Or

UXG Signal Generators:
Scale for Threat Simulation

Easily scale from a single UXG to a fully racked, 4-port EW solution[1]

Threat Simulation System Development

The workflow to test and evaluate an electronic warfare system will move in different stages from system simulation, to system integration, to hardware in the loop, to an installed system prior to open air range testing.

This process is:

- Time consuming
- Expensive
- Cost of failure is high and difficult to discover what went wrong.

Conducting RF tests that most resemble real-life conditions, early on in development, is very important as moving into open air range testing increases the cost of error.

Keysight has decades of RF expertise in test and measurement to help mitigate most of these issues.

[1]Some products mentioned are subject to US ITAR export controls, contact your Keysight representative

UXG-based platform benefits

The UXG is a versatile building block to achieve desired results at any stage.

High Density Simulation

- DDS Phase coherent and Phase continuous switching

All Test Environments & Fidelity Levels

- Pre-scripted, dynamic/reactive, closed-loop test
- R&D, HITL/RL, ISTF, OAR environments

Open Architecture

- "PDW to RF Transducer"
- Real-Time RF Stimulation (Data to RF)
    - NEWEG Compatible RFGEN Solutions
- Real-Time RF Signal Capture (RF to Data)
    - NEWEG MAA Content
- Create multi-emitter scenarios with many different scenario generation tools
- Legacy systems and source compatibility
- Enable process innovation

Variable and Scalable

- Scale and calibrate many UXGs for high channel and port counts
- Reconfigurable for changing requirements
- Leverage capital assets by integrating existing UXGs into multi-channel/multi-port racks

High Performance COTS

- Instrument grade, warranted specs
- Integrated racks include system level calibration and thermal control
- Automated RF Calibration & Verification
- Not a "one off" custom system
- Start testing sooner with fast delivery and less maintenance

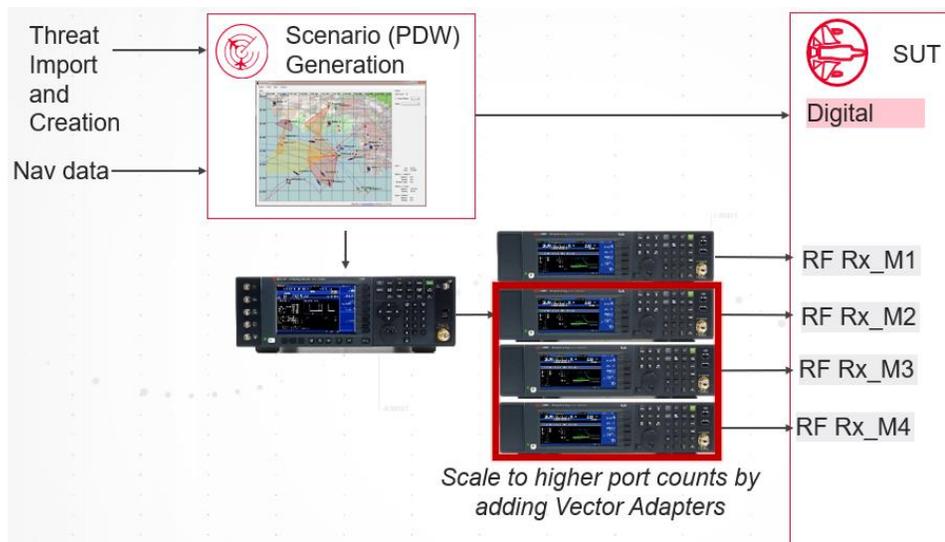## Benchtop Solution - Single UXG agile signal generator

The N5193A UXG agile signal generator's ability to fast frequency hop with phase continuity and repeatability makes it an ideal building block to efficiently simulate complex threat environments across the full 40 GHz range:

