Solution Brochure

Electromagnetic Spectrum Operations

Electromagnetic Spectrum Operations

As the electromagnetic spectrum becomes more congested and contested, Electromagnetic Spectrum Operations (EMSO) are increasingly critical to achieving and maintaining operational dominance across modern defense systems. EMSO includes electronic warfare, signals intelligence, spectrum management, and cyber electromagnetic activities (CEMA), all of which play a critical role in today's complex mission environments. These systems face growing challenges that require solutions capable of adapting, operating across multiple functions, and remaining resilient under pressure. Ongoing advances in technology and the changing demands of modern operations are leading to the development of more capable and integrated system designs.

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Trends and Challenges in EMSO Systems

As EMSO systems grow in strategic importance, rapid advancements in RF design are transforming how these capabilities are delivered and sustained. These innovations are resulting in more capable system designs. These include evolving solid-state design processes that incorporate technologies such as GaN, direct to RF wideband data converters, an increase in component and module integration, and devices in multi-element antennas.

These technology shifts are increasing system agility and mission responsiveness, but they also bring new layers of complexity. Highly integrated architectures that combine digital-to-RF conversion, embedded DSP, and antenna-in-package designs are more challenging to characterize and validate using traditional test methods. At the same time, modular, multi-element antennas, capable of forming multiple beams and operating across wide frequency ranges, demand precise calibration and signal fidelity across domains.

The result is a dual challenge: while EMSO systems are becoming more capable and adaptive, the testing and validation strategies required to ensure performance must evolve just as rapidly. Meeting this demand calls for mission-ready, multi-domain test environments that reflect the complexity of real-world operational conditions is critical.

