Key Considerations for Radar Test

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Overview

Many trends are driving innovation to advance technologies across multiple industries. Software-driven and multipurpose platforms are changing how people interact with their phones thanks to the over 2 million iPhone applications and more than 3.8 million Android applications now available. Low-latency processing is creating opportunities for people to interact differently with the world through virtual reality and gesturing technology. A more connected world has led to the Internet of Things (IoT), 5G, and connected cars. Big data processing and exposure to information are enabling companies to optimize logistics and helping doctors make medical advancements. Machine learning and artificial intelligence are allowing the recognition of patterns in data sets larger than any one human could process and making autonomous vehicles possible. These same trends advancing technologies in commercial products are evolving radar and electronic warfare (EW) systems that incorporate sensor fusion, hypersonic weapons, multistatic sensors, drones, a networked electronic order of battle, cognitive radar, and cognitive or predictive EW.

Radar and Electronic Warfare Trends

In radar and EW specifically, the operating environment and requirements for military radars are changing rapidly, and radar trends like the following are increasing the complexity of these systems to new extremes.

- Radar architecture proliferation, such as *active electronically scanned array* (AESA), bistatic, and passive radar, with a seemingly infinite number of software-defined techniques within "cognitive" radar and LPI radar, is increasing the range of testing required by test systems.

- Platform miniaturization is driving the consolidation of RF systems. Future radars, EW receivers, and communications will likely share the same sensor platform and be tested as a unit.
- Autonomy similar to the commercial vehicle market will drastically increase the amount of testing required across multisensor and multiplatform systems to ensure safety and reliability.

Radar modeling and target simulation is the only type of test that can be applied throughout the design process. The increased complexity of radar systems makes flexible radar modeling and simulation during development critical to decreasing the cost of expensive full-system testing, finding and resolving design problems earlier in the process, and reducing schedule risk.

New Radar and EW Component- and System-Level Test Considerations

Larger industry trends like software-driven and multipurpose platforms, low latency, a connected world, big data, and machine learning and artificial intelligence are accelerating new radar and EW system innovation. With all this innovation, you need to be familiar with some of the test challenges ahead so you can address them early in the test design process. This involves understanding the initial component- and system-level test considerations for the following new innovations in the radar and EW industry: fifth-generation jet fighter, hypersonic weapons, multistatic sensors and drones, networked electronic order of battle, and cognitive radar and cognitive or predictive EW.

The fifth-generation jet fighter is a software-driven aircraft made with over 10 million lines of code to control and connect a series of sensors working together so the aircraft can make quicker flight modifications. For systems that combine data from a group of sensors and make software-driven adjustments based on that data, two main component tests are critical: waveform variance test for antennas and signal integrity test for system inputs and outputs (I/O). Because antennas are multipurpose, you need to test them to account for waveform variance and verify that their isolation and directivity are both high. Due to the mix of sensors and the data these sensors are generating, the system I/O is complex. You need to conduct signal integrity testing to ensure and maintain high data throughput and the ability to use customizable system I/O. For system-level test, the heavy software suite and integration require further testing with a series of multifunction simulations to ensure the software is ready and able to manage potential error or unexpected inputs.

Hypersonic weapons systems and reacting platforms need dependable low-latency systems to adapt quickly enough to the environment. As a result, radar and EW systems have higher range requirements, so their antenna systems at the component level must feature more elements per antenna for the radar to conduct more precise beam steering with phase and amplitude control. At the system level, you need low-latency testing, specifically quick update rates for simulations, to ensure that your system can keep up with the hypersonic speeds and decision making of the weapons or anti-weapon system. To help simulators update more quickly and test these faster systems, you need test systems that can process data quickly and update the current state of models to accurately represent the simulation environment.

The requirement to know more information earlier about smaller radar targets or an environment has led to greater demand for systems that are multistatic and drones, which must work together to operate effectively in a more connected world.

Having connected systems at the component level drives the need for wider-band components that are linear and that might require you to understand and test non-traditional impairments. For elements on phased array antennas, high gain and directivity guarantee that each element has higher performance over a smaller area, while the entire system of elements ensures the correct coverage for the overall phased array antenna. Having high directivity and tighter beams allows the radar to find targets that are further away and smaller. At the system level, high resolution and wideband low-latency testing, with tightly aligned synchronization across multiple channels, are critical. To test the robustness and accuracy of these radar systems, you need to balance more channels with high-density and detailed EW simulation.

