Simulating radar signals for meaningful radar receiver tests

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ROHDE&SCHWARZ

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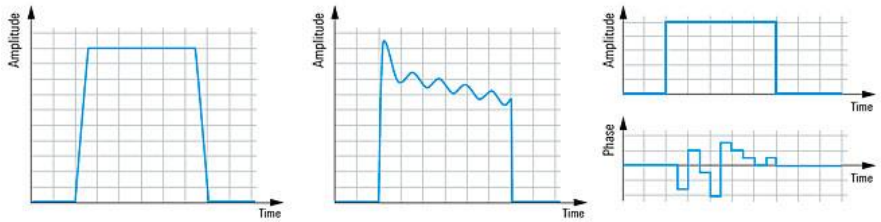
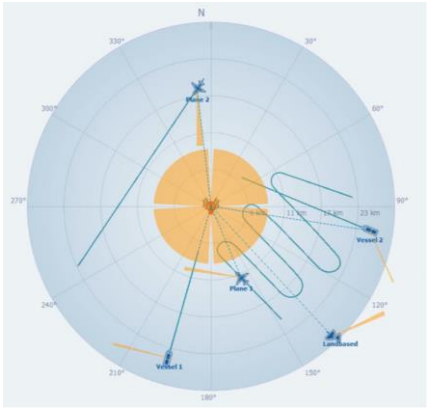




Building Blocks for an off-the-shelf Radar Signal Simulator

R&S®SGU100A

R&S®SGS100A

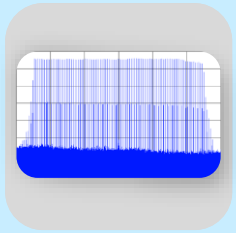
R&S®SMBV100B

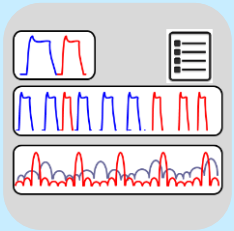
R&S®SGT100A

R&S®SMW200A

Outstanding hardware capabilities

- Up to 2 GHz internal baseband
- Dual path 20 GHz in one box
- RF frequencies up to 40 GHz
- Phase coherent signals up to 40 GHz





R&S®Pulse Sequencer software capabilities

- Generation of radar signals
- Real time sequencing
- Direction finding

Powerful radar signal simulator

- PC software
- Off-the-shelf signal generators
- Ultra flexible

Manual radar scenario definition with Pulse Sequencer software

- Full flexibility in scenario configuration
- Single or Multi Emitters scenarios
- Moving emitters and receiver
- Good for short and medium radar scenario length
- Intuitive software GUI and fast scenario configuration

Simple modelling of special shaped pulses

- Modulated and unmodulated pulses can be defined quickly
- Linear frequency modulation, Barker coding, polyphaser codes, phase shift keying or any classical analog modulation
- Customer specific modulation formats can be added

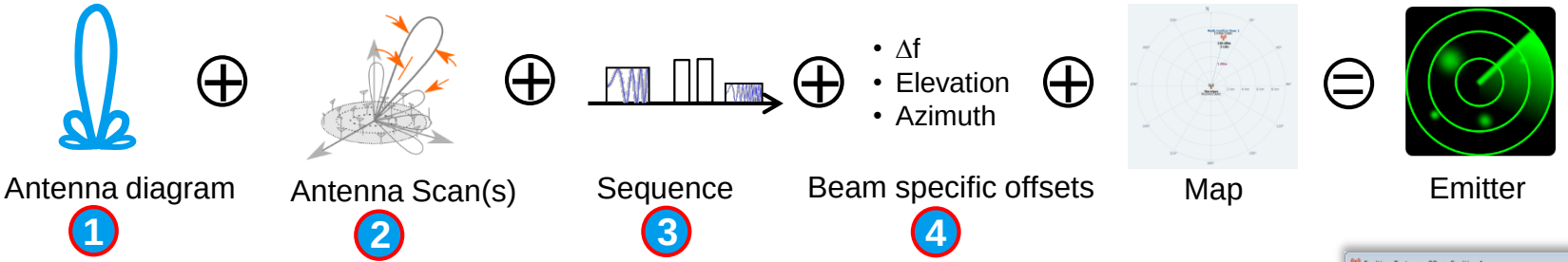
Unmodulated pulse with non-rectangular pulse envelope and with rising and falling edge

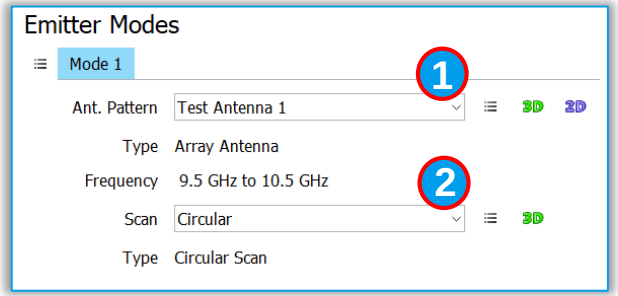
Overshoot, droop and ripple in an unmodulated non-rectangular pulse

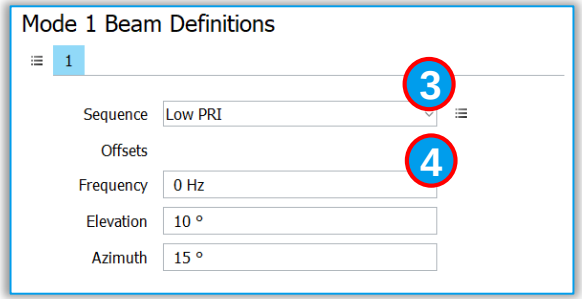
I/Q modulated pulse (MOP)

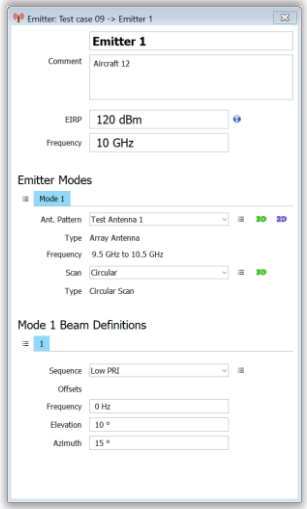
→ Simplify the creation of radar signals with intuitive pulse definition
→ Perfect for applications where precise pulse modelling is required

