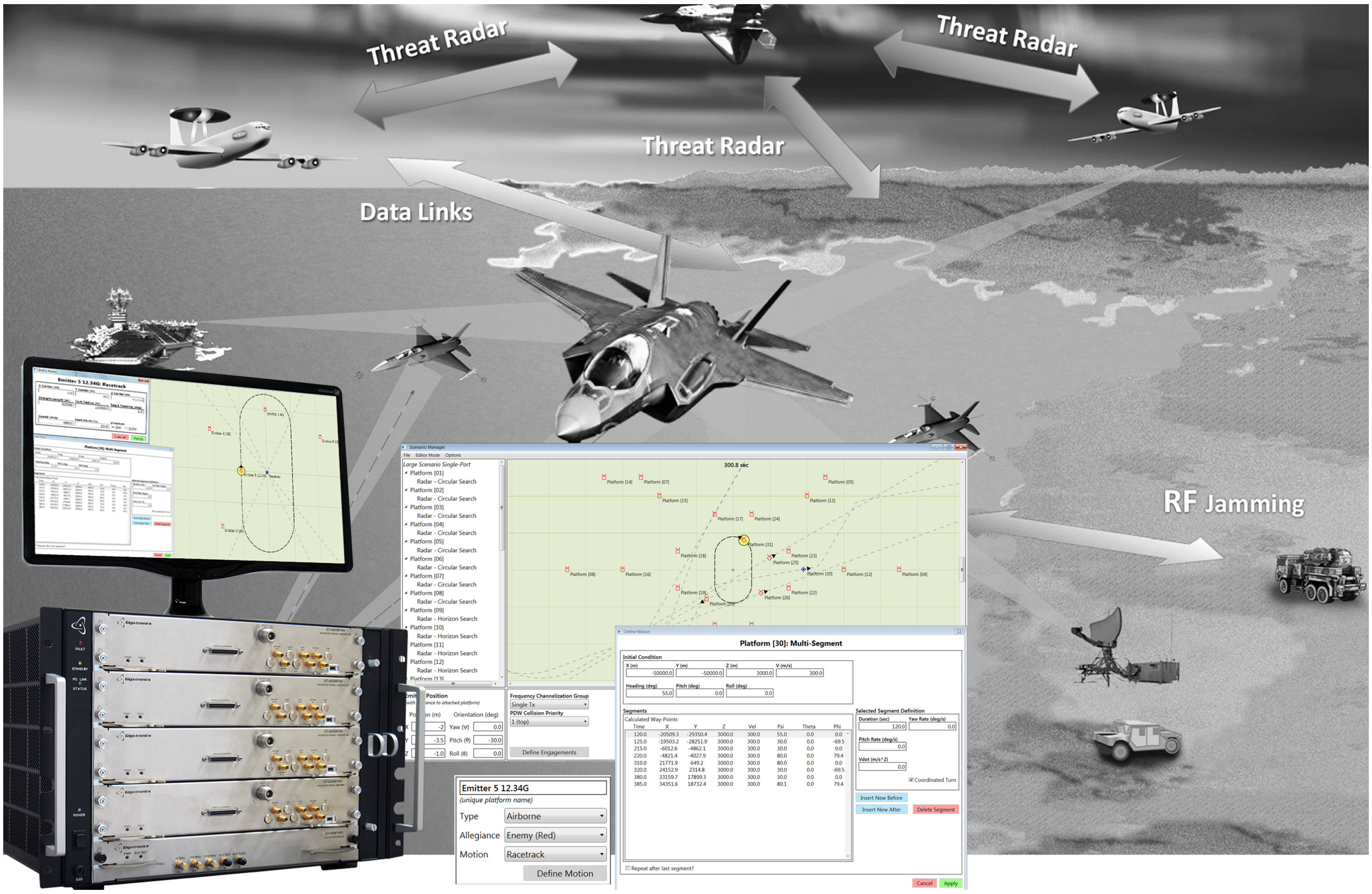
APPLICATION NOTE

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 using a modular, scalable approach along with open-loop software that allows designers to improve on their design throughout the system 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 accompany article "Why We Chose AXIe".

TEmS is the only test system that has both phase-coherent upconversion and a real-time interface to control frequency, phase, and amplitude at the RF carrier in real-time. 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 present.

To address Doppler effects, the TEmS system essentially combines the two approaches as 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 upconverter so time-of-arrival (ToA) statistics are accurate at the plane of the RF output port.

The system also 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, generate angle-of-arrival wave fronts, 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 precise control of phase at RF, for emulation of angle-of-arrival (AoA) wave fronts, 0.1-deg. control to any number of channels, and 90 dB of amplitude control for emulating complex modulation schemes and antenna patterns. This interface combined with the phase-coherent upconverter and downconverter effectively form hardware-in-the-loop substitutes for a closed-loop, agile threat emulator.

