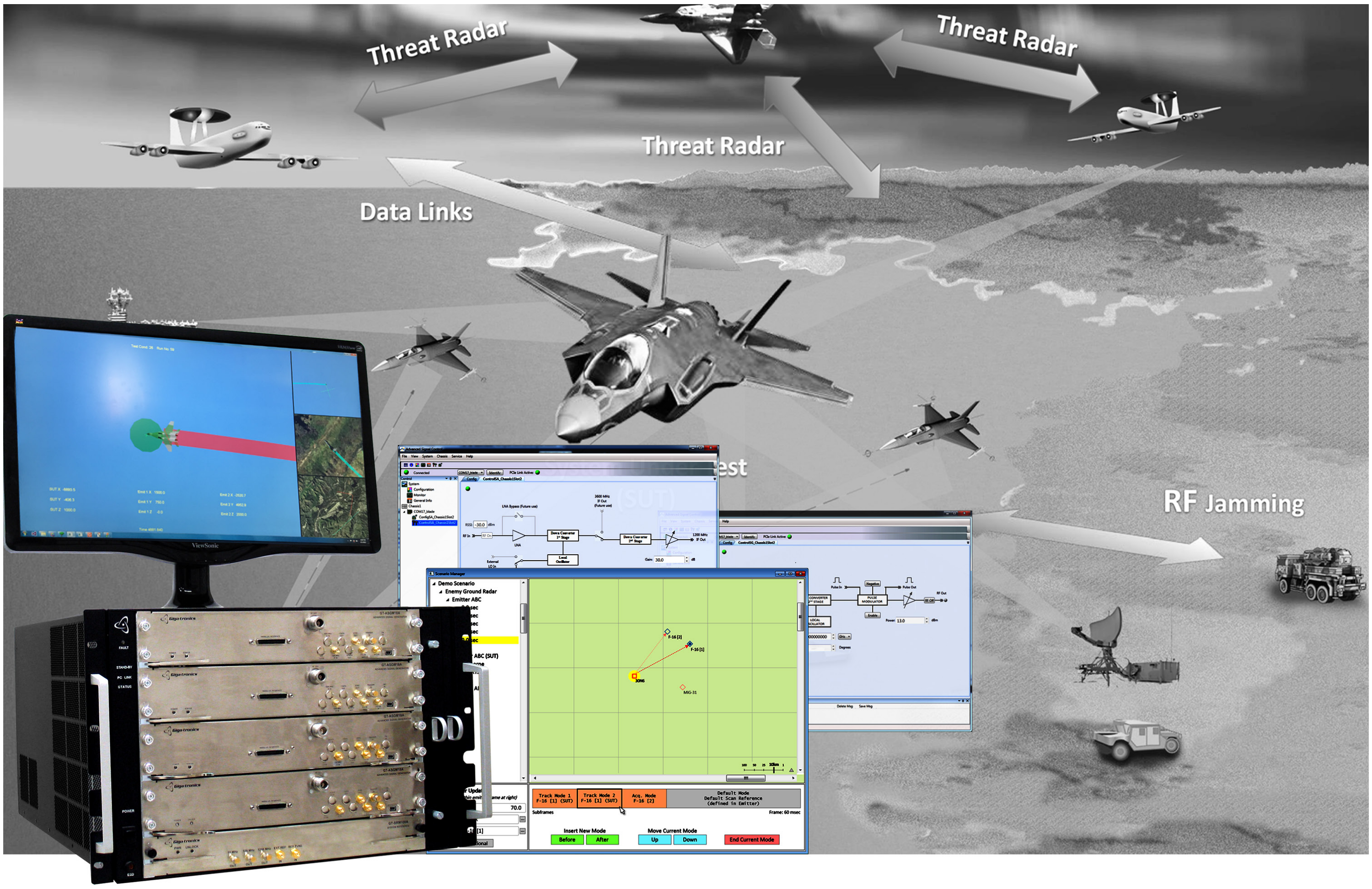
APPLICATION NOTE

An AXIe-based Real-Time EW and Radar Threat Emulation System



Giga-tronics

Solutions for Next Gen EW / Radar Test & Deployment

Military radar and EW systems must be exposed to signal environments as representative as possible to those they will ultimately experience, and this work should begin early in the design process when it's most cost-effective. Only by meeting these two criteria can designers be reasonably sure that their final design will deliver its desired performance in the exhaustive (and expensive) range tests that follow. The Giga-tronics Real-Time Threat Emulation System (TEmS) was created to make this achievable as a COTS-based bench-top emulation system. This modular approach allows the system to scale with individual modules rather than through addition of expensive stand-alone instruments.

