WHITE PAPER

Solving EW Challenges in the Lab Enables Mission Success

Test EW system performance in a more realistic environment by leveraging ongoing improvements in EW environment simulator scalability, signal diversity, and density.

KEYSIGHT

ElectroRent

Table of Contents

Overview

Ensuring mission success for electromagnetic spectrum operations (EMSO) grows increasingly difficult due to the crowded RF environment. Several decades ago, an electronic warfare (EW) system primarily had to contend with other military systems. Today's spectrum environment contains a growing range of commercial, industrial, military, and government wireless technologies operating across many frequency ranges. In this congested, contested environment, it is much more difficult to predict how an EW system will respond to quickly evolving and emerging threats. Facing this rising complexity demands that we confront heightened performance expectations for EW systems. Extensive testing of an EW system in the lab environment helps assess its performance before the mission to determine its readiness. As EW test laboratories scale up capabilities in signal density and diversity, they can more accurately represent the real world to help test systems before an actual mission.

Numerous EW systems currently exist or are in development to address the operational challenges in today's electromagnetic (EM) environment. These systems serve countless missions, creating a wide range of test scenarios to perform. Applications by prime contractors conducting research and development or a military unit upgrading firmware or software are both critical. However, both can be impacted by the budget and acquisition process, further driving the need for scalability in the design. All of this time and expense leads to a common goal: ensure mission success.

Given the unknowns and complexity faced by EW system engineers, such assurance demands an immense amount of testing and verification. This process is ongoing, as stringent testing must be completed for ongoing updates and other system changes. Most often, the goal is to perform full testing of all aspects of the system, stressing it against real-world simulations to ensure that the system responds as designed.

This test goal becomes increasingly challenging as systems increase their capabilities to serve multiple mission objectives. An example is the rising number of antenna apertures and active arrays. In response, EW systems must manage multiple simultaneous functions, including precise geolocation of emitters in multiple quadrants simultaneously. Being able to adequately test systems with real-time, closed-loop behaviors also demands that EW environment simulators address latency issues with more modern computing and data interfaces.

Most legacy systems can only perform open-loop test. Typically, these systems have limitations regarding angle of attack (AoA) simulation capability and accuracy. They may also lack the capability to react to a system under test (SUT) location and electronic attack (EA) conditions. A modern EW test environment must address these areas to be capable of testing real-world system performance.

Evolving EW Missions

Electronic warfare test labs must go beyond parametric testing to provide functional testing capabilities over a complete, complex scenario representing a mission. Many challenges can arise during a mission in the EMSO environment, requiring the successful completion of tasks like threat identification, geolocation, electronic attacks, and other countermeasures.

The goal of a mission is to succeed across various fronts, such as communicating between disparate groups, devices, or systems. To achieve this goal, they need to know the mission's safe limits. In other words, they want to know the range they need to stay within (or out of) and how they can protect the equipment, assets, and personnel inside that range. Often, they will want to test an EW system for a "what if" scenario. The goal is to safeguard the mission and its participants and evaluate the effectiveness of EA, if used.

To test whether the system performs as it should in the simulated lab environment, you often must go beyond parameters to evaluate the full system functionality and autonomous responses. The goal is to determine how well the system performs tasks it was designed to accomplish in a realistic environment.

Incorporating threats

Consider an aircraft EW receiver system, for example. In an EW test environment, the goal is not to gauge how that aircraft system operates in the presence of commercial ground radars. You want the presence of real enemy radars and operating modes on the ground so you can see how your system operates while being challenged. The system's goal may simply be detecting those radars. Alternatively, the aircraft may want to know if appropriate countermeasures have been selected.

By testing the EW system in a realistic environment in which it performs, against realistic threats, you gain insights into system performance strengths and weaknesses. This data provides key insights that will aid mission planning, such as details into system capabilities and how they will influence operation in a specific zone.