- **Multiple pulse-Doppler radars** at different frequencies while maintaining the original phase as the UXG hops from one emitter frequency to another
- **EW scenarios** with thousands of radar threat-emitters and millions of pulses per second with unique antenna scans
- **Expand high pulse density environments** by scaling up in the number of UXGs
  - Increases pulse density
  - Perform pulse-on-pulse simulations
  - Do multi-port angle of arrival (AoA) simulations
  - Staggering identical pulses played out of different ports (different UXGs) in time, phase, amplitude, or all three
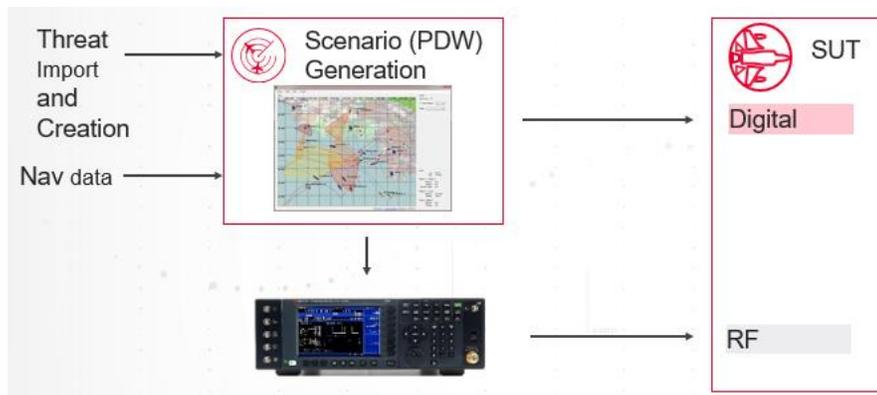
Benchtop Solution - Add UXG vector adapter

The N5194A UXG vector adapter has a 1.6 GHz bandwidth baseband generator to add more capability to simulate complex electromagnetic environments across the full 40 GHz range. The digital IQ baseband system in the UXG Vector Adapter enables you to create more complex pulses with variable rise/fall times and arbitrary modulation within the pulse, including non-linear chirps and comms signals.

Scale to higher port counts by adding Vector Adapters

UXG Comparison

AoA Amplitude/Phase/Time/Doppler	N5193A	N5193A + N5194A
Dynamic Range	80 dB	> 120 dB
Chirp	Linear – 10% of Carrier Frequency	Linear + Non-linear: 1.6 GHz and any shape
Discrete PMOP/FMOP	LFM- 4ns Bins	+AMOP - Exact
Pulse Shape (rise and fall time)	Fixed	Shaped
Digital IQ	No	Yes
SEI Waveforms	No	UMOP
Wideband IQ Playback	No	200 MHz and 1.6 GHz BW
PDW	PDW Parameters for MOP • Entire Pulse • Sub-pulses	PDW Parameters or I/Q Index for MOP • I/Q – Waveform ID (Index to pre-stored I/Q file for MOP) • Parameters – Real-Time Pulse Builder (accept MOP parameters and dynamically generate I/Q)

PDW Generation

The UXG's flexible architecture and legacy threat library import capability is an ideal replacement for current RF sources or integration into new threat simulators. Easily use already created Pulse Descriptor Word (PDW) libraries or create them using a variety of tools including Excel, MATLAB, or Keysight's **N7660C Multi-Emitter Scenario Generation Software (MESG) and Z9500A Simulation View Software.**
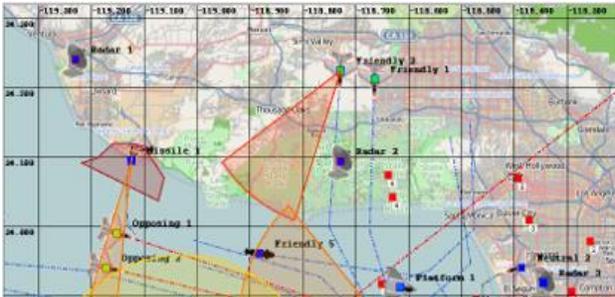

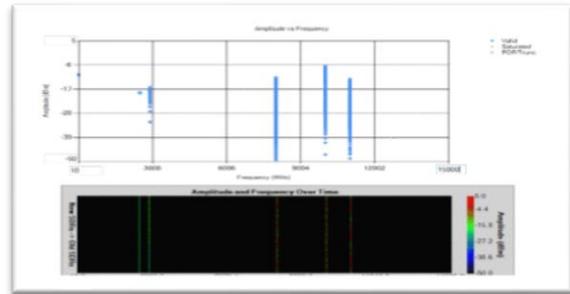Figure 1: Game board with real-time navigation data input