To realize this system, its architecture is designed to be very much like the EW and radar designs it will test. The system uses a modular, scalable architecture along with open-loop software enabling designers to improve on their system throughout the design and evaluation process. The hardware platform is based on the AXIe standard with customization in Zone 3, which was chosen for the reasons outlined in the accompanying article "Why We Chose AXIe".

TEmS is the only test system that has both phase-coherent up-conversion and a real-time interface to control frequency, phase, and amplitude at the RF carrier. While these parameters could have been controlled at baseband, the approach is limited for use in dense signal emulation environments because the digital-to-analog converter (DAC) must share its available output power across all simulated threats and have sufficient sample bandwidth to create agile emitters.

For example, generating an agile emitter that operates across X-band would require a sample bandwidth of over 30 GS/s to satisfy Nyquist. In addition, multiple emitters generated with direct digital conversion would need to share their output levels from the DAC's maximum voltage swing, typically 1 volt peak-peak. The greater the emitter density, the lower the signal-to-noise for each threat.

To address Doppler effects, the TEmS system essentially combines the two approaches. The effects are applied at baseband while frequency agility, phase shifts, and amplitude modulation are applied at the carrier frequency. It also compensates for the propagation delay through the system's up-converter so time-of-arrival (ToA) statistics are accurate at the plane of the RF output port.

The system uses a digital control interface with sub-microsecond switching speed that makes it possible to create agile emitters, add Doppler, jitter, frequency drift, and other impairments, and emulate complex antenna patterns in 0.5 dB steps. The TEmS' switching is phase-coherent, so multiple emitters can be created from a single generator if they do not overlap in time. The digital interface also provides 0.1-deg. control of phase at RF for emulation of angle-of-arrival (AoA) wave fronts. In addition, it provides 90 dB of amplitude control for emulating complex modulation schemes and antenna patterns.

THE SYSTEM

The open-loop TEmS system consists of a high-performance Windows workstation and the AXIe 7U chassis (Figure 1) that can house two or four channels configured independently or as ports to simulate AoA wave fronts. The underlying

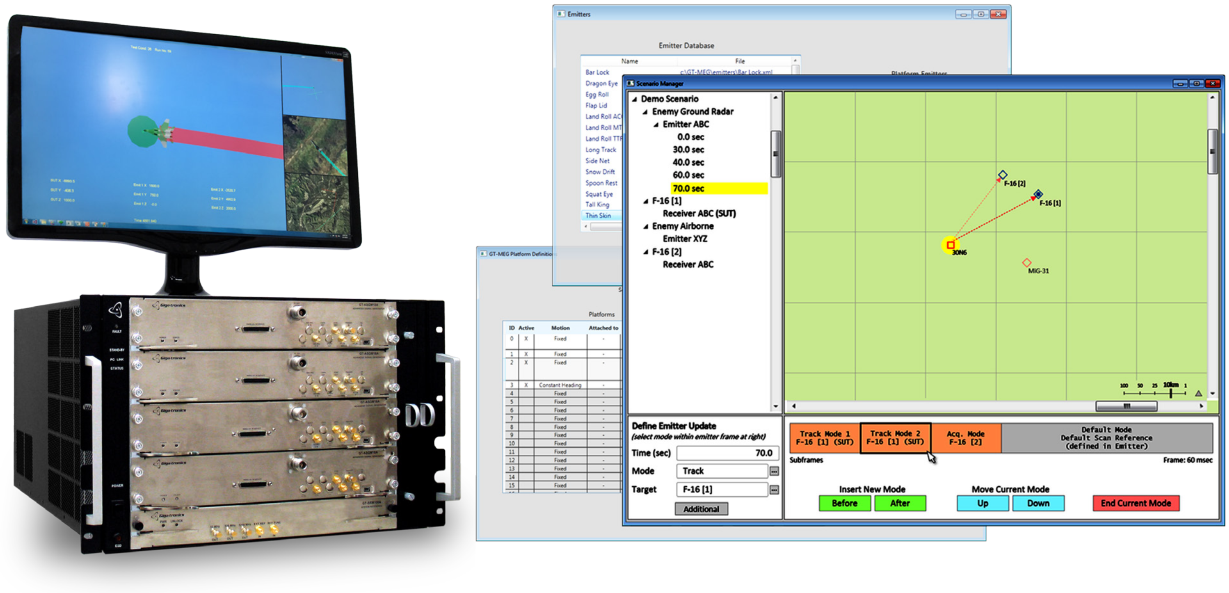


Figure 1 – The Giga-tronics TEmS system combines an AXIe-based hardware platform with comprehensive open-loop software that provides both real-time graphical interpretations of an evaluation, as well as PDW data in a binary file format.