Simple modelling of emitters







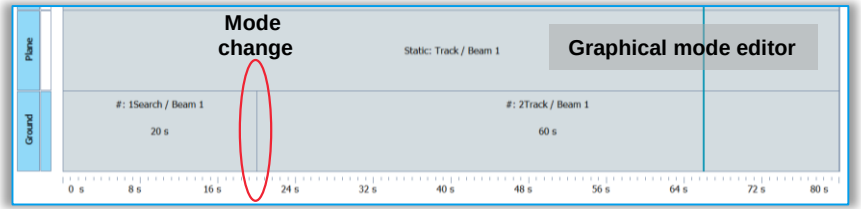


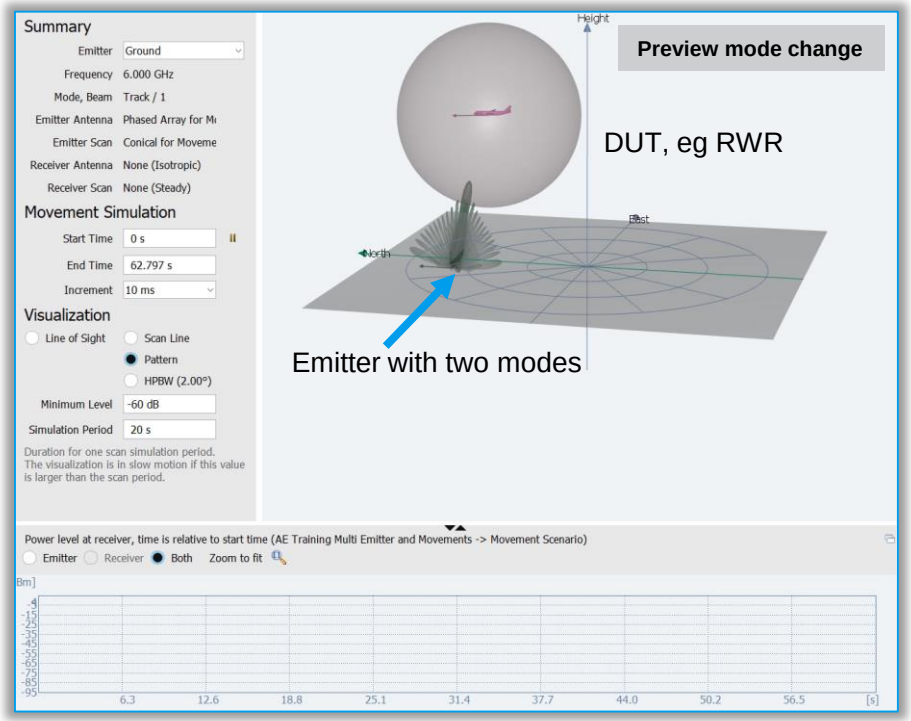
→ Quick and easy modelling of emitters
→ Supports antenna diagrams, scans and map for localized emitters/receiver

Mode changes – simple operation and powerful preview

- Mode change: Switch emitter parameters over time
  - Antenna patterns and scans
  - Offset frequency
  - Sequences (PRI, pulse width etc.)
- Application: search and track mode

→ Graphical mode editor allows fast and easy setup of modes and changes



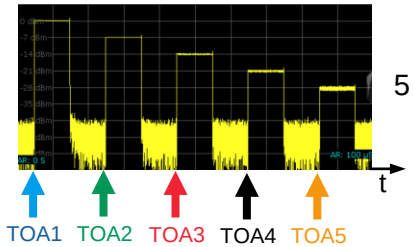


→ Graphical previews bring great confidence in scenario creation and save test setup time

PDW import in Pulse Sequencer Software and replay with R&S®SMW200A

What is a Pulse Descriptor Word?

- A Pulse Descriptor Word (PDW) is a set of parameters which fully describes a pulse
- It is THE language of radar systems and components
- It is used for exchange of pulse definitions from one system component to another
- Often used to store recorded radar scenarios
- No open industry standard, formats are often customer specific

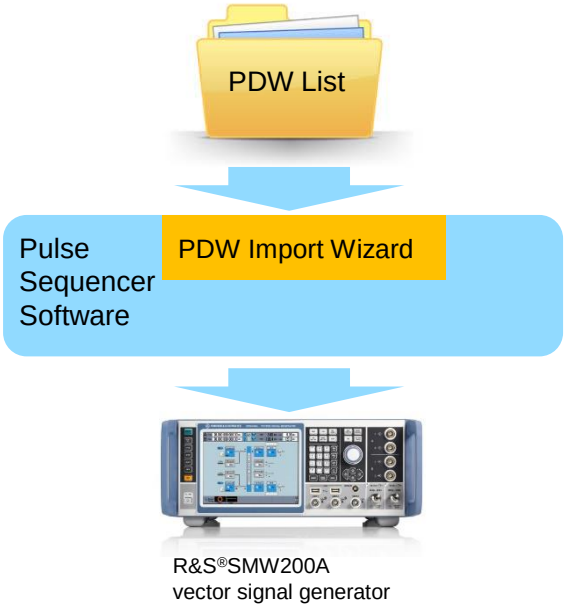


5 pulses <=> 5 independent PDWs
5 Time Of Arrival (TOA)

Radar receiver test using legacy PDW lists

- **Task**:
  Test the radar receiver with radar signals described in PDW lists
- **Initial situation**:
  - Large number of recorded or manually created PDW lists exist
  - Legacy PDW files often have different formats
  - Need a mechanism to convert stored PDWs back into a real radar RF signal
- **Solution:** PDW List Import into Pulse Sequencer Software
  - Highest flexibility -> import can be easily customized by the user, import all kind of formats
  - No re-formatting of legacy PDW lists
  - Generate signals with complex modulations on pulse from PDWs

→ Perfect for design verification and tests of radar receivers



R&S®SMW200A
vector signal generator

PDW Import and Interleaving in Pulse Sequencer Software

Customer PDW lists

```
  Offset   PW     Level  Phase   PRI
  MHz      µs     dB     Deg     µs
 ===================================
   00.000   60.0   0.0      0.0   2000.0
   100.000  20.0  -3.0      0.0   1000.0
   00.000   10    -10       0.0   500
```

PDW import template to map customer format to R&S format

```
1 : RFOFFSET      MHz     # Frequency offset
2 : WIDTH         us      # Pulse width
3 : LEVELOFFSET   dB      # Level attenuation
4 : PHASE         Deg     # Phase
5 : PRI           us      # PRI
```

