EFFICIENT TESTING OF MULTIPORT EW RECEIVERS

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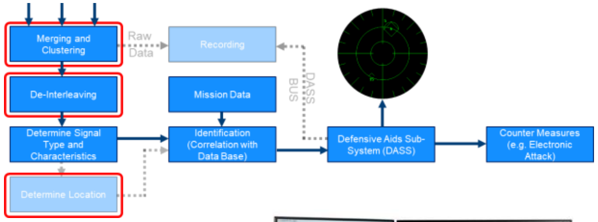
ROHDE&SCHWARZ

Make ideas real

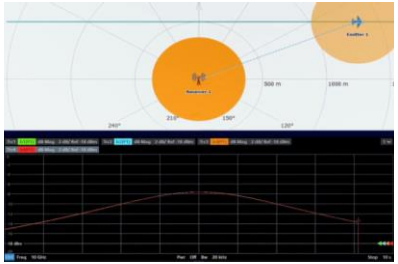
EFFICIENT TESTING OF MULTIPORT EW RECEIVERS
AGENDA

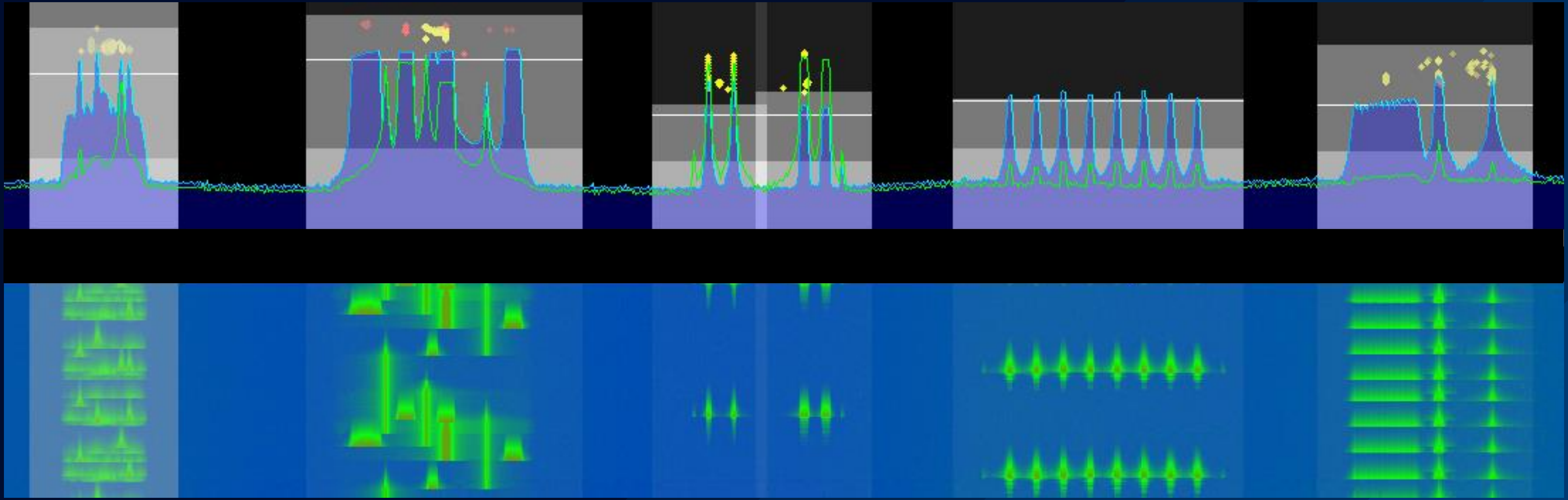
PART I
Backgrounds on ESM receivers



PART II
The R&S Radar Signal Simulator

PART III
Demonstration of an exemplary test setup

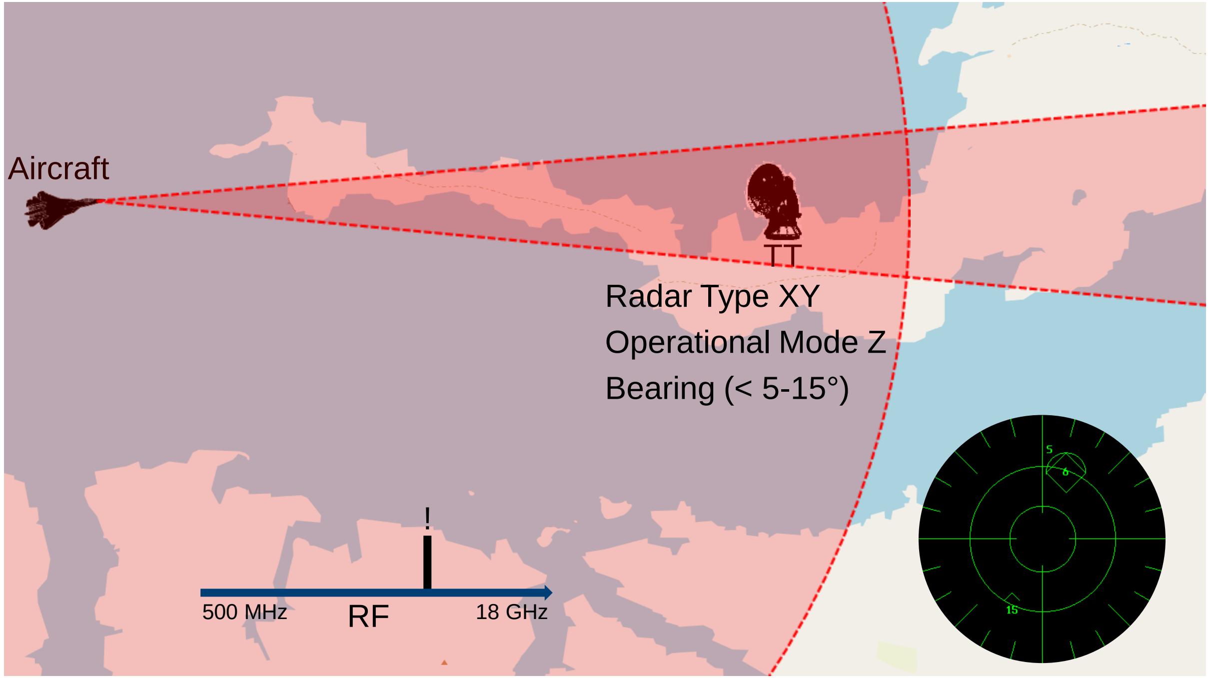




BACKGROUNDS ON ESM RECEIVERS

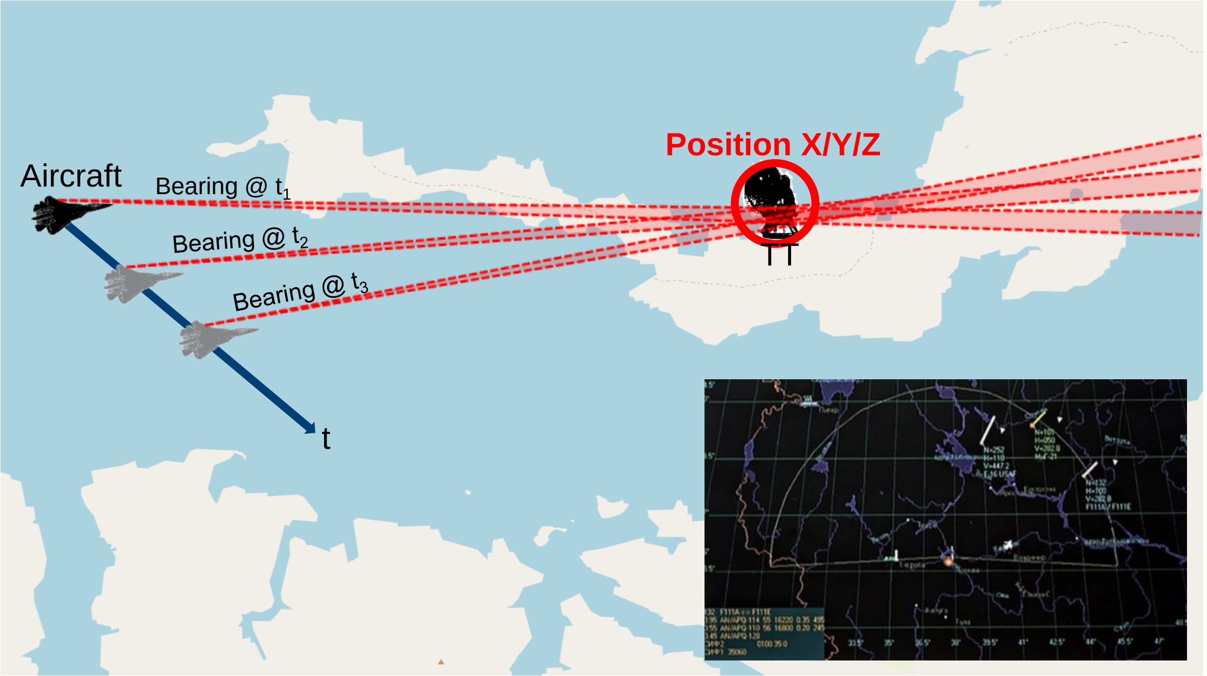
OPERATIONAL EXAMPLES
RADAR WARNING RECEIVER (RWR)