architecture supports any number of phase-coherent channels by daisy-chaining the master reference clocks between chassis (10 MHz for long-term stability and 100 MHz for low phase noise).

In the AXIe chassis are functional blocks (Figure 2): the phase-coherent, 100 MHz-to-18 GHz up-converter and a digital parallel interface on each of the converter modules that provides real-time control of frequency, phase, and amplitude. A system reference module provides frequency coherence for the up-converter modules inside the AXIe chassis and to external chassis. A PCIe digital waveform generator (DWG) supplies the intermediate frequency (IF) to the up-converter and is mounted in a Windows-based PC workstation. The system is controlled from a menu-driven graphical user interface that drives the DWG and the up-converter to generate the real-time signal environment. Up to four independent signal sources or up-converters can be accommodated per chassis. To increase the number of channels, multiple chassis can be locked together, synchronized by the master clocks.

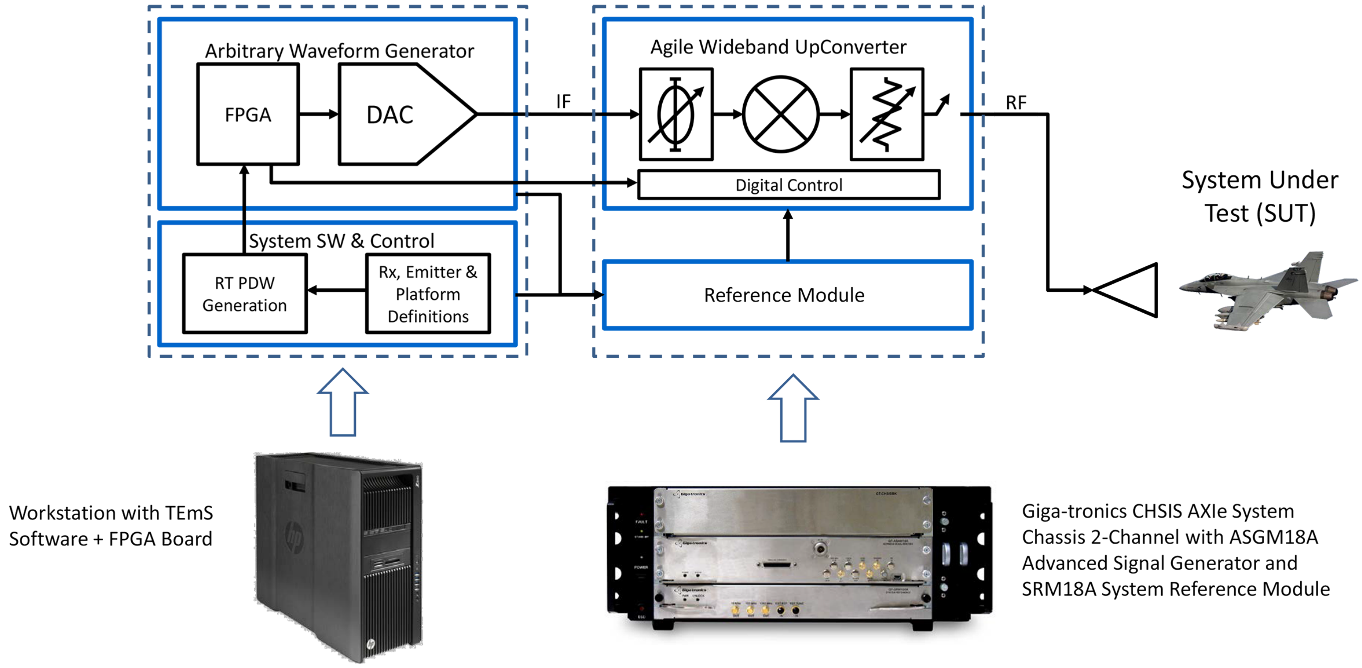


Figure 2 – The functional blocks of the TEmS system.