The connected world and big data trends have also inspired a networked electronic order of battle, which is a series of new types of sensors and devices working together to identify, locate, and classify other groups' movements, capabilities, and hierarchy. With the wide array of sensors used, testing at the component level requires more complex I/O analysis. The system level encompasses aggregated test structures that need parallel testing and high-speed data analysis. Systems also need intricate simulators that can provide higher fidelity and handle more complex threat scenarios.

All these systems are producing more data at faster rates with a series of sensors working together to use software to control the systems. As more data is generated at a higher rate, you need systems that are faster than humans at making decisions and organizing the data. This is why cognitive radar and cognitive or predictive EW systems were invented. For these systems, component and subsystem test program sets involve a wider range of frequencies and bandwidths than other systems. Also, traditional parametric testing is likely not enough to fully understand system performance, which means you need to conduct modeling and simulation testing early in the test process. At a system level, open-loop simulators aren’t a viable option anymore, and test assets need to more accurately emulate targets and environments instead of relying on traditional threat databases that do not assess all the capabilities of a cognitive radar system.

As increasing system complexity drives new technology advancements, you need test instrumentation at the component and system levels that adapts. You also need a well-thought-out test methodology to meet new requirements, ensure system robustness, and maintain test schedules.

Test Instrumentation Considerations and Trends

Four traditional test approaches are used for radar system integration and testing: delay lines, commercial off-the-shelf (COTS) FPGA-enabled instrumentation or RF systems on chip (RFSoCs), COTS radar target generators, and turnkey test and measurement solutions. Each method has its strengths and weaknesses.

Delay lines are robust, cost-effective, and meet low-latency requirements but are limited in capability, only suitable for simple functionality testing, and lack ECCM techniques and real-world environment simulations like clutter and interference.

COTS FPGA-enabled instrumentation or RFSoCs offer low capital cost, low latency, and flexibility for complex systems but require high initial development costs, are difficult to maintain, and need extensive firmware and software work for new test programs.

COTS radar target generators have lower initial engineering costs and can be tailored to specific applications, allowing domain experts to contribute early in the design process. However, they are expensive, require maintenance support, lack flexibility, and evolve slowly, relying on vendors for new functionality.

Closed or turnkey test and measurement solutions provide well-calibrated, dynamic range solutions that can be quickly leveraged across multiple programs. However, they are limited to vendor-defined functionality, difficult to configure for unique needs, produce higher latency, are not typically phase coherent and are often pre-scripted or open-loop systems, making them hard to scale for multichannel RF systems.

Industry trends affecting radar and EW technology are driving new test instrumentation trends like industry convergence, software-defined platforms, maintainability, and test system architectures. Test equipment vendors serve multiple industries, using instruments across automotive, 5G, and defense sectors. As technologies converge, test instrumentation must expand frequency coverage and operate at larger bandwidths with higher channel counts. Vendors are investing in software platforms for flexibility, test speed, and reliability, leveraging economies of scale to reduce costs and enhance capabilities.

Boxed instruments for test need to last 8 to 12 years, with firmware updates every 18 to 24 months and hardware upgrades every 18 to 36 months. These instruments are incorporating touch screens and modular devices for easier upgrades and creating “super boxes” for larger test coverage.

Modular instruments are growing in the industry, with increased radio front ends, multiprocessor architectures, and reporting and storage needs. Modular hardware and software platforms offer adaptability for various needs, faster design, reduced schedule risk, and compliance with future complex requirements. Improved flexibility with FPGA and RF hardware in the same device allows for multiple test types. However, modular systems trade off dense test systems for high-performance capabilities. Multipurpose modular instruments offer better measurement IP, components, signal processing, and software accessibility, leading to more compact test systems.

Overall, test instrumentation is evolving to meet the needs of new radar and EW technology by leveraging industry convergence, software-defined instrumentation, multipurpose test instrumentation, and modular test instruments.

Meet New Industry Expectations by Introducing Simulation Early in the Design Process with Modular Test Instrumentation

Many trends are driving technology advances across multiple industries including radar and EW. Software-driven and multipurpose platforms, low-latency requirements, a connected world, big data processing and information exposure, and machine learning and artificial intelligence are inspiring test innovation at both the component and system levels. To accelerate the rate of technology advancements in radar and EW and ensure design robustness, manufacturers are adapting traditional test and measurement equipment to meet new requirements. With modular instruments and more modeling and simulation during different test phases, you can address these radar and EW system trends. Modeling and simulation also reduce expensive full-system testing and help you identify and solve problems earlier in the testing process to reduce schedule risk. With new types of radar and EW technology on the horizon, you need to address new test challenges earlier in the test design process to find the right flexible test system that can meet new requirements and your application-specific needs.