- 360° coverage (“bubble”)
- High Probability of Intercept (instantaneous RF coverage of full relevant bands)
- Classification (friend or foe) and identification of radar
- Detection of operational mode (indication of threat level e.g. search vs. track)
- rough bearing of emitter to align instant maneuvers or counter measures (EA)



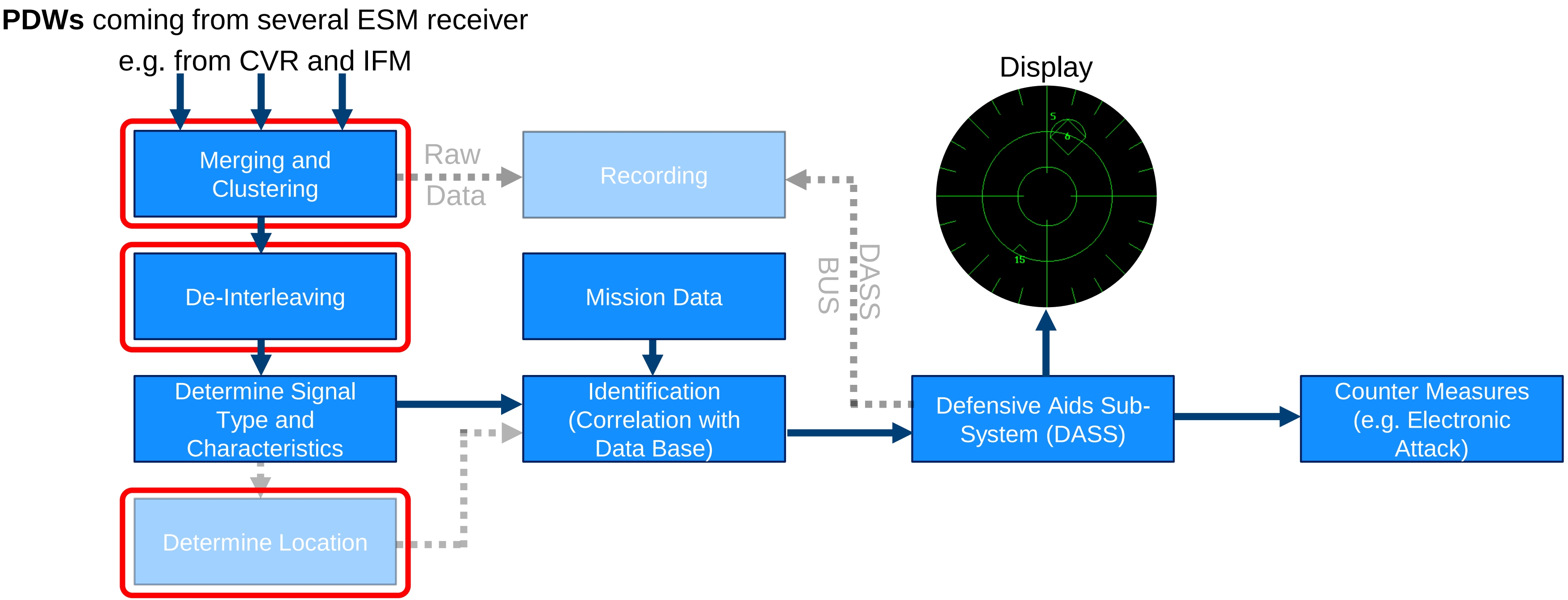
OPERATIONAL EXAMPLES
EMITTER LOCATION SYSTEM (ELS)

- ► Compared to RWR reaction times can be longer (~secs)
- ► 360° coverage not necessarily required
- ► Direction Finding has to be more accurate (~1-2°)
- ► Running fix processing along a flight path provide an exact position of an emitter
- ► Basic Data for Situational Awareness, Deployment of directed ECM or HARMs



BASIC PULSE PROCESSING
BLOCK DIAGRAM OF RWR/ESM PROCESSING

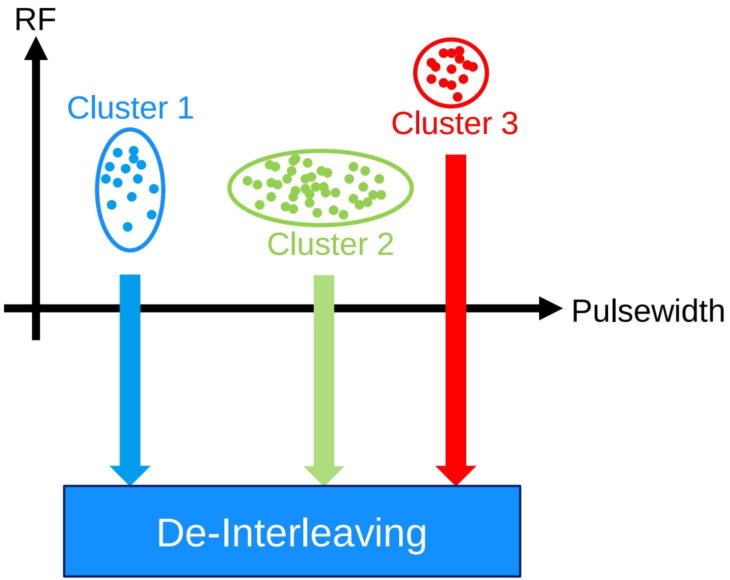
Block Diagram of ESM Processing



BASIC PULSE PROCESSING
CLUSTERING AND DE-INTERLEAVING

Clustering Part I

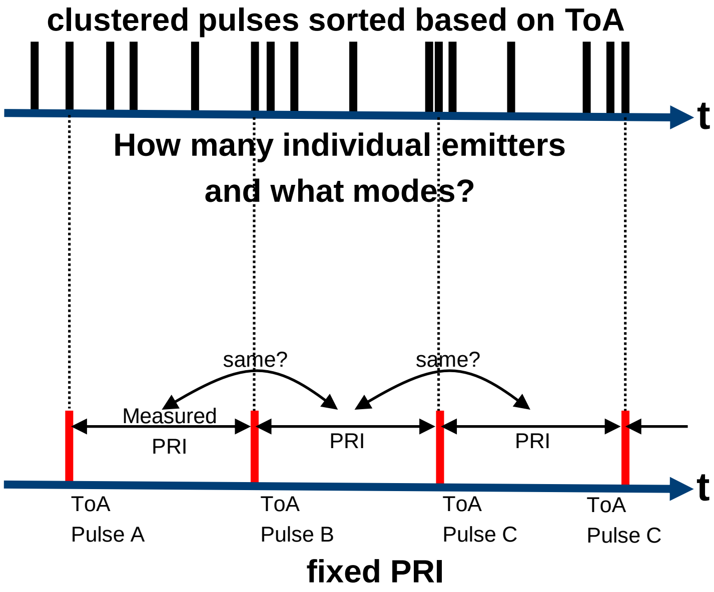
- To differentiate incoming signals normally clustering algorithms build “patches” of similar parameter
- In a modern scenario several million pulses per second must be processed in real-time
- PDWs of clusters are further processed by de-interleaveing



BASIC PULSE PROCESSING
CLUSTERING AND DE-INTERLEAVING

De-Interleaving and Identification Part I

- ► After clustering PDWs, multi-pulse analysis based on ToA of the individual pulses begins
  - – interpulse structures are evaluated iteratively
  - – this process is called de-interleaving, as it serves the purpose of separating individual modes and emitters
- ► Easiest example is an emitter with a fixed pulse repetition interval (PRI) structure
  - – PRI between two neighboring pulses is calculated
  - – is the PRI related to further pulses the same? If yes, then an emitter with a fixed PRI was found



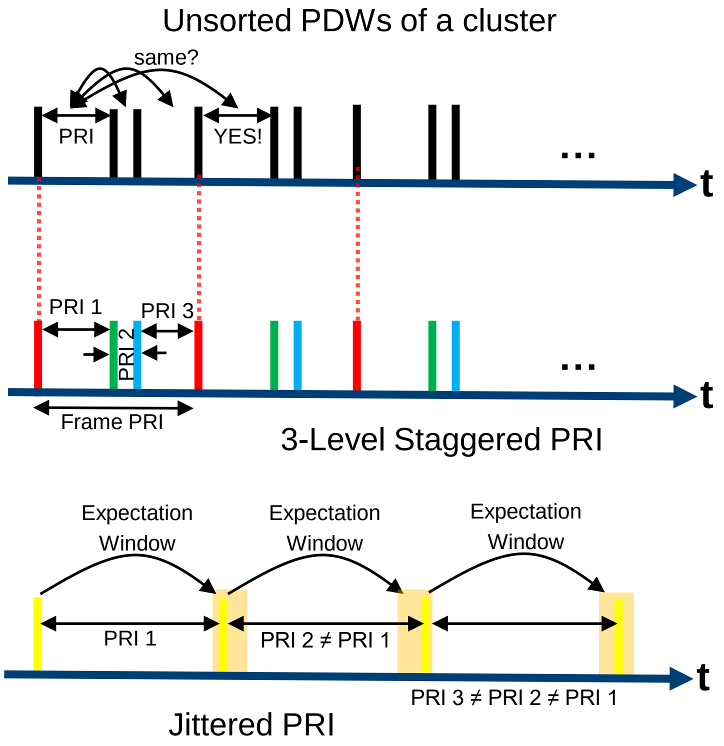
BASIC PULSE PROCESSING
CLUSTERING AND DE-INTERLEAVING

De-Interleaving and Identification Part II

- Two other examples on PRI structures

  Staggered PRI:
  - The PRI changes on a pulse basis but several fixed PRIs repeat in a (staggered) pattern
  - The time until the pattern repeats (the sum of individual PRIs) is called the frame PRI
  - Number of individual PRIs define the Stagger Level