Pulse Sequencer Software

PDW Import Wizard

PDW List A

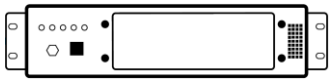
PDW List B

PDW List C

Interleaving

Interleaved PDW List

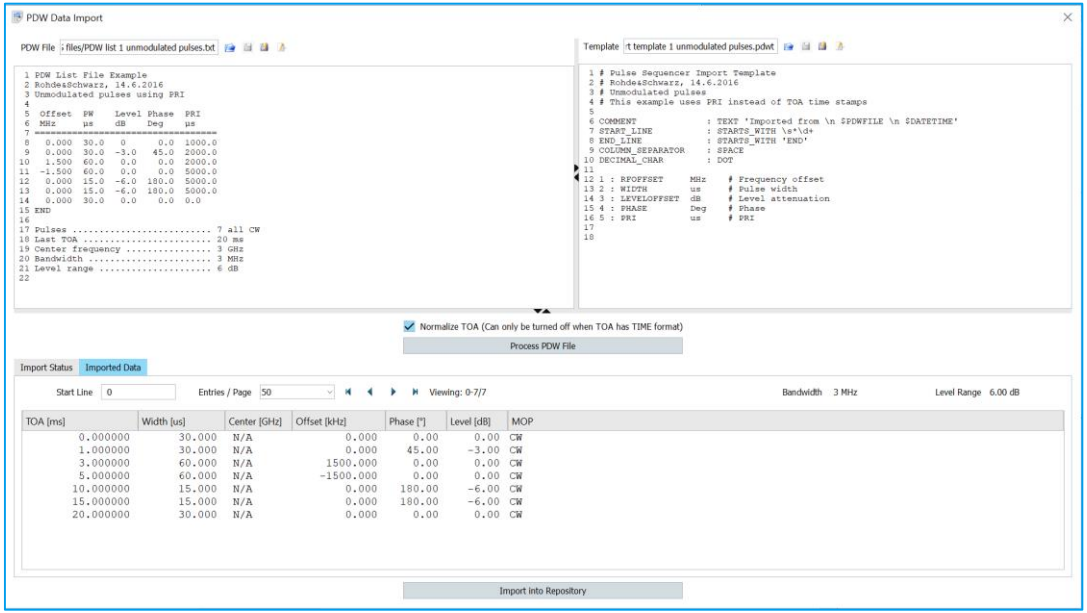
Receiver under test



→ Simple and fast generation of radar test signals using interleaved PDW lists

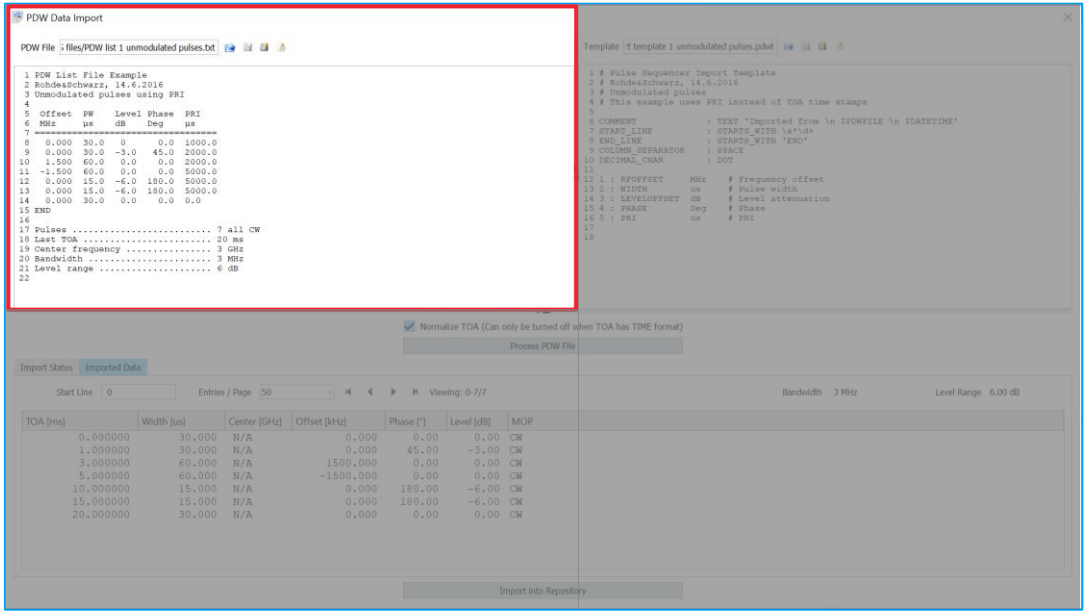
The PDW Import Dialog

- Part of Pulse Sequencer software
- Three steps to import and replay customer PDWs
  1. Prepare import template for customer PDW list
  2. Process and import customer PDW list
  3. Generate signals on signal generator



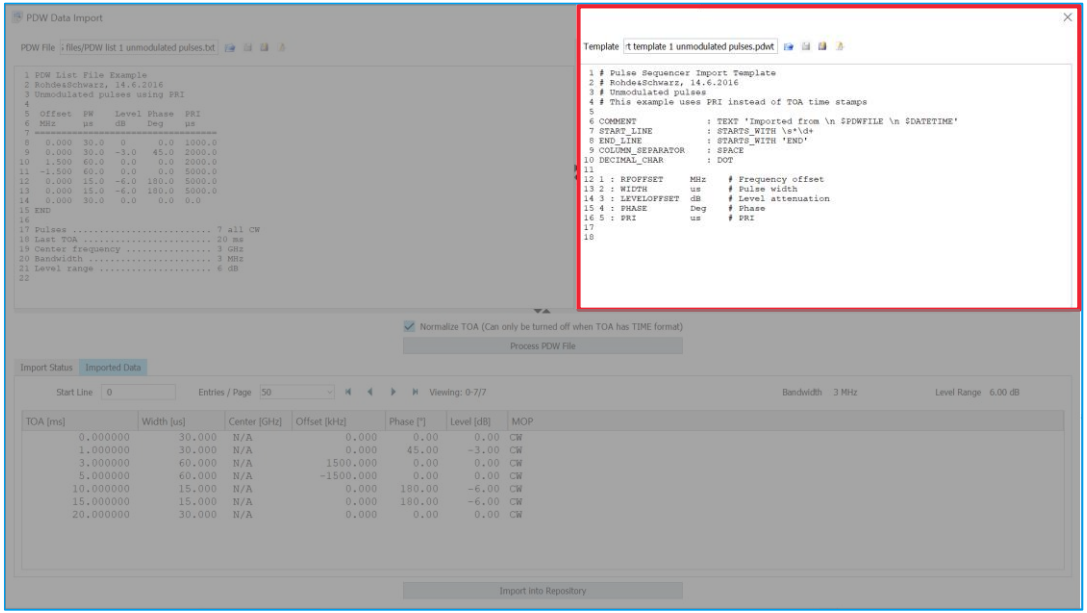
The PDW List File

- Prepared by the customer before running the wizard
- Customer specific text file
- Single rows per PDW
- Maximum file size of 1GB results in app. 60 Mio PDWs