Increasing Realism

Using signal generators and sophisticated software with open architectures, EW system designers and evaluation engineers can create scalable test environments. Open architectures allow the same test equipment to be used in multiple environments, depending on the level of need for fidelity and realism. All test levels can leverage the same simulation models and test equipment, as it is scalable from a single port to a large direct-inject system for installed system test facilities. These larger systems require highly accurate, multi-port AoA simulation across groups of widely separated apertures. By adding components like antennas and power amplifiers, in-chamber radiated and open-air-range test can also be achieved with synergistic approaches. Examples include using the same threat models employed for early validation. EW test systems with increasing sophistication and capability must also address the following:

Software ease of use

Most EW test and measurement labs prioritize efficiency to gauge results quickly. The goal is to develop a high-fidelity, extremely dynamic, and dense scenario. Achieving this goal usually demands some intensive programming, which can be very time consuming. Today's EW test systems cover more options related to use cases in software, decreasing the need to customize in the lab. EW threat simulation software can create scenarios ranging from pre-scripted to fully dynamic, all within the user interface. It also should offer the ability to support SUT interfaces with software plugins for specific test case optimization.

Often, test engineers and designers need to test receivers against legacy and current threats. Modern EW software interfaces also provide the ability to import threat libraries. As a result, EW system designers and test engineers can focus efforts on their scenarios and what they are trying to accomplish.

Scalability

Modern EW test systems provide increasingly scalable architectures. Leveraging digital advancements, higher-performance systems can simultaneously introduce variable signal types within, say, a 2.5-GHz radio-frequency (RF) bandwidth. As a result, receiver ports can be stimulated with overlapping pulse-on-pulse or pulse-on-interferer signals from a single RF output. Layering those signals previously required multiple instruments or the addition of a combiner network. New approaches leverage application-specific integrated circuits (ASICs), with aspects like internal signal combining providing accurate representation of EW threats.

Flexibility

When testing an EW or radar system, you must simultaneously simulate multiple signals. The warfighter increasingly encounters known and unknown signal types at the same time. More unknown variables arise from adaptive and cognitive systems in the environment, which dynamically change on the fly. These emitters may have some level of AI cognition, which enables them to adapt to their environment and change.

Flexibility boosts scalability in the EW test environment, helping you grow into this evolving market without a one-size-fits-all approach to test infrastructure. In the early research and development phases, you may start with a simple EW simulator that can do basic scripted emitter generation. As that system evolves into a more complex subsystem, however, the same capital expenditure investment allows you to scale up the complexity and size of the signal environment within the same framework of the original signal-generator investment.

Systems of systems

Such flexibility becomes more critical as test scenarios increasingly need to incorporate *systems of systems*. Here, multiple systems work together, even though they are technically different hardware units. They operate in concert, say through an IP link and a network backplane. This characteristic allows them to look like one system, even though they might be testing two different aircraft in two locations.

Another example of *systems of systems* is a piloted aircraft accompanied by five unmanned aerial vehicles (UAVs). The primary aircraft may distribute tasks and functions to the crewless aircraft as they collaborate on the same mission. Often, a fighter jet entering an environment for a mission could have two or three UAVs accompanying it. Those additional entities can perform various tasks to create diversions, if needed, to ensure mission success. Propagation effects on data links may also need to be part of the test setup.

The receivers on UAVs and piloted vehicles both need to see the environment. If they do not have situational awareness and intelligence, they cannot succeed in their coordinated efforts. Systems of systems offer an excellent example of the unpredictable complexity and unknown threats and countermeasures encountered during a mission scenario. To verify performance of these complicated systems of systems, the latest test systems must account for all of their software and algorithms when signals are produced via a signal generator.

Rising Density and Complexity

To test so many variables, the features most transforming the test lab are signal density, signal diversity, and system-behavior model complexity. EW test engineers now look to test in very dense signal environments with large numbers of emitters, producing millions of pulses per second. They also must confront the added complexity of representing both modern communications and radar signal types.

Figure 1. Software such as PathWave Vector Signal Analysis (VSA) for EW helps you identify and log key metrics for pulse-modulated radar signals in aerospace, defense, and EW.