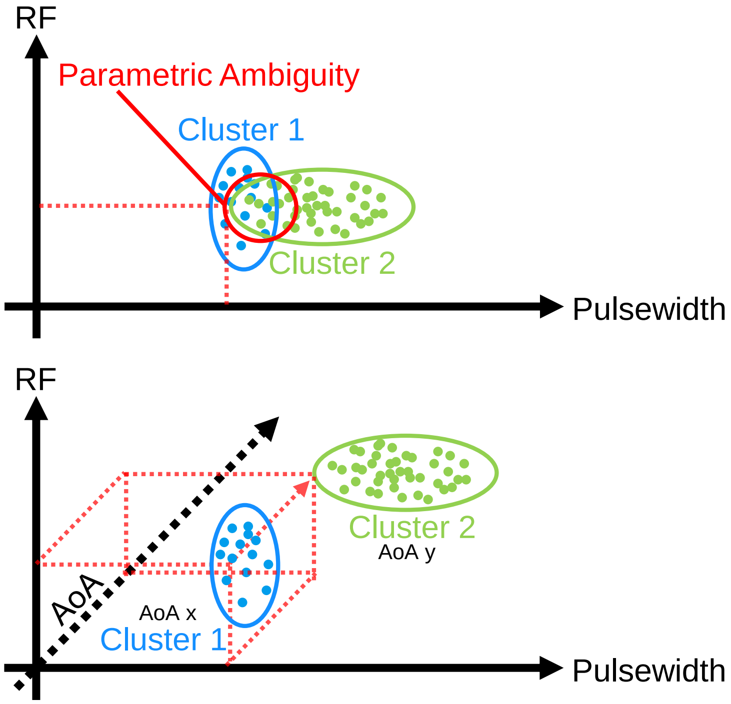
  Jittered PRI:
  - Radar does not operate with a determined PRI, but the PRI jitters (from ESM receivers perspective)
  - For matching, ToA of the next pulse has to be in an certain expectation window (jitter window)



BASIC PULSE PROCESSING
WHY ACCURATE ANGLE OF ARRIVAL IS NECESSARY

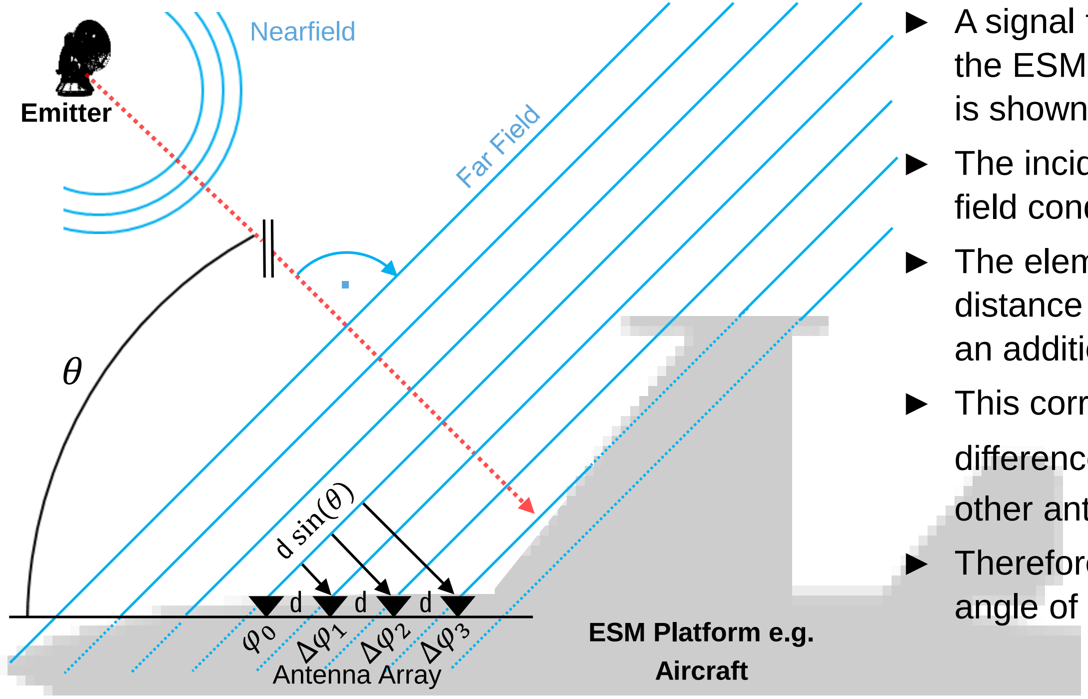
Clustering Part II

- Based on RF and PW only, emitters might overlap in their parametric
  - This poses a challenge to de-interleaving and identification as time stamps (ToA) are mixed for those emitters
- adding degrees of freedom per PDW for x-dimensional clustering helps to resolving those ambiguities. Most common:
  - intrapulse modulation schemes (FMOP etc.)
  - angle of arrival (high spatial resolution is necessary → Interferometry)



BASIC PULSE PROCESSING
PHASE MONOPULSE AOA (INTERFEROMETRY)

Phase Monopulse Angle of Arrival (Interferometer) – Part I

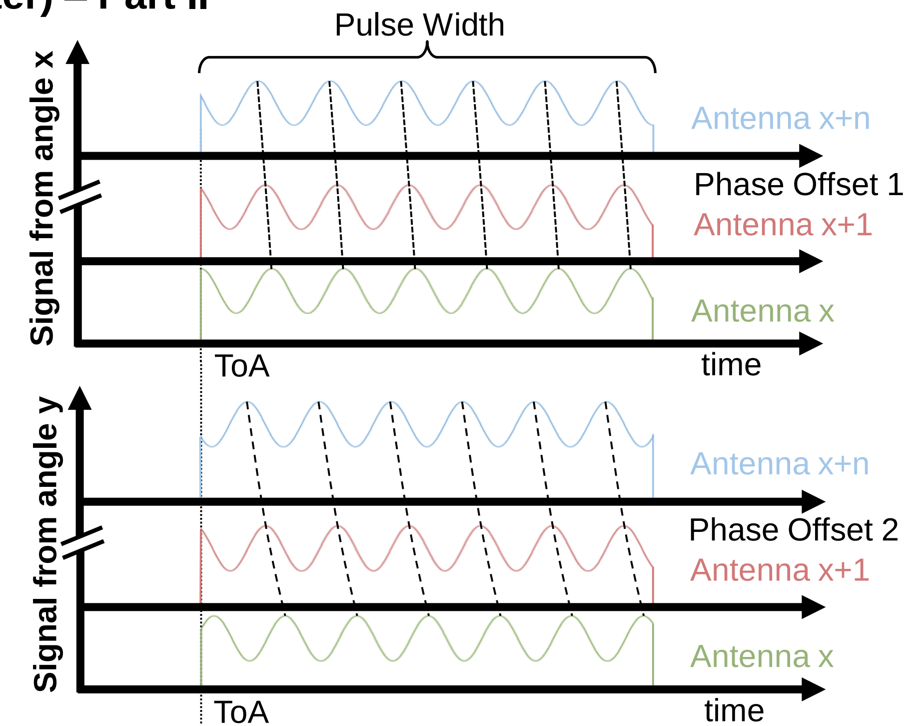


- A signal from an emitter with an angle θ compared to the ESM receiver antennas spatial plane as reference is shown
- The incident isophase surfaces are parallel due to far field conditions
- The elements of the antenna array are separated by a distance d, therefore the received signal has to travel an additional distance of $\mathrm{d} \cdot \sin(\theta)$
- This corresponds to a frequency dependent phase difference of $\Delta\varphi_n = \frac{2\pi}{\lambda} d \sin\theta$ between a reference and other antenna elements
- Therefore, with a measured phase difference the angle of arrival θ can be calculated

BASIC PULSE PROCESSING
DIRECTION FINDING AND EMITTER LOCATION

Phase Monopulse Angle of Arrival (Interferometer) – Part II

- Angles of arrival of the incident wave front translates to different phase offsets between the array elements
- The array architecture (number of elements) is dependent on the requirements of angular resolution



EFFICIENT TESTING OF MULTIPORT EW RECEIVERS
CHALLENGES REGARDING T&M

- An ESM receiver must be tested in an **complex signal environment**
  - The key question is, can ambiguous emitters be resolved
  - If a signal generator has to **drop pulses** due to pulse-on-pulse situations, the **de-interleaver is not tested under real-world conditions**!
  - High PRI Modes and High Duty Cycle Waveforms of modern radar systems and overall emitter density **make those situations the standard**, not the exception
- Testing of **interferometric based direction finding** requires signal generators, that are
  - **phase-coherent** over all ports, with good long time stability
  - **scalable**, especially in terms of number of ports
  - **easy to calibrate**