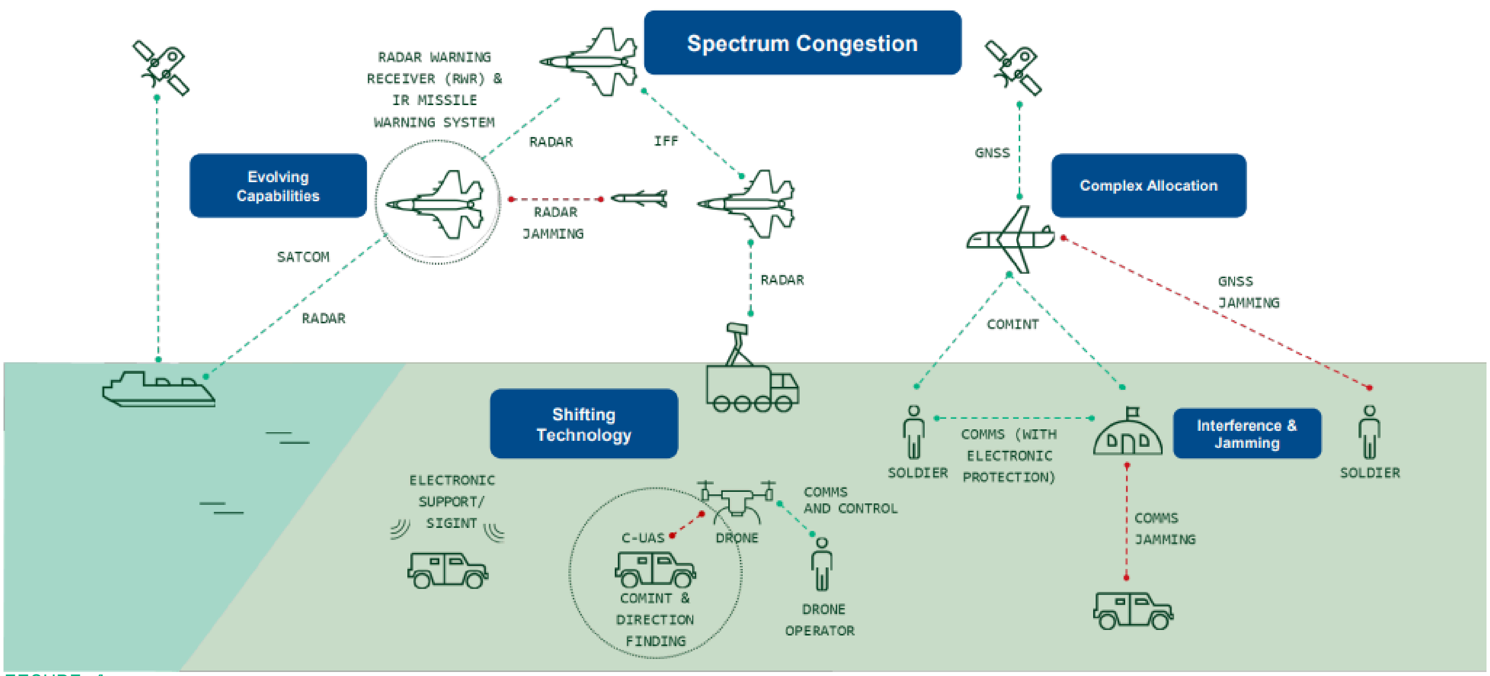

FIGURE 1

Modern EMSO systems must be adaptable, multi-functional, robust, and multi-domain for all possible test scenarios, uses, and configurations on the range.

As these systems become more complex and capable, they also require more sophisticated validation approaches. Traditional test processes, which include digital modeling, hardware-in-the-loop integration, open-air range trials, and live mission execution can be time-intensive and cost-prohibitive, especially when deferred until later development cycles. As you you move closer to range and live testing, validation becomes increasingly expensive and risk-prone, making it critical to shift system-level insights earlier into the process. High system integration, software-defined functions, and multi-domain interoperability make it difficult to isolate performance issues or simulate realistic mission conditions early in the process cycle. Delaying system-level validation until range or mission testing can lead to late-stage failures and schedule risk.

To address these challenges, reduce risk, and accelerate development, organizations are shifting mission-scale fidelity testing earlier in the design lifecycle. By integrating digitally simulated environments with hardware-in-the-loop and RF validation labs, teams can rapidly iterate and identify issues before deployment. This approach reduces dependency on expensive range testing, enables earlier performance verification, and supports more agile system development. The result is faster, more confident delivery of EMSO capabilities equipped to meet today's dynamic operational demands.

NI System Software

NI's RF HWIL system software addresses these challenges with cohesive, mission-specific solutions to EMSO system validation. The Multi-Emitter Generator, Radar Target Generator, and RF Record and Playback software offer mission-scale fidelity across key threat environments to create a common, flexible platform. These software tools enable more integrated testing with the speed and adaptability needed to stay ahead of evolving operational demands.

NI Multi-Emitter Generator Software

The Multi-Emitter Generation (MEG) Software includes applications and APIs to help you operate the PXI Vector Signal Transceiver (VST) as an open-loop threat simulator for validation of EMSO systems. The MEG software works with scenarios provided from a file. With this software, engineers can inject up to 8 independent emitters with configurable parameters such as time of arrival (ToA), initial phase, frequency, amplitude, as well as modulation on pulse. In its default personality, the VST is a calibrated RF generator and analyzer.

Beyond the standard VST calibration, the MEG software includes multi-channel synchronization and compensation routines to deliver best-in-class waveform synthesis. The VST analyzer can be used in conjunction with the generator and MEG software to provide synchronized monitoring and analysis of the scenario being simulated and potential system responses.

By delivering synchronized, high-fidelity RF signal generation with support for key emitter parameters, the MEG software enables the simulation of complex EMSO environments for validating radar warning receivers and other EMSO systems. The MEG software is well-suited for validation of Electromagnetic Spectrum Operation (EMSO) systems such as Radar Warning Receivers.