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 architecture supports any number of phase-coherent channels by daisy-chaining the master reference clocks (10 MHz for long-term stability and 100 MHz for close-in phase noise) with that of the references in other chassis.

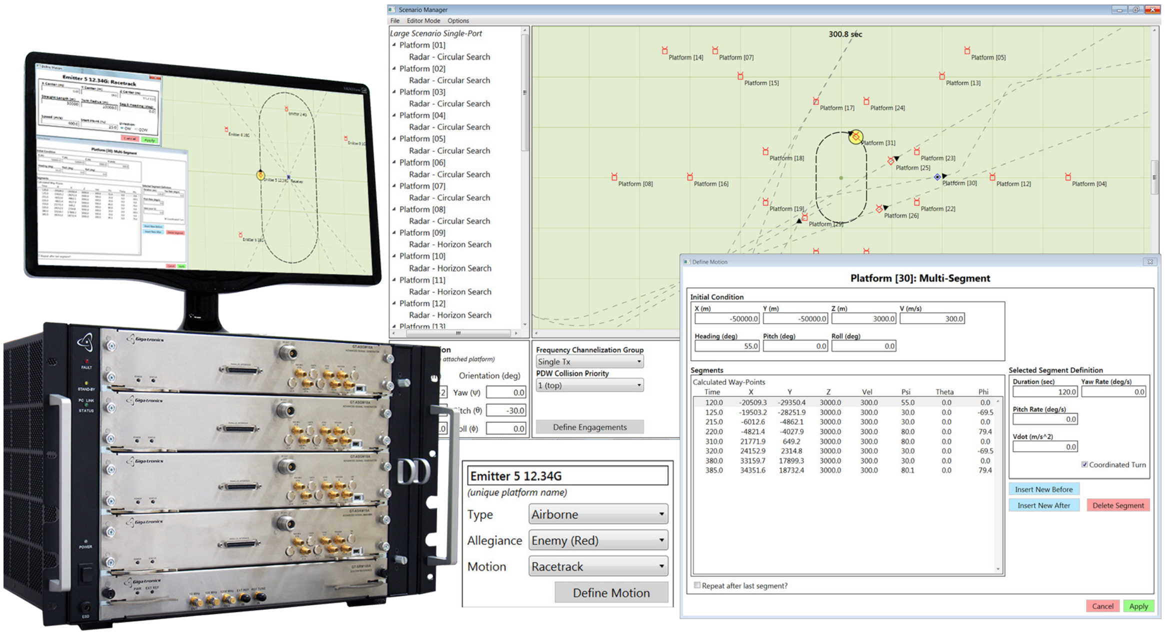


Figure 1 – The Giga-tronics TEmS system combines an AXIe-based hardware platform with comprehensive open-loop software that provides both real-time graphical interpretations of an evaluation, as well as PDW data in a binary file format.

In the AXIe chassis are functional blocks (Figure 2): the phase-coherent 100 MHz-to-18 GHz phase-coherent upconverter 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 upconverter modules inside the AXIe chassis and to external chassis. A PCIe arbitrary waveform generator (AWG) serves as an intermediate frequency (IF) digital waveform generator and is mounted in a the workstation. The entire system is controlled from a menu-driven graphical user interface which generates the real-time signal environment that drives the AWG and digital control interface in the upconverter. Up to four independent signal sources or upconverters can be accommodated per chassis. To increase the number of channels, multiple chassis can be locked together, also synchronized by the master clocks.