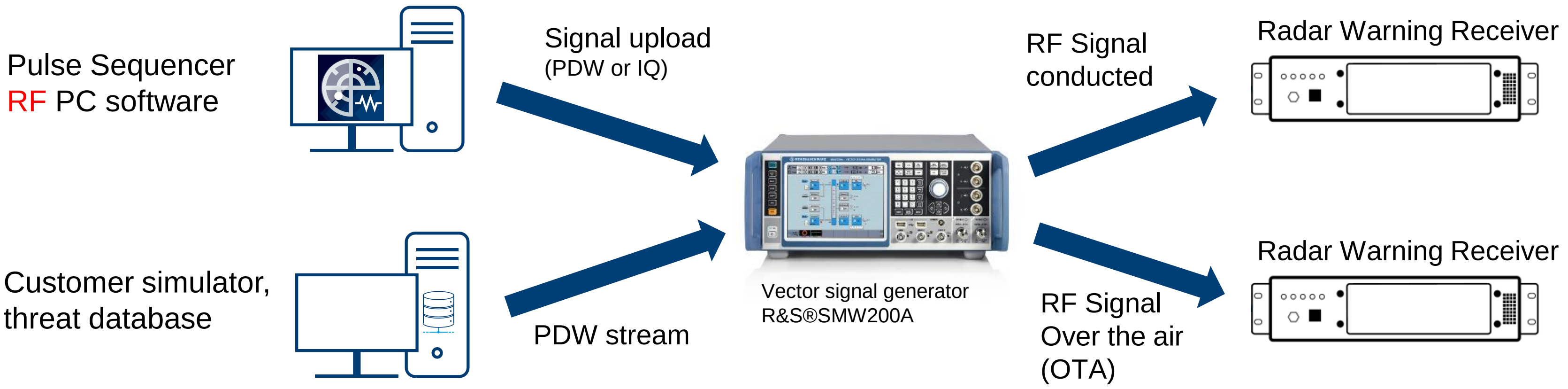
EFFICIENT TESTING OF MULTIPORT EW RECEIVERS
RADAR SIMULATOR MAIN CHALLENGES

- ► Scalable simulator hardware and software
- ► Phase coherent multiport testing
- ► Multi emitter signal generation

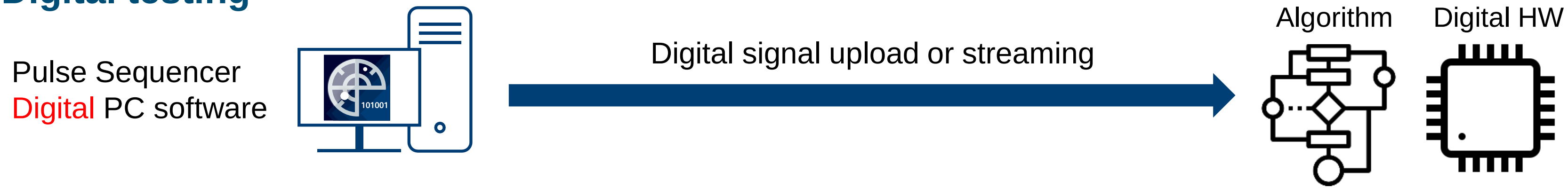
R&S COTS Two-port Radar Simulator

EFFICIENT TESTING OF MULTIPORT EW RECEIVERS
DIFFERENT FLAVOURS OF RWR TESTING

RF based testing



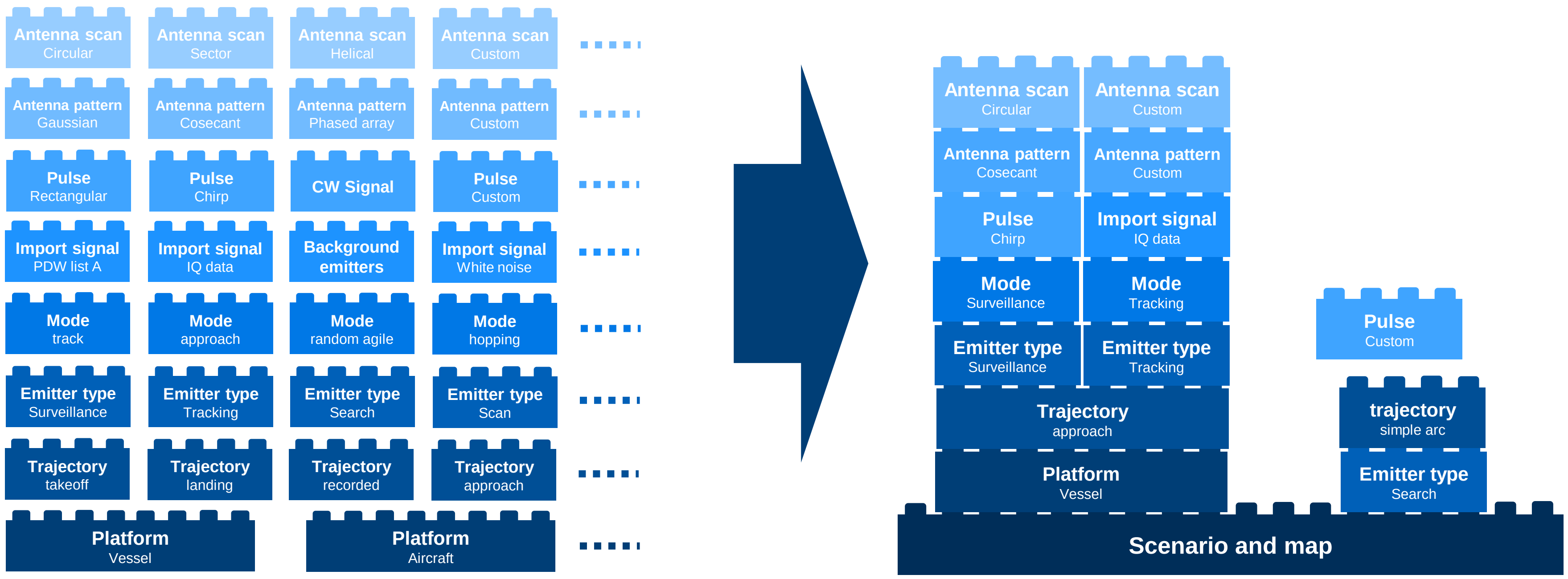
Digital testing



EFFICIENT TESTING OF MULTIPORT EW RECEIVERS
PULSE SEQUENCER SOFTWARE SCENARIO GENERATION

Pulse Sequencer bricks in data base

Pulse Sequencer Scenario



EFFICIENT TESTING OF MULTIPORT EW RECEIVERS
MULTIPORT SCALABILITY

2 RF Ports

Desktop

2x phase sync 44 GHz paths
2x3 pulse-on-pulse signals
2x6 MPDW/s or 1x12 MPDW/s

4 RF Ports

Mobile Rack

4x phase sync 44 GHz paths
4x3 pulse-on-pulse signals
4x6 MPDW/s or 2x12 MPDW/s
Including network analyzer

8 RF Ports

Rack Mounted

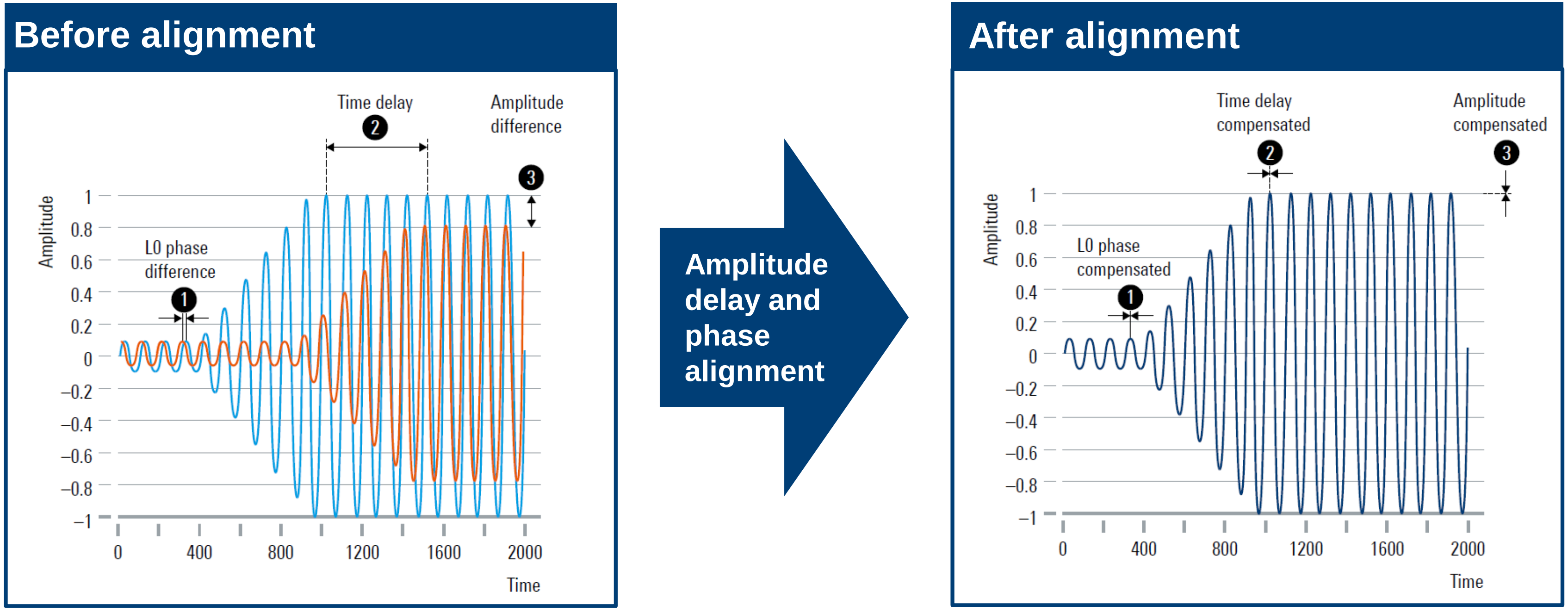
8x phase sync 44 GHz paths
8x3 pulse-on-pulse signals
8x6 MPDW/s or 4x12 MPDW/s
Including network analyzer

