

Latest RF Signal Monitoring and Analysis Trends & Solutions in Aerospace & Defence Applications

Andrew Benn, Application Engineer

Innovators

 **start here**

Keysight's Breadth and Depth Supports Your Innovations



¹As per company estimate ²Includes indirect channel ³As of fiscal year end ⁴As per external sources
⁵Sites with >50 R&D engineers

Key Statistics

\$5.4B
2022 Revenue

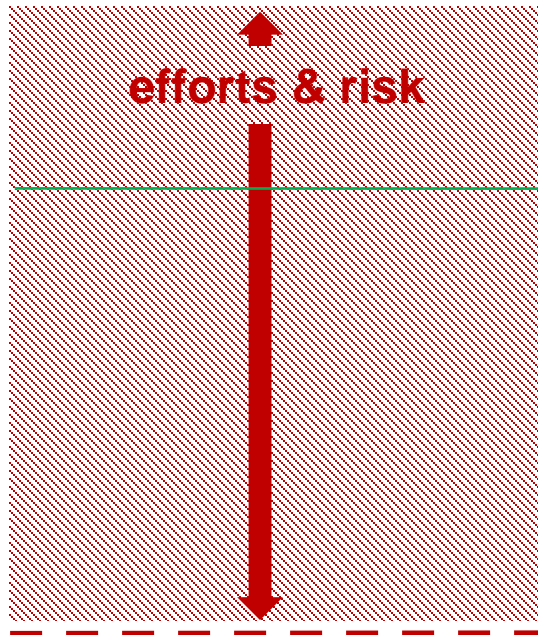
2,000+
Patents

100+
Countries Served

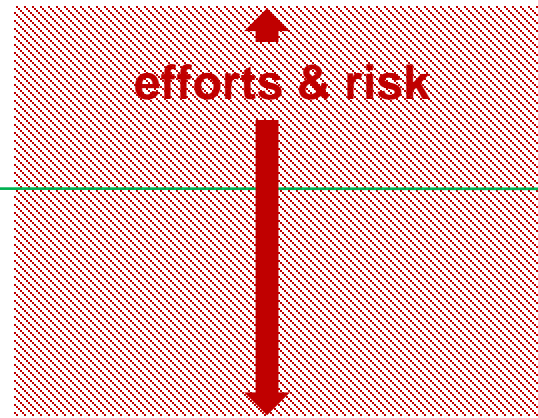
~14.3K
Employees

Keysight Different Solution Abstraction Levels

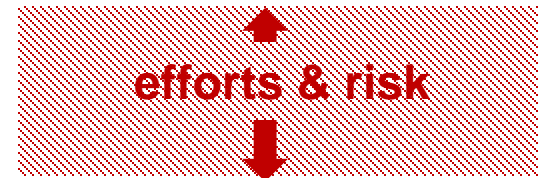
Solution Level: higher confidence, shorter dev. time, less risk



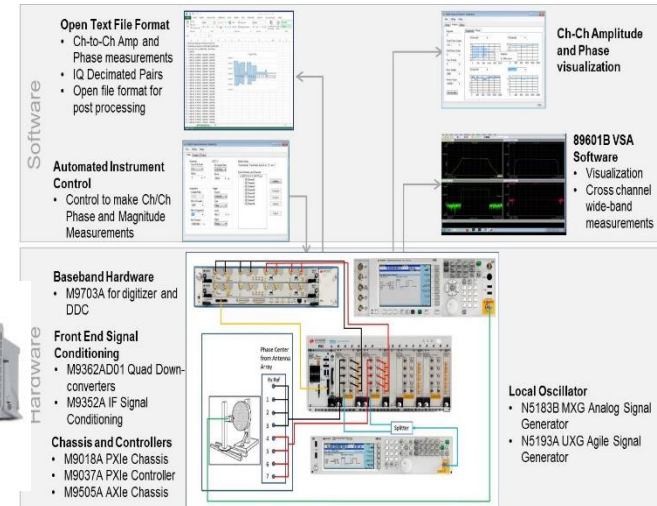
Instruments



**HW & SW Components
Consulting services**



Keysight Application Solution



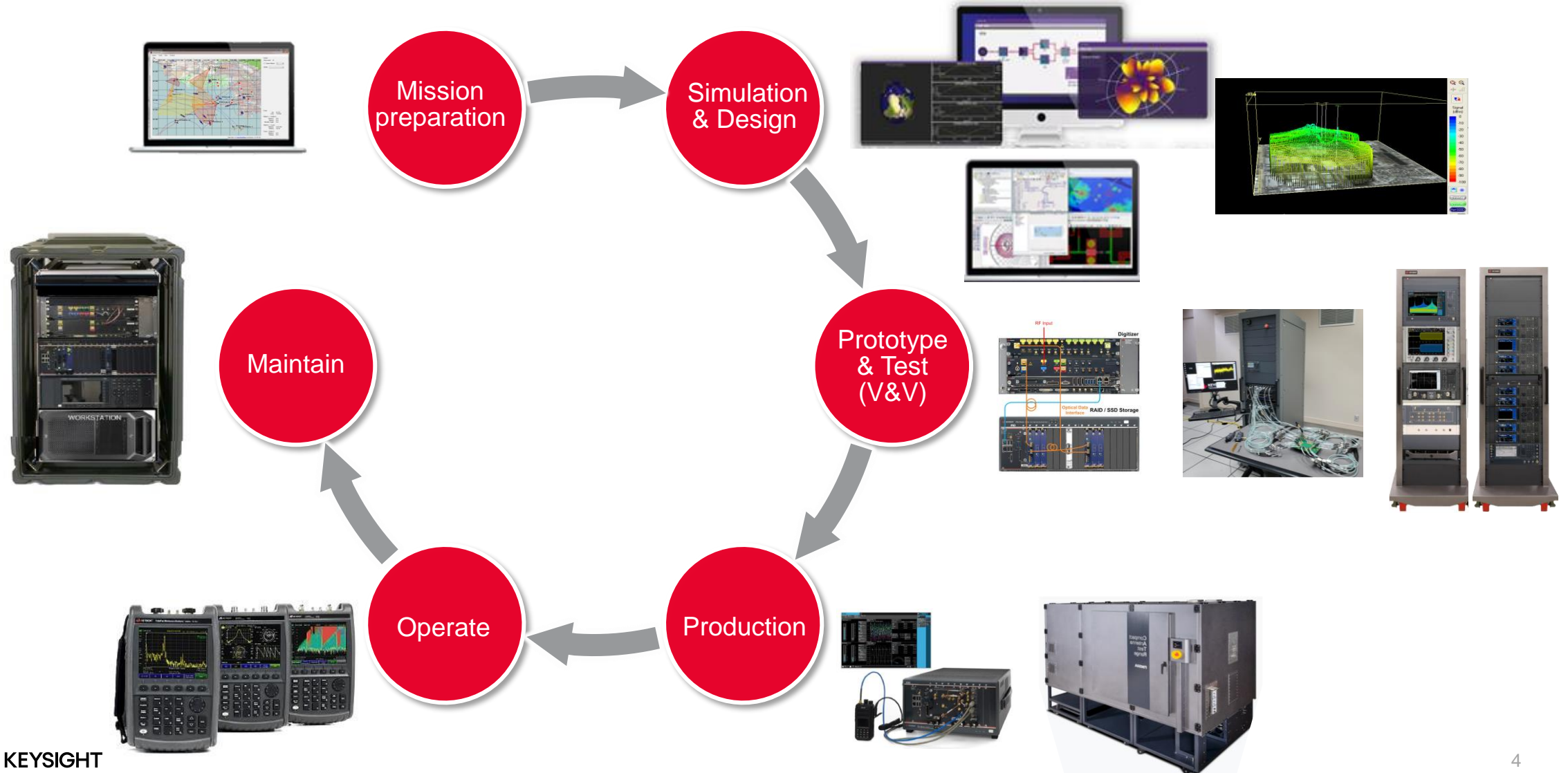
**Keysight Custom
& Turnkey Solution**



Modular and scalable architectures

Keysight solution approach

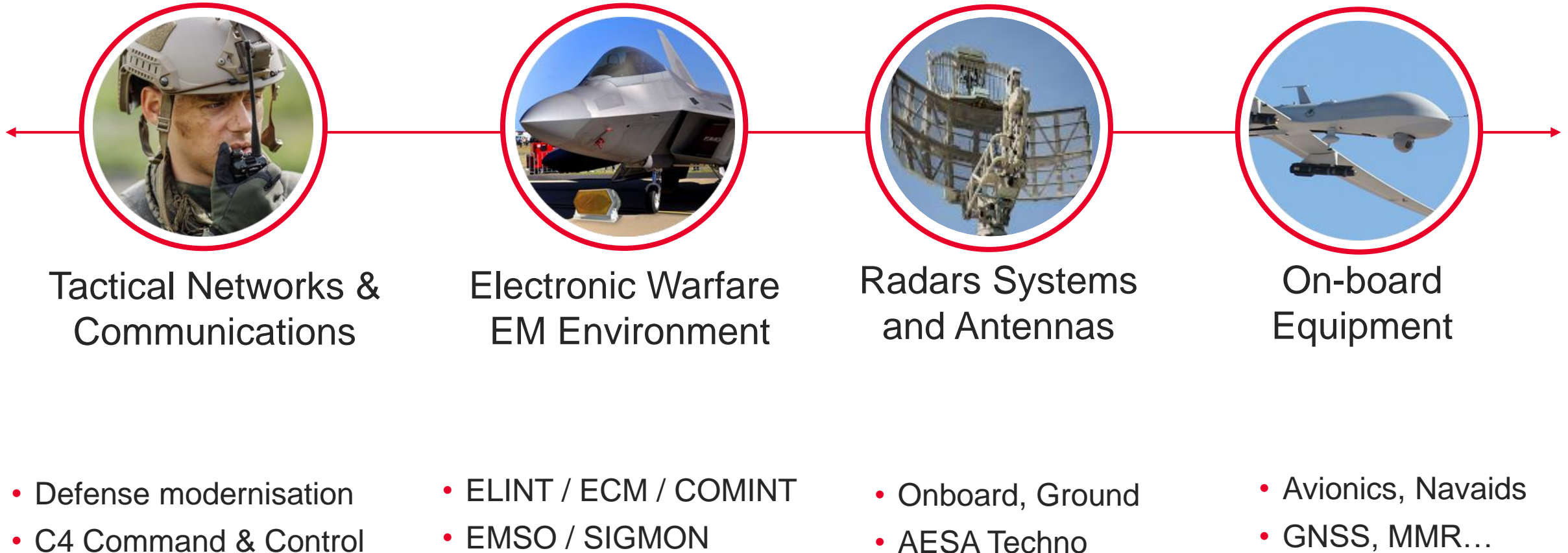
TOOLS THAT SUPPORT THE ENTIRE LIFECYCLE OR WORKFLOW



Latest signal analysis trends in Aerospace & Defense



Defense applications and Key challenges



EXata Network Modeling

Application
Presentation
Session
Transport
Network
Data Link
Physical

L1-L7 Protocols

Routing
Encryption
QoS
Latency
Multi-hop

mobility

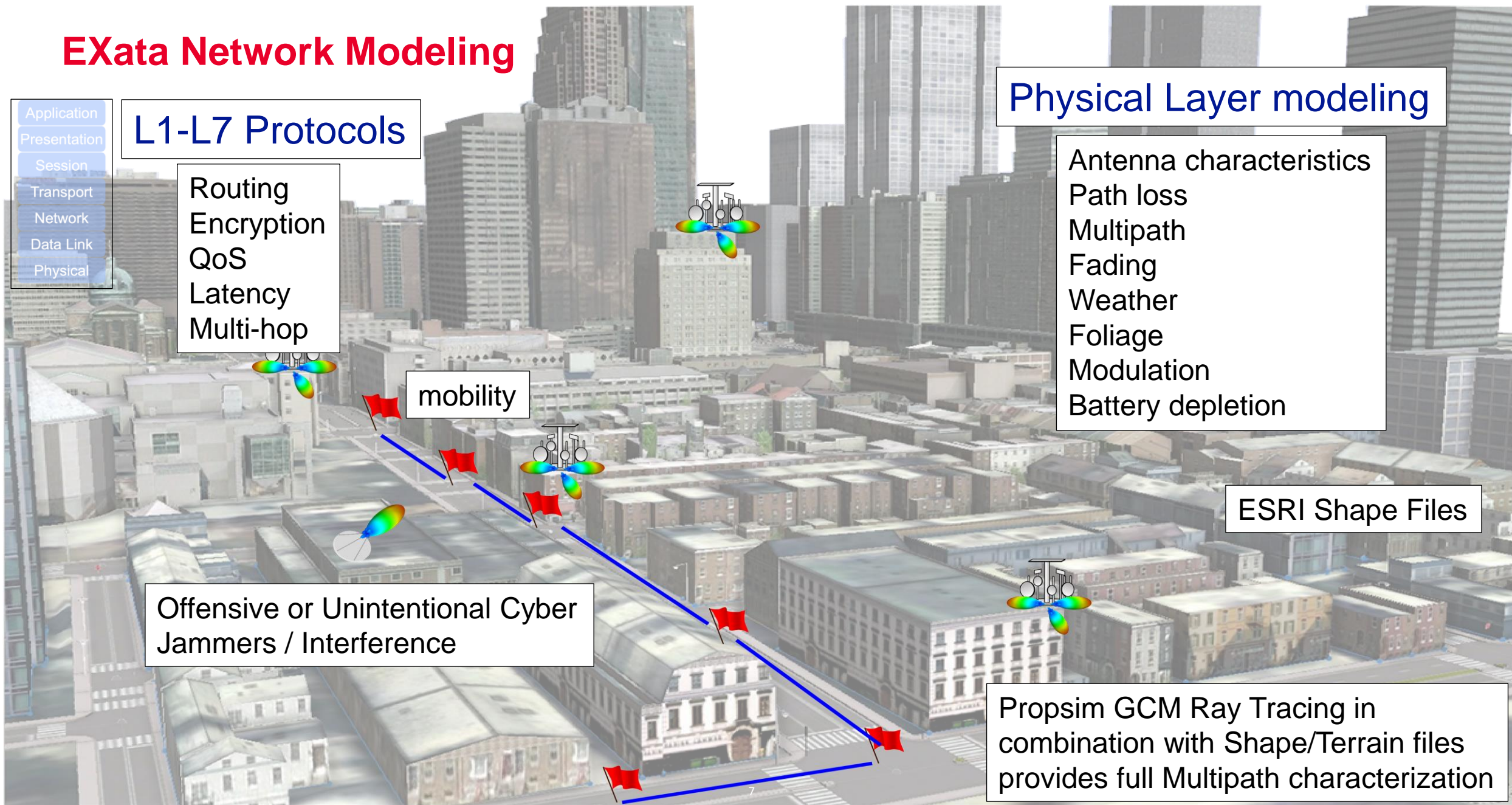
Offensive or Unintentional Cyber
Jammers / Interference

Physical Layer modeling

Antenna characteristics
Path loss
Multipath
Fading
Weather
Foliage
Modulation
Battery depletion