In addition to the AWG, the workstation hosts the TEmS open-loop software that acts as the user interface and simulates the real-time environment for each emitter and the receiver under test. Each emitter and receiver is attached to a platform (air, land or sea-based) that can move through the battlespace in three dimensions via six degrees of freedom. The TEmS 3D battlespace is simulated using a 500-km2, flat earth, three-dimensional environment with a 200-km altitude limit. Platforms are defined as assets on which emitters and receivers are attached, and have a physical position in the battlespace and a defined motion. PDWs from every emitter are calculated in real-time with 10-ns timing resolution as the platforms move through the gaming area.

The signal power present at the receiver is calculated in real-time from each emitter as each platform moves though the battlespace and constitutes a “Scenario” that defines the movement of the platforms over time (Figure 3). The result is generation of a realistic threat environment that can be radiated over the air or injected into a receiver under test to validate the capabilities of a candidate radar receiver or jammer. The software can also run in a simulation-only mode so users can analyze and determine how well the simulations meet mission requirements.

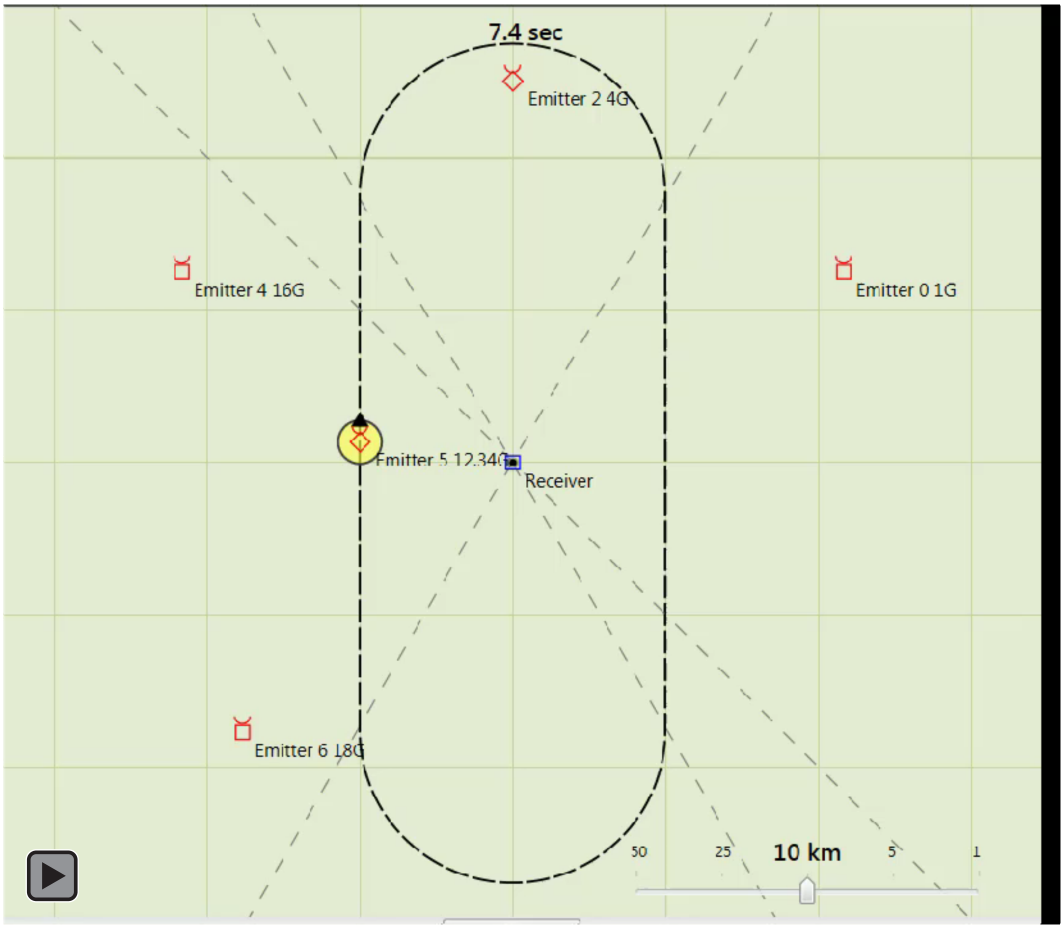


Figure 3 – How the TEmS software moves the platforms move through the battlespace.