24 RF Ports

Multi Rack

1x24 paths or 3x independent racks, each 8x 44 GHz
24x3 pulse-on-pulse signals
24x6 MPDW/s or 12x12 MPDW/s
Incl. calibration and 3x high performance LO

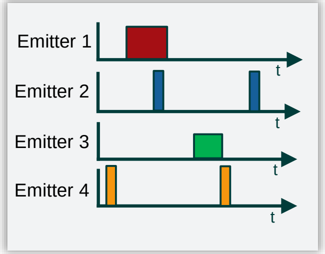
EFFICIENT TESTING OF MULTIPORT EW RECEIVERS
PHASE COHERENT RF SIGNAL GENERATION



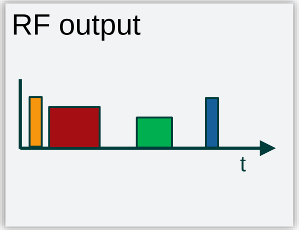
The RF Port Alignments software together with an R&S vector network analyzer provides a standard and tailored solution for calibrating amplitude, time and phase of multiport vector signal generator setups.

EFFICIENT TESTING OF MULTIPORT EW RECEIVERS
CHALLENGES IN MULTI EMITTER SIGNAL GENERATION

Scenario input

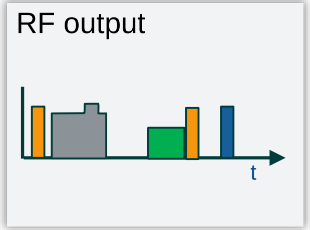


Interleaving of pulses



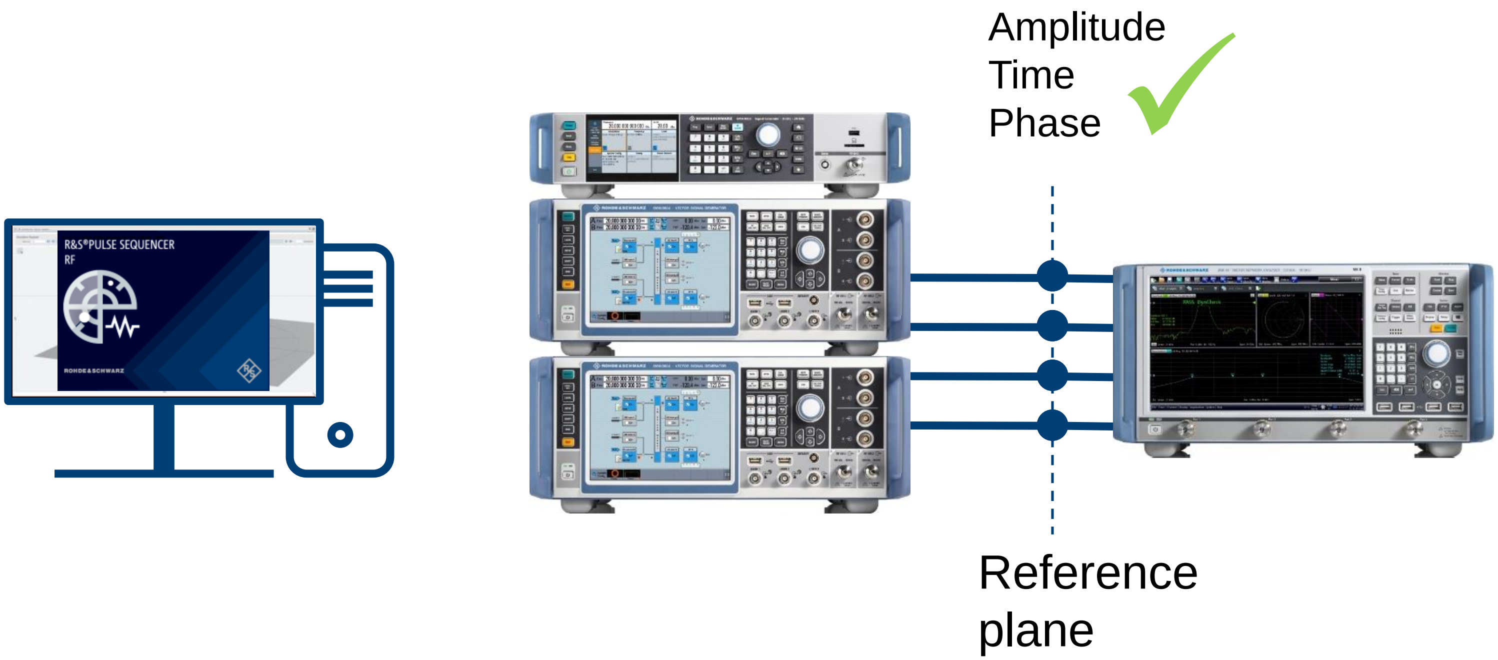
- If two pulses overlap in time, the least important will be dropped
- Emitter priorities can be assigned
- Good and cost efficient solution to simulate hundreds of emitters
- Signals are NOT realistic due to missing pulses