The PDW Import Template File

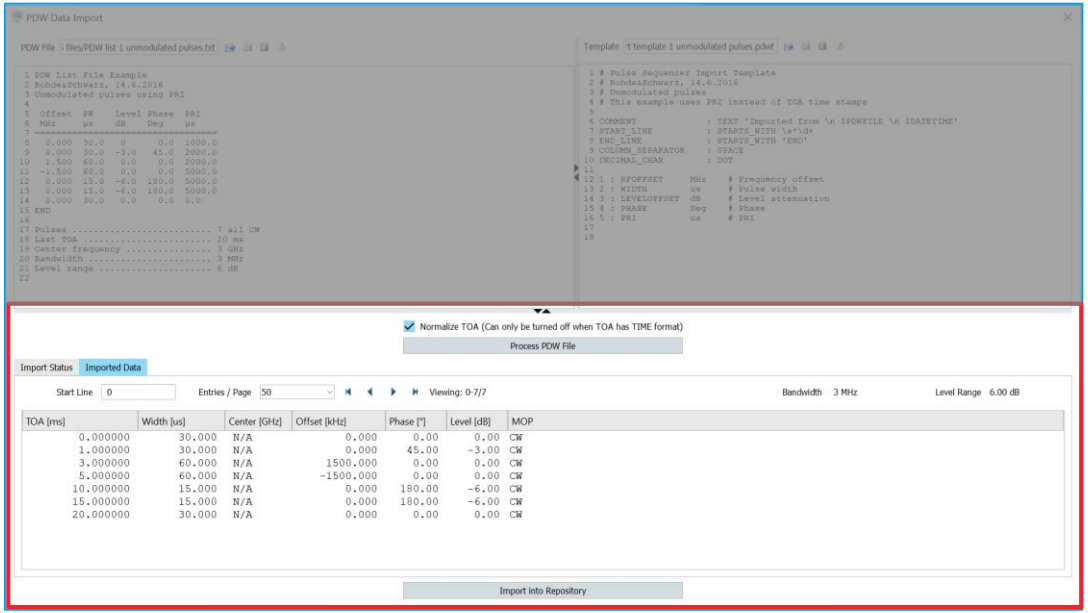
- Template maps user specific PDW format into R&S format
- Benefit is that virtually any custom PDW list according to R&S ICD can be imported and played
- Template is customer specific txt file
- To prepare the template the Interface Specification (R&S website) and supplied examples can be used *



* Examples for PDW list files and import templates are automatically installed with Pulse Sequencer SW

The PDW Import Wizard

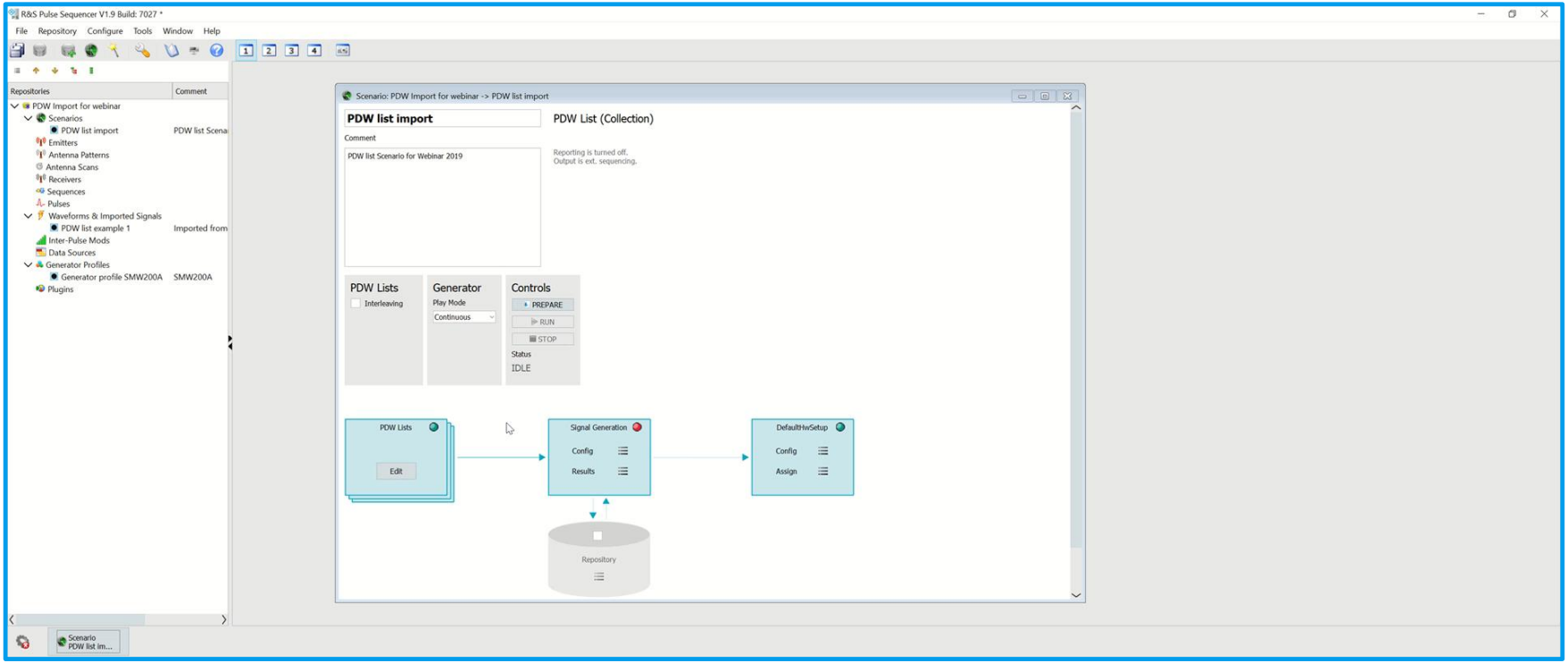
- Transfers the PDWs from the PDW list file into Pulse Sequencer Repository
- Processes and checks the PDW list file according to the import template instructions
- Shows the processed PDWs in a plain text table