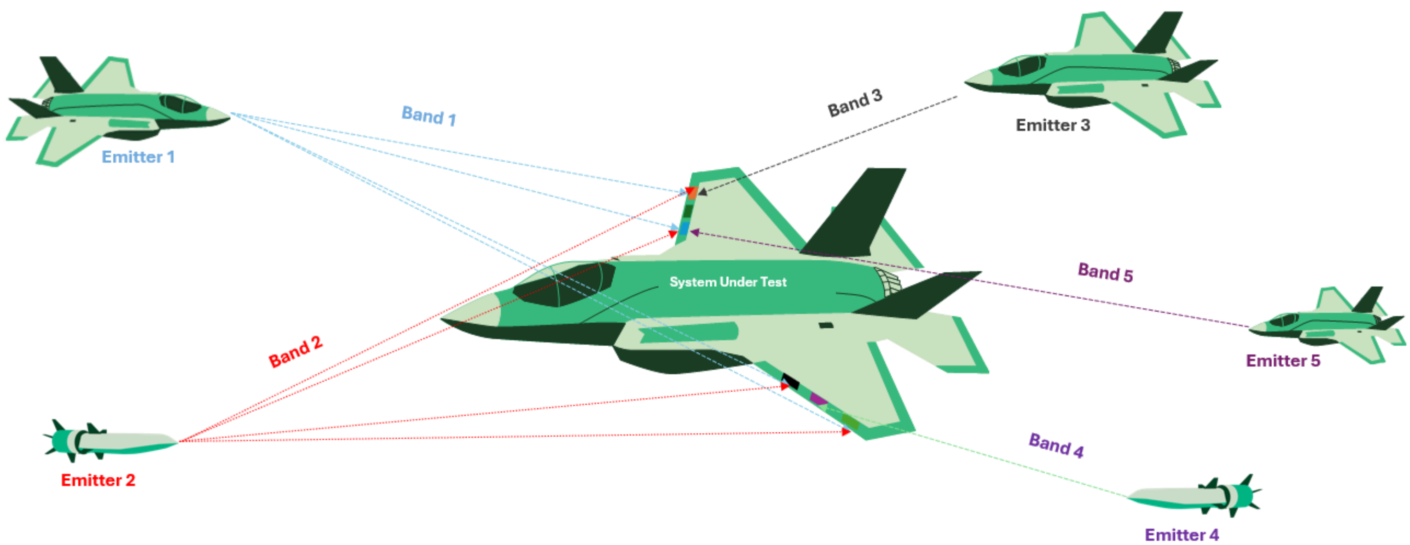

FIGURE 2

Typical wavefront configuration for validation of direction-finding algorithms,: Emitter 1 or 2 density configuration for validation dynamic range and identification: emitters 1 through emitter 5, simultaneously

NI Multichannel RF Record and Playback Software

Leverage best-in-class RF performance with reliable, high-bandwidth data movement with NI's record and playback solution (RPS) for labs, anechoic chambers, and open-air ranges. Users can validate the performance of their radar, EW, navigation, or communications systems, by leveraging reliable raw I/Q data recording that is scalable as channel counts, data rates, and instantaneous bandwidths increase.

The RPS system delivers channel-to-channel phase coherence and up to 2 GHz of IBW recording across a scalable number of channels. Built in calibration ensures accurate LO power, amplitude, and phase coherence across channels. With up to 180TB of storage, data is moved seamlessly and efficiently.

The system also supports real-time and offline analysis, enabling users to capture and replay complex RF environments for deeper insight into system behavior. Built-in time synchronization and trigger options ensure precise data capture, while remote access capabilities and support for open data formats like SigMF make integration into existing test workflows straightforward. Designed for scalability and performance, the RPS solution empowers users to adapt to evolving test needs with confidence.

NI Radar Target Generation Software

The NI Radar Target Generation (RTG) Software transforms supported PXI Vector Signal Transceivers (VSTs) into closed-loop, real-time radar target generators through dedicated applications and APIs. The software supports target scenarios calculated in real time, streamed from a scenario generator, provided as large datasets (with over 10 million entries), or derived from defined motion paths using linear motion models.

With the NI RTG, engineers can inject up to four simultaneous, in-beam targets per VST into a radar under test. Each target is configurable in range (time delay), velocity (Doppler frequency offset), and path loss (attenuation). With an integrated agile attenuator, precise, real-time control of signal levels to support dynamic path loss emulation are enabled. Targets can be positioned as close as sub-meter distances in a low-latency predictive mode, and as far as 64,000 km, enabling a wide range of engagement geometries.

In its default personality, the VST operates as a calibrated RF generator and analyzer. Beyond standard calibration, the NI RTG Software includes a loopback calibration routine that measures and compensates for system losses—de-embedding residual and external cable or fixture effects to ensure accurate time delay, attenuation, and optimal spectral performance.

The software also includes a coprocessor harness for executing custom IP, allowing inline parametric measurements or augmented signal processing within the signal generation chain.

NI RTG is best suited for basic functional radar validation, production test, and MRO (maintenance, repair, and overhaul) applications.