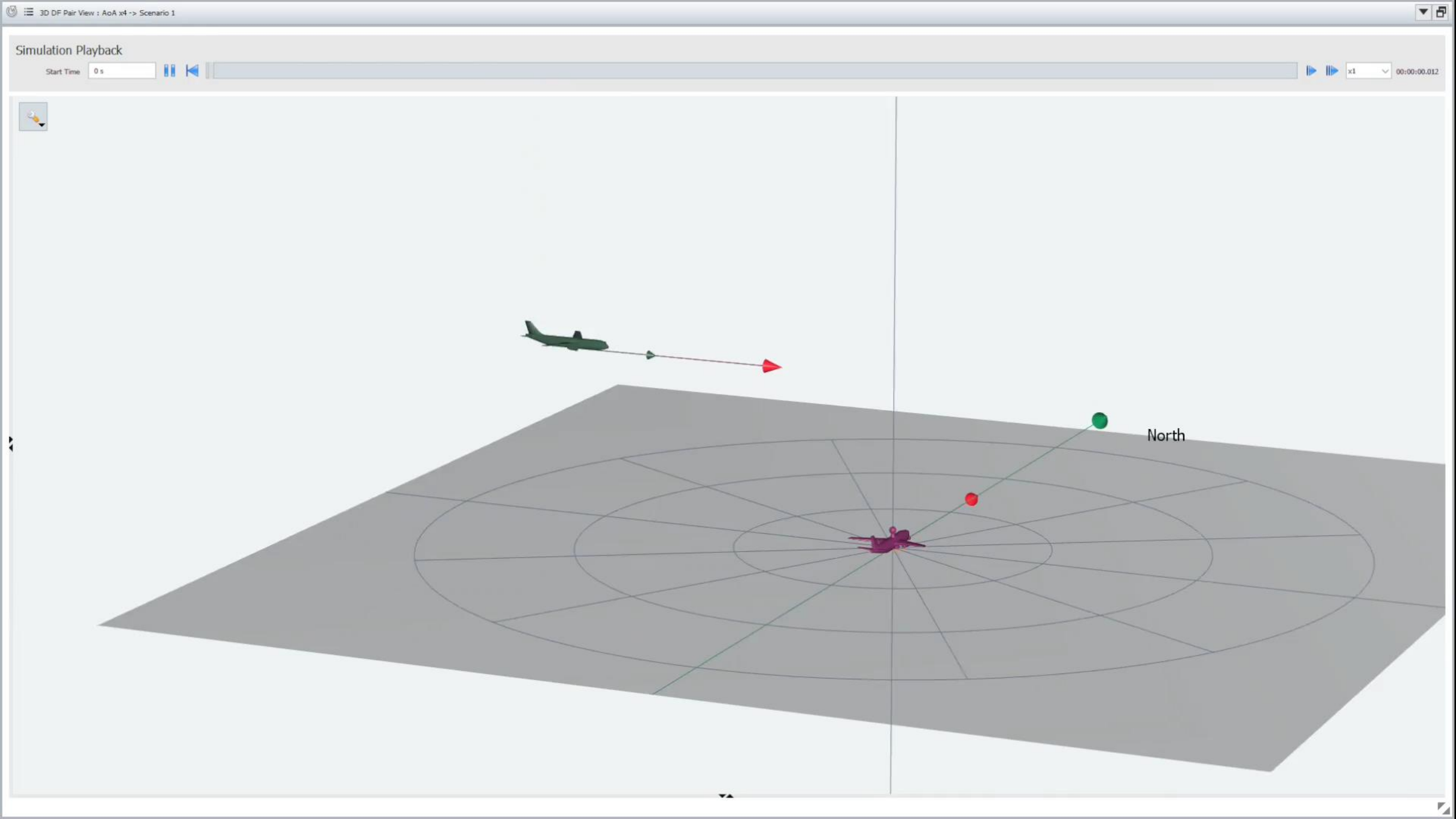
Pulse-on-pulse signals



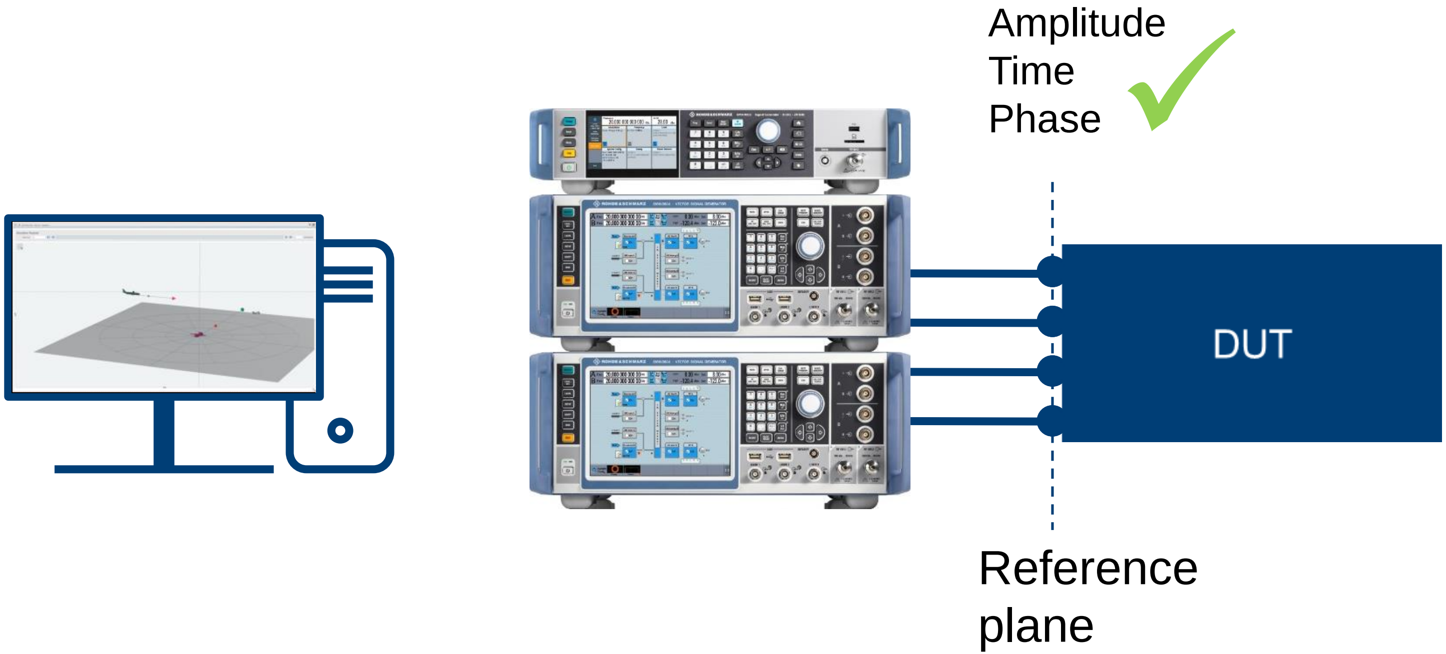
- NO pulse dropping
- Overlaps are treated like in the field
- 6 pulse-on-pulse emitters per RF path
- In the past, costly and bulky test setups
- Now, extremely compact one box solution

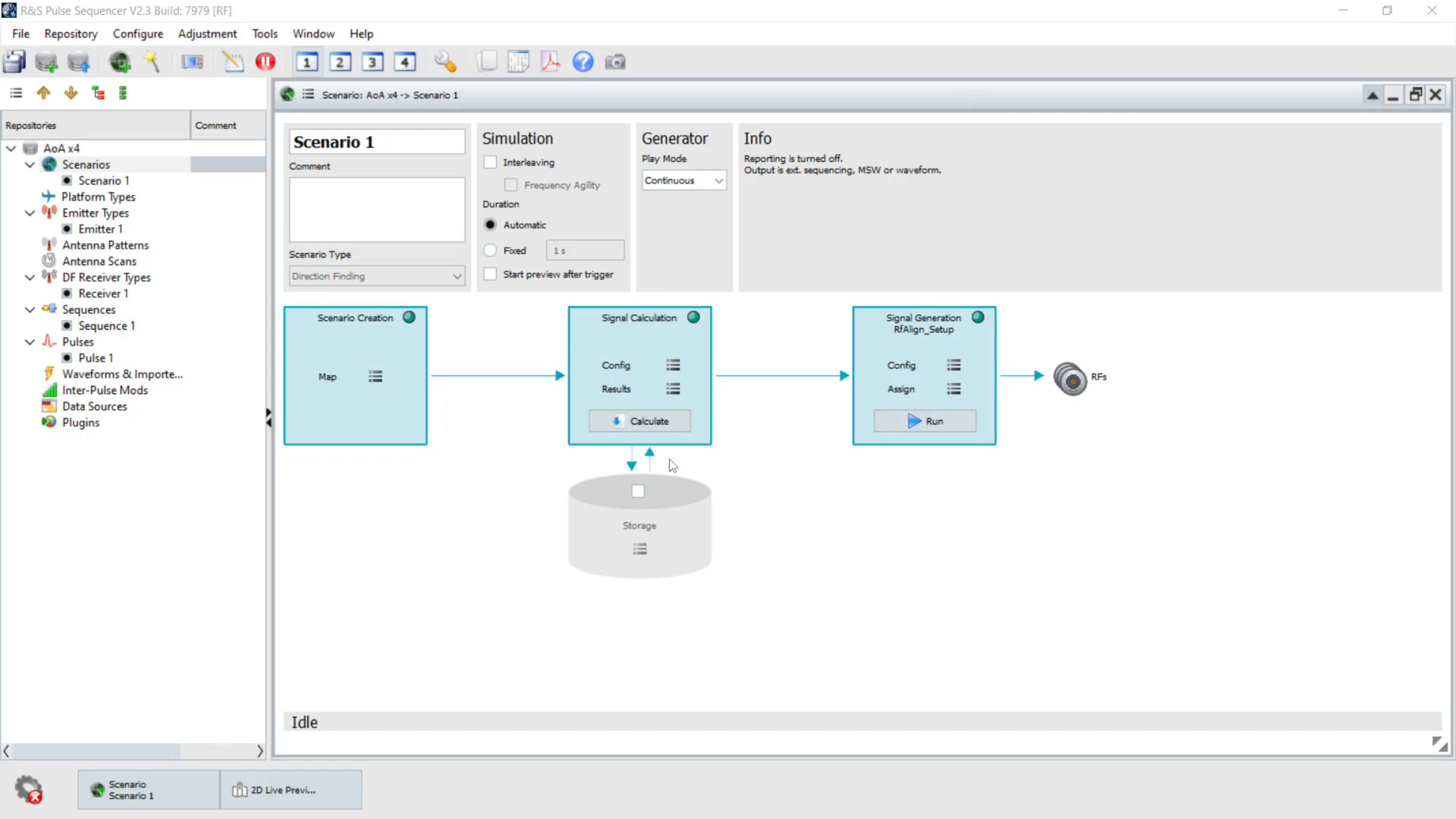
EFFICIENT TESTING OF MULTIPORT EW RECEIVERS
DEMONSTRATION OF AN EXEMPLARY TEST SETUP