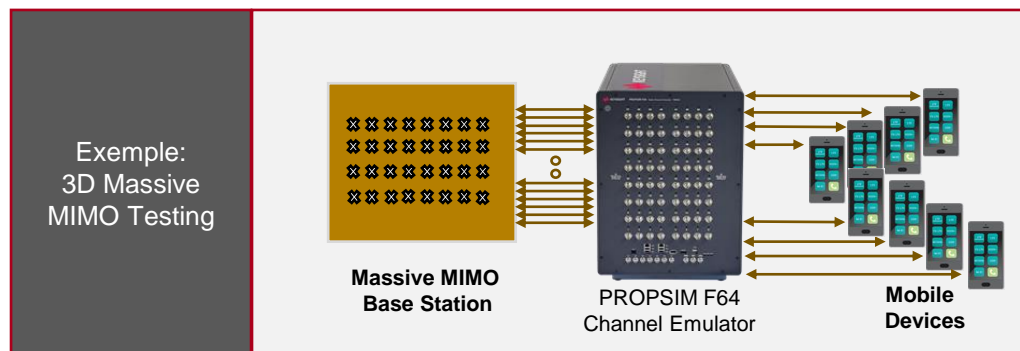
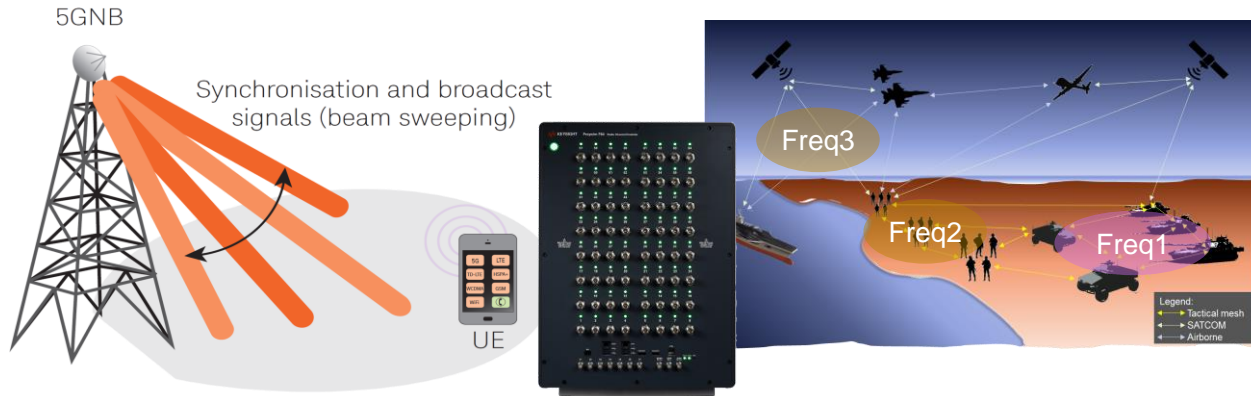
ESRI Shape Files

Propsim GCM Ray Tracing in
combination with Shape/Terrain files
provides full Multipath characterization



Tactical Mobile ad-hoc networks «MANET» Test

Keysight Virtual battlefield Emulation in laboratory based on Channel Emulation Solution - PROPSIM

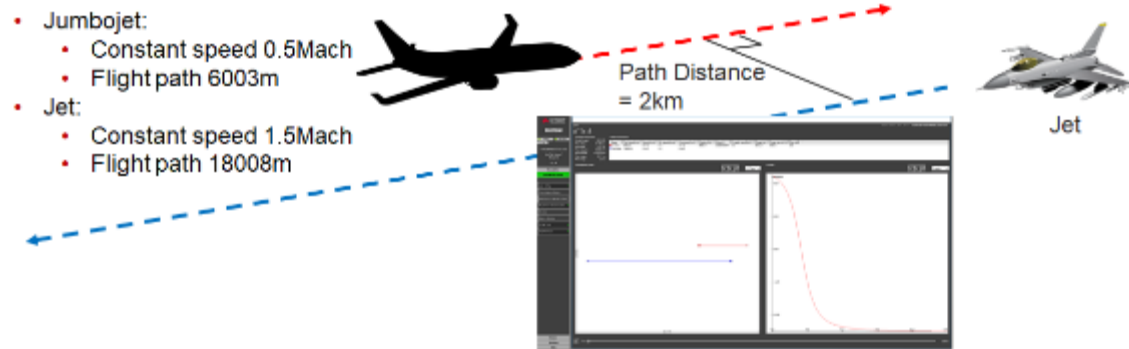


- Channel modeling tools with accurate signal fading processing (time, phase, and amplitude)
- Advanced and intuitive geometric channel modeling GCM tool to create mobile network dynamic topology
- Dynamic scenarios and advanced modeling of an entire operational environment, including multi-link and multi-antenna configurations.
- Terrestrial, Airborne (with High velocity) and Long-range emulation for SATCOM
- Test up to 64 Radios and supporting frequency hopping scenarios.
- Wide testing capacities...

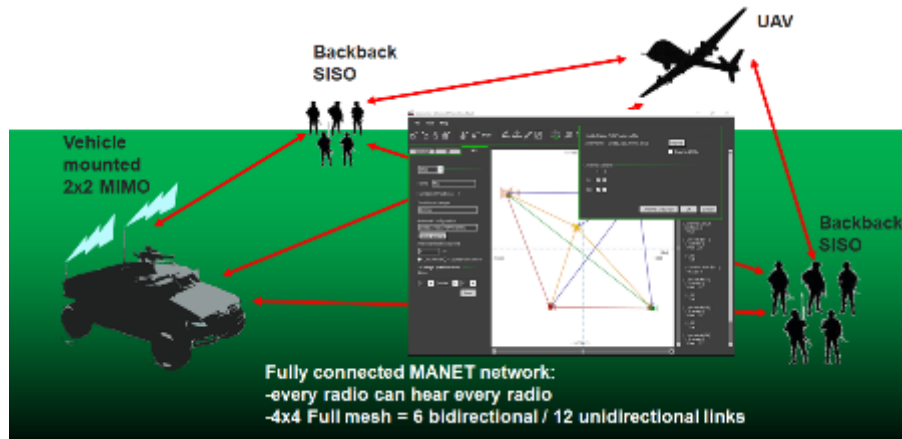
Key Benefits:

- Scalable Multi-Radio Network Emulation
- Duplicate realistic field conditions in an accurate and repeatable manner.
- Address end-to-end performance and interoperability testing of mobile

Aerospace channel emulation option



Aerospace & Defense Model creation for realistic environmental modelling



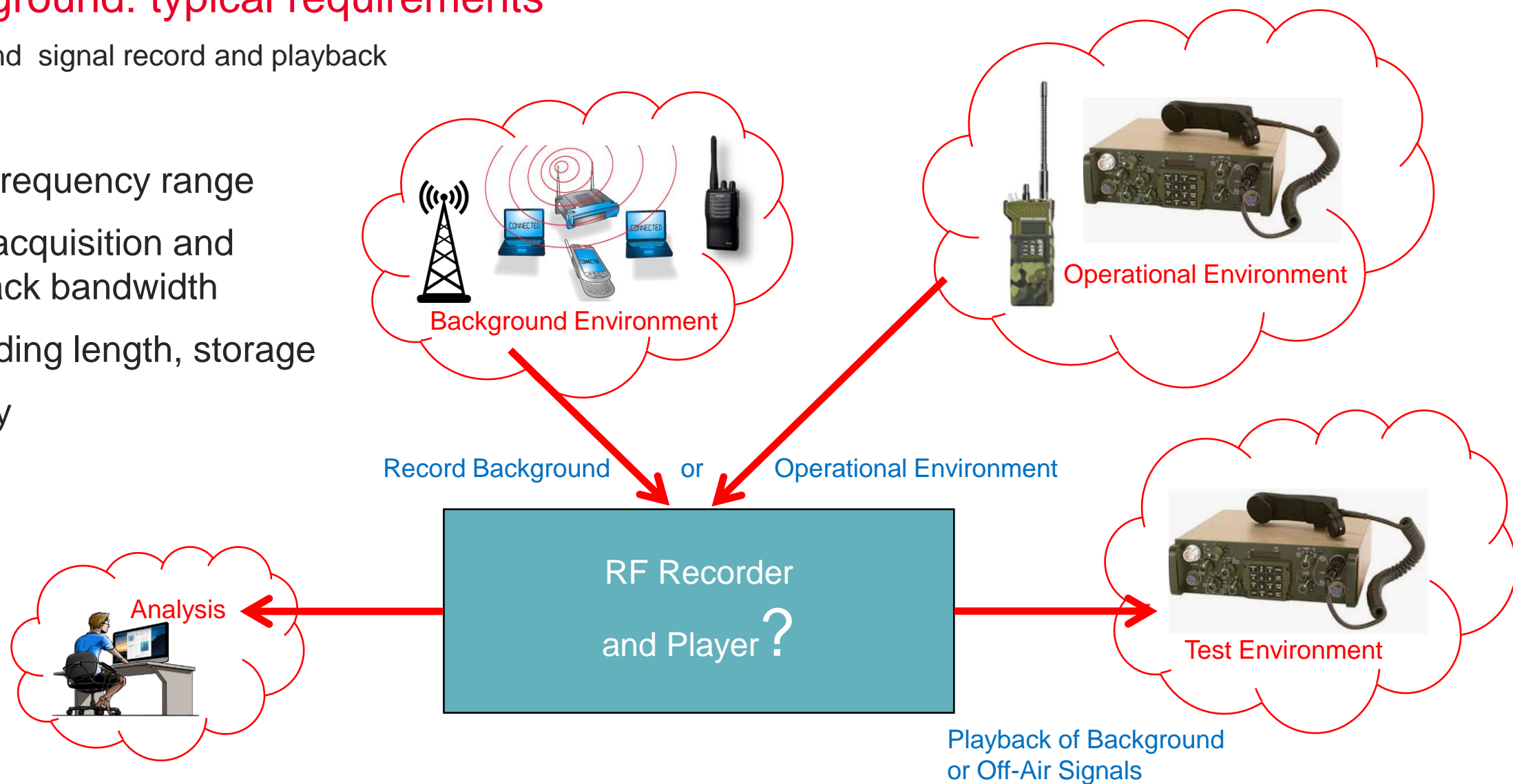
Aerospace Emulation option Key Technical specifications with PROPSIM FS16

- BW 125MHz (O16), EXT BW up to 1GHz (EX5)
- RF range 3-6000MHz, 6-12GHz (CIU). 24/30/44GHz (RRH)
- Delay spread up to >1000ms
- AGI Inc STK plugin reference implementation

Background: typical requirements

Wideband signal record and playback

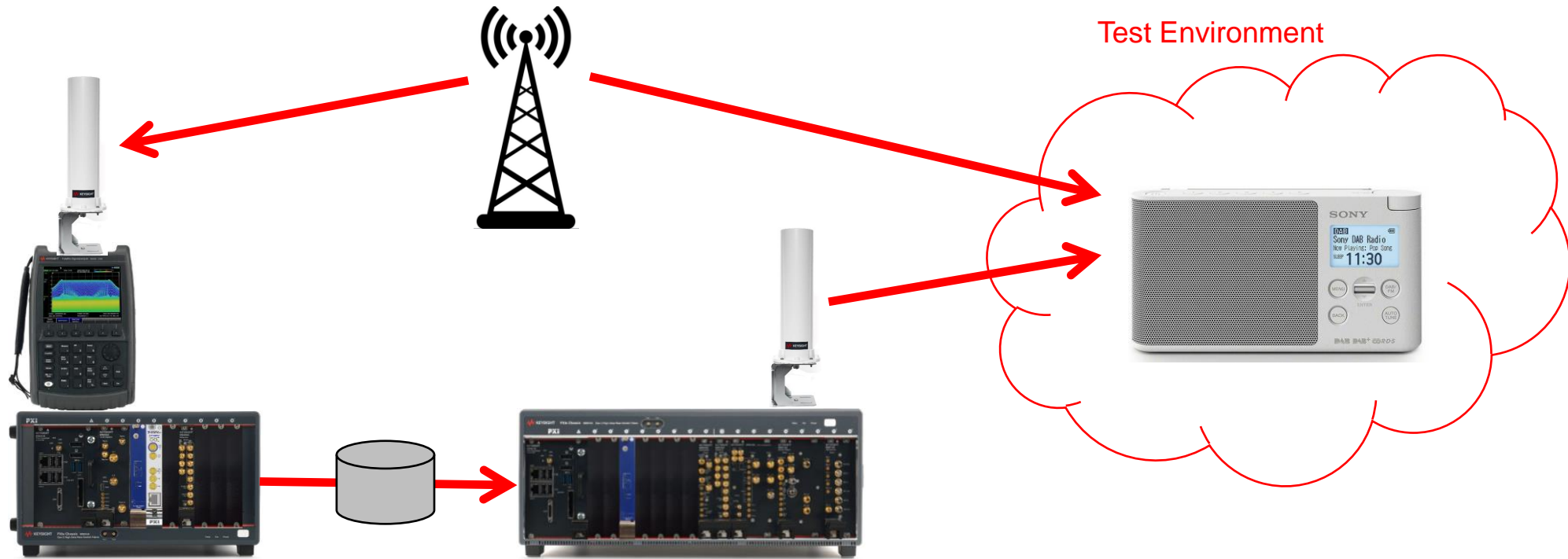
- Wide frequency range
- Wide acquisition and playback bandwidth
- Recording length, storage
- Fidelity



Simple Use/Demo Scenario

Wideband record and playback at RF

- Record off-air signals in different scenarios to an I/Q file
- Replay files as a repeatable test environment



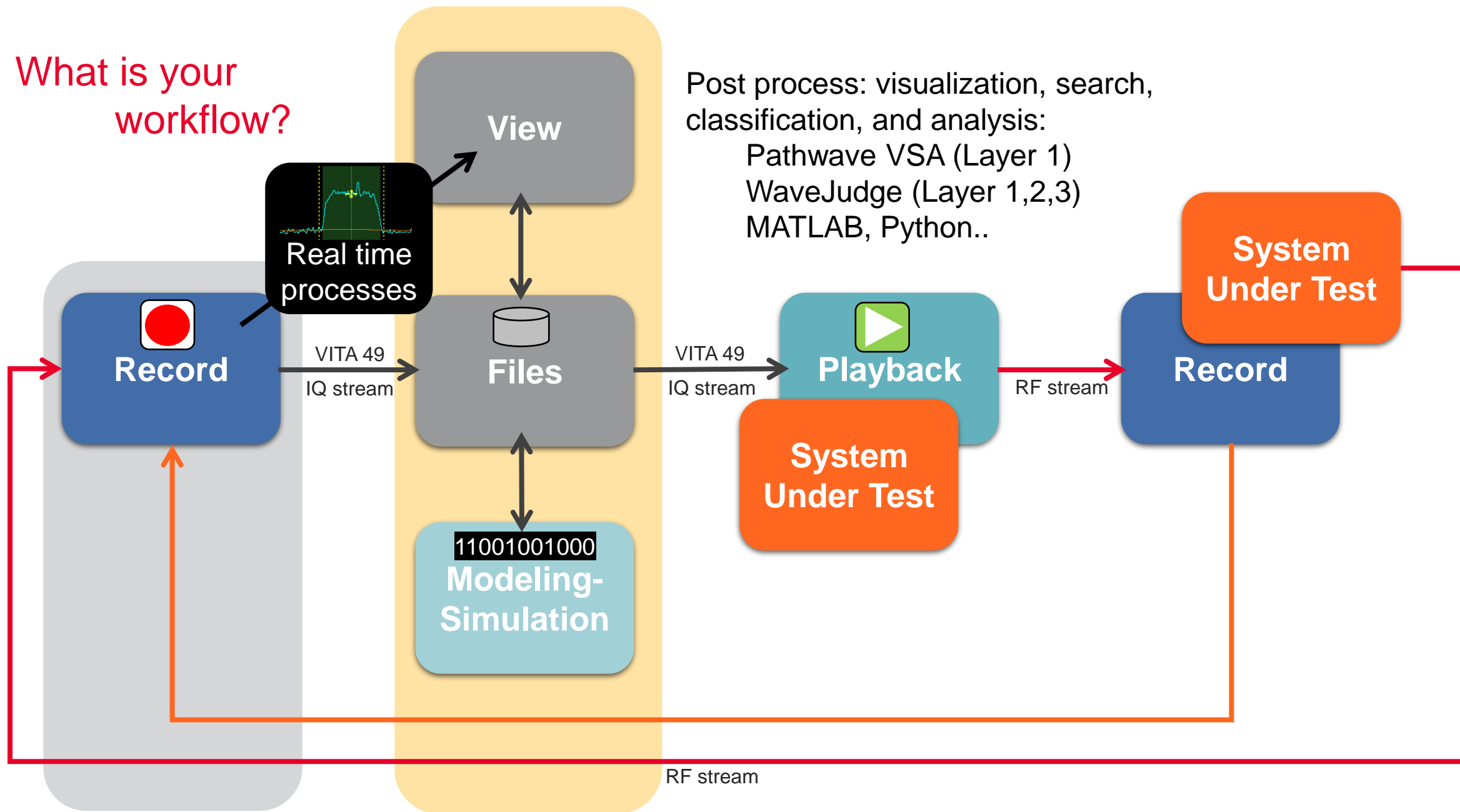
What is your workflow?