In the past, many sources were necessary to create such complex threat environments. Newer signal generators can provide many simultaneous digital channels. As a result, colliding pulses can be generated on top of each other and reside anywhere in frequency and amplitude (Figure 1). In addition to increasing system capability, for example, the VXG-C signal generator with signal descriptor word (SDW) offers a more compact physical lab footprint when high-density environments are needed.

Pulses may span many gigahertz of frequency, requiring the analysis of large data sets to identify individual pulses or patterns and quantify various figures of merit. By utilizing the PathWave VSA software's pulse train scoring and emitter recognition features, it becomes possible to pinpoint pulse trains of significance. Engineers also can highlight them on a visual interface using color coding and generate pulse tables to categorize distinct pulse trains for signal assessment within large data sets.

Evolutions in EW Test

EW test systems now boast the flexibility to handle these applications from early-stage research and development through operational test verification into the open-air range. In fact, some of today's highly evolved systems can also support the back-end step, where the system receives information about new signal types and parameters.

Figure 2. The multi-channel VXG-C vector signal generator and the Z9500A Simulation View software provide an open-architecture solution for testing a variety of EW scenarios against all complex signals in the mission environment.

With an open architecture, for example, a solution combining the Keysight VXG-C signal generator with the EW Threat Simulation software allows you to perform different levels of testing with a variety of EW scenarios (Figure 2). It also can handle communication as well as radar signals, helping to test systems against all of the complex signals in their mission environment. The latest EW test systems also emphasize the following:

- Form factor
- Calibrated results
- Output power

Form factor

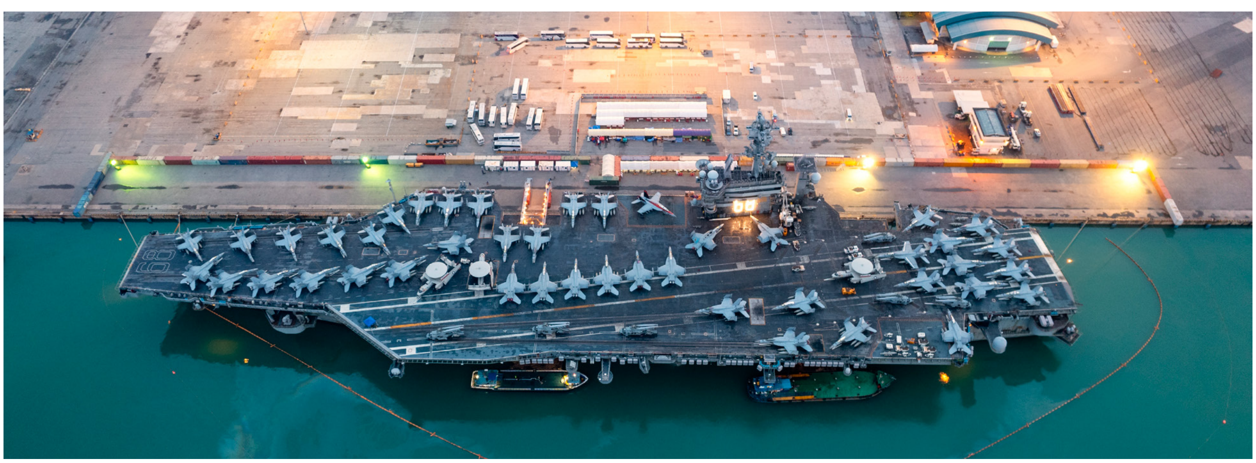
Newer EW test systems minimize their form factor to reduce space requirements and cost. You often need to perform threat simulation in tighter spaces. But today's complex environment and evolving threats demand growing functionality and sophistication. Given the increased complexity of modern systems, you can now attain a smaller form factor system with the advantages of virtual channel capability and other high-performance features.

Calibrated results

Test system accuracy also is vital to understanding and trusting system results. With calibration across the whole band, for example, a modern signal generator can emulate the AoA no matter where the emitter is in the range. Accurate amplitude, time, and phase difference of arrival start with high-performance calibration equipment with warranted specifications. This calibration equipment must be integrated with in-situ calibration methods and automated system-level calibration to ensure the highest level of confidence in validation and verification.