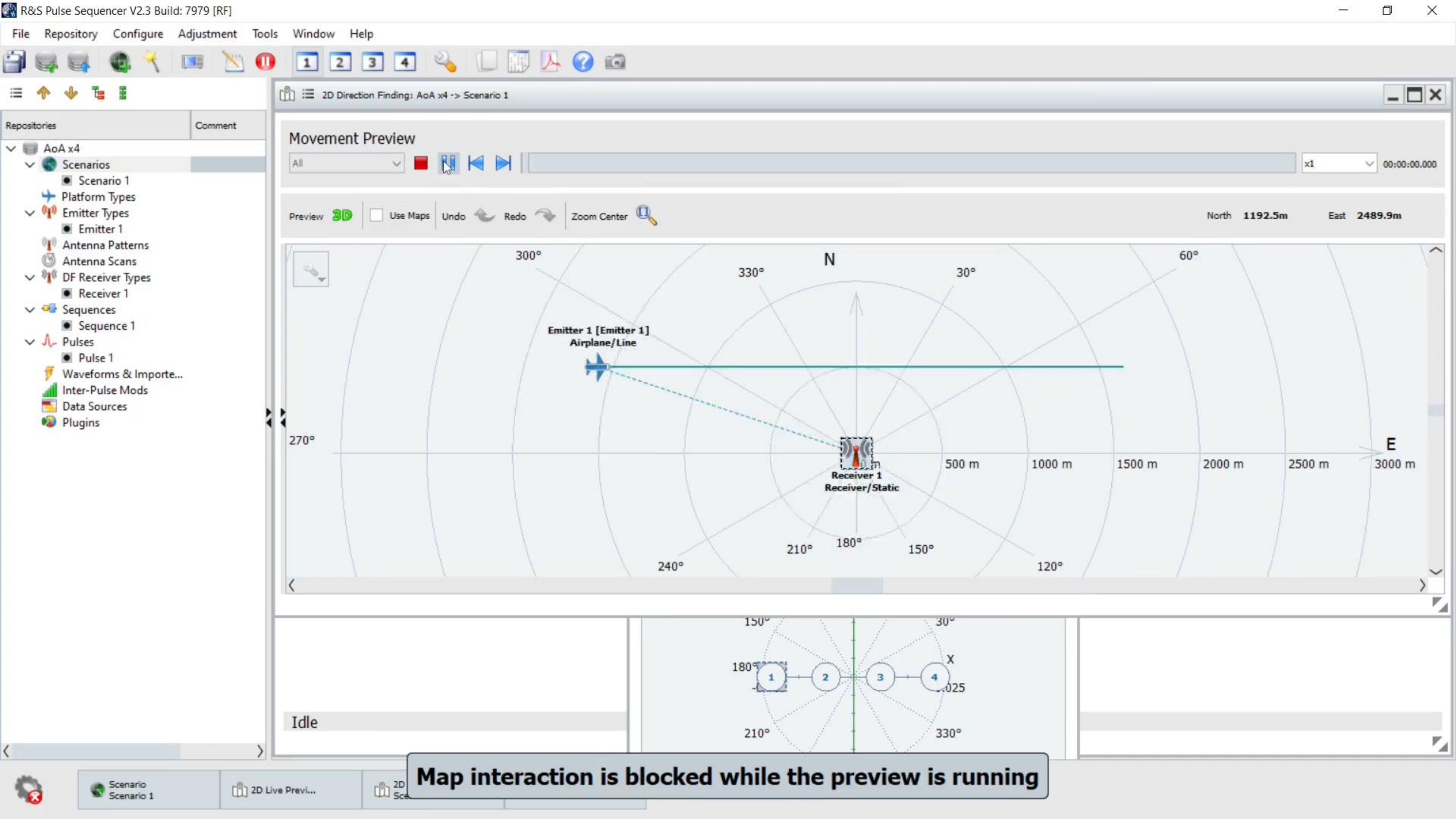


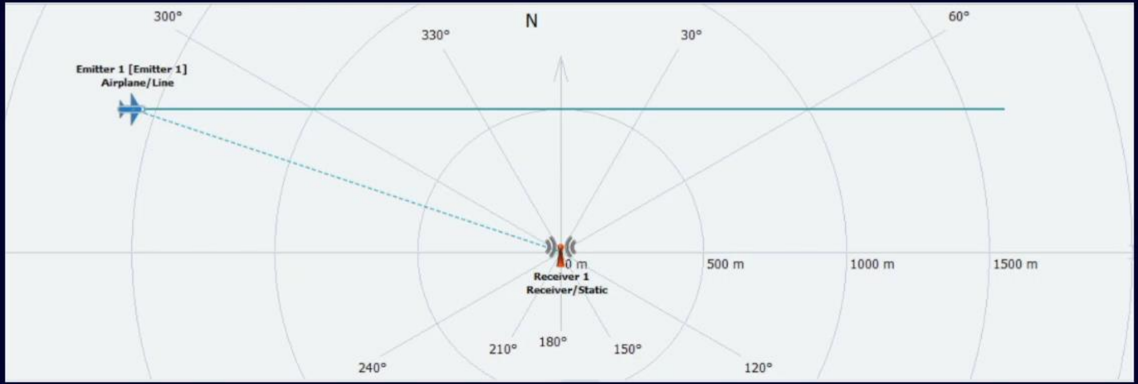

3D DF Pair View : AoA x4 -> Scenario 1
Simulation Playback
Start Time
0 s
x1
00:00:00.012
North

EFFICIENT TESTING OF MULTIPORT EW RECEIVERS
DEMONSTRATION OF AN EXEMPLARY TEST SETUP



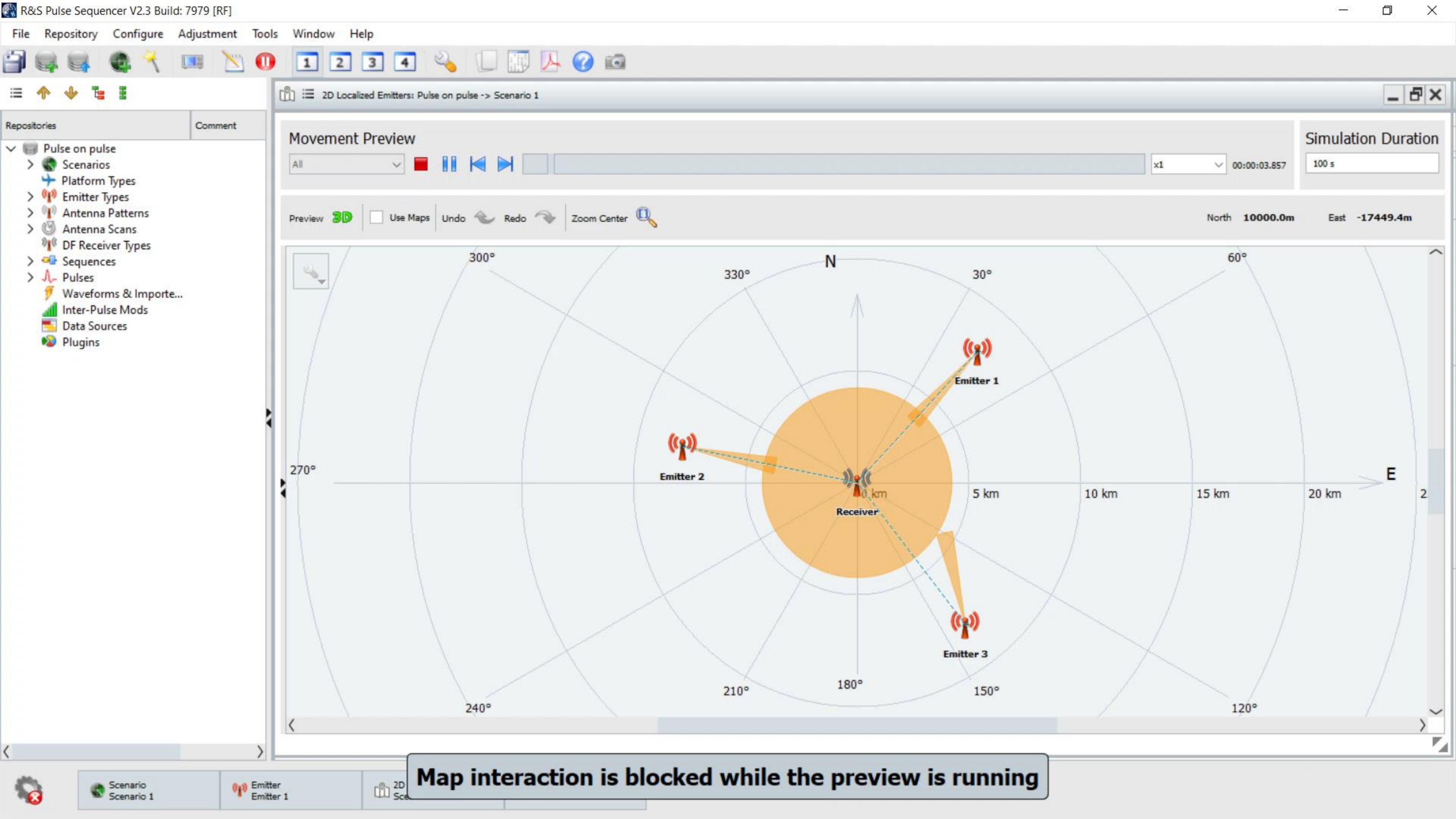

R&S Pulse Sequencer V2.3 Build: 7979 [RF]
File
Repository
Configure
Adjustment
Tools
Window
Help
Scenario: AoA x4 -> Scenario 1
Repositories
Comment
AoA x4
Scenarios
Scenario 1
Platform Types
Emitter Types
Emitter 1
Antenna Patterns
Antenna Scans
DF Receiver Types
Receiver 1
Sequences
Sequence 1
Pulses
Pulse 1
Waveforms & Importe...
Inter-Pulse Mods
Data Sources
Plugins
Scenario 1
Comment
Scenario Type
Direction Finding
Simulation
Interleaving
Frequency Agility
Duration
Automatic
Fixed
1 s
Start preview after trigger
Generator
Play Mode
Continuous
Info
Reporting is turned off.
Output is ext. sequencing, MSW or waveform.
Scenario Creation
Map
Signal Calculation
Config
Results
Calculate
Signal Generation
RfAlign_Setup
Config
Assign
Run
RFs
Storage
Idle
Scenario
Scenario 1
2D Live Previ...

