer software and the SMW200A vector signal generator. We learned how to validate scenarios using the Rohde & Schwarz FSW signal and spectrum analyzer and K6 Pulse Measurement application.

Subsequent application notes in this series will explain angle-of-arrival simulation, including calibration and validation, as well as real-time PDW calculations and streaming.

5 Literature

[1] F. Gerbl, "Radar warning receiver testing: multi-channel signal generation (to be published)"," Rohde and Schwarz, Munich, 2021.

[2] S. Kehl-Waas, "Generation of Radar Signals in a Hardware in the Loop (HIL) Environment," Rohde and Schwarz, Munich, 2021.

[3] W. Schulte, "Automated Emitter Creation and Mode Sequencing for Mission Data File Testing (to be published)," Rohde and Schwarz, Munich, 2021.

[4] D. Adamy, "EW 101: A First Course in Electronic Warfare," Artech House, 2001, p. 143.

6 Ordering Information

Designation	Type	Order No.
Vector Signal Generator	R&S®SMW200A	1412.0000.02
Frequency range 100 kHz to xx GHz for RF path A	R&S®SMW-B10xx	1428.xxxx.02
Frequency range 100 kHz to xx GHz for RF path B	R&S®SMW-B20xx	1428.xxxx.02
Wideband baseband main module, 2 I/Q paths to RF	R&S®SMW-B13XT	1413.8005.02
Wideband baseband generator, 500 MHz, 256 MS	R&S®SMW-B9	1413.7350.02
Fading simulator and signal processor	R&S®SMW-B15	1414.4710.02
Wideband Extended Sequencing for R&S®SMW-B9	R&S®SMW-K502	1413.9260.02
Realtime Control Interface	R&S®SMW-K503	1414.3620.02
High speed upgrade of PDW rate	R&S®SMW-K504	1414.3665.02
Pulse Sequencer Software	R&S®SMW-K300	1413.8805.02
Enhanced Pulse Sequencing	R&S®SMW-K301	1413.9776.02
Radar Platforms	R&S®SMW-K302	1413.8857.02
Moving Emitters and Receiver	R&S®SMW-K304	1413.8957.02
Multiple Emitters	R&S®SMW-K306	1413.9053.02
Direction Finding	R&S®SMW-K308	1414.1433.02
Import of 2D Maps	R&S®SMW-K309	1414.6706.02
Pulse on Pulse Simulation	R&S®SMW-K315	1414.6529.02
Signal Analyzer	R&S®FSW	1331.5003.xx
Analysis Bandwidth	R&S®FSW-Bx001	1331.xxxx.14
Pulse Measurements	R&S®FSW-K6	1313.1322.02

Rohde & Schwarz

The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, monitoring and network testing. Founded more than 80 years ago, the independent company which is headquartered in Munich, Germany, has an extensive sales and service network with locations in more than 70 countries.

www.rohde-schwarz.com

Certified Quality Management
ISO 9001

Rohde & Schwarz training

www.training.rohde-schwarz.com

Rohde & Schwarz customer support

www.rohde-schwarz.com/support