Post process: visualization, search, classification, and analysis:

Pathwave VSA (Layer 1)

WaveJudge (Layer 1,2,3)

MATLAB, Python..

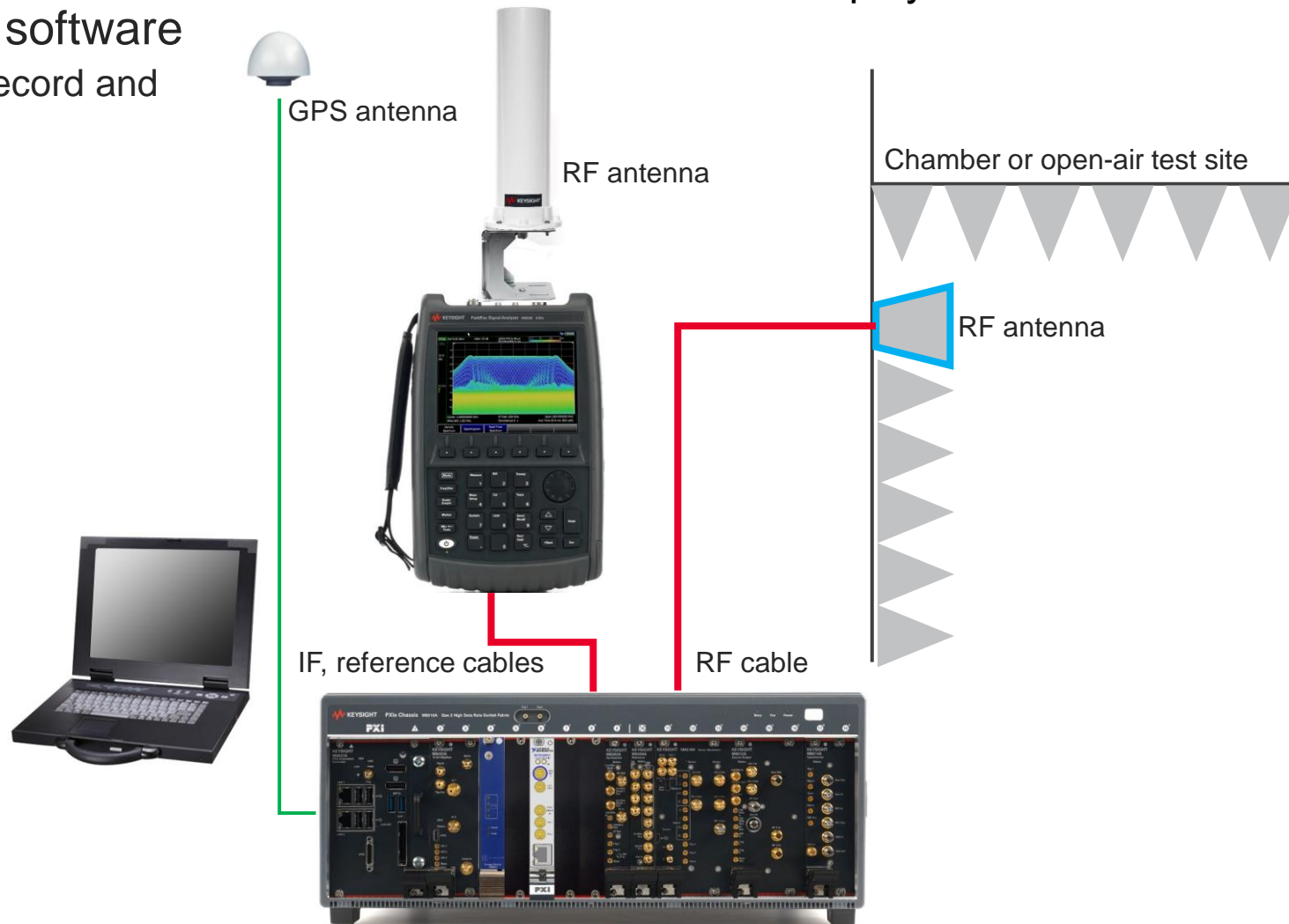


S7980A Series

Wideband streaming record and playback

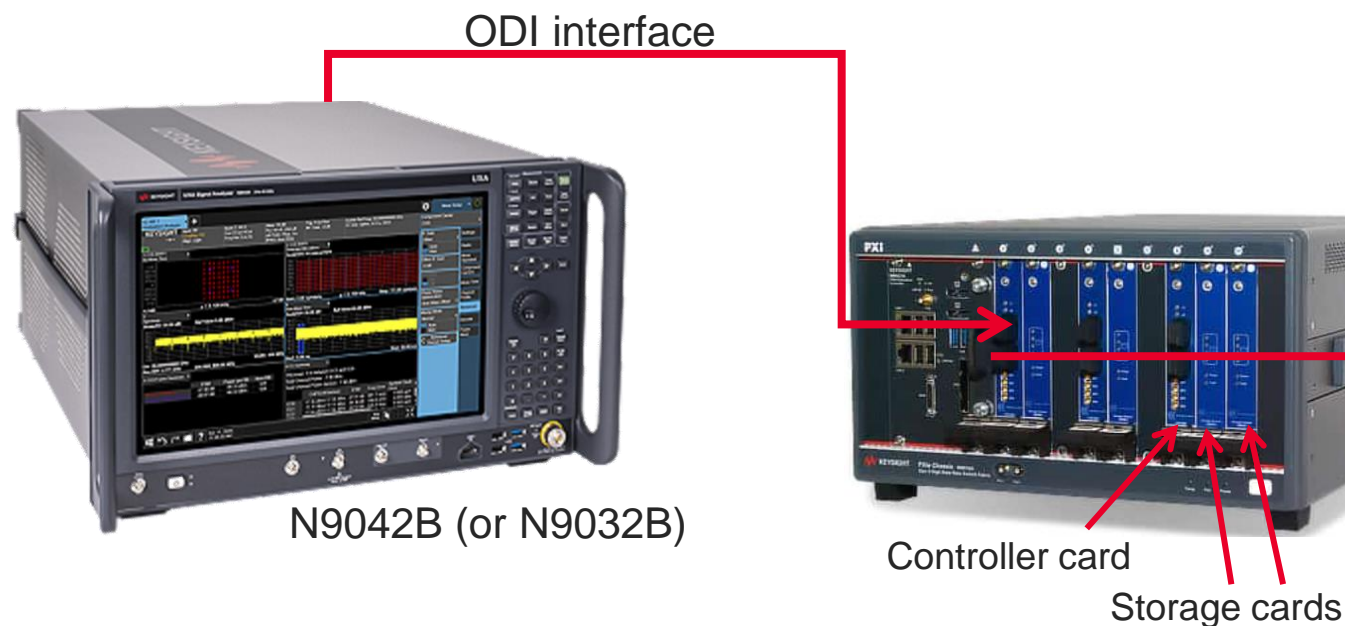
- System fully integrated with cables, software
 - N6880AR01, N6880AP01 RPM software record and playback licenses
 - FieldFox B (26.5 GHz or 44 GHz)
 - M9019A PXI chassis
 - M9037A embedded PC
 - M9203A ADC module
 - M9383A Vector signal generator module (20 GHz or 44 GHz model)
 - PXI Precision time (GPS) module
 - PXI storage module
- Record in the field, playback in the lab.

Model #	Frequency range
S7980A-020	26.5 GHz record, 20 GHz playback
S7980A-044	44 GHz record and playback



Wideband streaming solutions – X-series analyzers

N9042B – highest quality recording system from Keysight

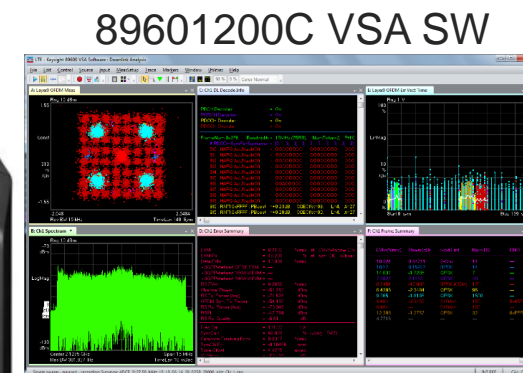
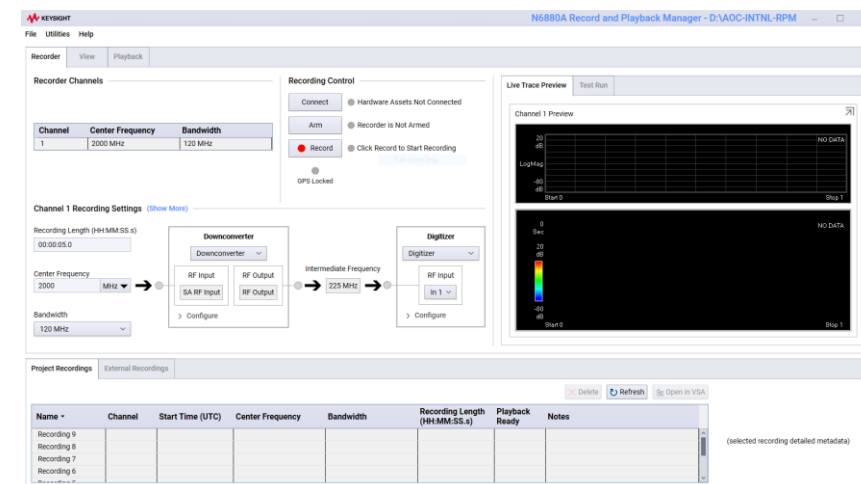


N9042B UXA Signal Analyzer, 2 Hz to 50 GHz | Keysight

N9032B PXA Signal Analyzer, 2 Hz to 55 GHz | Keysight



N6880AR02 RPM SW



N6880AR02 RPM software

Configuration and control of solution

KEYSIGHT N6880A Record and Playback Manager - C:\Users\josebona\Documents\Keysight\Record and Playback Manager\demo

File Help

Record View

Recorder Configuration

Channel	Center Frequency	Bandwidth
1	10000 MHz	

Recording Notes

Recording Control

Disconnect ☒ Hardware assets connected

Arm ☐ Recorder is not armed

Record ☐ Click Record to start recording

☒ Recording 2 Finished

Channel 1 Recording Settings [Show More](#)

Recording Length: 00:00:05.0

Center Frequency: 10000 MHz

Bandwidth (MHz): 2000 MHz

Receiver (XsaReceiver)

RF Input

RfInputChannel1

Channel 1

LogMag

Center 10 GHz Span 2 GHz

Real time full bandwidth spectrum

Project Recordings External Recordings

Load for View Rename Refresh Open in VSA

Name	Start Time (UTC)	Recording Length	Center Freq (MHz)	Bandwidth (MHz)	Recording File	Notes
Recording 2	2023/03/21 22:02:29	00:00:05.000000	10000	2000	✓	
Recording 1	2023/03/21 21:58:11	00:00:05.000000	10000	2000	✓	