In addition to the AWG, the workstation hosts the

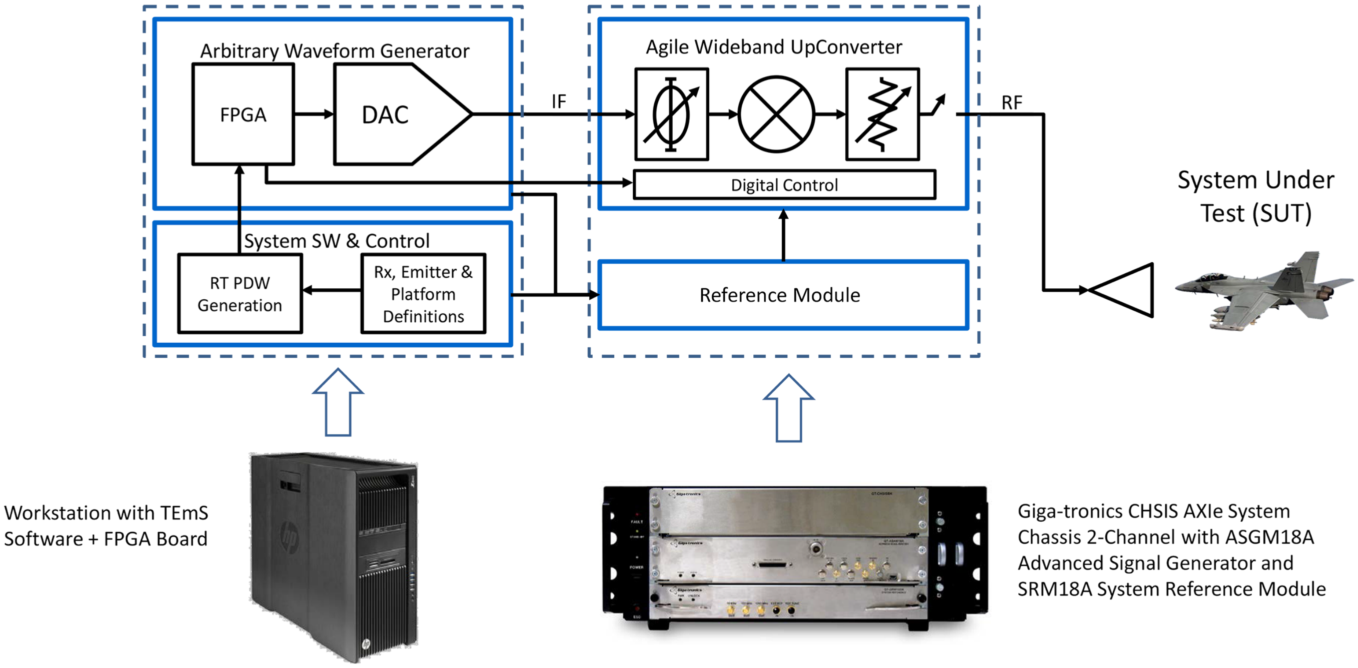


Figure 2 – The functional blocks of the TEmS system.

TEmS open-loop software that acts as the user interface and simulates the real-time environment for each emitter and the receiver under test (SUT). 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 km^2 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 in the battlespace 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.

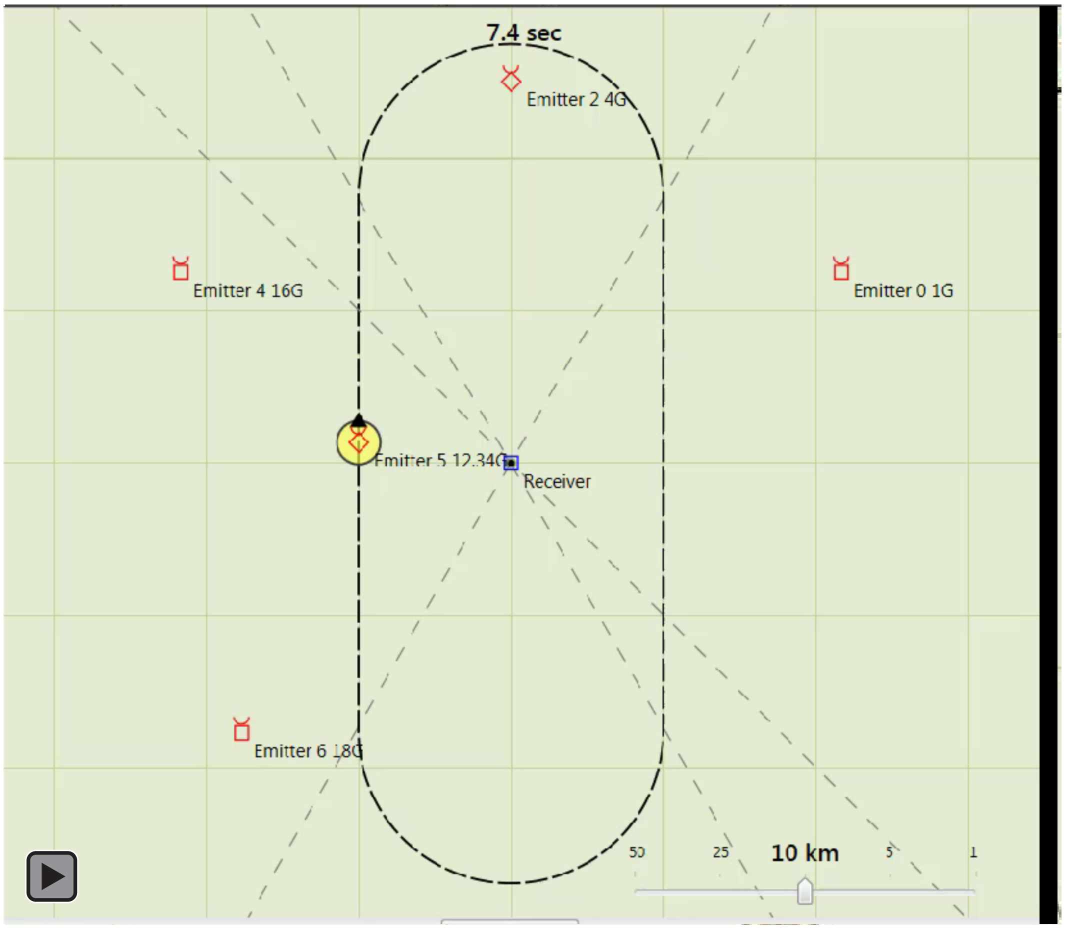


Figure 3 – How the TEmS software moves the platforms move through the battlespace.

