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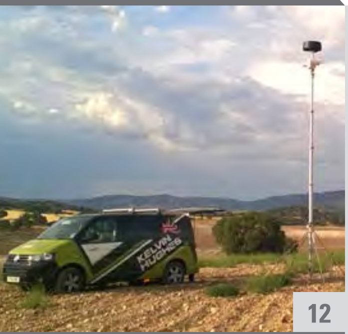

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ON THE COVER:
Top image: Lockheed Martin's Digital Array Row Transceiver (DART) is a combined transmit-and-receive line replaceable unit (LRU) with gallium nitride transmit/receive modules. Photo courtesy of Lockheed Martin.
Bottom image: With an architecture designed to support math-intensive processing and very-high-bandwidth data transfers, the Xeon D enables advanced cognitive electronic warfare (EW) applications to operate in small size, weight, and power (SWaP)-constrained platforms.

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GROUP EDITORIAL DIRECTOR John McHale jmchale@opensystemsmedia.com
ASSISTANT MANAGING EDITOR Lisa Daigle ldaigle@opensystemsmedia.com
SENIOR EDITOR Sally Cole scole@opensystemsmedia.com
ASSOCIATE EDITOR Mariana Iriarte miriarte@opensystemsmedia.com
E-CAST MANAGER Joy Gilmore jgilmore@opensystemsmedia.com
CREATIVE DIRECTOR Steph Sweet ssweet@opensystemsmedia.com
SENIOR WEB DEVELOPER Konrad Witte kwitte@opensystemsmedia.com
CONTRIBUTING DESIGNER Joann Toth jtoth@opensystemsmedia.com

VITA EDITORIAL DIRECTOR Jerry Gipper jgipper@opensystemsmedia.com
PICMG EDITORIAL DIRECTOR Joe Pavlat jpavlat@opensystemsmedia.com
MANAGING EDITOR Jennifer Hesse jhesse@opensystemsmedia.com

SALES

SALES MANAGER Tom Varcie tvarcie@opensystemsmedia.com (586) 415-6500
STRATEGIC ACCOUNT MANAGER Rebecca Barker rbarker@opensystemsmedia.com (281) 724-8021
STRATEGIC ACCOUNT MANAGER Eric Henry ehenry@opensystemsmedia.com (541) 760-5361
STRATEGIC ACCOUNT MANAGER Kathleen Wackowski kwackowski@opensystemsmedia.com (978) 888-7367
SOUTHERN CALIFORNIA REGIONAL SALES MANAGER Len Pettek lpettek@opensystemsmedia.com (805) 231-9582
SOUTHWEST REGIONAL SALES MANAGER Barbara Quinlan bquinlan@opensystemsmedia.com (480) 236-8818
NORTHERN CALIFORNIA REGIONAL SALES MANAGER Twyla Sulesky tsulesky@opensystemsmedia.com (408) 779-0005
ASIA-PACIFIC SALES ACCOUNT MANAGER Elvi Lee elvi@aceforum.com.tw
EUROPE SALES ACCOUNT MANAGER James Rhoades-Brown james.rhoadesbrown@husonmedia.com

OpenSystems media®

WWW.OPENSYSTEMSMEDIA.COM

PUBLISHER Patrick Hopper phopper@opensystemsmedia.com
PRESIDENT Rosemary Kristoff rkristoff@opensystemsmedia.com
EXECUTIVE VICE PRESIDENT John McHale jmchale@opensystemsmedia.com
EXECUTIVE VICE PRESIDENT Rich Nass rnass@opensystemsmedia.com
CHIEF TECHNICAL OFFICER Wayne Kristoff
EMBEDDED COMPUTING BRAND DIRECTOR Rich Nass rnass@opensystemsmedia.com
EMBEDDED COMPUTING EDITORIAL DIRECTOR Curt Schwaderer cschwaderer@opensystemsmedia.com
TECHNOLOGY EDITOR Brandon Lewis blewis@opensystemsmedia.com
TECHNICAL CONTRIBUTOR Rory Dear rdear@opensystemsmedia.com
CREATIVE SERVICES DIRECTOR David Diomede ddiomede@opensystemsmedia.com
CREATIVE PROJECTS Chris Rassiccia crassiccia@opensystemsmedia.com
FINANCIAL ASSISTANT Emily Verhoeks everhoeks@opensystemsmedia.com
SUBSCRIPTION MANAGER subscriptions@opensystemsmedia.com

CORPORATE OFFICE
16626 E. Avenue of the Fountains, Ste. 201 • Fountain Hills, AZ 85268 • Tel: (480) 967-5581

SALES AND MARKETING OFFICE
30233 Jefferson • St. Clair Shores, MI 48082

REPRINTS

WRIGHT'S MEDIA REPRINT COORDINATOR Wyndell Hamilton whamilton@wrightsmedia.com (281) 419-5725

Goodbye to a gentleman and scholar

By John McHale, Editorial Director

My first meeting with Amos Deacon Jr., founder of Phoenix International Systems, was in the mid-1990s at the old AFCEA Technet show in Washington. With his booming voice, firm handshake, and arm around my shoulder he made an impression and made me a friend instantly during my first year in the military electronics industry. A more loyal friend in this business you could not find. Unfortunately, we lost Amos and his big heart in November, when he passed away from cancer at age 82.

Amos and his son Amos Deacon III, with whom he ran Phoenix International Systems, a maker of rugged data storage solutions, were fixtures, it seemed, at every military tech trade show during the last two decades. Both Deacon men were part of the extended family of the core group we had at *Military & Aerospace Electronics* magazine back in the nineties and most of the last decade. Wherever we traveled, stopping at the Phoenix booth felt like we were stopping at home, catching up with old friends.

A tough guy with a light touch, Amos would love teasing our late colleague Jerry Boyle, who retired in 2000 at the age of 80, for thwarting Amos' plans to be the oldest guy in the industry. Amos eventually achieved that distinction and even in his late 60s founded another company, called the All-Terrain Vehicle Corp., which builds PROWLER multi-mission configurable Light Tactical All Terrain Vehicle (LTATV) and Very Light Strike Vehicle (VLSV) for ground forces and law-enforcement applications.

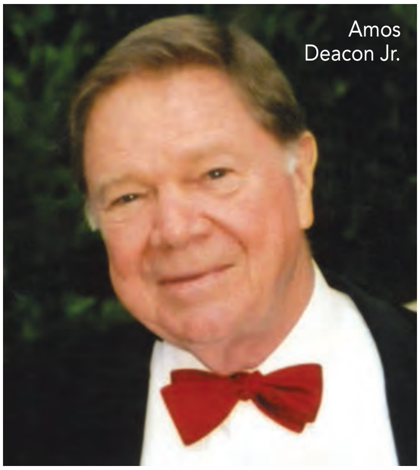
My favorite memory of Amos is of him rolling out one of the vehicles at the old COTSCon show our team at *Military & Aerospace Electronics* hosted. He had just started the company and sold one right on our show floor. Amos wore a big smile and scored another big win.

Paupers or kings, Amos could connect with anyone. He had a down-to-earth manner backed up by a top-notch mind. You may not know that he was a U.S. Naval Academy graduate, his high school valedictorian, and a member of Mensa. Most of what I've learned about data storage in military electronics I learned from Amos and his son.

Amos was born in Dunedin Isle, Florida, in a house on stilts in the Gulf of Mexico. He grew up in central Florida and Pennsylvania, graduating in 1951 as class valedictorian at Paradise High School in Pennsylvania, then heading off to Annapolis for the Naval Academy and then Lafayette College.

"Paupers or kings, Amos could connect with anyone. He had a down-to-earth manner backed up by a top-notch mind."

According to his family, Amos was hired by Hughes Aircraft Co. in 1962, relocated to Orange, California, where he got his MBA at the University of Southern California (USC), and was named to Beta Gamma Sigma, the highest honor given by the USC School of Business. Always the entrepreneur, Amos founded multiple enterprises including the establishment of MDB Systems, a pioneer in the minicomputer industry, before founding Phoenix International Systems and All-Terrain Vehicle Corp. Amos also is a past president and board member of the Orange Park Association, past president of the U.S. Naval Academy Alumni Association (L.A. chapter), past board member of the Carpenter Irrigation District, a member of the Rancho California Caballeros, and a philanthropic supporter of the J.F. Shea Therapeutic Riding Center, among others.



Amos Deacon Jr.

I'm grateful to have known Amos the last 20 years and to work with and learn from him. For those of you who never met Amos, I feel bad for you. But if you want to get a sense of what kind of man he was – the gentleman and the scholar – just meet his son Amos III. He is a true reflection of his father in each sense.

My former colleague, John Keller, also wrote a touching remembrance of Amos that speaks to his loyalty to his friends; read this tribute at http://www.military-aerospace.com/articles/2015/12/amos-deacon-obituary.html.

He is survived by his beloved wife of 60 years, Janet Eagleson Deacon; son and daughter-in-law Amos and Terry Hart Deacon of Orange; daughter and son-in-law Stephanie W.D. Aho and Toivo Aho, and grandchildren Raymond and Trevor Jenkins and Connor and Malia Aho, all of Irvine; his brother Jack Deacon of Murrieta; and sister Barbara Eckert of Extor, Pennsylvania.