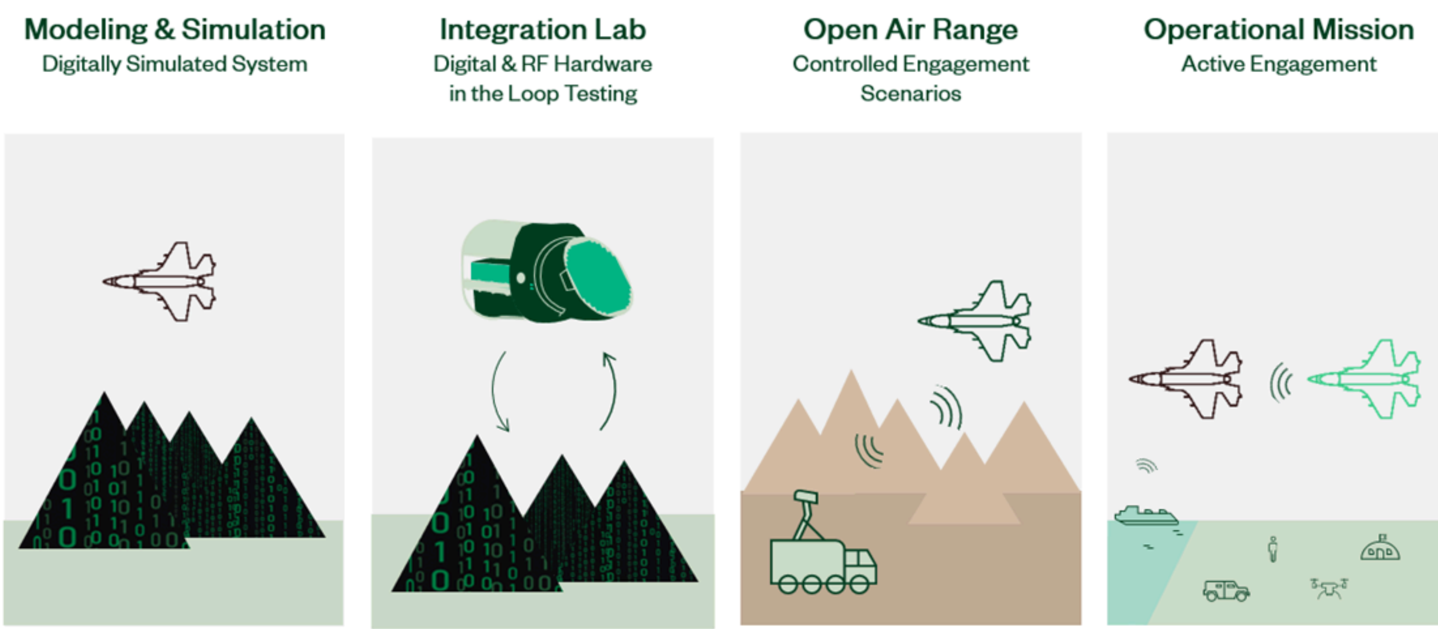

FIGURE 4

Phases of radar test, design, and validation

Compatible Hardware

NI EMSO test and measurement software works with COTS PXI modular instruments. The PXI chassis and controller are integral parts of the system, with the option to add coprocessing and timing & synchronization modules.

PXI Chassis

PXIe-1095, 18-Slot PXI Chassis

- High-bandwidth backplane with up to 24 GB/s of system bandwidth
- Up to 82 W of power and cooling in every slot
- Two hot-swappable power supplies to improve the mean time to repair (MTTR)
- Timing and Synchronization option that includes a built-in oven-controlled crystal oscillator (OCXO) for increased clock accuracy and external clock and trigger routing.
- Accepts PXI Express modules in every slot and supports standard PXI hybrid-compatible modules in up to five slots.

FIGURE 2

The PXI chassis plays an important role in transporting data between modules and the host controller, as well as providing cooling, timing, and synchronization.

PXI Controller

PXIe-8881, Intel Xeon 8-Core x86 Processor

- Ideal for processor-intensive and high-throughput streaming in RF applications.
- 24 GB/s system bandwidth
- Includes two Gigabit Ethernet ports, two USB 3.0 ports, four USB 2.0 ports, and two Thunderbolt 3 ports.
- Removable hard drive
- Available with 16 GB, 32 GB, or 64 GB memory

FIGURE 3

The PXI controller provides embedded computing within the PXI chassis, and runs any host-based processing functions.