→ Ready for further processing in Pulse Sequencer software

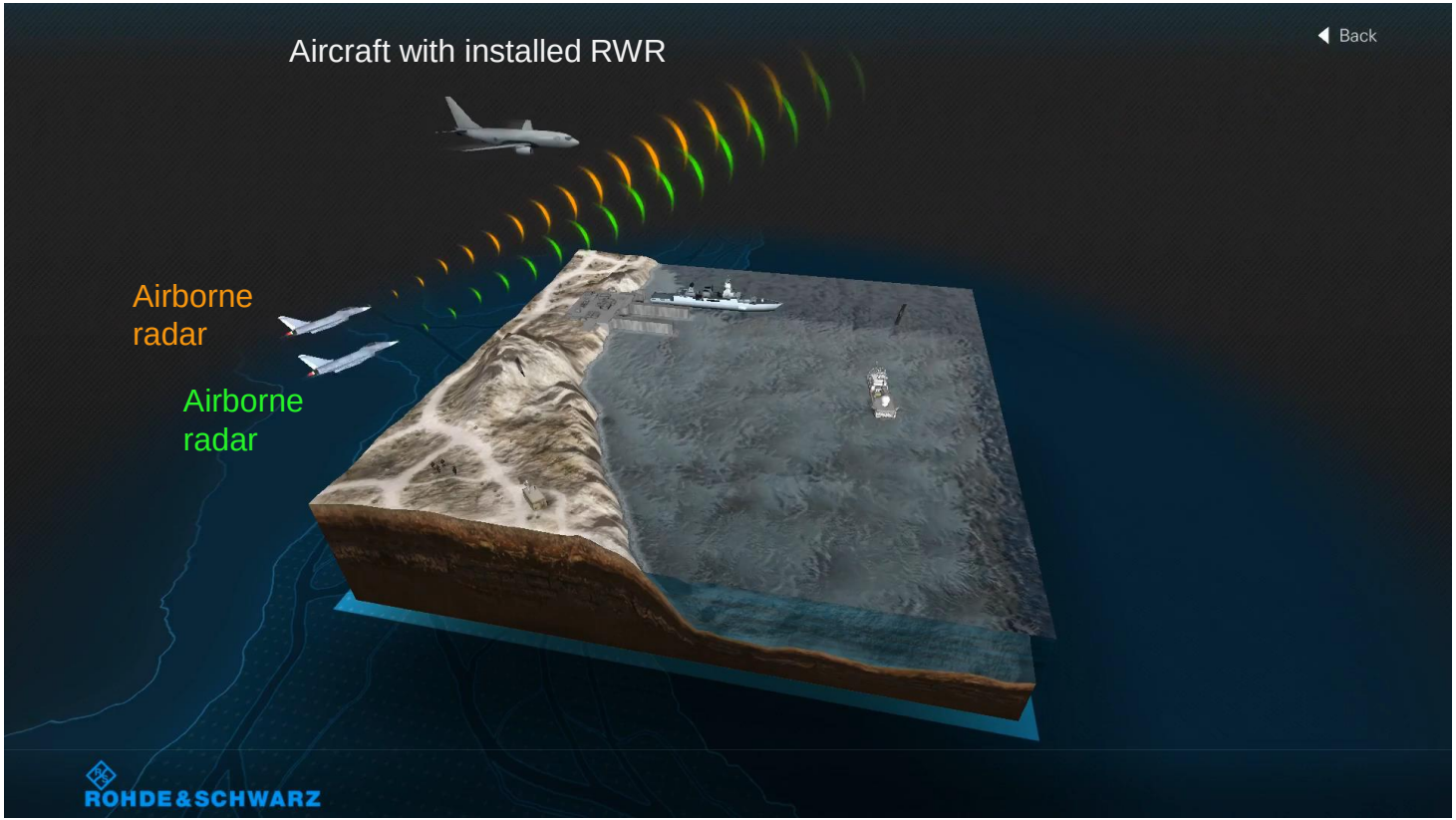
How to import legacy PDW lists in Pulse Sequencer Software