In lieu of flowers, the Deacon family suggest donations be made to the Wounded Warrior Project. To donate, please visit www.woundedwarriorproject.org.

Designing COTS for data security

By Charlotte Adams

An Abaco Systems perspective on embedded military electronics trends

We hear daily of security breaches – including successful attacks on powerful U.S. agencies such as the IRS and on corporate networks – that expose public and private data. Attacks on military systems are even more predictable, but their compromise can put lives as well as data at risk. It could be argued that the military's reliance on commercial off-the-shelf (COTS) hardware and software make defense systems more susceptible to compromise from these escalating attacks than in the days when the armed forces used custom hardware.

Tactical systems used on the front lines have especially large bulls-eyes on their backs. Yet they use the same mass-market silicon that has proved vulnerable in the past.

The military cannot afford to go back to the days of unique hardware, but the cost and performance advantages of COTS could potentially be negated by its vulnerabilities. Without "hardened" components and the building blocks from which customers can implement highly individualized antitamper and information assurance architectures, COTS systems could become as helpful to adversaries as to the intended users.

Major failures in the past were compounded by the simple fact that they lacked of some of the technologies that are available now. The crew of the U.S. Navy EP-3E intelligence aircraft, for example, failed to destroy sensitive electronics with their axes when their aircraft was forced to land in Chinese territory in 2001. Their efforts – not to mention the intelligence-gathering operations of the U.S. and its allies – would have benefited from the zeroizing-on-demand capability of today's chips and boards.

Good news

Designers and manufacturers have not been sitting on their hands, however. They understand the seriousness of the threats and are providing numerous options from which COTS customers may choose in order to implement their security requirements. Among these options are CPU chipsets with root-of-trust and secure boot capabilities, antitamper-hardened FPGAs into which customers can load security policies, strong encryption, and operating systems that can enforce these policies at the application level.

These and other security tools continue to multiply, so that it becomes less an issue of availability and more about users' willingness to understand and apply them and to accept the associated costs.

Chip makers such as Intel and Freescale provide elements from which the foundation of trustworthiness can be verified. This root of trust is used in the secure boot process to verify the integrity of the BIOS (Basic Input/Output System) code at system startup.

The CPU-based secure boot process is very limited in scope, though: When the board is activated, the processor performs the authentication operation and checks the BIOS software. It then boots the operating system, which brings up the applications. It is up to the user to beef up security so that an entity can detect and respond to attacks via firmware or software.

FPGAs in security applications

FPGAs are potentially attractive components in anti-tamper/information assurance solutions. Unlike CPUs, which are fixed quantities, FPGAs can be repurposed to implement security features under complete user control.

FPGA technology, for example, can be used to provide a "security hub" around which an antitamper strategy can be built. This hub can be designed to control I/O devices through a combination of active and passive antitamper features. FPGAs can be designed with hardware encryptors using 256-bit keys.

Figure 1 | The SBC328 3U VPX single-board computer from Abaco Systems features Microsemi SmartFusion2, an FPGA customizable for antitamper and information-assurance purposes.

FPGAs can be programmed to detect intrusions by monitoring data for unauthorized changes. The FPGA can sanitize a device, zeroizing memory, destroying data, and then confirming that the information is gone. A technology known as "pseudo-physically unclonable functions (PUFs)," moreover, can be encoded into the silicon die at the factory yet not exposed in manufacturing or in later use. This technology can then be used to generate crypto keys. FPGAs also can be hardened against passive, "side-channel" attacks.

An example of an enhanced-security COTS product is the Abaco Systems SBC328 (Figure 1), a 3U VPX board featuring Intel's newest Skylake CPU (with secure boot) and the Microsemi SmartFusion2, an FPGA customizable for antitamper and information-assurance purposes.

The many hardware and firmware security features offered in today's COTS-based embedded systems make it possible for users to lock down their data with confidence. FPGAs, with the latest cryptographic tools, have become harder to break than ever before. In the final analysis, however, it is up to the users to exploit these features in order to protect the most sensitive military applications.

www.abaco.com

Selecting a rugged LCD display

By Kevin Rooney
An industry perspective from Curtiss-Wright Defense Solutions

Designers of liquid crystal display (LCD) systems should understand a number of important technical features before selecting a rugged LCD display for their platform. These options include environmental protection, LCD temperature and reliability, and screen reflection.

To begin with, designers must consider the need for protection from dust, sand, and salt spray: For example, a Coast Guard helicopter and its associated equipment is subject to a lot of salt spray; it will also be prone to condensation and water drips. A display that is open to the environment, whether through fans or air holes, will suffer in that environment. What's needed is a display that is sealed or has a pressure relief valve, thereby making it appropriate for different altitudes. Airborne displays often hew to DO160, a standard specification that addresses condensation and water splashing conditions. In another example, a pressurized hose is often used to wash the floor of a ground vehicle. Displays for ground vehicles should satisfy the IP67 immersion specification, supporting immersion in water down to a meter.

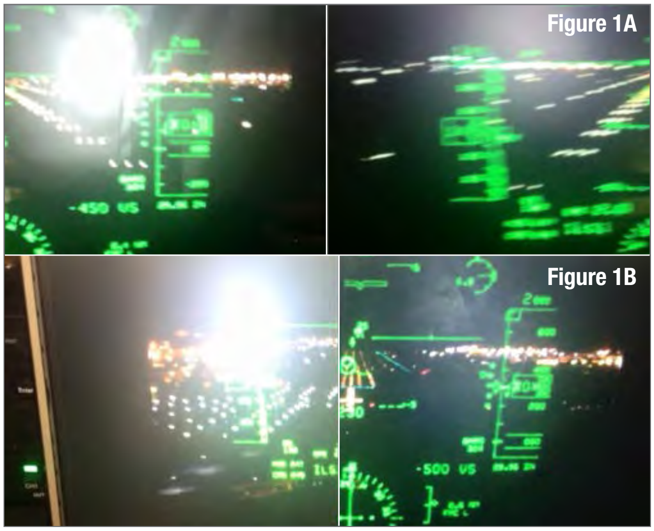


Figure 1A and 1B | The Curtiss-Wright AVDU5500 21.5-inch touchscreen mission display – designed for use in airborne applications – is a rugged LCD display that addresses the issues of waterproofing, temperature range, readability, and glare.

The harsh operating temperatures of deployed platforms can also affect the display's operation. Commercial LCDs, particularly in larger sizes, don't support the full military-temperature operating ranges. In order to operate at -40 °C, different manufacturers adopt various techniques to overcome the discrepancy between MIL-STD temperatures and what the LCD is capable of. Some manufacturers will simply provide a display with the hope that it works at -40 °C; while in many cases the commercial LCDs will in fact operate at -40, their life expectancy will be much lower. Commercial LCD materials semi-solidify at lower temperatures and when switched on in that state they will be damaged. The damage may not happen right away, and the display might even pass the qualification test.

The issue lies in the lifetime reliability of the product over the full temperature range. For a rugged display, system designers should look for a preheater built inside the display to heat the LCD to its specification level before switching it on. While this preheating approach builds in delay, it does significantly improve reliability.

The main function of a military display is readability: The goal is to defeat any form of light that will reflect off the screen and interfere with the image the viewer is trying to see. All forms of LCD, glass, and plastic are susceptible to reflections, and various techniques are used to reduce these reflections. The worst-case scenario comes from early night/early morning environments, where the sun is very low in the sky and reflects directly off the screen into the operator's eye. A more typical problem is full-daytime sunlight hitting the observer, turning the person into a brightly lit object that reflects off the screen into their own eyes. Frequently users will only specify a requirement for "very good daylight readability." Unfortunately, such a requirement is not really specific.

Another issue is glare: Some users will specify a requirement for antiglare coating. While coating does help, instead of eliminating glare, it instead diffuses and distributes the light reflection, so less of the reflection hits the viewer's eyes directly. Coatings only affect the outer layer of the display's glass. Light also goes through and reflects off the display's inner layers of glass, and the antiglare coatings do nothing to prevent that. In a very simple display there are often three or four layers of glass and plastics, while a more complex display may have seven or eight layers. As the light passes through each layer, there will be changes in the refractive index, resulting in some form of reflection. This distortion is made much worse by displays that have air gaps between their glass stack-up.

The best solution: Select a display that optically bonds each layer of glass, directly connecting them to greatly reduce the change in refractive index between layers. Ideally, a circular polarizer should be employed within the glass stack-up to polarize the light on the way into the screen. This technique rotates the polarization so that when the light reflects off the LCD or the inner layers of glass, the light is out of phase with the polarizer and cannot escape. (See Figure 1A and 1B.)

Kevin Rooney, Managing Director – Video, Displays, Systems
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DEFENSE TECH WIRE

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By Mariana Iriarte, Associate Editor

NEWS

Air Force radar support program won by BAE Systems

BAE Systems won a U.S. Air Force Instrumentation Radar Support Program (IRSP) contract to give multiple agencies a wide range of radar support services. IRSP provides services across the U.S. Department of Defense (DoD), the U.S. Department of Energy, NASA, and at least seven foreign governments.