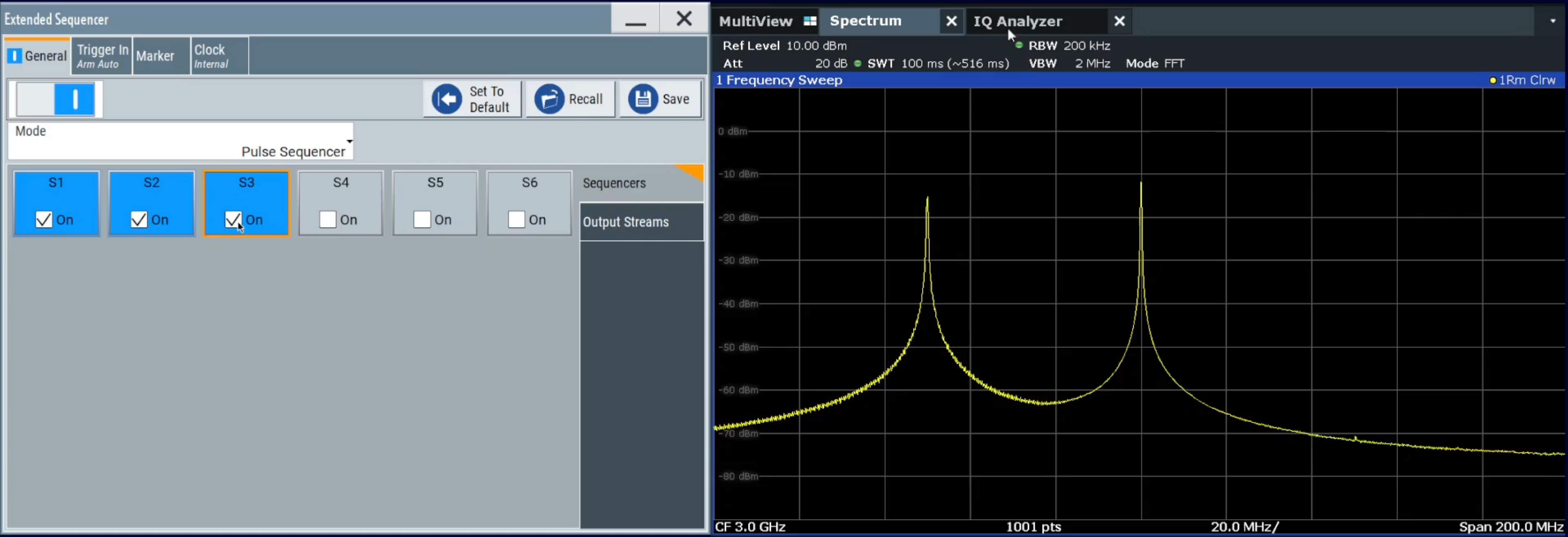

R&S Pulse Sequencer V2.3 Build: 7979 [RF]
File Repository Configure Adjustment Tools Window Help
2D Direction Finding: AoA x4 -> Scenario 1
Repositories
Comment
AoA x4
Scenarios
Scenario 1
Platform Types
Emitter Types
Emitter 1
Antenna Patterns
Antenna Scans
DF Receiver Types
Receiver 1
Sequences
Sequence 1
Pulses
Pulse 1
Waveforms & Importe...
Inter-Pulse Mods
Data Sources
Plugins
Movement Preview
All
x1
00:00:00.000
Preview 3D
Use Maps
Undo
Redo
Zoom Center
North 1192.5m
East 2489.9m
N
E
300°
330°
30°
60°
270°
240°
210°
180°
150°
120°
500 m
1000 m
1500 m
2000 m
2500 m
3000 m
Emitter 1 [Emitter 1]
Airplane/Line
Receiver 1
Receiver/Static
Idle
1
2
3
4
X
Scenario
Scenario 1
2D Live Previ...
Map interaction is blocked while the preview is running

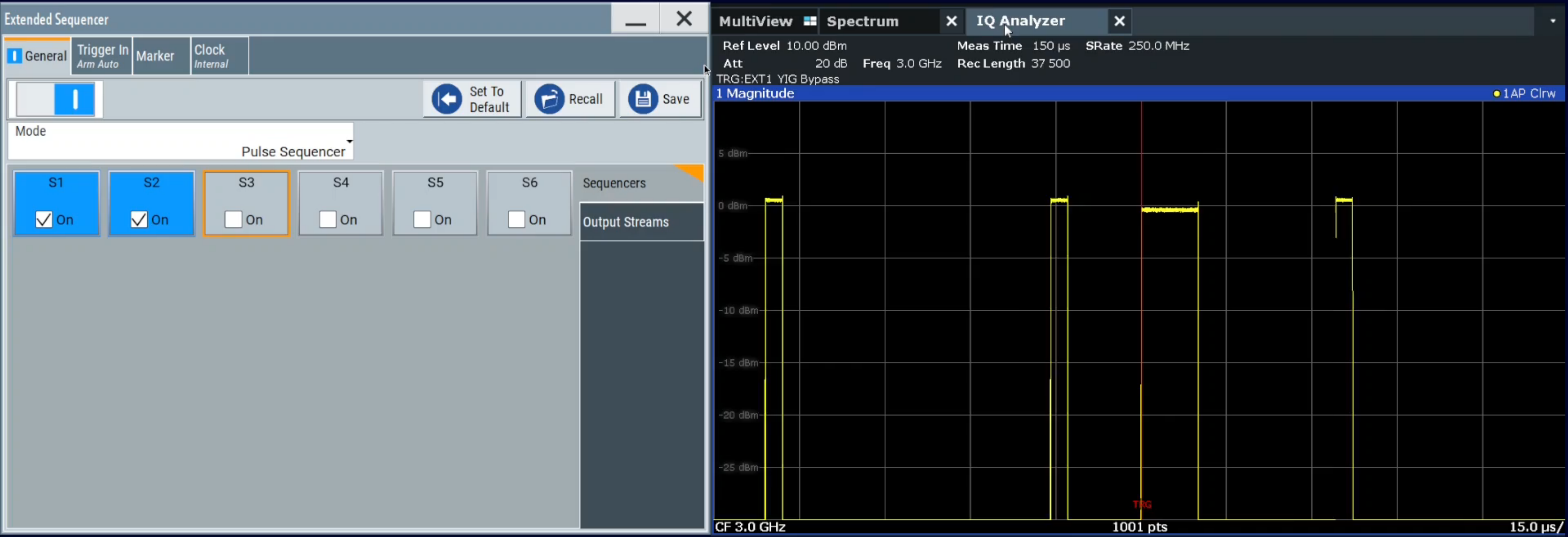


Amplitudes
(all traces coincident)

Phase differences
(all traces coincident)


R&S Pulse Sequencer V2.3 Build: 7979 [RF]
File Repository Configure Adjustment Tools Window Help
Repositories
Comment
Pulse on pulse
Scenarios
Platform Types
Emitter Types
Antenna Patterns
Antenna Scans
DF Receiver Types
Sequences
Pulses
Waveforms & Importe...
Inter-Pulse Mods
Data Sources
Plugins
2D Localized Emitters: Pulse on pulse -> Scenario 1
Movement Preview
All
x1
00:00:03.857
Simulation Duration
100 s
Preview 3D
Use Maps
Undo
Redo
Zoom Center
North 10000.0m
East -17449.4m
N
E
300°
330°
30°
60°
270°
240°
210°
180°
150°
120°
5 km
10 km
15 km
20 km
Emitter 1
Emitter 2
Emitter 3
Receiver
Scenario
Scenario 1
Emitter
Emitter 1
Map interaction is blocked while the preview is running


Extended Sequencer
General
Trigger In
Arm Auto
Marker
Clock
Internal
Set To Default
Recall
Save
Mode
Pulse Sequencer
S1
S2
S3
S4
S5
S6
On
Sequencers
Output Streams
MultiView
Spectrum
IQ Analyzer
Ref Level 10.00 dBm
Att 20 dB
SWT 100 ms (~516 ms)
RBW 200 kHz
VBW 2 MHz
Mode FFT
1 Frequency Sweep
1Rm Clrw
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
CF 3.0 GHz
1001 pts
20.0 MHz/
Span 200.0 MHz


Extended Sequencer
General
Trigger In
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Set To Default
Recall
Save
Mode
Pulse Sequencer
S1
On
S2
On
S3
On
S4
On
S5
On
S6
On
Sequencers
Output Streams
MultiView
Spectrum
IQ Analyzer
Ref Level 10.00 dBm
Att 20 dB
Freq 3.0 GHz
Meas Time 150 µs
Rec Length 37 500
SRate 250.0 MHz
TRG:EXT1 YIG Bypass
1 Magnitude
1AP Clrw
5 dBm
0 dBm
-5 dBm
-10 dBm
-15 dBm
-20 dBm
-25 dBm
TRG
CF 3.0 GHz
1001 pts
15.0 µs/

R&S RADAR SIMULATOR

- The powerful radar environment simulator
- Unprecedented flexibility
- Scalable COTS hardware & software
- Pulse-on-Pulse signals out of a single unit
- Up to 44 GHz with 2 GHz bandwidth

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