A short example

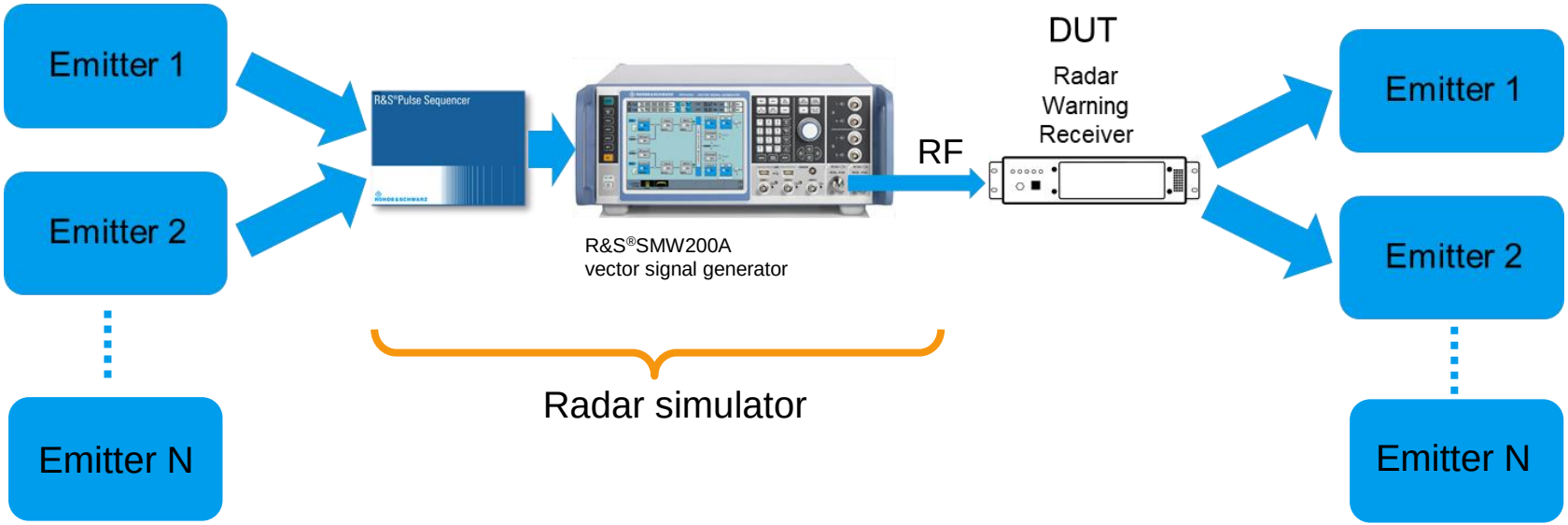


Create Complex Radar Scenarios with Pulse Sequencer Software

Simulation of multiple moving emitters and receiver



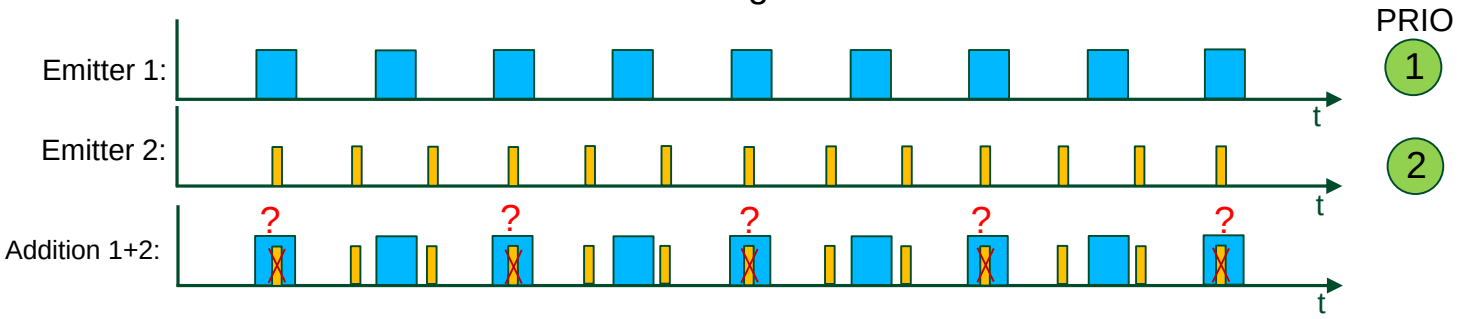
General test case for radar warning receivers



Concepts of simulation of many emitters in parallel

Challenge and solution

- **Task:** Two emitters need to be simulated and generated at the same time



- **Questions:** What will happen if two pulses occur at the same time?

- **Possible solutions:**
  - Interleave pulsed signals and drop pulses if they overlap according to a priority scheme with optimized low drop rate
  - Generate both pulses together (co-pulse or pulse-on-pulse scenario)

Use Case: Simulate Multi Emitters without geometric location

List emitters and prioritize them before interleaving – industry standard

Configure interleaving process

Alias Name	Emitter	Frequency	Enable	Time Offset	Prio [0=Highest]	Level Offset	Group
Emitter 0	Airborne 1	9 GHz	☑	10 us	3	-5 dB	Group 1
Emitter 1	Airborne 2	10 GHz	☐				
Emitter 2	Landbased 2	10 GHz	☑	400 us	1	0 dB	Group 2
Emitter 3	Landbased 4	9 GHz	☑	0 s	0	-20 dB	Group 2
Emitter 4	Airborne 2.1	10 GHz	☑	0 s	4	0 dB	Group 1

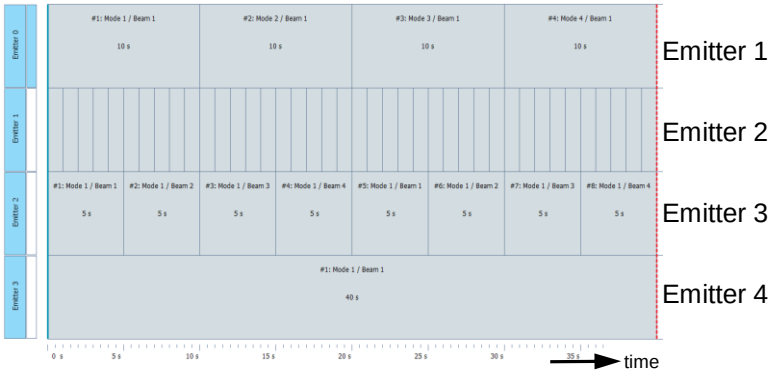
create or import

select emitters for interleaving

optimize for small pulse drop rate

Allocate emitters to groups

Four emitters, each emitter has different modes



Interleaving statistics

ID	Name	Prio	Total 1429672	Dropped 21060	Dropped % 1.473	Density (pps) 35215.3 pps
1	Emitter 0	3	990275	17401	1.757	24321.9
2	Emitter 1	2	224149	3554	1.586	5515.56
3	Emitter 2	1	212914	62	0.02912	5321.3
4	Emitter 3	0	2334	43	1.842	57.3968

>1 Mio pulses

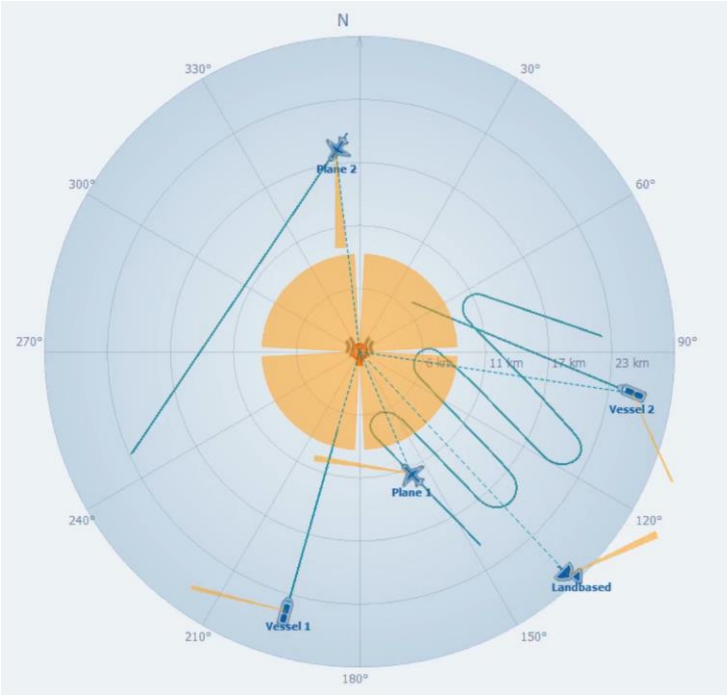
playtime

Lowest drop rate

Pulses: 1429672, Playtime: 40 s, Interleaved: 1408612, Dropped: 21060 (1.473%), Density: 35215.3 pps