The company will deploy serviceable components and subsystems for 28 test ranges with radar, telemetry, and optical tracking systems worldwide.

The five-year contract is valued at a total of $278.5 million and will be incrementally obligated. The work will be mostly performed at the BAE Systems' IRSP component repair facility in Fort Walton Beach, Florida, and is expected to be finished by the end of 2020.

Figure 1 | Today, IRSP supports more than 500 systems with work that ranges from logistical upgrades to depot-level overhauls. Photo courtesy of BAE Systems.

Harris to provide electronic warfare tech to U.S. Navy

U.S. Naval Research Laboratory officials have tasked Harris to provide electronic warfare (EW) technology and engineering services for the Advanced Decoy Architecture Project (ADAP). The three-year, single-award, indefinite delivery/indefinite quantity (IDIQ) contract is worth an estimated $54 million.

Under contract, Harris will provide the project payloads designed to lure missiles away from their intended targets. They will also provide research and engineering services to help advance the Navy's capabilities to meet present and future EW mission requirements.

DARPA A2P program aims to assemble atom-sized pieces for micromachines

DARPA officials are looking to develop technologies and processes to build nanometer-scale pieces whose dimensions are near the size of atoms – into systems, components, or materials that are at least millimeter-scale in size. To this end, DARPA launched the Atoms to Product (A2P) program and chose ten groups to solve this challenge.

The ten companies seeking to develop for DARPA are Zyvex Labs, SRI, Boston University, the University of Notre Dame, HRL Laboratories, PARC, Embody, Voxtel, Harvard University, and Draper Laboratory.

The program calls for closing this assembly gap in two steps: From atoms to microns and from microns to millimeters. DARPA partners are required to address one or both of these steps and have been assigned to one of three working groups, each with a distinct focus area.

NAVAIR Advanced Airborne Sensor testing continuing on Navy P-8A Poseidon

Navy personnel continue the integration and testing of the Naval Air Systems Command's (NAVAIR's) first Advanced Airborne Sensor (AAS) aboard the P-8A Poseidon aircraft.

Testing will confirm that the P-8A and AAS can operate safely and efficiently together, which will enable production decisions that lead up to the AAS's initial deployment.

AAS is an externally mounted radar that is a follow-on system to the Littoral Surveillance Radar System (LSRS). Like LSRS, the AAS is an integrated Intelligence, Surveillance, Reconnaissance, and Targeting (ISR&T) asset, but has an additional capability of Mast and Periscope Detection (MPD). It enables a situational-awareness advantage through information dominance throughout all campaign phases, and provides sensor data that supports precision targeting.

Figure 2 | AAS is dubbed the APS-154. Photo courtesy of the U.S. Navy.

Navy shipboard Laser Weapon System Demonstrator contract won by Northrop Grumman

Northrop Grumman has won a contract from the U.S. Office of Naval Research (ONR) to design, produce, integrate, and support shipboard testing of a 150-kilowatt-class solid-state (electric) laser weapon system. The contract, dubbed Laser Weapon System Demonstrator (LWSD), will have three phases.

During Phase 1, Northrop Grumman engineers will develop a detailed design for the new system. Phase 2 will include assembly and ground test of the system, and Phase 3 will consist of at-sea testing of the system aboard the Navy's Self Defense Test Ship (SDTS) – the former USS Paul F. Foster (DD-964). The Navy will lead the testing, with Northrop Grumman providing the technical support.

Engineers designed the system to be installed with minimal modification or additional costs for demonstrations onboard the Navy's DDG-51 FLT II-class destroyers, officials say. The initial award of $53 million will support work planned for the next 12 months. The contract could grow to a total value of $91 million over 34 months if ONR exercises all of its contract options.

Figure 3 | Pictured is the Navy's Self Defense Test Ship, the former USS Paul F. Foster (DD-964). Photo courtesy of Northrop Grumman.

Tactical ISTAR contract won by Elbit Systems for Asia-Pacific nation

Elbit Systems won a contract to provide an airborne, intelligence, surveillance, target acquisition and reconnaissance (ISTAR) solution to an unnamed Asia-Pacific country.

Elbit Systems' – the prime contractor for this program – ISTAR division will do work on the three-year contract, which is valued at about $50 million.

The solution will further develop the customer's existing intelligence and surveillance capabilities by upgrading already-deployed, long-range electro-optical (EO) cameras and sensors from Elbit Systems, and supplementing them with ELTA Systems Ltd.'s (which is a subsidiary and division of IAI), advanced SAR/GMTI Reconnaissance systems. The solution will also enable operators to perform advanced functions such as mission planning, battlefield management, terrain analysis, and simulation modeling – before and during intelligence-gathering operations.

DoD C4ISR market revenue to benefit from COTS and IoT systems

Analysts at Frost & Sullivan say that they expect DoD command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) spending to be flat through 2020 due to force structure reductions. However, activity and revenues should increase for the application of commercial off-the-shelf (COTS)-based computing, security, storage, networking, and collaboration tools.

Internet of Things (IoT) systems, along with cloud and big data technologies, will be necessary to complement the adoption of COTS-based smart phones, tablets, wireless networks, and productivity applications of all kinds. According to a Frost analysis, a total of $39.54 billion has been earmarked for 2016 DoD programs for C4ISR, electronic warfare, and information operations as well as for multipurpose technologies. This amount is an increase of 8.8 percent from 2015. The C4ISR spending will continue to grow at a compound annual growth rate (CAGR) of 1.4 percent during 2014 through 2020.

Combat systems integration, collaborative targeting, and improved surface ship self-defense are priorities for the U.S. DoD through 2020, according to Frost.

Engineers will upgrade Apache helicopter cockpits

Lockheed Martin engineers will upgrade the Modernized Target Acquisition Designation Sight/Pilot Night Vision Sensor (M-TADS/PNVS), giving pilots color in the cockpit on the U.S. Army AH-64E Apache helicopter.

Under a contract, engineers will produce 35 M-DSA kits and spares for both the U.S. Army and Qatar Emiri air force. Pilots can identify targets through additional field of view and extended range picture-in-picture quality with the Phase 2 upgrades. The Army has obligated $54.3 million to Lockheed Martin through the Modernized Day Sensor Assembly (M-DSA) Phase 2 Lot 1 contract, with the total value not to exceed $130.6 million.

Work will be performed in facilities in Orlando and Ocala, Florida, through March 2019. Lockheed Martin is currently producing 860 Modernized Laser Rangefinder Designator (M-LRFD) kits under an M-DSA Phase 1 Lot 4 contract.

Figure 4 | M-TADS/PNVS brings color to pilots in the cockpit. Photo courtesy of Lockheed Martin.

EXECUTIVE INTERVIEW

Spike Hughes

Solid-state pulse Doppler radar tracks small targets in high-clutter environments

By John McHale, Editorial Director

The Kelvin Hughes SharpEye SxV radar, shown in a mobile single-mast arrrangement, can monitor and intercept threats from drones in remote or difficult-to-access locations. Photo courtesy of Kelvin Hughes.

Militaries worldwide are increasing funding for radar systems that can track small targets such as rubber boats in high-clutter littoral environments as well as on the high seas. In this Q&A with Spike Hughes, Sales and Marketing Director for Kelvin Hughes, he discusses how solid-state, pulse Doppler radar technology enables those capabilities and how it is being developed to counter the threat of small unmanned aircraft. Edited excerpts follow.

MIL-EMBEDDED: ***Please provide a brief description of Kelvin Hughes such as the markets it serves, key technology areas, etc., and your role within the company.***

HUGHES: Kelvin Hughes effectively has two main divisions. One focuses on charts – nautical charts and publications for the commercial shipping industry. The second is the radar equipment division, which serves two main markets – commercial shipping and the military. I am Sales and Marketing Director for this division.

This division complements the activities of the charts division by providing type-approved X- and S-band radars to commercial shipping customers. On our military side we provide naval navigation radar and have more recently added a security division, which targets border security, drone detection, and critical infrastructure applications with smaller versions of our naval radar solutions.

MIL-EMBEDDED: ***For military radar programs where do you see the most investment from militaries around the world – maritime, airborne, ground, etc.? Is the military radar growing globally or is it more flat?***

HUGHES: We have taken the view that it is a growing market for what we specialize in, which is maritime surface search, tracking small objects, and littoral applications. As threats in these areas increase – such as terrorists in small rubber boats or the proliferation of small drones – militaries worldwide are looking for ways to counter them and the radar technology best suited for that is X-band solid-state pulse Doppler radar.

There has also been an increased requirement for stealth in radar systems. Ship designs that have traditional aluminum casting antenna turning units have degraded stealth capabilities. But by using a carbon composite housing formed with a stealth profile for the stealth structure, the radar cross section can be reduced by 90 percent. Notably the SharpEye transceiver is also located inside the turning unit housing making the system an upmast radar transceiver system unlike typical magnetron and other radar systems being downmast.