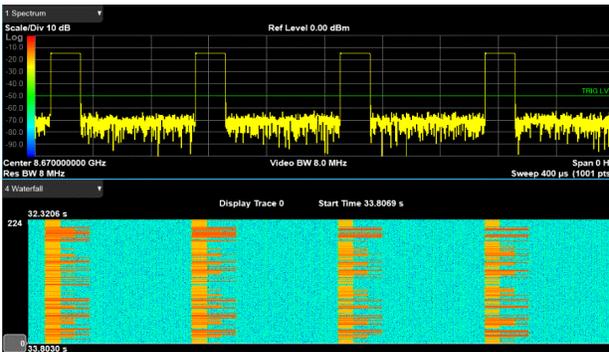Figure 2: PDW Reports and SUT monitoring

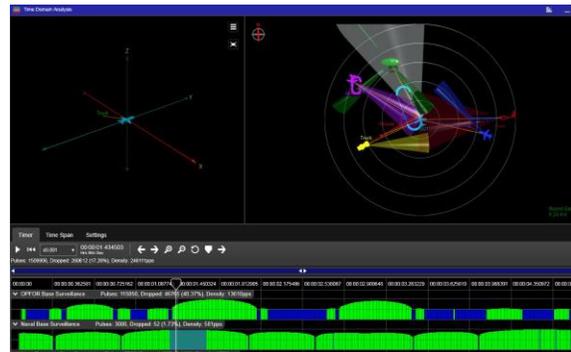Figure 3: Automated RF Verification with PDW reports and SUT monitoring

Figure 4: 3D Visualization Tools

Keysight offers EW RF threat simulation software to create dynamic multi-emitter scenarios with high quality visualization tools to enhance user experience including Game Boards, 3D emitter volumes and RF pulse signal plots and lists. Create validated, EW scenarios with N7660C Multi-Emitter Scenario Generation (MESG) for pre-scripted scenarios and Z9500A Simulation View for dynamic real-time scenarios. Both software applications do not require signal generation hardware to get started but are compatible for PDW generation with the UXG Agile Signal generators to stimulate your EW system under test[1].

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[1] EW software subject to US ITAR export controls. For more information, contact your Keysight representative.

	N7660C	Z9500A
Automatic AOA and Kinematic calculation	✓	✓
Multi-emitter support	✓	✓
Dropped Pulse Reporting	✓	✓
Legacy Data Translation	✓	✓
Scenario Game Board	✓	✓
Plug-in Open Architecture		✓
War Gaming with DIS protocol		✓
Navigation Data Input		✓
Real-time PDW streaming		✓
Automated RF output Verification		✓

Software Selection

Type	Method	Characteristics	Hardware Requirements
Generation	CSV File	Simply create PDWs in a spreadsheet and add complex IQ modulation on pulse in MATLAB or other software tools	UXG Agile Signal generator for RF signal output
Generation	N7660C MESG	Pre-scripted test scenario creates PDWs for N5193A and N5194A	UXG agile signal generator for RF signal output
Generation	Z9500A Simulation View	Plug-in based open architecture EW simulation software for pre-scripted test scenarios and real-time PDW streaming for N5193A and N5194A	UXG agile signal generator for RF signal output
Analysis	N9067C and 89601B pulse analysis software	Capture and characterize the EW environment	X-Series Signal Analyzers, Oscilloscopes Digitizers
Analysis	Z9500A	Automated UXG or SUT RF verification with Z9500A plug-in	X-Series Signal Analyzers, Oscilloscopes, and Field Fox

Integrated system solution

Keysight's UXG-based threat simulation systems provide many options for scaling to higher port counts, higher performance calibrations, thermal control, customized switching, and more. Keysight's systems team has decades of experience in delivering and supporting solutions across multiple industries, greatly reducing risk and long-term costs.