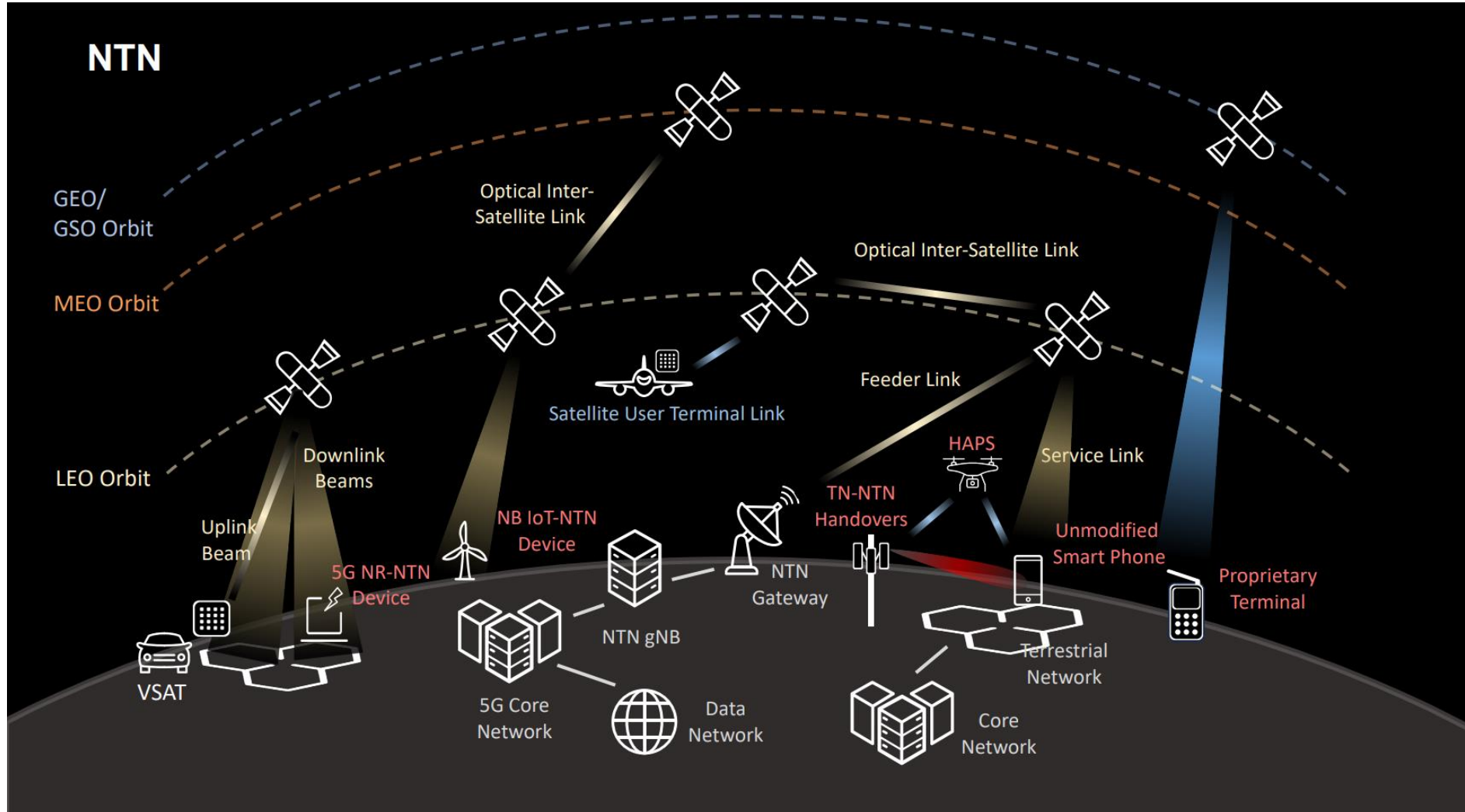
Manage recordings

Non-Terrestrial Networks



Non-Terrestrial Network

Application Domain & Environment

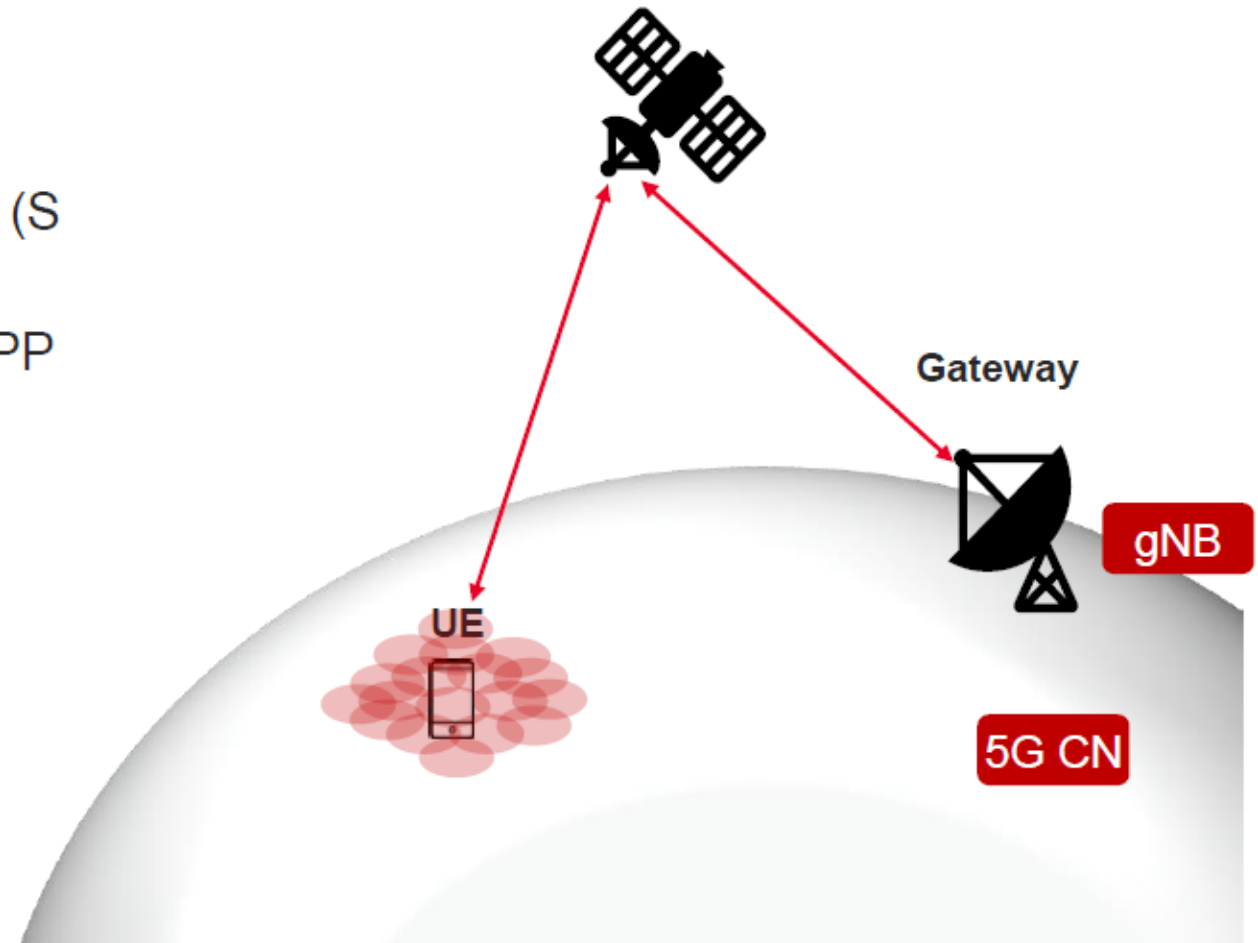


3GPP NR NTN Technology Architecture

High level 3GPP definition for Rel-17 NR NTN

- Focused on already authorized bands for terrestrial and non-terrestrial
 - Rel-17 is focused on 1.5GHz and 2.1GHz bands (S and L bands)
 - Ka / Ku bands are being investigated in later 3GPP releases (>10 GHz)
- GEO and LEO orbiting scenarios
- UEs with GNSS capabilities are assumed

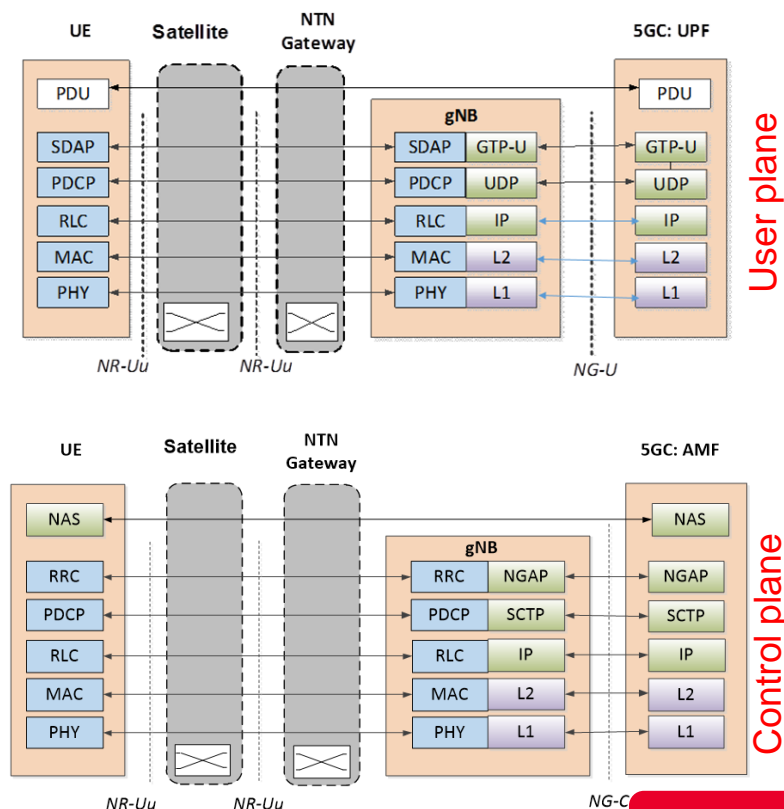
Deployment Scenario 1



Rel-17 NR NTN Network Architecture

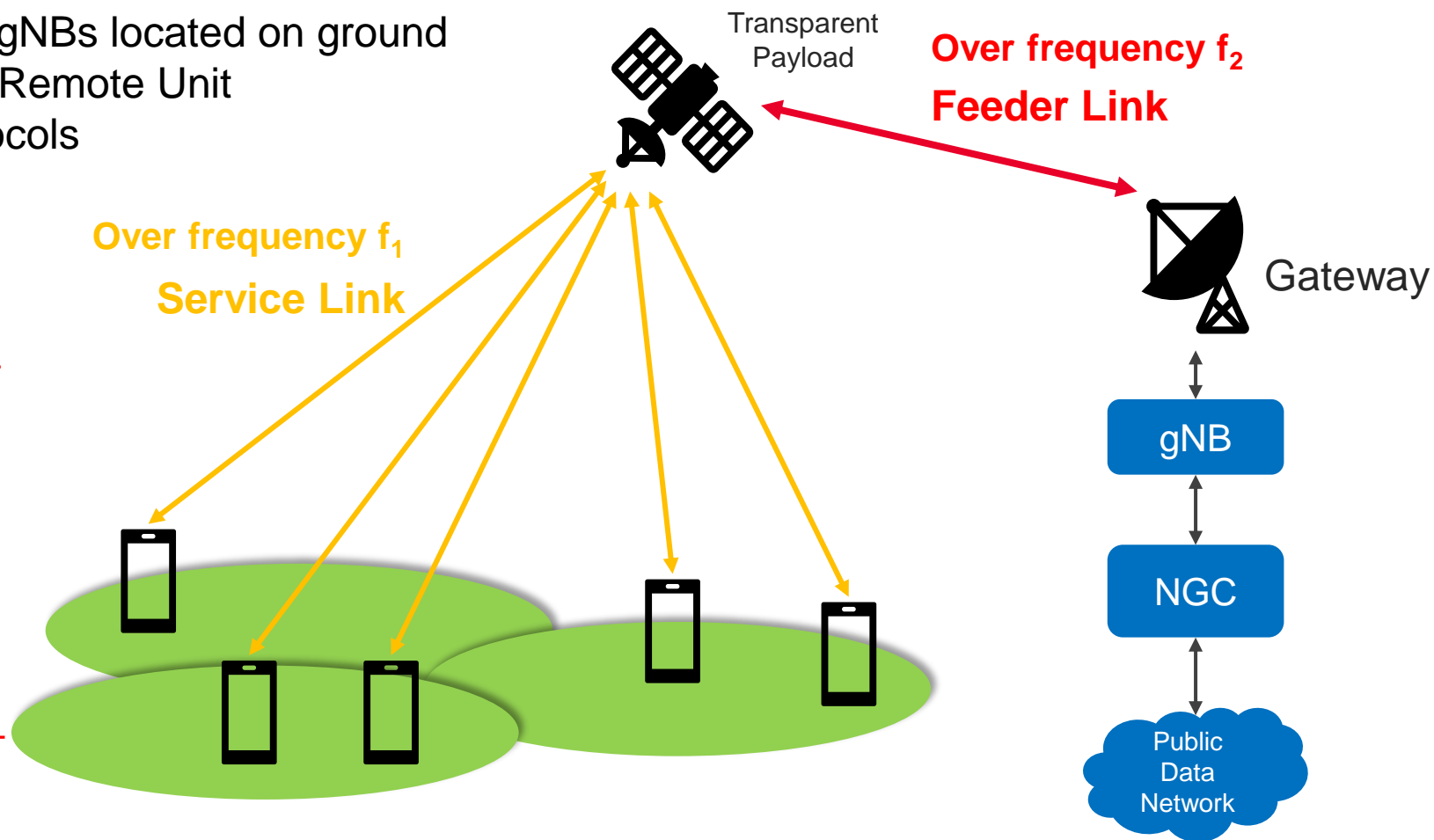
Transparent Payload

- NR signals generated from gNBs located on ground
- Satellite equivalent to a RF Remote Unit
- Transparent to the NR protocols