Use Case: Simulate Multi Emitter scenarios on a map

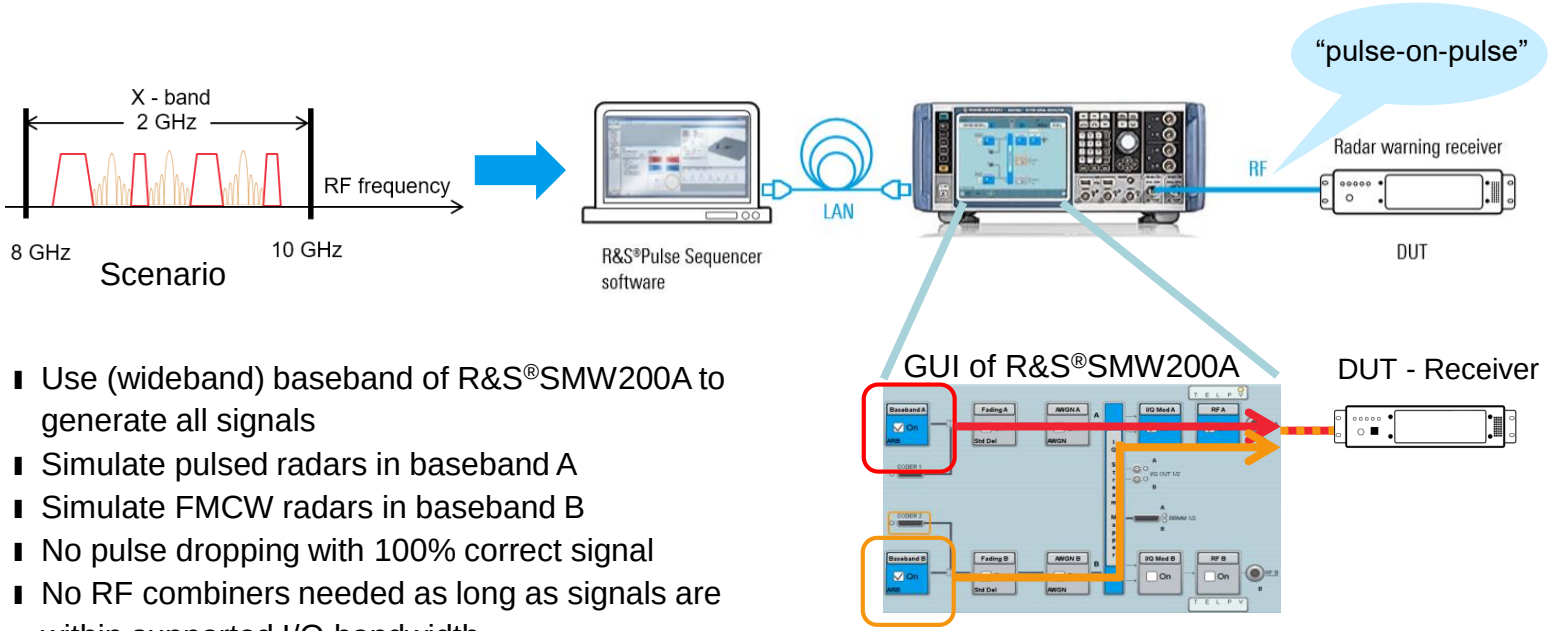
Multi emitter simulation in 3D space



- Live scenario with multiple radars
  - Two patrol aircrafts with pencil beam
  - Imported real flight trajectory for patrol aircraft plane 1
  - Predefined trajectory for plane 2
  - One land based static radar
  - Several vessels with navigation radars

Solution from R&S for simulating two emitters in same radar band

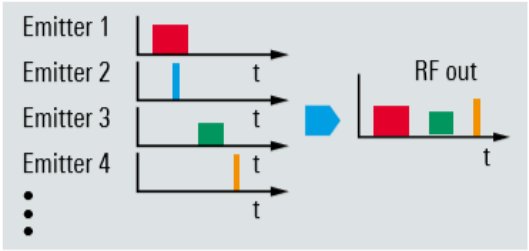
Simulate the most important radar bands with two basebands in R&S®SMW200A



- Use (wideband) baseband of R&S®SMW200A to generate all signals
- Simulate pulsed radars in baseband A
- Simulate FMCW radars in baseband B
- No pulse dropping with 100% correct signal
- No RF combiners needed as long as signals are within supported I/Q bandwidth

Solution for simulating many emitters in one radar band

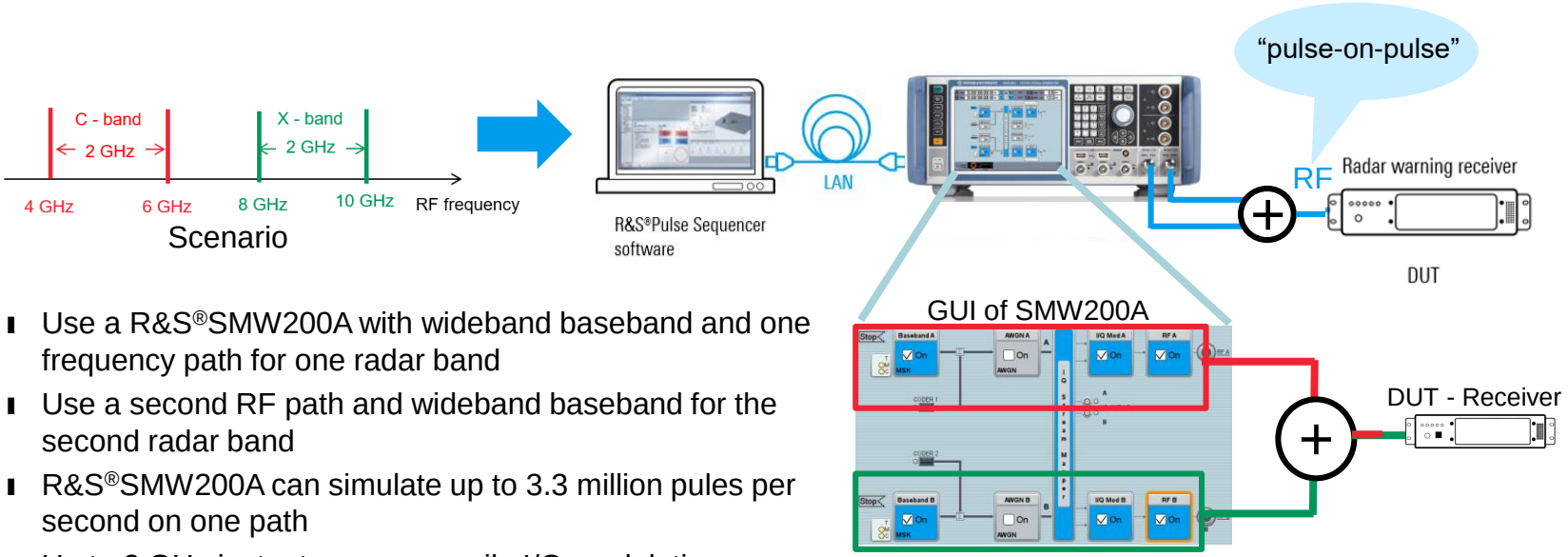
Interleave emitters with lowest drop rates