Create high-density AoA simulations with flexible multi-port configurations
- Ensure coherency across multiple sources with calibration of amplitude, phase, and time
- Threat simulators compatible with MESG software or other dynamic PDW-based scenario generation systems
- Perform automated, inline AoA calibrations for time, phase, and power that compensate for temperature drifts with constant thermal control using commercial off the shelf (COTS) equipment

Why does temperature compensation and inline re-correction matter?

Phase and Amplitude responses of instrumentation, connectors, and cables ALL drift due to temperature. This becomes more prevalent at higher frequencies

- Keysight's thermal control and monitoring provides the user with temperature logs, automatic drift reduction, and full amplitude & phase re-corrections without disconnecting cables
- High fidelity Angle of Arrival (AoA) testing with relative phases and/or amplitudes - Thermal control and inline calibrations are VITAL
- Time based AoA (TDOA) test - Thermal control may not be necessary

Temperature Drifts

Test Cables and Adapters

AoA test workflow **with** thermal control and inline calibration
- Full, inline calibration is done (~1-2 hours)
- Temperature logging and thermal control is running
- Drift occurs while testing
- Thermal control reduces system drift, and may prompt user for recalibration if the temperature swing is very high
- Testing is done, with thermal logging to correlate with testing
- If necessary, re-correction is done (~1-2 hours)

AoA test workflow **without** thermal control and inline calibration
- Calibration is done with equipment, then connected to DUT/SUT, adding errors along the way (many hours)
- Drift occurs, with no way of reducing AoA errors and correlating with test data (is the data even sound?)
- Testing is done, with no way to troubleshoot errors
- Constant cycles of troubleshooting and recalibrations occur (many more hours)
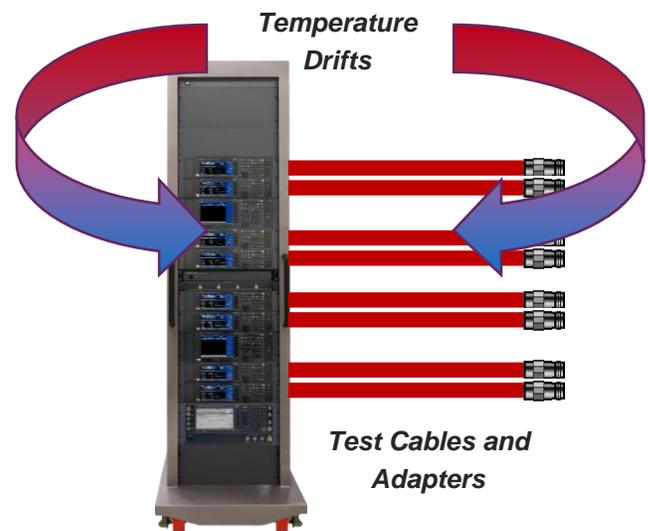
Expand to 1-Ch, 2-Port system

Configurations	Model Number	Minimum Requirements	Software Options
Integration of two 20 GHz customer furnished UXG vector adapters and one UXG signal generator LO	Z2098B-170-2V2	1x - N5193A - 520, SS4, FR1, CC1 2x - N5194A - 520 2x – N7665C MSC software	N7660C MESG, Z9500A Simulation View
Integration of two 40 GHz customer furnished UXG vector adapters and one UXG signal generator LO	Z2098B-170-4V2	1x - N5193A - 520, SS4, FR1, CC1 2x - N5194A – 540 2x – N7665C MSC software	N7660C MESG, Z9500A Simulation View
1-Channel, 2-Port 20 GHz rack	Z2098B-166-2V2	None	N7660C MESG, Z9500A Simulation View
1-Channel, 2-Port 40 GHz rack	Z2098B-166-4V2	None	N7660C MESG, Z9500A Simulation View