Output power

Higher output power enables the scenario to run with realistic power levels within closer ranges. Previously, simulators were often limited in output power. Once you got within a certain range, the power in the scenario could not match what it saw. Not having to adjust for inaccurate power levels improves performance and the accuracy of results.



Pathway to Larger-Scale Systems

Synchronizing chassis in new EW test systems creates a roadmap for larger-scale system support. These systems are evolving toward a more simplified block diagram instead of adding complexity (Figure 3). For large-scale EW simulators, a smaller form-factor source with shorter RF paths is inherently more stable and can maintain calibration over temperature with less drift.

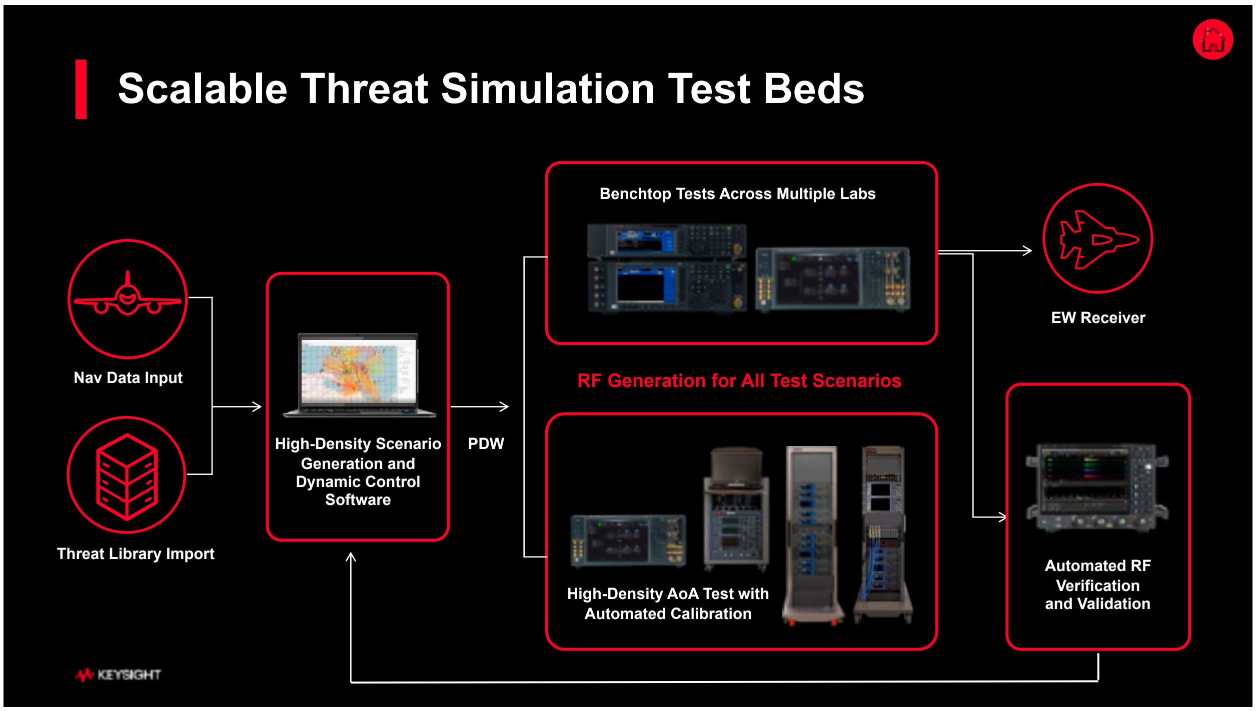


Figure 3. Threat simulation test beds scale to provide multi-program asset utilization, benchtop to multi-port AoA/high-density tests, and integrated analysis and verification.