User plane

Control plane

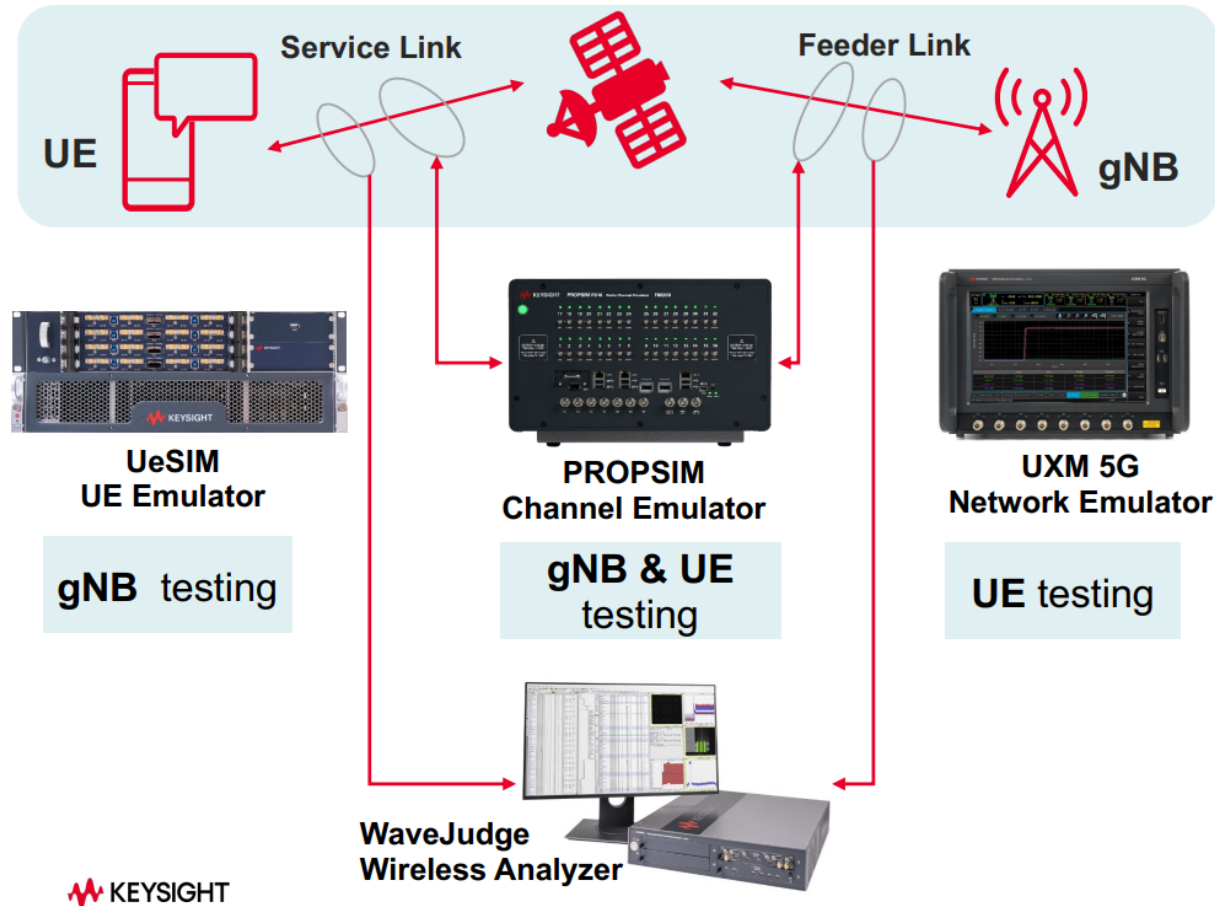


5G Network and NTN Test

SOLUTION DESCRIPTION & ADDED VALUE

Emulate & Analyse Rel-17 Non-Terrestrial 5G

Complete Emulator portfolio for 5G NTN UE and Network development

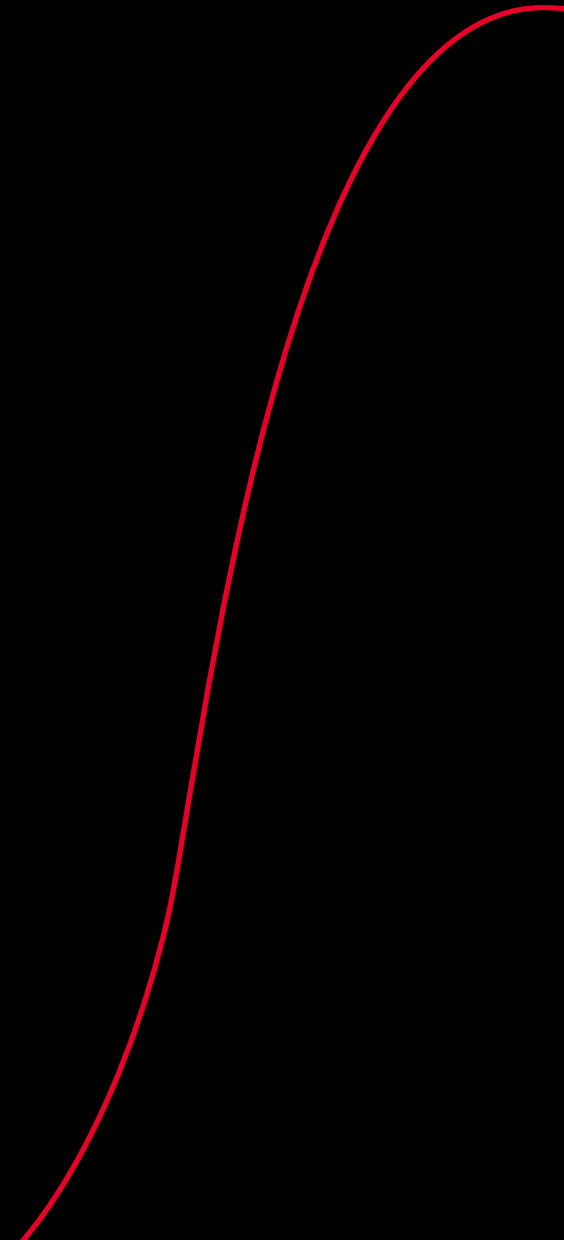


M9484C VXG Vector Signal Generator | Keysight

PROPSIM Platforms | Keysight

E7515B UXM 5G Wireless Test
Platform | Keysight

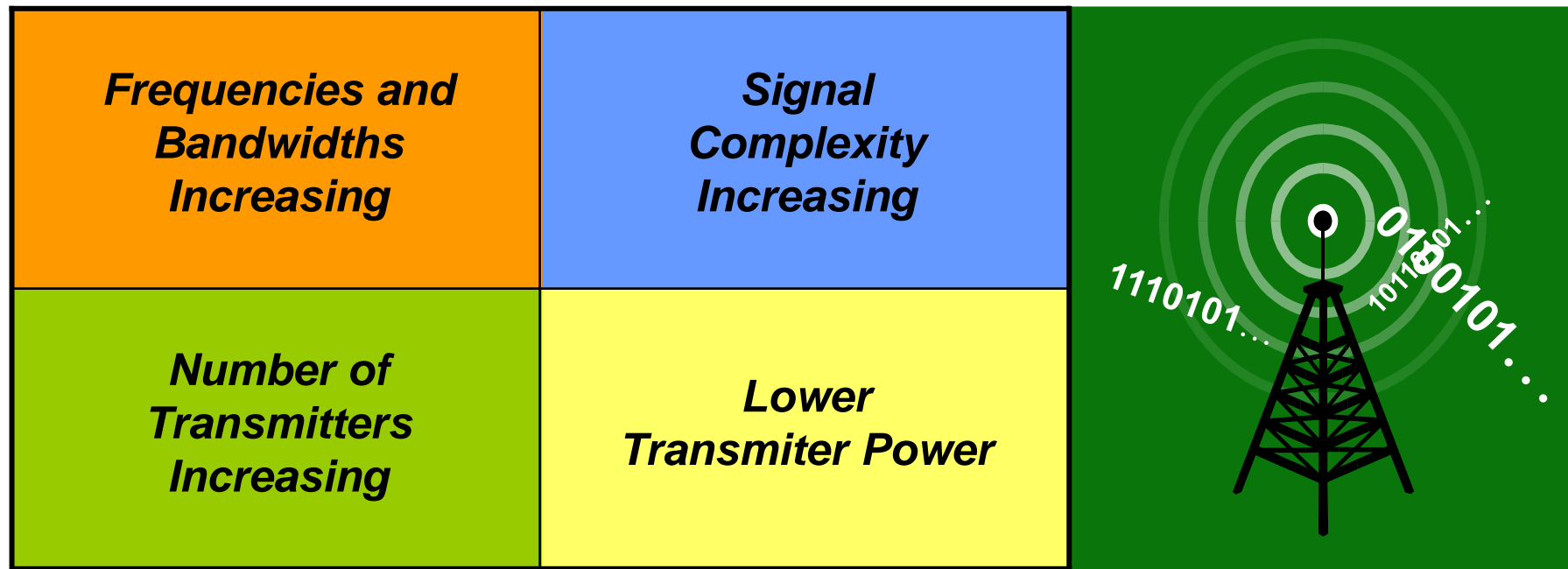
Electromagnetic Spectrum Operations



Why Geo-Location? - Trends in RF Technology

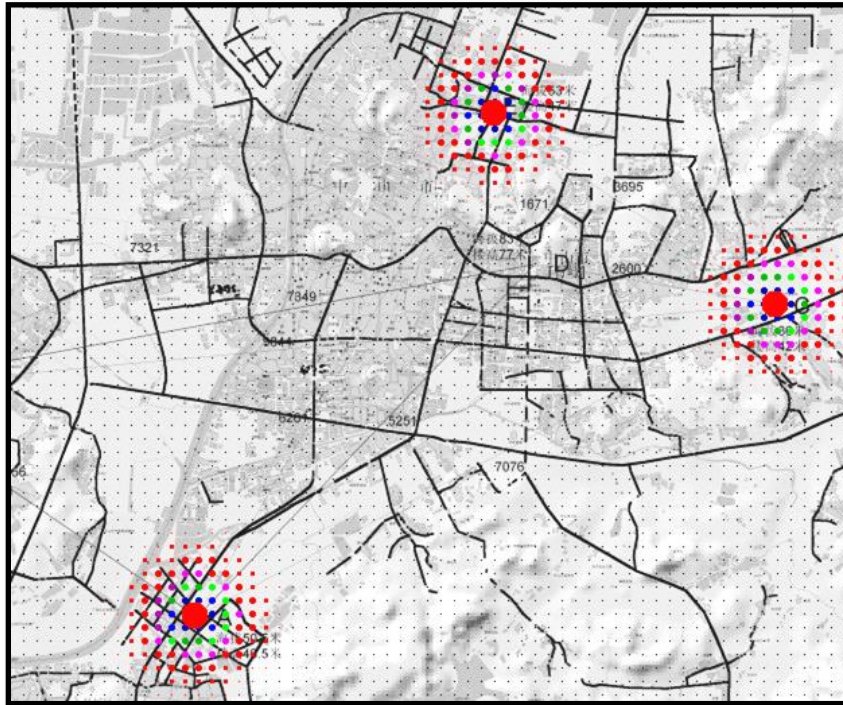
Customer's Challenge:

Quickly **detect** and **locate** non-cooperative modern signals which may be intermittent, be of short duration, spread spectrum, have low power and/or low energy.

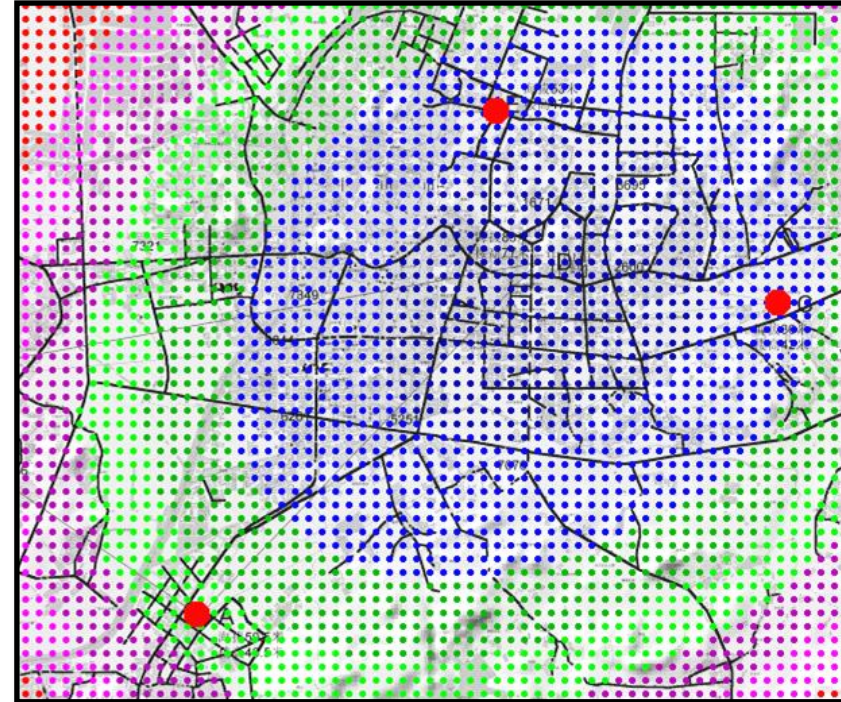


AOA (Angle-Of-Arrival) vs TDOA (Time-Difference-Of-Arrival)

***Traditional Monitoring Stations
using Non-Coherent Detection***

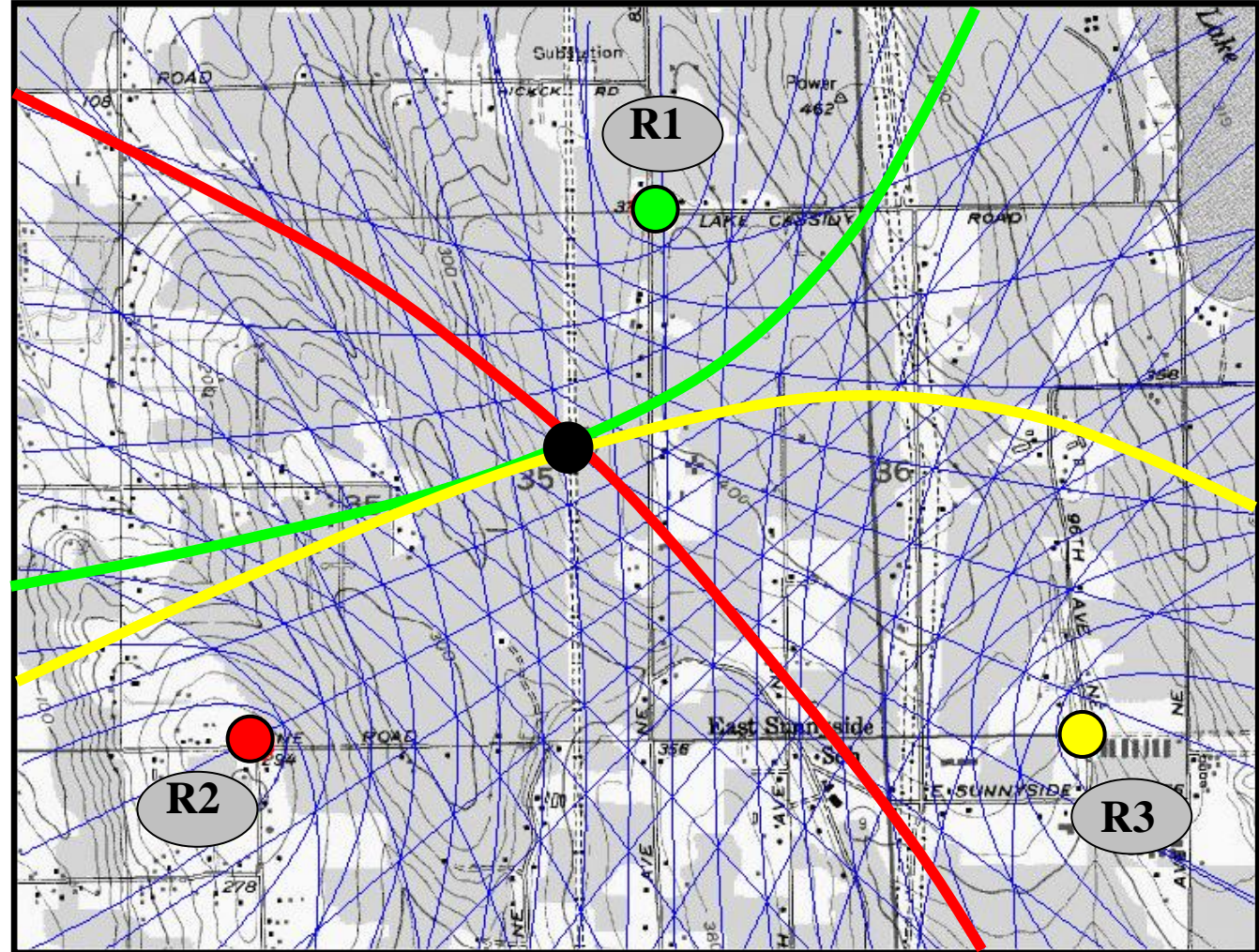


***Synchronized Receivers using
Coherent Detection***



TDOA with 3 Receivers

- Computes time difference of signal
- Calculates location based on timing and spectrum comparisons (cross-correlation)
- Signal location based on where cross-correlation is maximum
- Time synchronization is key (< 20 ns)
- Accuracy not solely dependent on receiver location