MIL-EMBEDDED: ***What are a couple of key military platforms that use your radar technology?***

HUGHES: Our systems are on the Trinidad and Tobago Coast Guard Damen Stan Patrol 5009 ships and our bridge systems and SharpEye Doppler

radar systems are on the United Kingdom Royal Navy Tide Class, also known as the MARS Tanker. The SharpEye systems will also be on the UK Royal Navy's three new River class Batch 2 Offshore Patrol Vessels (OPV) to be named HMS Forth, HMS Medway, and HMS Trent. In the Far East our SharpEyes are used on the Republic of Singapore navy's new Littoral Mission Vessels (LMVs).

MIL-EMBEDDED: ***Could you please explain solid-state pulse Doppler radar and how it differs from other radar technology in use today?***

HUGHES: Basically about five years ago Kelvin Hughes transitioned from a magnetron radar-based product company to a solid-state transceiver, pulse Doppler radar. We didn't invent them, but they've been around a long time, since the late 1980s.

Pulse Doppler radar can differentiate between moving and non-moving targets essentially via zero Doppler filters. The radar determines the range to target by timing pulses. Doppler processing enables clutter removal without picture degradation and by using solid-state transceivers you have less wear parts, which reduces maintenance costs and improves reliability.

The big difference between it and magnetron systems is in the operational benefit. The ability to detect range of Doppler radar transmissions is a fraction of what it would be with magnetron radar. A ship or submarine that uses pulse Doppler radars is far less likely to be heard than those using magnetron radars.

Having then adopted pulse Doppler technology we designed radar systems for marine applications. The radar systems can look at small, slow-moving targets – those moving at less than 100 knots. It is also efficient at tracking helicopters (See Figure 1).

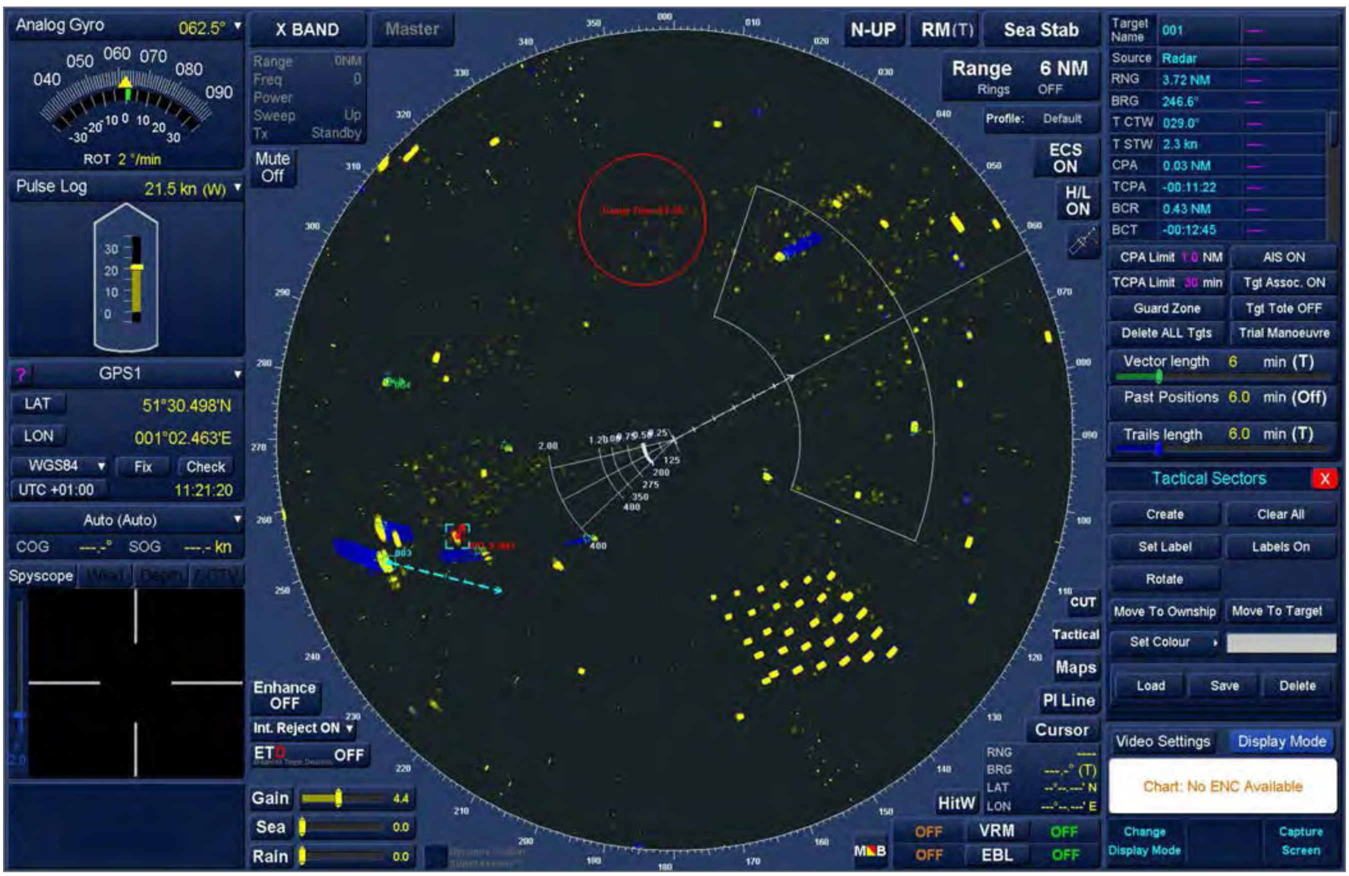


Figure 1 | An X-Band radar system display from Kelvin Hughes tracks helicopters from maritime platforms.

We are able to add flexibility in that we can change the radar systems transmission to optimize it for particular type of target. For example, we could set it up in a mode that enhances the detection of helicopters, while decreasing its ability to see other things. We can also do the same with submarine periscopes.

MIL-EMBEDDED: ***Do you leverage open standards and commercial signal processing technology for your radar solutions, such as VPX?***

HUGHES: We don't use VPX, but where possible we do use commercial standards. The digital output coming from the SharpEye radar system transceiver is ASTERIX, an open source air-traffic management (ATM) protocol. Using this standard makes integration with legacy and other systems in various platforms much more cost-effective for the customer. [Editor's note: ASTERIX, or All Purpose STructured Eurocontrol SuRveillance Information Exchange, is an ATM Surveillance Data Binary Messaging Format which enables transmission of harmonized information between any surveillance and automation system, according to the Eurocontrol website.]

MIL-EMBEDDED: ***It seems every piece of electronic equipment today is getting smaller – GPS systems, radios, etc. How have reduced size, weight, and power requirements affected your radar designs? What are the tradeoffs with smaller tech?***

HUGHES: The biggest problem we face when we get smaller is dissipating the heat. It is a boring problem to have, but can be quite complex. It is a critical part of our designs, as we want to avoid using air conditioning (AC) systems that add size, weight, and power. Some radar designers in the coastal surveillance market put AC systems up the mast. Of course, then, in a remote station, you have to double that AC system with a user that does not like to add extra weight.

So we made our solution smaller and dispensed with heat through power management and the design of the transceiver housing. When we did militarize on the smaller variant we reduced the power we were transmitting and thus reduced the transceiver size enabling it to be enclosed within a radome, which also houses the antenna. This made this smaller variant of SharpEye called SCV suitable for small watercraft.

MIL-EMBEDDED: ***Kelvin Hughes also designs radar systems for submarines. How does submarine radar differ from that used on surface ships?***

HUGHES: There are two main types of submarine radar. One is with a transceiver sitting inside the pressure hold in the downmast system where you pass a waveguide through the pressure hold and have with the turning motor and antenna located upmast.

The second type puts the transceiver outside the pressure hold upmast as close as possible to the antenna and then going to pressure hold is a line cable.

From a submarine designer's perspective, the latter is more preferable, but you bring in new complications by having the transceiver outside of the pressure hold. Unlike sailors on surface ships, submariners hate using radar as it is like having a loud speaker. Aside from when they come in and out of harbor they shy away from it. However, by having a SharpEye solid-state transceiver, it results in a quieter operation in transmission terms that makes it more viable for uses outside of harbor entry/exit.

MIL-EMBEDDED: ***What are the next challenges/threats your military customers are looking to counter with radar technology and what innovation in radar systems will be necessary to counter those threats?***

HUGHES: The proliferation of submarines around the world has increased, as has that of threats from adversaries using small boats. Seeing a submarine periscope with radar is a demanding type of task and requires a better type of radar. Seeing small targets in degraded conditions requires phased-array radars with SharpEye Doppler processing technology.

Drones are also an increasing concern to ships at sea and to operations on land. Similar requirements also exist in border security and critical infrastructure applications where our customers are looking to spot people as far out as four or five kilometers.

Non-Doppler, typically magnetron radars, cannot see through heavy clutter. During my service in the navy when we were on exercises and it was raining, we would drift with the rain cloud while being almost undetectable to adversaries. Today with solid-state Doppler radar, you are not just able to track smaller targets, but you can track targets in conditions where you could not in the past. It is no surprise that many of our key customers are located close to the equator, as that's where you get heavy rain. Smugglers and pirates in heavy rain are difficult to see in their rubber boats when using a magnetron radar. Not so with solid-state Doppler systems.