2-Channel, 4-Port system or 1-Channel, 8-Port system

Flexible
configuration

The number of UXGs
will be the same for
2-CH, 4-port

and

1-CH, 8-port
configurations

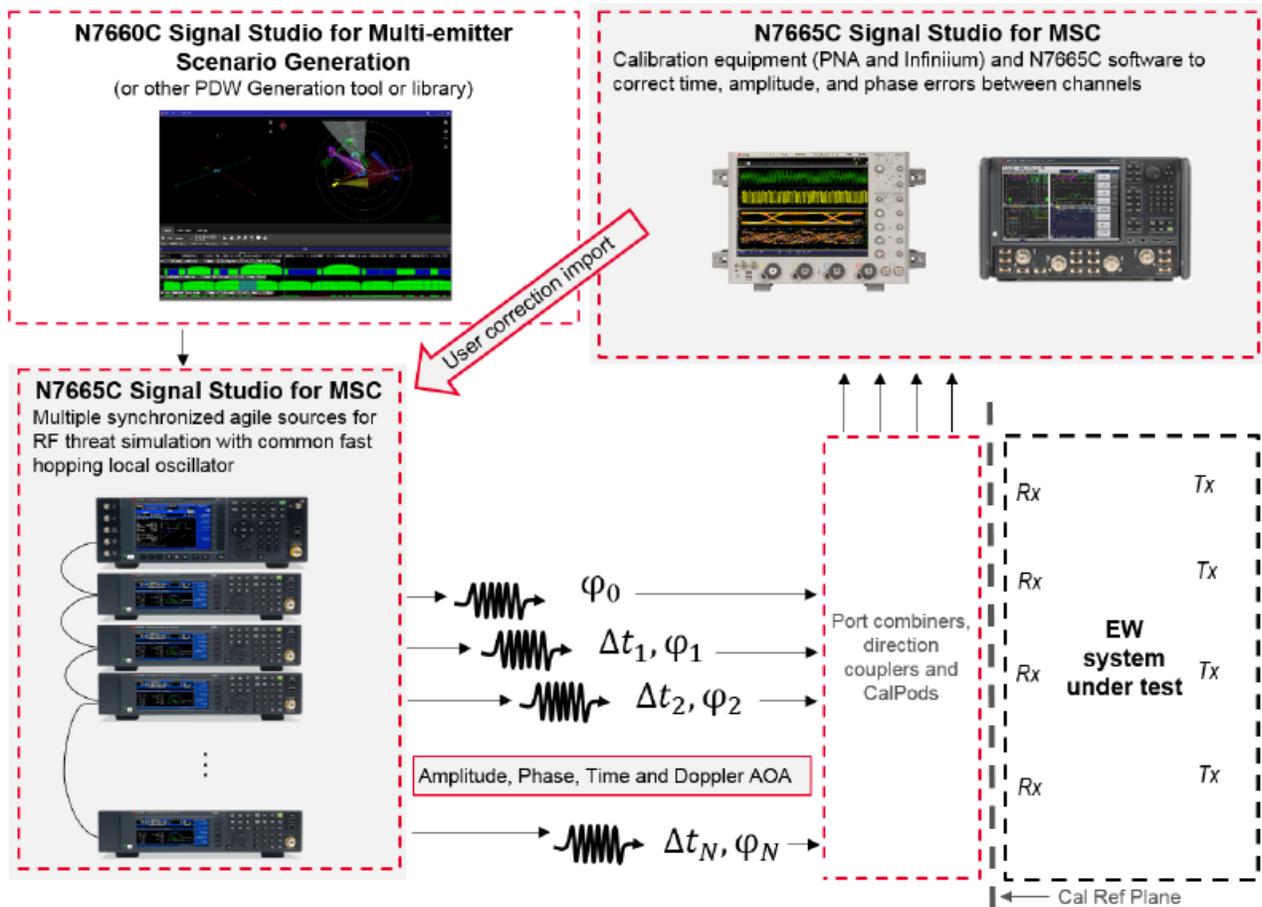| Configurations	Model Number	Minimum Requirements	Software Options
Integration of eight 20 GHz customer furnished UXG vector adapters and 2 UXG signal generator LOs	Z2098B-170-2V8	2x - N5193A - 520, SS4, FR1, CC1 8x - N5194A - 520 8x - N7665C MSC software	N7660C MESG, Z9500A Simulation View
Integration of eight 40 GHz customer furnished UXG vector adapters and 2 UXG signal generator LOs	Z2098B-170-4V8	2x - N5193A - 520, SS4, FR1, CC1 8x - N5194A – 540 8x – N7665C MSC software	N7660C MESG, Z9500A Simulation View
2-Channel, 4-Port or 1-Channel, 8-Port 20 GHz rack	Z2098B-171-2V8	None	N7660C MESG, Z9500A Simulation View
2-Channel, 4-Port or 1-Channel, 8-Port 40 GHz rack	Z2098B-171-4V8	None	N7660C MESG, Z9500A Simulation View