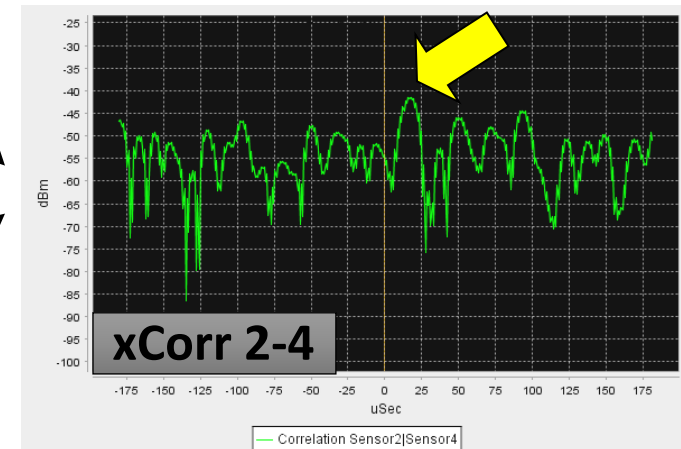
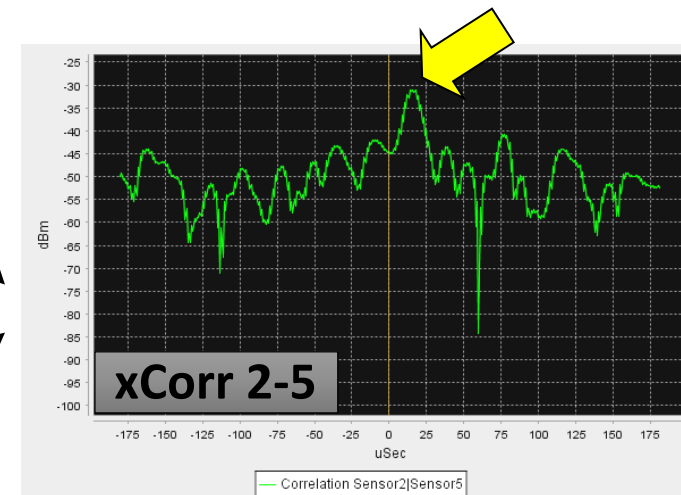
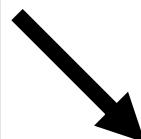
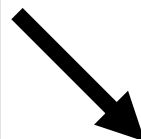
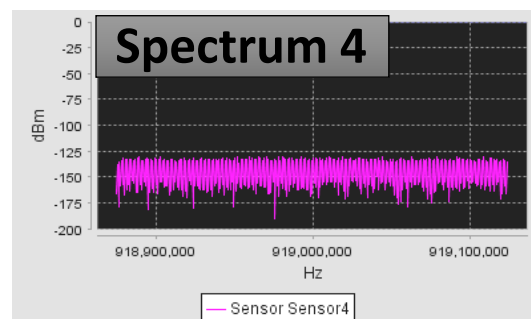
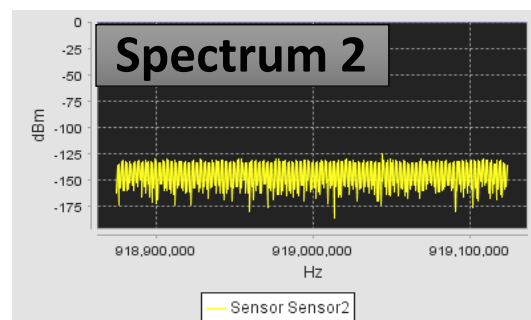
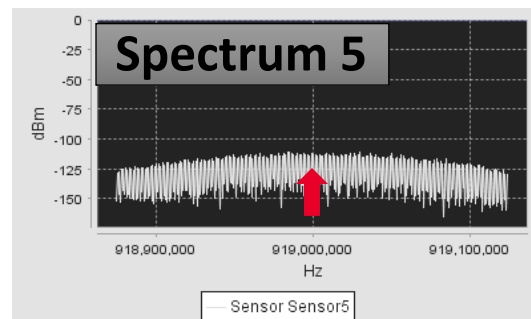


Coherent Signal Detection using Cross-Correlations

An LTE signal is visible in the sensor 5 spectrum, but not in the spectrums for sensors 2 and 4.

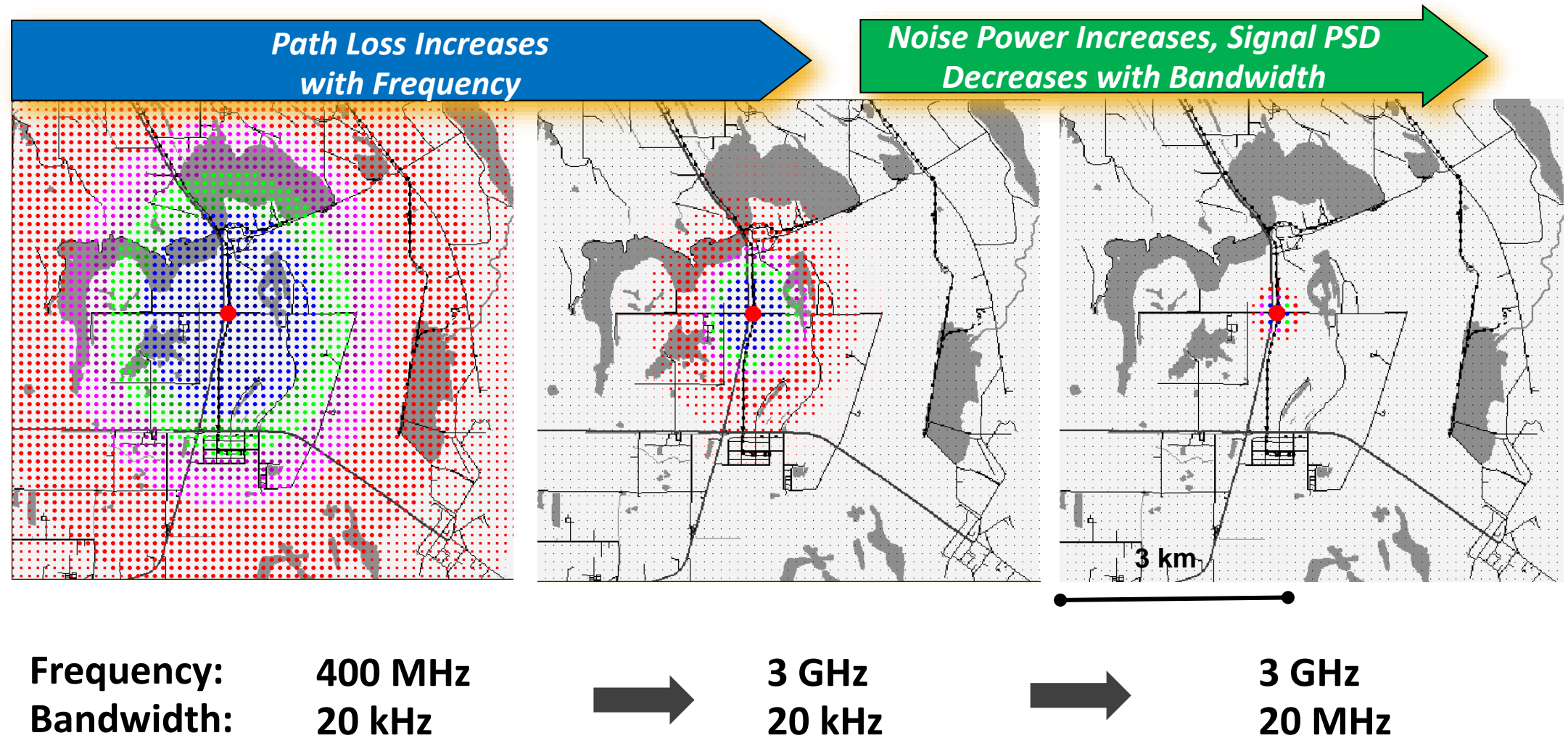
Even without a visible signal in the spectrums for sensors 2 and 4, the cross-correlation between data from these two sensors produces a clear correlation peak.

With the LTE signal clearly visible in the spectrum for sensor 5, it's expected that the sensor 2-5 cross correlation would have a stronger peak.



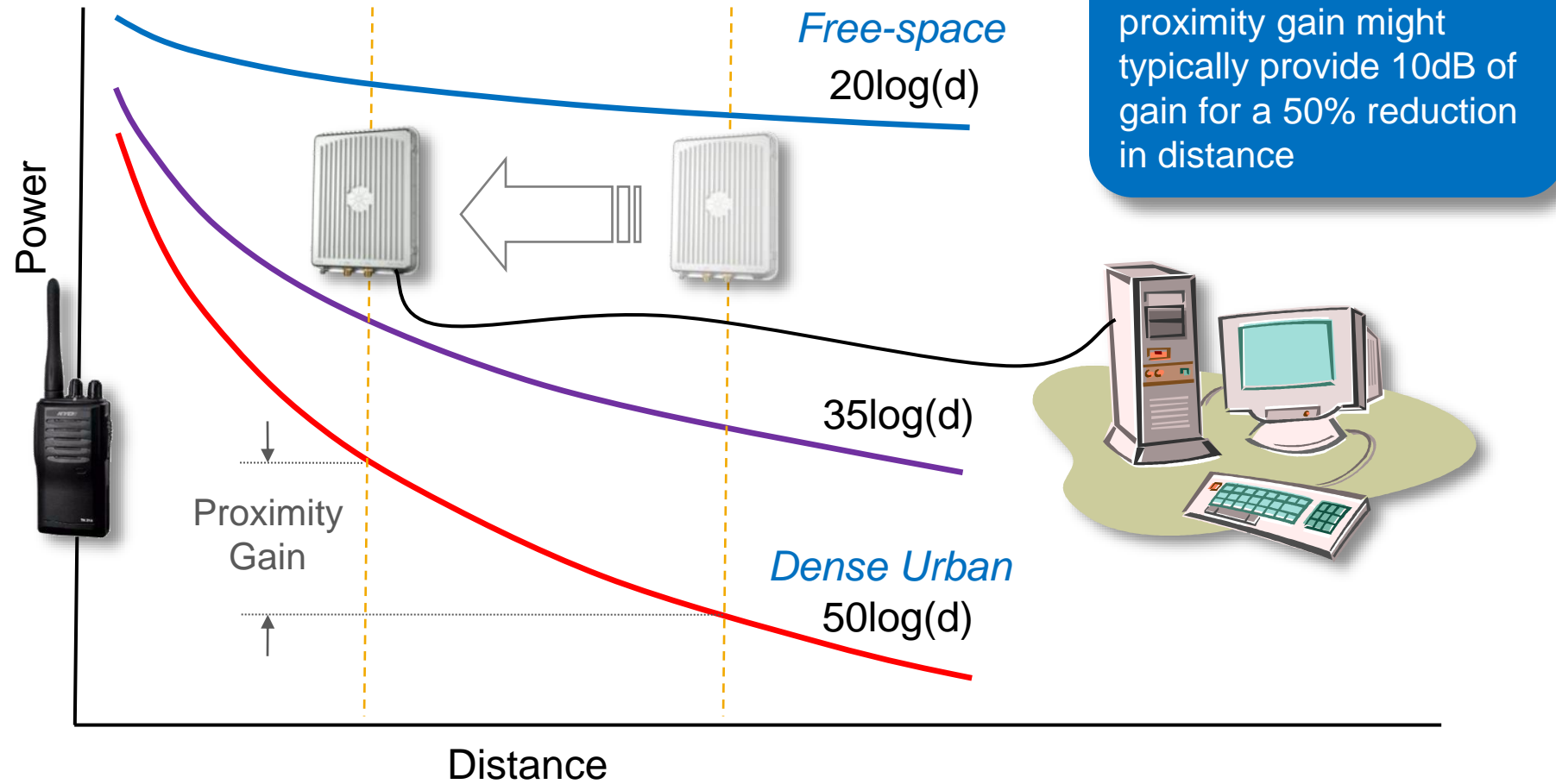
Even with two usable cross-correlations, signal can be located