MIL-EMBEDDED: ***Is Kelvin Hughes working on any solutions for unmanned aerial vehicle (UAV) detection from single aircraft to swarms?***

HUGHES: We get about four to seven inquiries a week just on drone detection. In the radar business, that is a lot of inquiries and shows how important that particular application is to the market.

What we've been doing involves algorithms and waveforms for our portable SxV radar. Currently the range is just under a kilometer for picking up quadcopters and similar sized aircraft. We think can do better than that and are working to refine those algorithms. SxV is a low-powered, small radar. It will have more flexibility to be placed on top of a land rover, or a man-portable mast. The system is very easy to operate. I've actually done it and to get it up and running takes ten minutes. The display and attached cameras can be cued from the radar.

We are participating in about 20 trials and at the moment are testing the algorithms and refining the system in the field. (See lead photo.)

MIL-EMBEDDED: ***You served in the Royal Navy more than 30 years ago. How would you say radar technology has changed since your days in the service?***

HUGHES: I was in the Navy from 1975 to 1988 and there is not a lot of difference from the radar we used then and the magnetron radar of today. The big difference is the development of solid-state Doppler transceivers for radar. It is a more recent technology, as magnetron had been around since 1947. It was tweaked and played with and refined by the 1970s and 1980s, but was not able to go much farther in terms of performance, and is why the switch has been made to solid-state pulse Doppler radar.

MIL-EMBEDDED: ***Looking forward, what disruptive technology/innovation will be a game changer for radar technology? Predict the future.***

HUGHES: Adapting solid-state radar technology for general use in addition to specialist users such as the military. When you start removing all rotating parts in systems it becomes affordable for a wide user market. Phased-array radars today are quite expensive beasts. As technology improves here the price will come down.

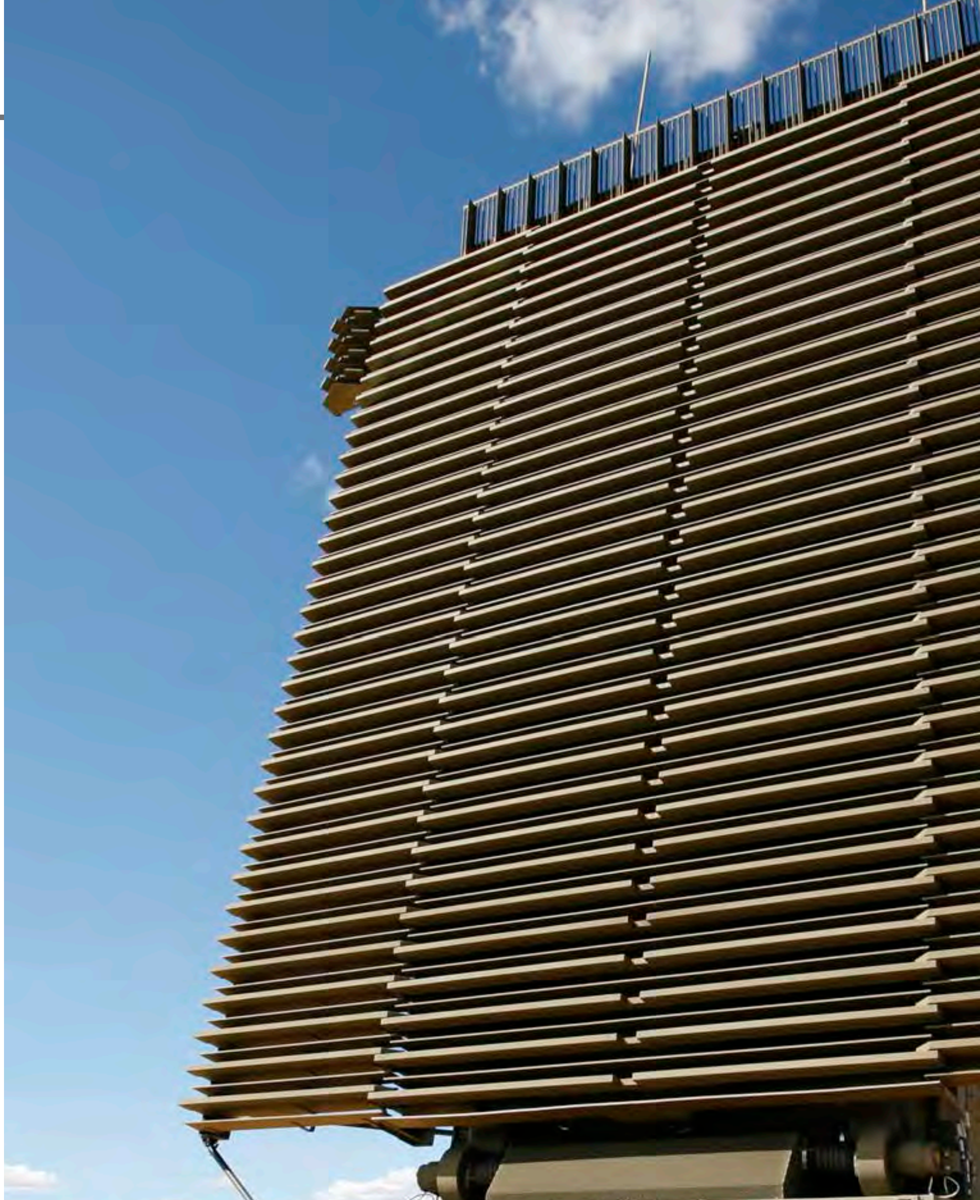
It will be similar to what happened with GPS devices. I remember when we were selling GPS products for pretty close to $50,000 a pop and now they are cheap and found in wristwatches. The same approach can be applied to solid-state radar. When we went down the solid-state route, we had no idea we'd be developing drone-detection solutions. With developing phased-array systems we cannot fully predict how the technology will be used as time goes on. **MES**

Spike Hughes was named Director of Sales and Marketing at Kelvin Hughes in 2007. During his tenure he has helped expand the company in the commercial marine radar and navigation equipment, maritime defense, Vessel Traffic Services (VTS), security, and coastal surveillance radar sensor market sectors. He joined Kelvin Hughes in 1998 as an Area Sales Manager and was appointed to General Manager – Asia in 2001. Spike then led the company – from Singapore – in the Far Eastern maritime market before returning to the U.K. headquarters. He also had a 13-year navigation career in the Merchant and Royal navies.

Next-gen military radar system design innovations

By Sally Cole, Senior Editor

Gallium nitride (GaN) transmitters, radio frequency (RF) tiles, and solid-state modular 3-D radar are among the latest innovations in next-generation military radar systems to embrace commercial-off-the-shelf (COTS) components to reduce costs. Designers of these systems have also adopted modular design to streamline installation and maintenance.



Lockheed Martin's Digital Array Row Transceiver (DART) is a combined transmit-and-receive line replaceable unit (LRU) with gallium nitride transmit/receive modules. Photo courtesy of Lockheed Martin.

Designers of next-gen military radar systems are under constant pressure to deliver enhanced capability to track and counter increasingly sophisticated threats, all at the lowest cost possible, while also factoring in ease of installation and upgrades.

Three such recent industry designs include the Digital Array Row Transmitter (DART) from Lockheed Martin, SPAR Tiles from MACOM, and the Artisan 3-D radar system from BAE Systems.

Lockheed Martin's next-gen radar technology

Lockheed Martin designed its Digital Arrow Row Transceiver (DART) to be form- and fit-compatible with the current transmit-and-receive line replaceable units (LRUs) in its legacy radar system antennas.

"Leveraging the prime power, efficiency, and cost benefits GaN (gallium nitride) transmitter technology offers, DART combines the basic functionality of the antenna transmitter LRU and receiver LRU into one," says Mark Mekker, director of surveillance radar for Lockheed Martin. "A modular design provides enhanced maintenance capabilities to lower life cycle costs."

In terms of detection capabilities, although DART was initiated with obsolescence and affordability goals in mind, the technology can also be used to increase RF performance. "With GaN technology, the power handling capability and higher junction temperature tolerances of DART provides an opportunity to increase the duty cycle on the radar system," Mekker says. "And with finer controls of critical transmit output parameters, we can enhance the system's radar beam-shaping capabilities. Lockheed Martin works specifically with customers to configure their radar systems to their mission objectives, and DART certainly increases the options to support this."

As for anti-jamming and anti-spoofing, DART "provides finer control of critical transmit output parameters that could certainly apply to special anti-jamming or anti-spoofing capabilities," Mekker notes.

Perhaps the most surprising aspect of DART is that the maturity of GaN technology isn't being driven by the military industry, as Mekker points out, but instead was primarily driven by the telecom industry well over a decade ago.

"Lockheed Martin recognized the strength of this technology and how it could be used in radar systems and so we partnered with several leaders to develop GaN technology. While others in the military radar industry have opted to develop and build GaN technology in-house, we adopted a foundry-neutral approach for our new transmit/receive capability," Mekker explains.

This enables Lockheed Martin to "leverage the most mature GaN processes in the industry – being used by many instead of one – and provides multiple sources of supply for GaN devices to help drive competition and lower costs," Mekker says. "As a result, Lockheed Martin had GaN working in operational radar systems more than six years ago, which allows us to pass cost savings to our customers."