Broad Flexibility

If the receiver definition is modified to be a single-channel, multi-port configuration, the threat generator can emulate the signals required for AoA and ToA testing. Instead of one up-converter, four up-converters are used phase-coherently with their outputs offset in phase according to the physical orientation of the antenna ports on the platform.

When acting as a multi-port, single-channel generator, high-density threat environments can be emulated with multiple outputs summed together for direct injection into a single-port receiver under test. The TEmS software monitors pulse dropouts when emitters overlap in time. Adding additional physical channels increases pulse-on-pulse capabilities.

To increase realism into the gaming area, other electromagnetic effects can be added using legacy simulators or by adding streaming I and Q signal recordings. Threat-specific definitions for modulation, antenna pattern, and pulse characteristics may also be uploaded via .xml or .csv files.

Summary

The Giga-tronics TEmS system provides unique capabilities for test and evaluation of EW and radar systems. It's up-converting, real-time digital interface and phase-coherent architecture provide users with a bench-top emulation tool for generating complex signal environments. TEmS significantly benefits from the AXIe standard based on its form factor suitable for microwave test solutions, the Zone 3 provision allowing for customization (that Giga-tronics uses for coherent distribution of analog signals), and the inherent scalability and interoperability of the platform. More information about TEmS, including videos demonstrating is open-loop software capabilities, constituent components, and performance specifications is available at http://go-asg.gigatronics.com.

Why Giga-tronics Chose AXIe

When Giga-tronics created its Advanced Signal Generation and Analysis platform for the Real-Time Threat Emulation System (TEmS), the company began with the proverbial blank sheet of paper. Research conducted prior to entering the electronic warfare test and evaluation market indicated engineers working in the segment frequently employed solutions with multiple signal generators. It became clear that designing the signal generators as modules in a chassis would reduce rack height and cost and ease integration when compared to designing them as separate boxes. The goal then was to select a modern, modular instrumentation platform that satisfied both the initial requirements and a technology roadmap for the future.

When evaluating a modular instrumentation standard, it is important to learn of any limiting factors that might dictate what functions a system can and cannot accommodate. For example, although PXIe is very popular for modular instrumentation, it has relatively small form factor that can lead to suboptimal partitioning of subsystems as microwave hardware can often be large and bulky. It also leads to more interconnects and cabling between the modules.

While the approach accomplishes the task, it can make servicing more complicated. In a failure situation, it is often difficult to identify the problem when a signal generator comprises multiple modules such as the local oscillator, up-converter, and digital waveform generator. The inevitable patch panel of interconnecting cables between the modules introduces the possibility of human error when modules are serviced, as it is quite easy for a connector to be torqued improperly or even put back in the wrong place.

AXIe eliminates these problems as it is large enough to allow a complete instrument to be made in one or two slots. AXIe is optimized for horizontal placement, making full use of the available space in a 19-in. rack and providing adequate room for functions such as filtering and cooling along with unrestricted airflow (Figure 1). The architecture also eliminates many front-panel interconnects, which more effectively accommodates RF and microwave systems whose

Figure 1. The Giga-tronics CHASIS2A (left) and CHASIS4A (right) AXIe System Chassis 2-Channel and 4-Channel

cables are sensitive to repeated flexure and connectors are highly sensitive to mishandling.

The most compelling argument for selecting AXIe turned out to be AXIe's provision for a user-customizable section of the backplane known as Zone 3. This unique feature separates AXIe from other modular instrumentation solutions. Giga-tronics took advantage of this feature by employing a separate frequency reference module and distributing its RF and synchronizing signals to all synthesizers in the chassis via a custom Zone 3 interface design. This allows multi-channel generator and analyzer systems from Giga-tronics to exhibit superior phase stability and coherence between channels than solutions available from vendors requiring stacking separate boxes, which often requires extra hardware and expense to accomplish the same job.

By remaining within the mechanical and electrical mandates of the standard, Giga-tronics has successfully integrated other standard AXIe products into its chassis even with the custom Zone 3 interface present, such as arbitrary waveform generators and digitizers. This makes it possible to deliver complete multi-vendor solutions to customers that require a turnkey COTS solution.

In short, AXIe was the best choice for Giga-tronics' TEmS system. In addition to the benefits of Zone 3, it combines compact size and compatibility with LXI, VXI, and PXI, with scalability to 14 slots and 200 W power handling per slot. AXIe also offers very high-speed local bus streaming between modules and easy integration with rack-and-stack instruments.

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