Detection Probability varies with Signal Frequency & Bandwidth



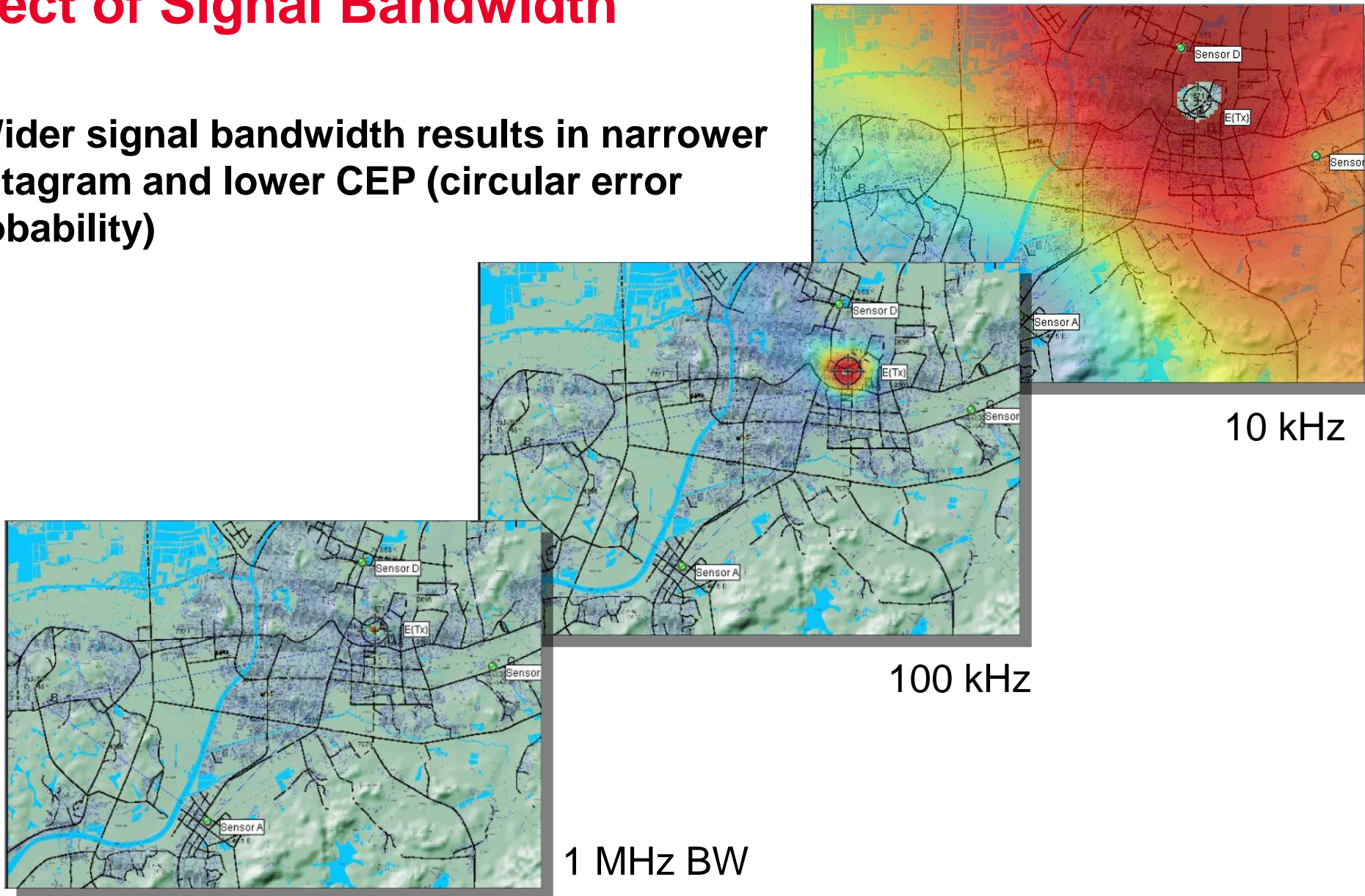
Proximity Gain

Signal Strength Increases with Decreasing Distance

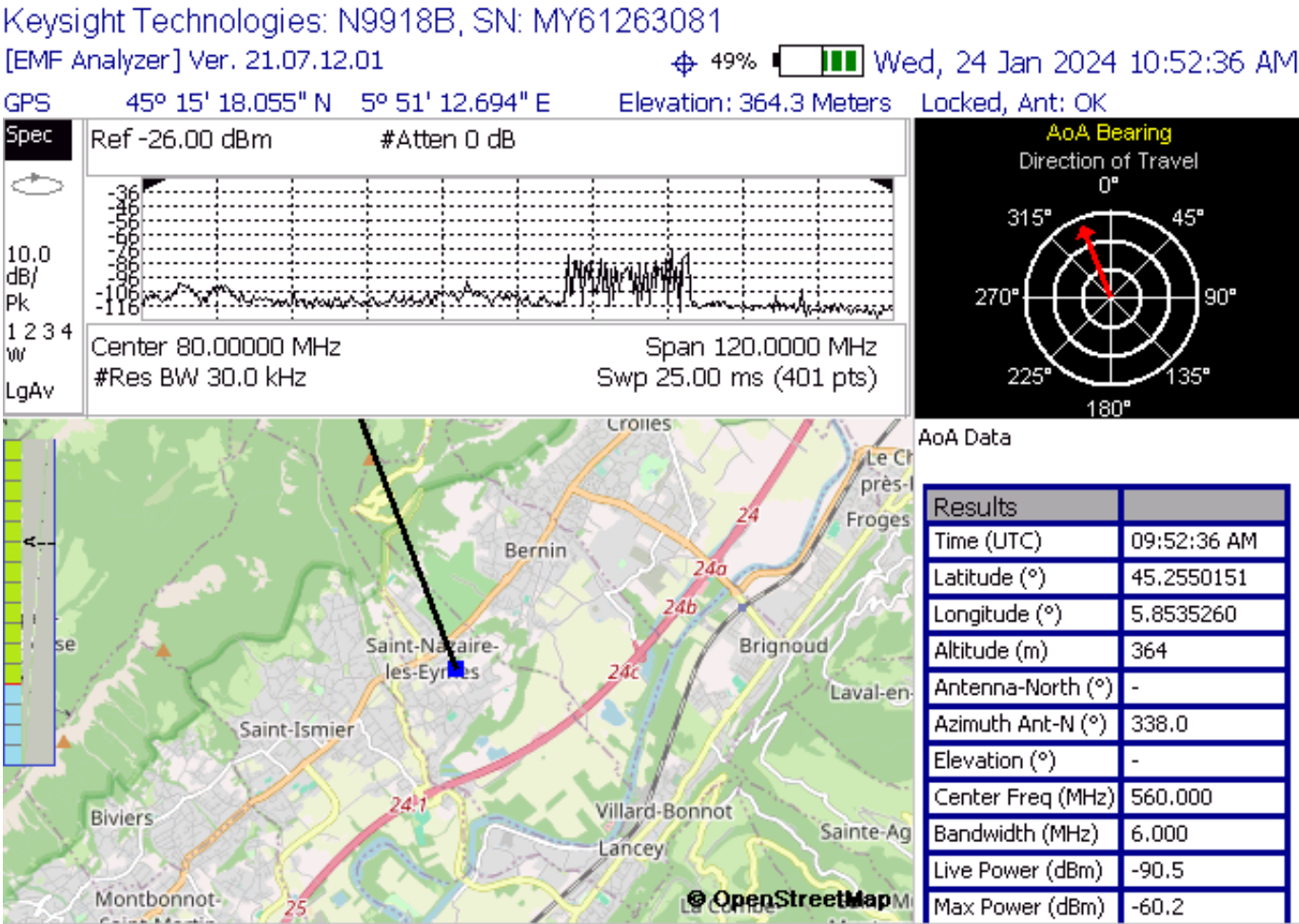


Effect of Signal Bandwidth

- Wider signal bandwidth results in narrower tentagram and lower CEP (circular error probability)

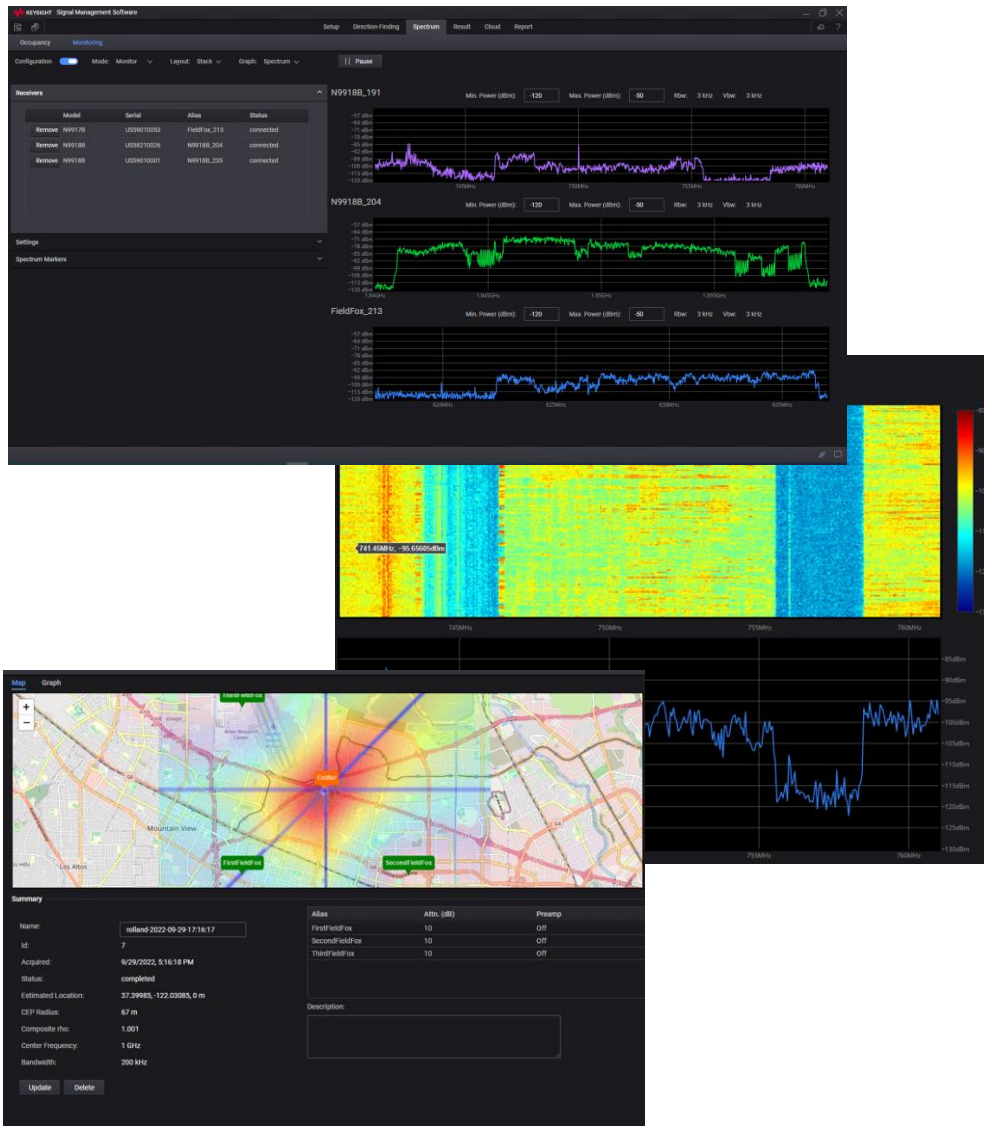


Manual DF - AoA



85574A Handheld Direction Finding Antenna | Keysight

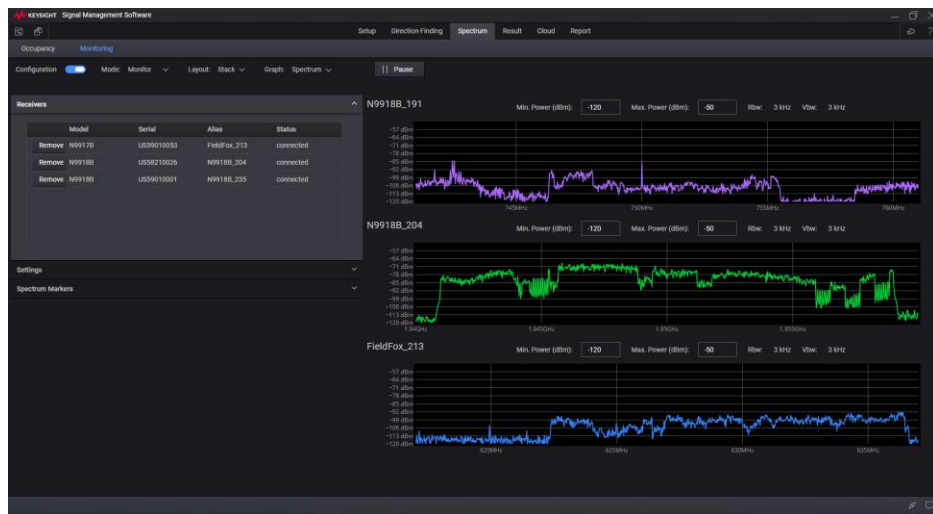
Keysight Spectrum Management Software (KSMS) at a Glance



- Signal monitoring
- Signal verification
- Spectrum occupancy report
- DF: TDOA
- DF: RSS
- Hybrid DF to combine TDOA and RSS
- Spectrum recording and playback
- Remote control FieldFox
- Mapping
- PostgreSQL support
- Interface with Keysight VSA software, Wavejudge and other third-party software

Spectrum monitoring

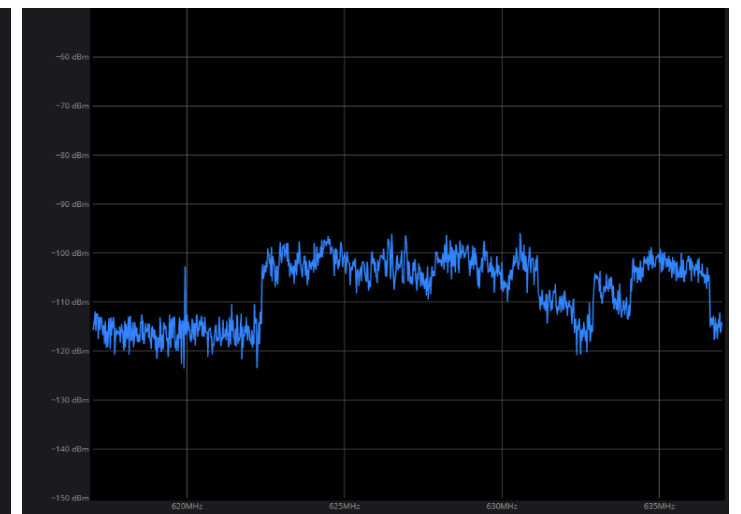
- Monitor multiple receivers at same time
- Spectrum trace from each receiver can be in single window, stack and overlay



Multi- receiver stack mode display

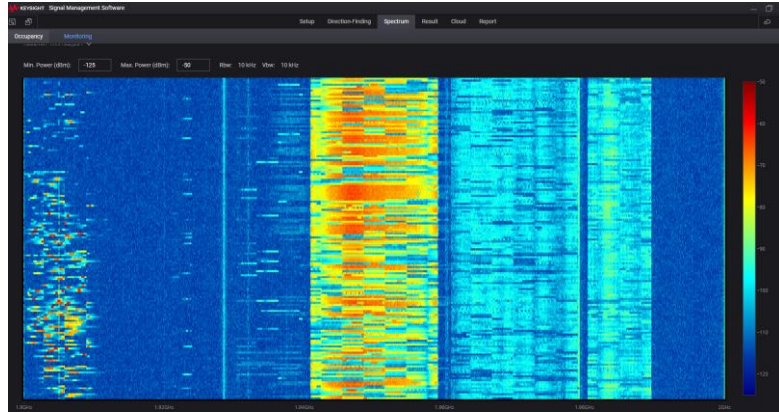


Spectrum overlay



Single receiver spectrum

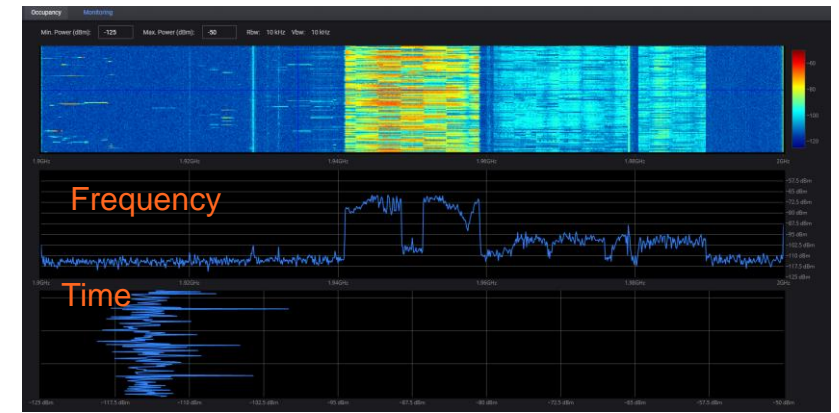
Spectrograms



Single receiver spectrogram



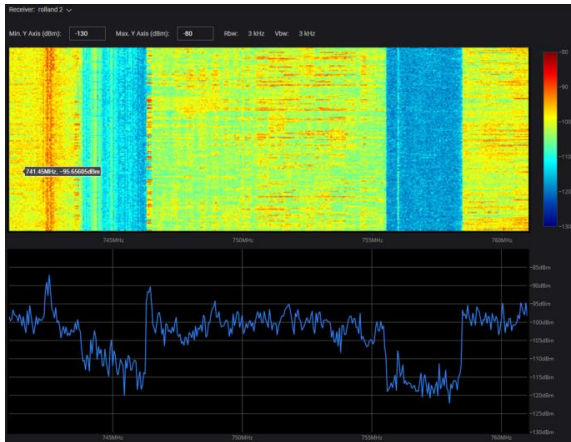
Multi-receiver spectrogram



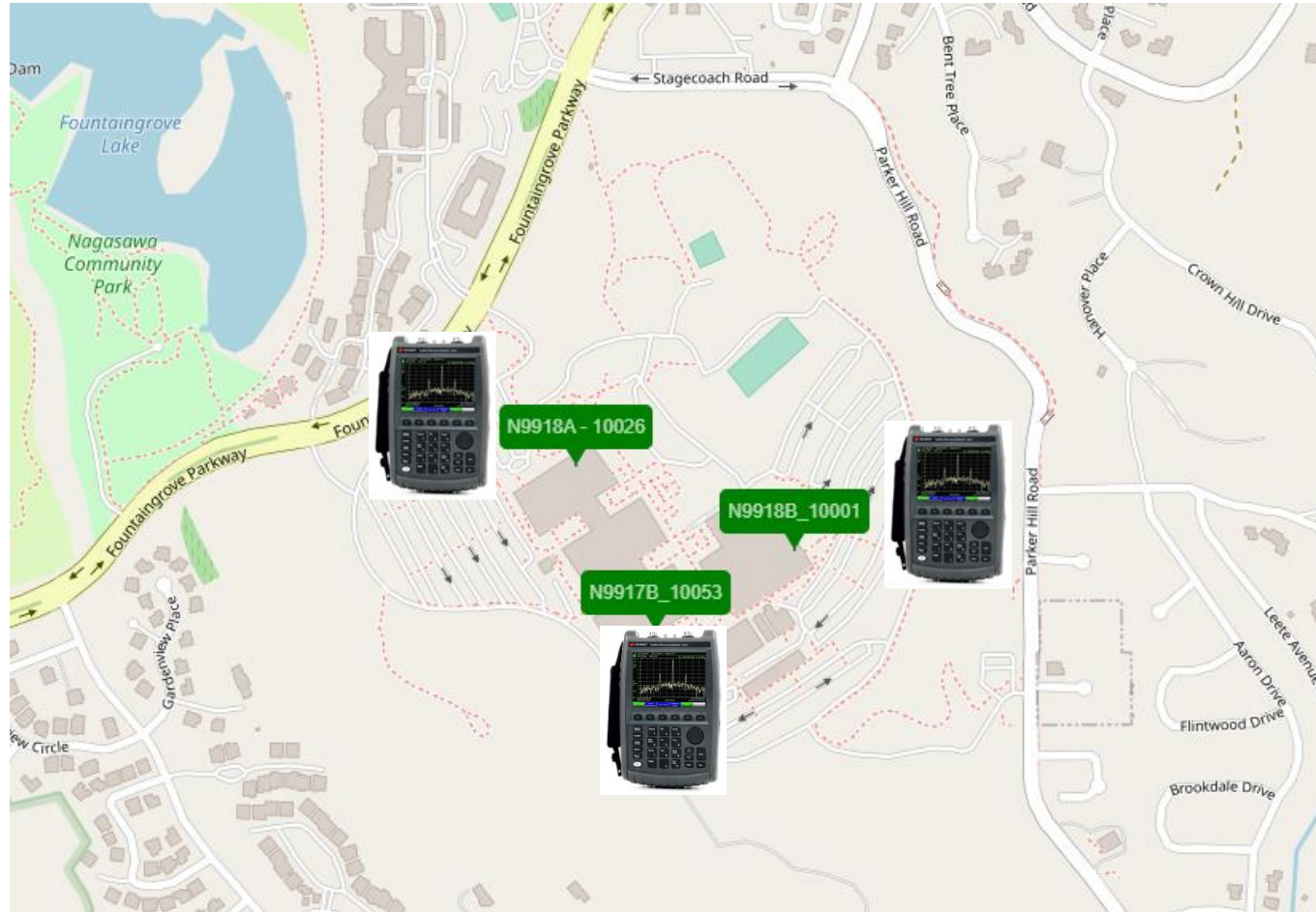
Cross domain spectrogram

- Top: spectrogram
- Middle: spectrum trace at marker or current record
- Bottom: time domain display at marker frequency