MACOM SPAR Tiles

MACOM engineers created SPAR Tiles, which are RF assemblies containing antenna elements, gallium arsenide (GaAs) and gallium nitride (GaN) semiconductors, transmit and receive modules, and RF and power distribution networks.

"When combined with other signal-generation and receive-and-control electronics, the composite assembly forms the foundation for the multifunction phased-array radar (MPAR) planar active electronically scanned antenna (AESA) for the radar system," says Doug Carlson, vice president of strategy for MACOM. (See Figure 1.)

In fact, SPAR Tiles are a fundamental change in the way the industry can go about building phased arrays or any active antenna. "For most of the history of these systems, they were built using a slat-style design or brick architecture in which the electronics were perpendicular to the antenna face," Carlson explains. "With SPAR Tiles, also known as scalable planar array tiles, everything is built using a completely planar technology. This allows us to exploit commercial manufacturing technologies and lower the overall manufacturing costs of civil and defense systems."

The size of SPAR Tiles is determined by the wavelength of the system it is operating in. "Our S-band tile, for example, is about 16 inches square. In future high-frequency applications of this technology, as they move into 5G applications, they'll become quite small," Carlson adds.

The main benefit of SPAR Tiles? While they preserve the most advanced characteristics of radar systems, the cost point is as much as five times lower than current technology. "The major thrust here is affordability, but to also support multifunctionality, multimission capability – aimed at land, sea, and eventually air domain applications," he says.

For military applications, "if you think of a radar as a sensor, we use sensors in installations on the battlefield, where it's a huge asset," Carlson continues. "If the sensor can be made more affordable, sensors can be used as a distributed network of sensors on trucks and UAVs

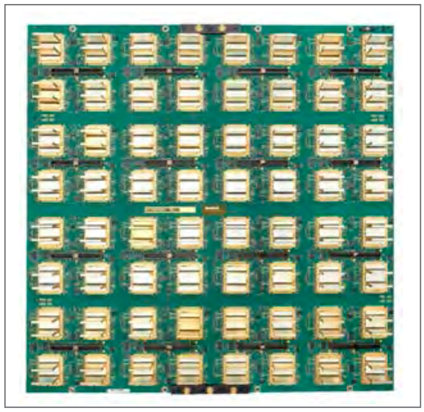


Figure 1 | Pictured is a SPAR Tile developed by MACOM. Photo courtesy of MACOM.

[unmanned aerial vehicles] – all over the battlefield, operating at different frequencies to watch out for different threats. It'll change the way we view the battlefield and usher in a new level of information and communications on the move. The directivity and agility that active antennas bring to the battlefield are enabling effective communications while in motion – without detection by the adversary."

MACOM manufactures SPAR Tiles by exploiting the same manufacturing technologies used to build the motherboard in computers or electronics. "It's a very different approach than having dedicated factories building one radar system over a long period of time. By exploiting the larger electronics industry, we can get the absolute lowest possible manufacturing cost," Carlson explains.

Another way to reduce costs is to use a combination of custom and COTS to build these products. "In general, in power and digital control it's all COTS components … power regulators, FPGAs, etc.," he says. "Closer to the antenna, the solution becomes more custom."

One of the most surprising aspects about SPAR Tiles is the cost reduction that comes from simply changing manufacturing approaches. "Most systems implemented today are in a brick architecture approach," Carlson says. "But within the military domain, virtually every antenna application is moving to an active antenna – whether it's communications or radar – so making these systems affordable is paramount to getting them implemented. This cost reduction offers a path forward."

What sorts of radar trends is MACOM seeing? One of the biggest involves the shift to going digital. "Do you go digital to an element or to a subarray?" points out Carlson. "It's currently a cost versus performance tradeoff, but there's a very active push toward going digital to the element. We're very active with this technology thrust. Another one is to increase broadband capability that will enable a broad array of missions to be accomplished by a single array. Very broad frequency ranges make it possible to do communications radar, electronic warfare, jamming, etc., simultaneously out of the same array."

As far as a timeline for SPAR Tiles, shipping in low production rates has already begun. "By 2020, this will be the de facto standard of how systems are built by the DoD (Department of Defense)," Carlson says. "We're looking at a similar timeline for next-generation civil telecommunications and air traffic control within the U.S."

What's next for the technology? In the defense domain, Carlson believes the technology is going to go from ground to sea applications, and then eventually to air. "It'll evolve to higher frequencies and much broader bands," he adds.

On the civil side, Carlson says he expects it to go in the direction of telecommunications. "If you look at next-generation network architectures, they're expected to become highly dependent on active antenna technology or phased-array technology to optimize signal link and data rate," he says. "In the telecom domain, cost is of primary importance. For those implementations, this technology will support applications spanning 2.5 GHz and 3.5 GHz base stations all the way up through upper millimeter-wave E-band and beyond."

BAE Systems' Artisan 3-D radar system

BAE Systems has developed the "Artisan 3-D radar system" for the U.K. Procurement Agency. The system was designed to meet the challenges of operating within the naval domain – including detecting fast and agile air and surface threats that materialize with little warning.

To this end, Artisan can operate within signal-populated environments and cut through an interference equivalent to 10,000 mobile phone signals. It can also track more than 800 targets at any given time, and identify a target the size of a tennis ball hurtling toward it at a speed of Mach 3 (>2,000 mph) from more than 25 kilometers (approximately 15.5 miles) away. All of this capability comes with an antenna that weighs less than 700 kilograms (just over 1,500 pounds), which is roughly equivalent to the weight of an adult male polar bear. (Figure 2.)

"Our system's performance can be achieved amid the most difficult of environments – mixed land and sea clutter, challenging climatic and atmospheric conditions, and real-world objects – such as hostile electronic countermeasures," says Dominic Morley, BAE Systems' international business development manager for naval radar. Artisan delivers

Figure 2 | This image shows the Artisan 3-D system in the process of being installed on a Queen Elizabeth Class carrier. Photo courtesy of BAE Systems.

"a simultaneous air and surface picture that provides situation awareness and target detection to support the weapons system and provide improved ship defense."

Artisan contains a range of advanced signal and data processing techniques, which according to Morley, provides "high-quality tracks at low latency."

The system was developed primarily to satisfy multiplatform, multirole military applications for medium-range data to enable an air picture compilation; furnish multimode operation to suit all prevailing operational scenarios; contribute advanced target indication capability (integrated with the Sea Wolf and Sea Ceptor weapons systems) to support any of the currently active surface-to-air missiles; track classification and characterization to support combat ID; and provide accurate data for successful weapon system operation, including resolution of targets.

"Artisan provides surface surveillance, air-traffic management, jammer suppression, surveillance and tracking, and graceful degradation to meet maximum operational availability," Morley says.

The radar offers "optimized performance in littoral regions with severe clutter by using adaptive techniques and a dedicated littoral warfare defense mode," he adds. It also provides "electronic countermeasures (ECM) via adaptive beamforming techniques in severe ECM environments."

Artisan is low-maintenance, thanks to its modular solid-state construction. Moreover, the install time is typically within four to eight weeks. This makes the radar "ideally suited to ship refits," Morley says.

This modern system also happens to be software-defined and highly adaptive. "One of our key considerations during the trials leading up to the first operational deployment was to fully replicate the exceptional sensitivity achieved in the land-based test environment and to tune it for the seagoing environment," he says.

As of late 2015, this process was largely complete and the system is currently fitted to 10 Royal Navy warships, including eight Type 23 frigates and the future aircraft carrier HMS Queen Elizabeth.

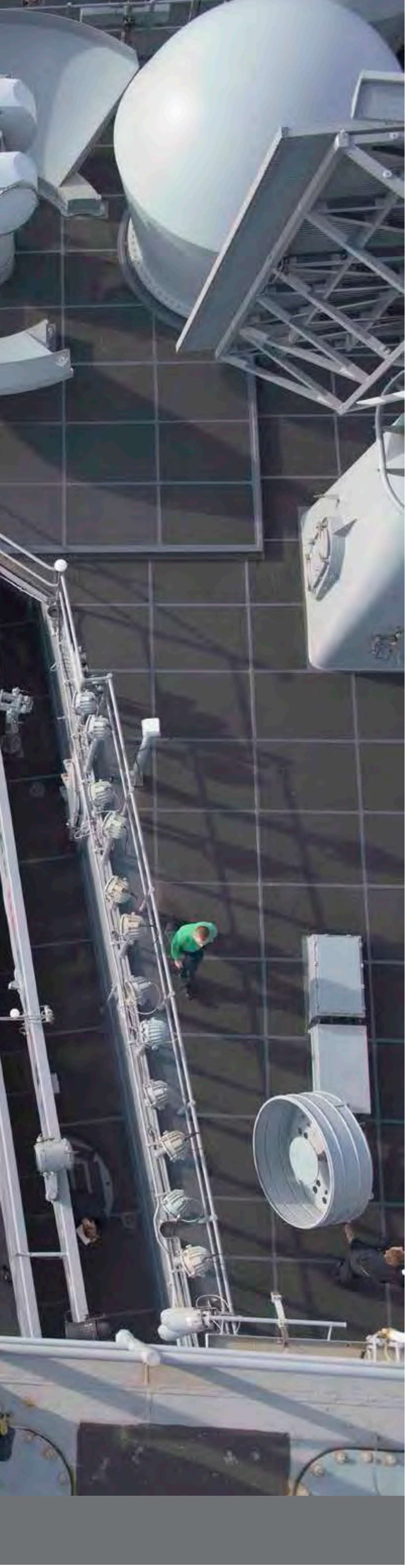
"Artisan is already proving to be a highly capable radar – providing significantly greater track detection ranges than its predecessor against more complex and demanding threats," Morley notes. "Trial analysis and assessment are ongoing to ensure that all aspects of performance are met." **MES**