The goal is for these newer architectures to achieve superior performance in both time synchronization and phase alignment across RF channels and system under test (SUT) ports. Modern solutions based on direct digital synthesis (DDS) that include sample rate conversion can also generate a true Doppler effect flying to or from a transmitter, including pulse compression. In terms of in-phase / quadrature (IQ) data, test systems will be able to play signal files at any sample rate, conserving memory space and allowing customers to use existing IQ data.

Where to Start

With so many use cases and such mission diversity in the EMSO environment, the needs for EW test labs shift dynamically. Test cases may start very simple, but become more complex and representative of real-world conditions. These changes make it more challenging for EW sensors to identify threats and not confuse them with friendly actors. For a single instrument, for instance, a typical first use would be to look at RF energy in early-stage research and development. A microwave signal generator, connecting to its RF port, stimulates the receiver to determine if it sees energy in the environment as it should. If you add more complex software to that receiver, you can evolve its functionality to discern if it is seeing a friend or foe. It recognizes them by their pulses, as it knows how they should look and can identify them accordingly.

Adding a couple of baseband virtual channels lets one receiver play the friendly signal while the other plays the threat signal. EW systems continue to incorporate more intelligence in terms of signal recognition. By adding intelligence and functionality to your system, you can simultaneously run various software tools, even stacking them on top of each other, while recognizing and following them to distinguish good actors from bad actors.

In the R&D lab, engineers are designing their next-generation radar warning receiver or another type of receiver. Here, a signal generator like the VXG-C provides the benefit of scalability and flexibility to handle multiple types of signals. The interfaces enable real time, low-latency data to RF capability to support high-fidelity testing of advanced EW systems. If you need to create a very dense environment, you can add signals on top of signals within a single port, coupled with software that utilizes these high-speed interfaces.

Real-World and Operational Testing

Beyond research and development, EW testing needs to move toward maintaining operational readiness using the latest intelligence data on evolving threats. Engineers must perform testing with a realistic RF background for specific regions or missions. Software can work seamlessly with the interfaces on a signal generator, such as the VXG-C, to create basic or more complex scenarios representing the actual mission.

When the warfighter enters a conflict or a situation where multiple things are happening in the spectrum simultaneously, you can model that in software. The interfaces on a signal generator like the VXG-C enable you to connect to a software-simulated environment and produce it at RF across multiple ports. This simulation incorporates the physics and math necessary for calculating the phase, amplitude, time difference of arrival, and frequency difference characteristics. Evaluating the EW system in a simulated environment allows you to accurately correlate with open-range testing.

Increased Support from EW Test

To cover all stages of the EW workflow, modern signal generators also support the initial task of searching out RF energy through the increased detection and recognition of signals. You can add more software-based generators to start scaling up the system capabilities with multiple ports and different types of time-coincident signals. You also can add channels or ports to achieve a level that matches the EW system's complexity and systems of systems receivers.

For example, say you decide to scale up the test system. You could configure the test setup to have 16 ports to match a specific number of apertures on your aircraft. You may have 16 ports running from a VXG-C in the lab today. However, you may only need four ports for a simplified test tomorrow. The system can easily be reconfigured to support four simultaneous test scenarios, optimizing the use of these assets and reducing the bottleneck in the test lab.

What the Future Holds

This flexible, adaptable signal-generation approach strives to keep up with EW testing missions in the fast-changing EMSO environment. The flexibility needed today will only increase going forward. EW test systems also will continue to add new capabilities, such as the ability to represent higher fidelity transmitters, emulating realistic behavior with the true physics of RF propagation. Such features will provide insight beyond static test cases or playback of RF recordings, which have limited usefulness in a dynamic test environment. Higher fidelity simulations with more realistic RF environments, propagation, and behaviors enable you to see elements that your system will face in real-world scenarios.

Optimal results will come from a system that handles not just EW and radar, but the commercial environment as well. You can use one system, like the VXG-C, to incorporate fifth-generation (5G) and previous cellular technologies as well as early sixth-generation (6G), Global Positioning System (GPS), and other satellite and commercial technologies.