Mobile spectrum management with Keysight FieldFox



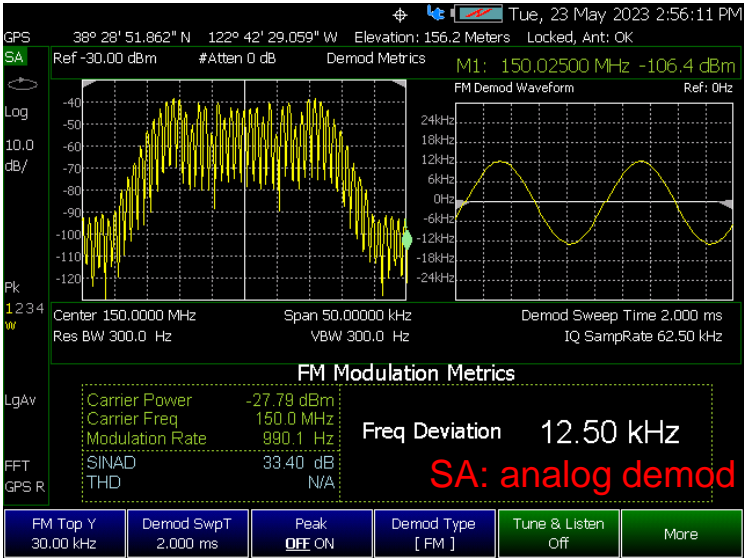
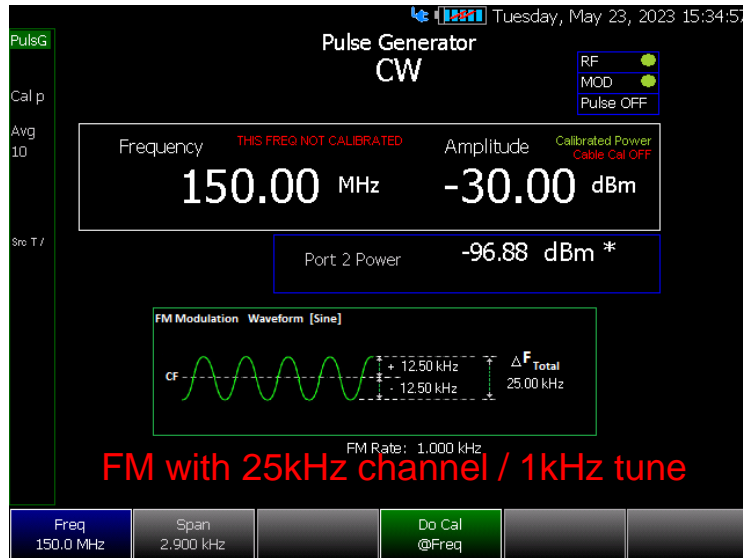
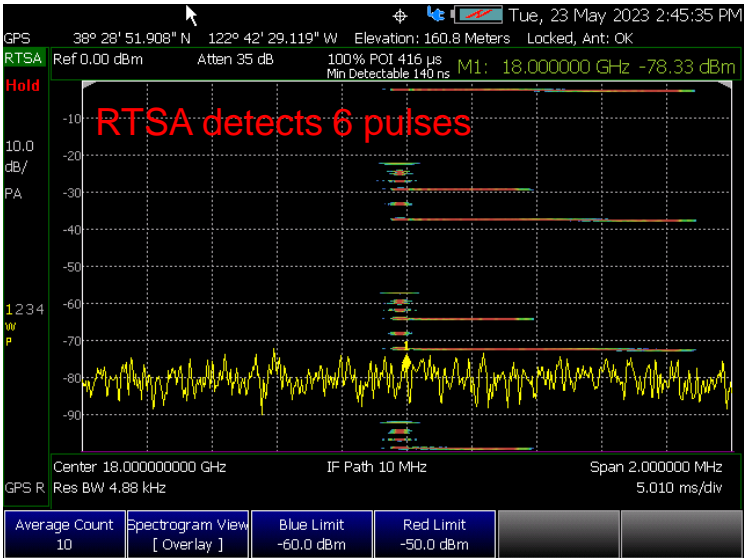
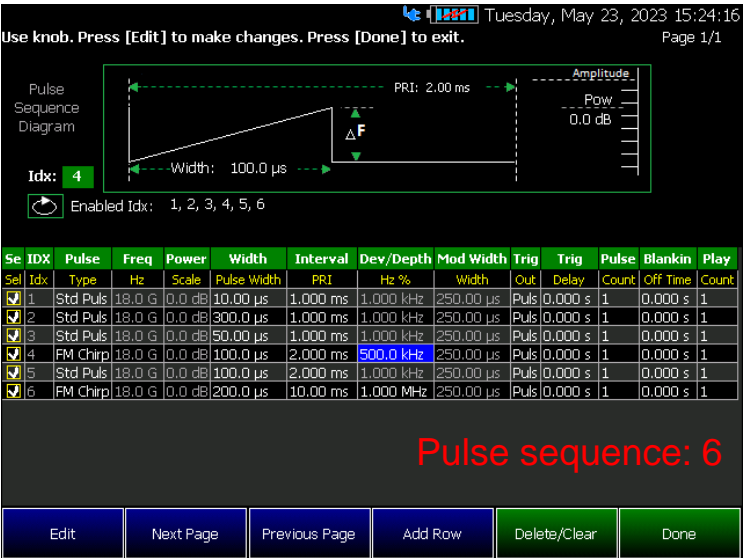
KSMS Software



Keysight Spectrum Management Software

- Signal monitoring
- Spectrum occupancy report
- DF: TDOA
- Hybrid DF to combine TDOA and RSS
- Spectrum recording and playback
- PostgreSQL support

Pulse Generator (Option-357) all B & C Models



	Features
Frequency	30 KHz to 54GHz (model dependent)
Output power	Calibrated with SA
Pulse width	> = 1us
Modulation	Pulse, chirp, triangle, FM and AM
Pulse sequence	From keypad, stored for recall
FieldFox	B & C Models

FieldFox C model Series: NEW

3 KHz to 4GHz, 6.5 GHz or 10 GHz

Key Specifications:

- Frequency range: 3 KHz to 10 GHz (N9913/14/15C, N9933/34/35C)
- Accuracy: ± 0.01 ppm (frequency), ± 1 dB (<4.5 GHz) (Absolute amplitude accuracy) -10 to +55°C
- Sweep time (zero span): 1 μ s to 6000 s.
- Analysis bandwidth: ≤ 120 MHz
- DANL: -140 dBm (2.6 to 4.5 GHz), -158 dBm (Preamp On) -10 to +55°C

Key Features:

- Over 25+ license key options: upgradeable in the field, anywhere, anytime
- FFT-based Spectrum Analyzer for Real-time signal capture and analysis
- BASEBAND mode (DANL: -160 dBm, 20 KHz to 6.5 MHz)
- Zero warm-up time (InstAlign technology)
- MIL PRF-28800F Class 2, IP53 rated, MIL-STD-810G for explosive environments

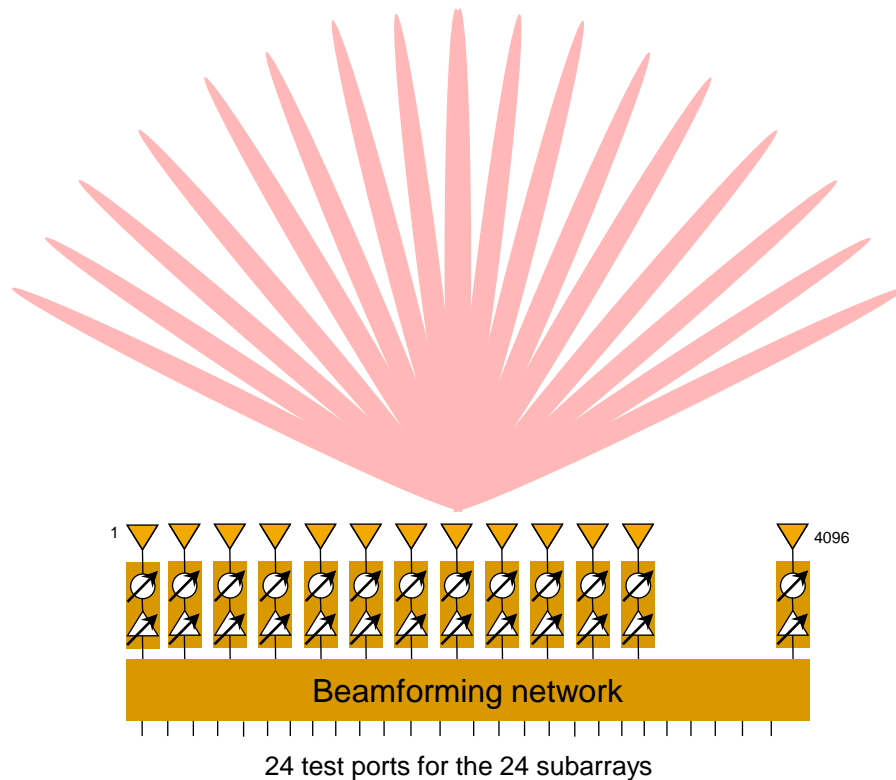


Phased-Array Antenna Measurements

Antenna Measurements

AESA Measurements

- Measuring all antenna patterns of an AESA is extremely time consuming



Θ scan angle: $\pm 45^\circ$

Φ scan angle: $\pm 45^\circ$

24 test ports

2 polarizations

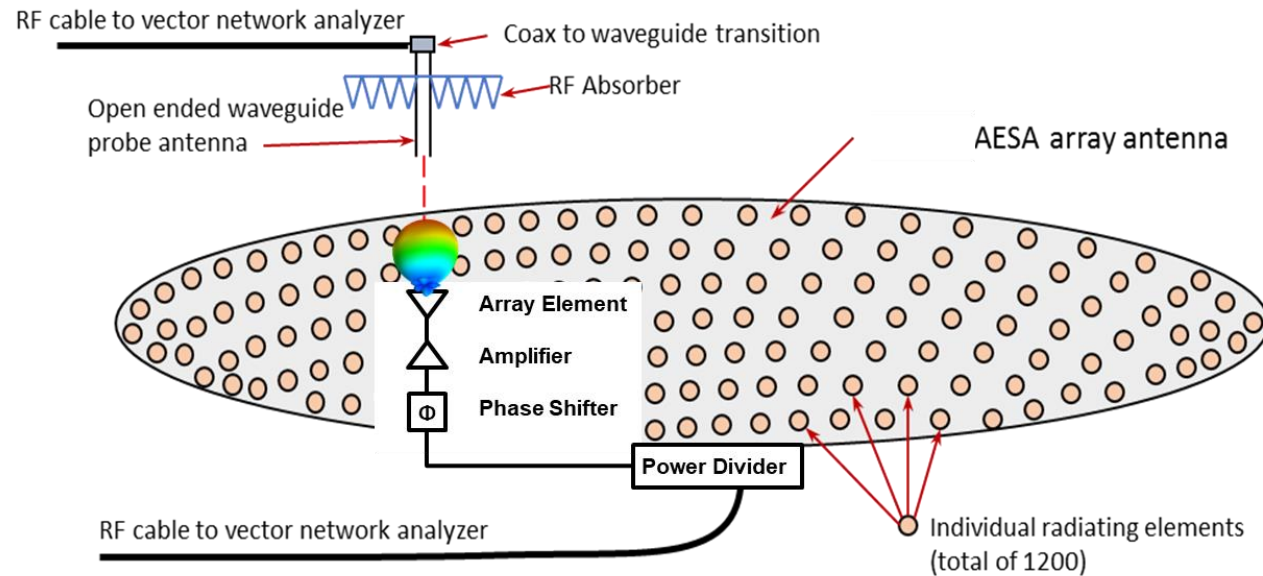
21 frequency points

8281 'beam' positions per port,
polarization, & frequency

$8281 \times 24 \times 2 \times 21 = \underline{\sim 8.3 \text{ million antenna patterns!}}$

All AESA antenna developers utilize
near-field measurement techniques
to measure their antenna patterns

Phased Array Calibration and Characterization: CATR vs. Planar Near Field



Conventional Near Field Probe-Scanning Method:

F9650A Compact Antenna Test Range (CATR) | Keysight

Over-the-Air Antenna Test

Keysight's CATR portfolio is optimized to provide accurate over-the-air (OTA) measurements.

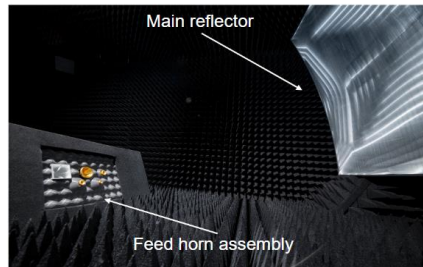
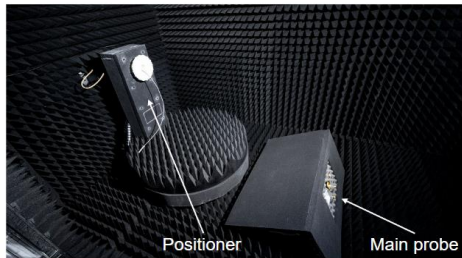


Overview

- OTA testing of connector-less devices with patch antenna arrays
- Supports test requirements across Protocol, RF, Functional and Performance tests
- Easy to use positioner control software allowing fast alignment
- Advanced calibration method
- Supporting beamforming and multiple Angles of Arrival (AoA)
- Scalable Keysight Test Automation Platform (TAP) for Hardware instrumentations interface

Key Benefits:

- No intrusive and accurate measurement
- Proven and mature solution
- Scalable architecture
- Maintenance and Support Services



Thanks for your Time!

A thick red curved line starts from the bottom right corner and curves upwards and to the left, ending near the top right corner of the slide.