Bandwidth is king in aerospace and defense applications

By Ian Beavers

Wider frequency communication bands require not only a larger observed bandwidth from a system analog-to-digital converter (ADC), but can also push the need for a higher full-power bandwidth. In some applications, such as electronic warfare (EW) and active phased-array radar, this can require the use of a higher order Nyquist rate band. Next-generation gigasamples per second (GSPS) ADCs allow GHz sampling well into the 3rd and 4th Nyquist band with decimation options to get the dynamic range benefits of oversampling. If an ADC's input bandwidth is high enough, it is possible to downconvert directly in the ADC by undersampling the infrared (IF) signal of interest. Higher-bandwidth input signals and sample rates enable direct RF sampling of wider band signals and possible reduction of an entire stage in a signal chain for lower system power and simplicity.

Defense applications, including electronic warfare and active phased-array radar, require high full-power bandwidth from the analog-to-digital converter (ADC). A single direct RF-sampling ADC can help designers lower a system's cost, time to market, board size, weight, and power consumption. Photo courtesy of U.S. Navy.



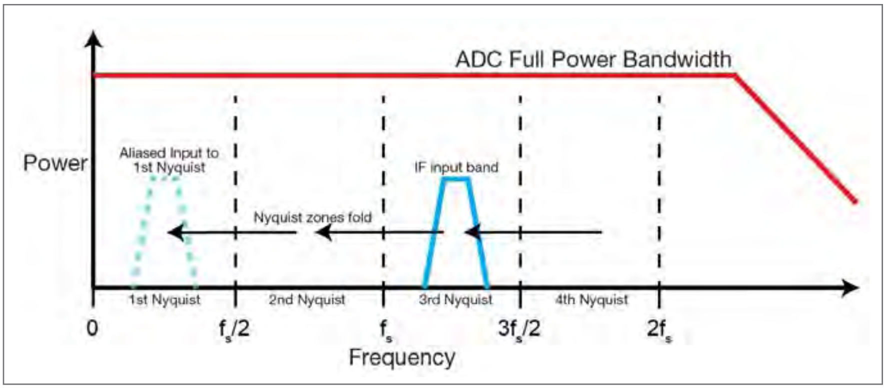


Figure 1 | Wide ADC full-power bandwidth enables the use of higher order Nyquist bands. Band pass filtering of the unused Nyquist zones is mandatory to remove unwanted signal energy that could potentially fold back into the first Nyquist, thereby impacting dynamic range.

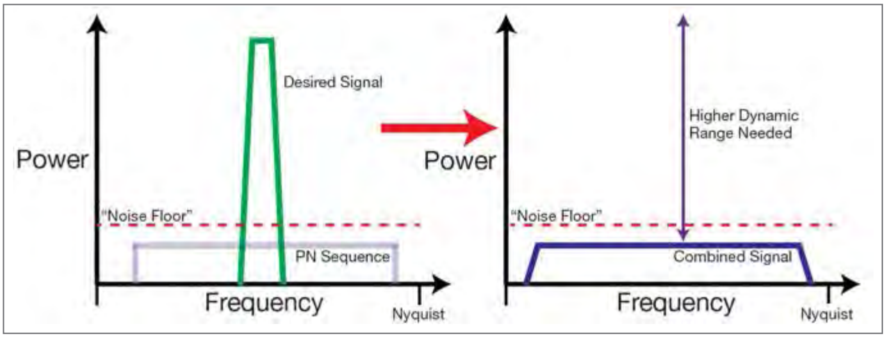


Figure 2 | Direct Sequence Spread Spectrum systems require a wide receiver bandwidth and high dynamic range as the signal band of interest is combined with pseudorandom noise (PN) to push the communication into the noise floor.

ADC undersampling is essentially the technique of using a sampling frequency that is less than twice the maximum frequency component in the signal. This technique can also be referred to as harmonic sampling, band pass sampling, or super-Nyquist sampling. To reconstruct the original signal perfectly from the sampled version, the Nyquist-Shannon Sampling theorem indicates that the sample rate must be twice the signal bandwidth of interest. This technique should not be mistaken with a sample rate that is twice the maximum IF frequency component.

If BW is the signal bandwidth of interest, then a sample frequency of Fs > 2BW is required. The signal bandwidth of interest can be between DC to BW or from A to B where BW = A – B. As long as the bandwidth of interest does not overlap an ADC's Nyquist band, which is half the sample rate (Fs), undersampling can work for higher signal bands with ADCs that have a high full- power bandwidth (FPBW) relative to their respective sample rate (Figure 1).

Secrecy is an important aspect of military operations. To reduce the probability of intercept or detection, a radar transmission's form and magnitude is designed in many cases to spread energy over the widest possible frequency range. Low Probability of Intercept (LPI) and Low Probability of Detection (LPD) are classes of radar systems that possess certain performance characteristics that make them nearly undetectable by today's modern intercept receivers. LPI features prevent the radar from tripping alarm systems or passive radar-detection equipment.

To provide resistance to jamming, systems can be architected by intelligently randomizing and spreading the radar pulses over a wide band so there will only be a very small signal on any one band, an approach known as Direct Sequence Spread Spectrum (DS-SS), as seen in Figure 2. Frequency Hop Spread Spectrum (FH-SS) also provides some protection against full band jamming. In these cases, the wide transmission signal consumes bandwidth that is in excess of what is actually needed for the raw signal of interest. Therefore, a wider receiver bandwidth is needed to continue to advance system capability.

One of the most important factors for success in an LPI system is to use the widest signal transmission bandwidth possible to disguise complex waveforms as noise. This technique conversely provides a higher-order challenge for intercept receiver systems that seek to detect and decipher these wideband signals. Therefore, while LPI and LPD are improved, radar transceiver complexity is increased by mandating a system that can capture the entire transmission bandwidth at once. The ability of an ADC to simultaneously digitize 500 MHz, 1,000 MHz, and even larger chunks of spectrum bandwidth in a single Nyquist band helps provide a means to tackle this system challenge. Moving these bands higher in frequency beyond the first Nyquist of the ADC can be even more valuable.

Today's wideband ADCs offer systems potential for multiple wide Nyquist bands within an undersampling mode of operation. However, using a high order ADC Nyquist band to sample requires strict front-end anti-alias filtering and frequency planning to preventing spectral energy from leaking into other Nyquist zones. It also ensures that unwanted harmonics and other lower frequency signals do not fall into the band of interest after it is folded down to the first Nyquist. The bandpass filter (BPF) upstream of the ADC must been designed to filter out unwanted signals and noise that are not near the nominal bandwidth of interest.

Since a direct sampling technique folds the signal energy from each zone back into the first Nyquist, there is no way to accurately discriminate the source of the content. As a result, rogue energy can appear in the first Nyquist zone, which will degrade signal-to-noise ratio (SNR) and spurious free dynamic range (SFDR). Spectral issues can potentially plague government and military applications, both for sensing and communications.

Digital radio transceivers for military communications are another example of the use of high-speed ADCs and digital-to-analog converters (DACs) that can potentially replace a traditional

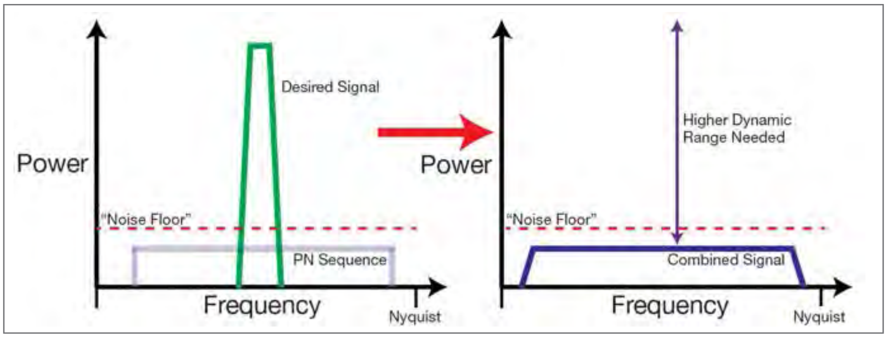


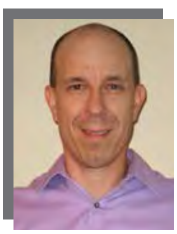
Figure 3 | Direct Sequence Spread Spectrum systems require a wide receiver bandwidth and high dynamic range as the signal band of interest is combined with pseudorandom noise (PN) to push the communication into the noise floor.

baseband mixer stage. The architecture has several advantages because tight filtering and adjacent channel rejection can be done in the digital domain for the baseband conversion.