AOA Calibration Options

M9800A Series 20 & 40 GHz Multiport VNA modules

	2-4 Port Benchtop UXG		> 4-Port and multichannel	
AOA Type	**Phase / Amplitude**	**TDOA**	**Phase / Amplitude**	**TDOA**
Calibration Method	Manual calibration can be done with MSC. Must consider temperature drift and test setup changes.		In-situ calibration with calpods and controllers	
Calibration SW	N7665C MSC or SLC	N7665C MSC	SLC	SLC
Calibration HW	PXI VNA USB VNA	PXI VNA USB VNA (Oscilloscope for N5193A)	PXI VNA USB VNA	PXI VNA USB VNA (Oscilloscope for N5193A)
Thermal Control	Recommended	TBD	Required	TBD
PDW Generation	CSV, MESG, Z9500A, Government owned			

N7660C Signal Studio for Multi-emitter Scenario Generation
(or other PDW Generation tool or library)

N7665C Signal Studio for MSC
Calibration equipment (PNA and Infiniium) and N7665C software to correct time, amplitude, and phase errors between channels

User correction import

N7665C Signal Studio for MSC
Multiple synchronized agile sources for RF threat simulation with common fast hopping local oscillator

φ_0

$\Delta t_1, \varphi_1$

$\Delta t_2, \varphi_2$

Amplitude, Phase, Time and Doppler AOA

$\Delta t_N, \varphi_N$

Port combiners, direction couplers and CalPods

Rx | Tx
Rx | Tx
Rx | EW system under test | Tx
Rx | Tx

Cal Ref Plane

Signal Studio for Multi-Source Calibration (MSC) is designed to automate alignment of AoA parameters (Amplitude, phase and/or Time) for a set of UXGs in a system with a calibration reference plane at the connection ports of the SUT.

- Automated process ensures more precise-level control of AoA parameters for multiple emitter environments, ensuring enhanced realism and greater confidence during the test and evaluation process
- Creating AoA means staggering identical pulses played out of different ports (UXG Signal Generators) in time, phase and amplitude
    - For accuracy UXGs must be aligned in time, phase and amplitude.
    - Without calibration, differences the UXG outputs leave the potential for creating false AoA simulations due to significant amplitude, phase and timing differences
    - MSC measures the relative differences of the UXG outputs and applies corrections to each source to ensure they are all at the same starting place. Allowing the user to then create AoA simulations by altering phase, amplitude and timing of each pulse

SLC – System Level Calibration is a higher-level calibration in the integrated system that utilizes MSC.

- Provides unattended/automated user calibration, verification, and maintenance
    - Minimize human error and reduce the amount of time to perform system recalibrations
    - Amplitude, phase and time corrections across all ports and channels are done with multi-port VNAs
    - System calibration and verification can be performed without disconnecting the SUT RF Cables
    - UXA signal analyzer and an oscilloscope can be used to support automated RF emitter validation. SLC allows the T&E Community to focus on testing the SUT not the RF Simulator

Conclusion

Keysight's UXG signal generators offer flexibility and performance as a foundation for building an EW Threat Simulation system. The scalability of UXGs will allow designers to move through the different stages of development as budget and testing requirements change, from benchtop to multi-rack systems. Our systems teams are experts in RF and calibrations to minimize development setbacks.

Keysight can reduce risk to schedules by providing high performance COTS equipment that requires less maintenance and faster delivery.

Learn more at: www.keysight.com

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus

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