Vector Signal Transceivers

PXI Vector Signal Transceivers

This software supports the following models:
PXIe-5830, PXIe-5831, PXIe-5832, PXIe-5841, and PXIe-5842

- Combines RF generation and acquisition into a single PXI module
- Up to 21 GHz frequency coverage, extendable to 44 GHz with frequency extender
- Up to 1 GHz instantaneous bandwidth
- Features the flexibility of a software defined radio architecture with RF instrument class performance
- Utilizes NI-TClk timing and synchronization technology to synchronize with more VSTs or other instruments, for multichannel applications

FIGURE 4

Vector Signal Transceivers provide the RF generation and acquisition capability needed for EMSO systems

High-Speed Serial Coprocessor

The PXIe-7903, 28 GSps, 8-Channel High-Speed Serial Instrument

- Designed for engineers who need to validate, interface through, and test serial protocols.
- Includes a Xilinx Kintex UltraScale+ FPGA to implement various high-speed serial protocols.
- Programmable in LabVIEW FPGA for maximum application-specific customization and reuse.
- Takes advantage of FPGA multigigabit transceivers for up to eight TX and RX lanes.
- Industry-standard QSFP28 connectivity (compatible with QSFP+)
- 8 GB onboard DRAM

FIGURE 5

The PXIe-7903 High-Speed Serial Instrument as an FPGA coprocessor can be used for augmented signal processing and inline measurements.

Timing and Synchronization

PXIe-6674T, OCXO Synchronization Module

- Generates and routes clocks and triggers between devices in a PXI Express chassis
- Can generate two types of clock signal:
    - Highly stable 10 MHz clock based on an onboard precision oven-controlled crystal oscillator (OCXO) reference.
    - Clock from the direct digital synthesis (DDS) clock generation circuit.

FIGURE 6

The PXIe-6674T OCXO PXI Synchronization Module may be optionally added for certain systems

Software Defined Radio

The NI USRP Software Defined Radio (SDR) platform empowers Electromagnetic Spectrum Operations (EMSO) with a flexible, high-performance solution for radar, electronic warfare, and secure communications applications. By integrating general-purpose processors, field-programmable gate arrays (FPGAs), and wideband RF front ends into a unified architecture, USRPs enable rapid prototyping and deployment of advanced RF systems. Whether for spectrum sensing, radar target emulation, EW signal generation, or agile comms link prototyping, the USRP family spans from low-cost research units to rugged, multichannel, deployable systems trusted across defense and intelligence communities.

Supporting both LabVIEW and open-source workflows, the USRP ecosystem offers seamless integration with GNU Radio via the open-source USRP Hardware Driver (UHD). Real-time signal processing can be implemented directly on the FPGA using inline digital signal processing (DSP) blocks, enabled by the RF Network-on-Chip (RFNoC) framework and LabVIEW FPGA. This accelerates development for mission-critical applications requiring low latency, high dynamic range, and rapid reconfiguration across the RF spectrum.

NI USRP Product Family

Type	NI USRP Model	NI Ettus USRP Model	Bandwidth	Tx/Rx Channels	Frequency Range
Stand-Alone, FPGA Enabled High Performance	USRP X440		Up to 1.6 GHz	8 TX/8 RX	30 MHz to 4 GHz
	USRP X410		400 MHz	4 TX/4 RX	1 MHz to 7.2 GHz
	N/A	USRP N320, USRP N321	200 MHz	2 TX/2 RX	10 MHz to 6 GHz
	N/A	URSP N310	100 MHz	4 TX/4 RX	10 MHz to 6 GHz
	USRP 2974	N/A	160 MHz	2 TX/2 RX	10 MHz to 6 GHz
Host Connected, FPGA Enabled, High Performance	USRP 2944	X310 +UBX	160 MHz	2 TX/2 RX	30 MHz to 6 GHz
	USRP 2945	X310 + TwinRX	80 MHz	0 TX/4 RX	10 MHz to 6 GHz
	USRP 2954	X310 + UBX + GPSDO	160 MHz	2 TX/2 RX	30 MHz to 6 GHz
	USRP 2955	X310 + TwinRX + GPSDO	80 MHz	0 TX/4 RX	10 MHz to 6 GHz
Low SWAP, Stand Alone Embedded	N/A	USRP E310 / E312 / E313	56 MHz	2 TX/2 RX	70 MHz to 6 GHz
	N/A	USRP E320	56 MHz	2 TX/2 RX	70 MHz to 6 GHz
Low SWAP-C, USB Connected	N/A	USRP B206mini-i	56 MHz	1 TX/1 RX	70 MHz to 6 GHz
	USRP 2900	USRP B200	56 MHz	1 TX/1 RX	70 MHz to 6 GHz
	USRP 2901	USRP B210	56 MHz	2 TX/2 RX	70 MHz to 6 GHz

ni.com/EMSO