- R&S Pulse Sequencer software together with R&S®SMW200A vector signal generator
  - Simulates the radar scenarios
  - Uses a smart algorithm to interleave signals with priority scheme
  - Drops pulses in case they collide and ensures lowest drop rates
  - Up to 3.3 million pulses per second per band
- Example
  - Pulse from emitter 2 (blue pulse) is dropped as it overlaps with the pulse from emitter 1 (red pulse)

Solution for simulating emitters in two radar bands

Simulate the most important radar bands with a two path R&S®SMW200A

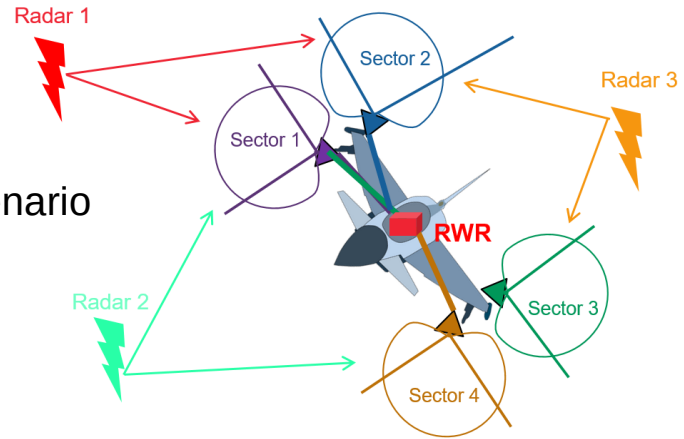


- Use a R&S®SMW200A with wideband baseband and one frequency path for one radar band
- Use a second RF path and wideband baseband for the second radar band
- R&S®SMW200A can simulate up to 3.3 million pules per second on one path
- Up to 2 GHz instantaneous or agile I/Q modulation bandwidth for radar simulation
- Does not lose pulses

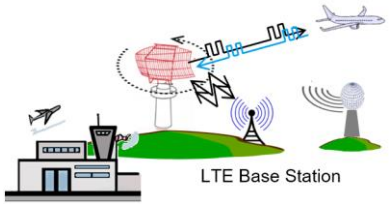
Simulation Angle of Arrival in the lab

This setup …..

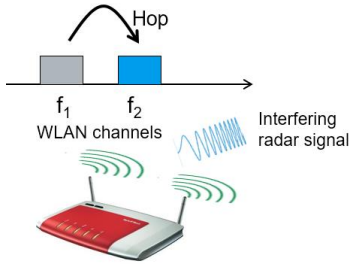
… simulates this scenario



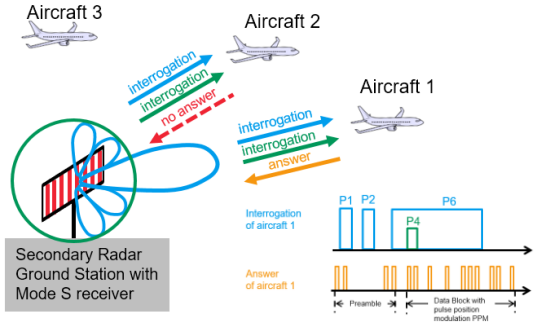
Other applications served by the R&S Pulse Sequencer software



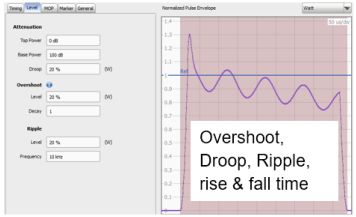
Co-existence testing of air traffic control radars with commercial base stations



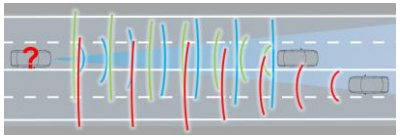
Testing DFS capability of WiFi routers



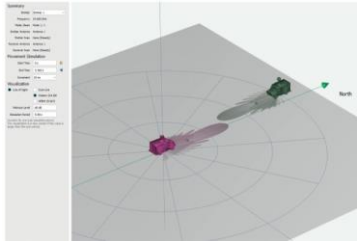
Simulation of Mode S interrogation and answer patterns for testing receivers used with secondary radar signals



Component testing with user-impaired pulsed signals or simple pulses



Simulation of automotive FMCW fast chirp sequences of interferers for testing robustness of automotive radar sensors together with AREG100A



High Speed PDW Streaming with R&S®SMW200A

Applications for PDW streaming

- Control the radar signal from a stream of PDWs
- Change the radar scenario during testing

Main differences of importing PDWs vs streaming PDWs

PDW import into Pulse Sequencer software

- Pulse Sequencer Software acts as radar simulator
- PDW list (scenario) exists
- Import file and generate the scenario as a whole
- PDWs can have any format

→ Perfect for quick reuse of legacy PDW lists

PDW streaming

- Customer radar simulator ready to stream PDWs
- PDWs can be generated during test
- Generate the signal pulse by pulse
- PDW lists must conform to R&S format

→ Perfect for flexible customized solutions

PDW Streaming using R&S®SMW200A vector signal generator

- Customer radar simulator calculates the scenarios and streams radar signal as PDWs to signal source
- High pulse density is achieved for radar scenarios with long playtime with classical pulses and I/Q modulated waveform segments
- Adaptive changes of signal parameters in radar simulator during playtime is possible as the signal does not need to be pre-calculated
- Good for ultra long radar scenarios

High Speed PDW Streaming with R&S®SMW200A

- The more radars there are in the scenario, the higher the pulse rate the receiver must be able to handle.
- Maximum pulse density is a key performance parameter of a Radar Warning Receiver (RWR)
- Use R&S®SMW200A vector signal generator with real-time control interface software option for PDW streaming
- PDW execution rate in R&S®SMW200A up to 2 Mpulse/s per baseband board
- Up to 4 Mpulse/s using one instrument with 2 baseband boards

Download the Pulse Sequencer software!

- Download Pulse Sequencer software from the Rohde&Schwarz homepage and try it out