Building toward Mission Success

Electromagnetic spectrum operations provide the landscape for countless, constantly evolving missions. Without being able to predict the pace of change in the EMSO environment, you need to maximize your system's performance with the best capabilities and accuracy. Given the scalability and flexibility of today's modern EW test systems, your test system should be able to run a receiver through the most complex systems, simulated real-world environments, and different scenarios you can devise.

By knowing how your system will respond to the true representation of threats in the real-world mission environment, you gain assurance in your system and greatly increase the chances of mission success.

For more information about these solutions, check out these resources:

Technical Overview: Signal Generator for High Density Electronic Warfare Simulation

https://www.keysight.com/us/en/assets/3123-1508/technical-overviews/Signal-Generator-for-High-Density-Electronic-Warfare-Simulation.pdf

Technical Overview: Keysight EW Threat Simulation View

https://www.keysight.com/us/en/assets/7018-06878/technical-overviews/5992-4339.pdf

AMERICAS

Corporate Headquarters USA
8511 Fallbrook Ave,
Suite 200, West Hills,
CA 91304, USA
+1 800 553 2255
sales@electrorent.com

Canada
210 Brunel Rd, Unit 1-2,
Mississauga, ON L4W 4M2,
Canada
+1 800 553 2255
sales@electrorent.com

Latin America
8511 Fallbrook Ave,
Suite 200, West Hills,
CA 91304, USA
+1 800 553 2255
sales@electrorent.com

ASIA

Asia Pacific Headquarters & Malaysia
Plot 253, Jalan Kampung Jawa,
Bayan Lepas FIZ Phase 3,
11900 Bayan Lepas, Penang, Malaysia
+604 614 6000
info.asia@electrorent.com

China
Room 101, 1st Floor,
East Side of Building 6,
Courtyard 18, Ziyue Road,
Chaoyang District,
Beijing, 100102, China
+86 400 819 2800
info.china@electrorent.com

India
4051-53, Vipul Square, B Block,
Sushant Lok Phase - I,
Gurgaon 122002,
Haryana, India
+91 124 4831 400
info.india@electrorent.com

Singapore
38 Beach Road, #30-19
South Beach Tower,
189767 Singapore
+65 6773 9136
info.asia@electrorent.com

Taiwan
12 F., No. 508, Sec. 5,
Zhongxiao E. Rd.,
Xinyi Dist., Taipei City 11083,
Taiwan (R.O.C.)
+886-701 0152 200
info.china@electrorent.com

EUROPE

Belgium
Intercity Business Park,
Generaal de Wittelaan 9/18,
B-2800 Mechelen, Belgium
+32 (0) 15 740 800
belgium@electrorent.com

France
Parc Tertiaire Icade,
43 Avenue Robert Schuman,
94150 Rungis, France
+33 (0) 1 45 12 65 65
france@electrorent.com

Germany
Borsigstrasse 11,
64291 Darmstadt,
Deutschland
+49 6151 360 41-0
germany@electrorent.com

Italy
Via Melchiorre Gioia 8,
20124 Milano, Italia
+39 02 9239 2801
infoitaly@electrorent.com

Nordics
Intercity Business Park,
Generaal de Wittelaan 9/18,
B-2800 Mechelen, Belgium
+32 (0) 15 740 800
belgium@electrorent.com

Poland
ul. Długa 44/50,
00-24 Warszawa,
Polska
+48 22 331 66 66
poland@electrorent.com

Spain
Calle Gabriel Garcia Márquez nº 4,
1ª Planta, Las Rozas de Madrid,
Madrid, 28232
+34 91 076 21 90
spain@electrorent.com

The Netherlands
Fokkerstraat 29,
3905 KV Veenendaal,
Nederland
+31 (0) 318 588 688
netherlands@electrorent.com

UK & Ireland
Unit 1, Waverley Industrial Park,
Hailsham Drive, Harrow,
HA1 4TR, UK
+44 (0) 20 84 200 200
info.eu@electrorent.com

MIDDLE EAST & AFRICA

Unit 1, Waverley Industrial Park,
Hailsham Drive, Harrow,
HA1 4TR, UK
+44 (0) 20 84 200 200
info.eu@electrorent.com