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 upconverter, four upconverters 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 four outputs summed together for direct injection into a single-port receiver under test. The TEmS software can actually generate many more emitters if no two emitters overlap in time, which would cause a pulse to be dropped. However, by adding another physical channel this limitation can be mitigated.

To increase realism into the gaming area, other electromagnetic effects can be added using legacy simulators a user may already have 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 possesses unique capabilities for evaluation of EW and radar systems. It's upconverting 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 chassis, leveraging the flexibility of Zone 3, allows greater functionality through backplane customization, far more so than any other standards used for modular test equipment. 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 building a modular test and measurement system, a key limiting factor has traditionally been the instrumentation standard, which among other things dictates what functions it can and cannot accommodate. When Giga-tronics created its Real-Time Threat Emulation System (TEmS), the company began with the proverbial blank sheet of paper with the goal of finding a chassis solution that best satisfied the requirements both initially and over the long term. Although PXIe is now very popular for modular instrumentation systems the AXIe standard, although new at the time, appeared to provide unique advantages.

Validating next generation weapon systems requires testing under real-world conditions early in the design cycle so engineers can find and fix issues prior to operating the asset on an open-air range. The Giga-tronics TEmS system allows users to emulate up to 30 simultaneous emitters. Emitter energy seen by the receiver under test is modeled using the total number of emitters present, the free-space range equation, the number of antenna ports on the receiver and its characteristics and the receiver’s physical location in battlespace. Such realism allows the user to validate target recognition and threat processing algorithms. And, because the TEmS system is COTS it fits on the bench, its affordable and can be quickly reconfigured to test new threat paradigms as they emerge.

Choosing a Chassis

There were several reasons for choosing AXIe. It is optimized for horizontal placement, making full use of the available space in a 19-in. rack while also providing adequate room for functions such as filtering as well as cooling overhead and unrestricted airflow that are mandatory for subsystems (Figure 1). AXIe is also well suited for complex subsystems such as microwave synthesizers as it is large enough to allow a synthesizer to be fabricated in a single blade or in the case of the Giga-tronics system two slots. If using PXIe or other architectures, functional blocks must split into their main functional blocks, which increases system size and requires large numbers of cables and connectors.

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

Figure 1 -- The AXIe system chassis is available in two-channel (4U) and four-channel (7U) configurations. AXIe Zone 3 implements a coherent analog synchronization bus for sharing frequency reference signals and critical timing clocks from the reference module. The approach eliminates a significant amount of front-panel cabling and uses AXIe's active backplane for external PCIe and Ethernet interfaces. The chassis reports its status over PCIe or Ethernet and will signal a fault condition via a front-panel LED.

While this approach accomplishes the main task, servicing becomes complicated. For example, it is not easy to identify which module is failing, such as the local oscillator, upconverter, or digitizer, as only testing the complete subsystem can typically reveal the answer. In contrast, AXIe eliminates this problem as it allows a complete instrument to be made in one piece.

However, the most compelling reason turned out to be AXIe's Zone 3, which unlike other modular instrumentation solutions allows significant customization. Not only does it include power and digital communication interfaces on the backplane, Zone 3 also allows analog and other types of signals to be routed on the backplane without cables rather than on front panel. With these interfaces on the backplane as is the norm in most embedded systems, it more effectively accommodates RF and microwave signals whose cables are sensitive to repeated flexure and connectors are highly sensitive to mishandling.

A patch panel approach introduces possibility of human error when modules are serviced, as one is put back together is quite easy for connector to be torqued improperly or even put back in the wrong place. It also results in a much "cleaner" solution and when modules are introduced identification and initialization is virtually automatic.

The benefits of Zone 3 are invaluable for Giga-tronics as it allows a highly-custom test system to be constructed while remaining within the mechanical and electrical mandates of the standard. However, this essential makes the system, or at least a portion of it, "non-standard", so steps must be taken to ensure that no damage will occur if a standard AXIe module is plugged into the chassis no damage occur. This was easily achieved and if this occurs the module simply will not take advantage of the custom features implemented in Zone 3.

In short, AXIe's compact size, compatibility with LXI, VXI, and PXI, scalability to 14 slots, 200-W power per slot, very high-speed local bus streaming between modules, easy integration with rack-and-stack instruments, when combined with the benefits of user-defined Zone 3, made the standard the best choice for Giga-tronics' TEmS system.

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