Several advantages are offered by direct RF sampling for radar RF front end designs. First and foremost, it can allow component count reduction, as shown in Figure 3, when an entire downconversion stage can be eliminated. It also removes the need to design a mixing chip to fit a uniquely tailored frequency plan. Second, it can simplify the design of next generation receivers for future signal bandwidths that become available as radar systems are modernized and updated. All that may be needed to work with a new carrier frequency is to select an appropriate sampling rate and incorporate an appropriate band pass filter. Third, it is possible to make a single RF front end suitable for multiple frequency bands. This approach to multifrequency radar receiver front end design eliminates the need for multiple front ends.

Current generation ADCs now offer a plurality of internal digital down conversion (DDC) processing blocks. Each DDC can apply its own decimation rate and numerically controlled oscillator for tuning placement within a Nyquist band. Processing gain can be achieved within a narrower bandwidth that digitally filters out-of-band noise. This reduces the required ADC output data and minimizes processing complexity in FPGAs and DSPs. However, additional channelizer signal processing can also be done downstream of the ADC.

Wideband communications and sensing systems require extremely high-speed data converters. GSPS ADCs from Analog such as the AD9234, AD9680, and AD9625 not only offer high sample rates for a wider instantaneous bandwidth, but also the ability to sample high frequency inputs above the first Nyquist. A single direct RF-sampling ADC used at a high bandwidth can potentially replace an entire IF-sampling or zero IF-sampling subsystem of mixers, local oscillator (LO) synthesizers, amplifiers, and filters while achieving greater flexibility. This setup can significantly reduce the system's bill-of-materials (BOM) cost, design time, board size, weight, and power consumption. **MES**



Ian Beavers *is an applications engineer for the High Speed A/D Converters team at Analog Devices in Greensboro, North Carolina; he has worked for the company since 1999. Ian has more than 20 years of experience in the semiconductor industry and earned a bachelor's degree in Electrical Engineering from North Carolina State University and an MBA from the University of North Carolina at Greensboro. Readers can contact the author at IanB on Analog Devices' EngineerZone Online Technical Support Community.*

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SIGNAL PROCESSING IN RADAR, SONAR, AND ELECTRONIC WARFARE

COTS processing drives modern electronic warfare systems

By John McHale, Editorial Director

Designers of signal-processing systems for electronic warfare (EW) applications faced with requirements for reduced size, weight, and power (SWaP) along with more processing power are creating multifunction systems that leverage high-speed field-programmable gate array (FPGA) technology.

Modern electronic warfare systems such as the U.S. Navy's Surface Electronic Warfare Improvement Program (SEWIP) will rely on open architectures and commercial signal processing technology. In this photo, an early Block 3 version of SEWIP is being brought on board a Navy vessel during the multinational Rim of the Pacific (RIMPAC) maritime exercise near Hawaii in 2012. Photo courtesy of Lockheed Martin.

Electronic warfare, for decades, has been a kingdom rife with customized systems and stovepipe technology based on closed architectures. As enemy threats become more sophisticated, EW designers face pressure to create systems that can adapt and respond effectively in real time. Their efforts are resulting in multifunction systems that marry different types of EW, such as signals intelligence (SIGINT) and electronic intelligence (ELINT), as well as EW and radar functions in one box.

"I see a trend toward more multifunction systems to handle both radar and EW processing in a single system," says Lorne Graves, Technical Director at Mercury Systems in Chelmsford, Massachusetts. "Some will be CPU-centric and some will be FPGA-centric in terms of processing; it will just depend on the mission. It just makes sense to combine the functions of a radar and EW system in the same box, as they have common processing components, while only differing when it comes to RF components.

"Multifunction systems also enable development of high-level hardware that can allow one to run digital algorithms for a combination of CPU and FPGA resources," Graves continues. "You could have the ability to switch between jamming, radar tracking, and communication elements."

"ELINT, SIGINT, and radar systems all have similar hardware, such as analog-to-digital converters (ADCs), digital-to-analog converters (DACs), FPGAs, maybe graphics processing units (GPUs) or central processing units (CPUs) as well as similar arrays or sets," says Noah Donaldson, Vice President of Product Development for Annapolis Micro Systems in Annapolis, Maryland. "Therefore, designers industrywide are looking to meld all that functionality into one system that, for example, can look at signals while at the same time performing jamming functions."

"The Department of Defense's (DoD's) push for spectrum warfare and dominance is driving even more requirements," Donaldson says. "Spectrum dominance is also contributing to the convergence of EW and radar, as in future systems the end user might want radar to look like an EW and vice versa."

"In years past, a SIGINT asset would go and gather information for a mission, and the signals basically had the ability to understand the electromagnetic spectrum and we used that as strategic advantage," Graves says. "Now when you look at it from an anti-access/area denial (A2/AD) perspective, you can have the SIGINT payload fly in with EW capability that can protect and spoof. This requires sophisticated processing elements such as high-performance CPUs and FPGAs that reduce overall platform SWaP."

Radar vs. EW processing

While radar and EW systems both rely heavily on commercial off-the-shelf (COTS) processing technology, there are differences in their requirements from a signal processing system.

"Radar systems transmit a pulse out that then it comes back, so they need more sensitivity since they are trying to receive a reflected signal," Graves says. "These systems need more dynamic range and more processing gain. Also, how much processing you need is often defined by the waveform you use to transmit and receive.

"EW systems need to handle much more instantaneous bandwidth and ingest more data at wider bandwidth and they require low latency, which is crucial for responding to threats in near real-time," he continues. "EW systems typically do not require the same sensitivity as radars, but they cover a much broader bandwidth."

Latency continues to be a challenge, as EW processing systems evolve from parallel to serial architectures. "Data converter manufactures are increasingly moving from parallel to serial interfaces, such as JESD204B. Unfortunately, when you move from parallel to serial interfaces, latencies increase," says Denis Smetana, Senior Product Manager for FPGA products at Curtiss-Wright. "The growing demand for more bandwidth is fueling the move toward serial lines in order to reduce the challenges of having very wide, fast data buses which are difficult to route on PCBs. What's more, parallel interfaces consume a lot of pins on digital converter devices and FPGAs. There's concern in the industry that with JESD204B, latency is much higher than has been previously experienced with parallel low-voltage differential signaling (LVDS) interfaces, making it unsuitable for low-latency EW functions. The good news is that there is a new version in the works, JESD204C, as well as other options, that provide promising approaches to resolving the serial latency issue."

Cognitive EW

FPGAs, mainly those from Xilinx and Altera (now Intel's Programmable Logic Group), are providing performance advantages for military EW and enabling a concept called cognitive EW.

"Cognitive EW represents a significant new step in EW, moving beyond the ability to just make decisions on the fly to being able to create new responses on the fly," Smetana says. "Adaptive responses are predetermined and then used at given times depending on the environment and mission. Cognitive EW will help deal with threats never encountered before, by creating the appropriate response for that scenario in real time. To accomplish this, cognitive EW techniques also require learning capability.

"To enable true cognitive EW, not only do you need more processing, you also need to move the processing closer to the sensors to enable real-time analysis," Smetana continues. "In addition, cognitive EW, like adaptive EW, requires the ability to reconfigure existing hardware, for example with FPGAs, to ensure the system is optimized for SWaP."

"FPGA-centric types of EW systems in particular are enabling a concept called cognitive EW," Mercury's Graves says. "There is a big push toward cognitive EW as we need real-time adaptation in environments where we encounter threats never seen before. These adversarial threats are able to adapt very quickly because the adversaries have access to similar commercial technology leveraged in modern radar systems. FPGA-based solutions enable the number-crunching and statistical analysis necessary for countering these new threats as FPGAs provide wider bandwidth and lower latency."

EW FPGA advantages

The addition of cognitive EW into radar systems is coinciding with the blurring of capability between traditional processors and FPGAs.

"As the lines start to blur between pure FPGAs and pure processors, a move towards the convergence of processor and FPGA functions in EW and radar signal-processing systems has emerged," Smetana explains. "At the same time, the RF environment is becoming more complex. That makes it imperative for both radar and EW functions to work with each other more effectively. The radar system needs to know what EW techniques are being used, and the EW system needs to make use of radar information. Historically, FPGAs tend to be used for front-end signal processing where multiple parallel sensor data streams need to be handled. Processors are used to handle the interpretation of the data and the calculation of appropriate responses. As the EW battlefield becomes more complex and intertwined, the use of embedded processor cores in FPGAs and the use of FPGA logic within microprocessors will become more prevalent."

Unlike CPUs and GPUs, FPGAs offer "many unique features critical for military and aerospace systems," says Rodger Hosking, Vice President and founder of Pentek in Upper Saddle River, New Jersey. "Their reconfigurability lets designers arrange and interconnect hardware resources in parallel to match even the toughest real-time requirements. We are now delivering FPGA products with 3,600 DSP engines and two million logic cells, with the ability to reconfigure those elements under software control during a mission to adapt to evolving threats. FPGAs also provide configurable interfaces for wideband sensors like ADCs and DACs operating at gigahertz sampling rates, as well as gigabit serial system interfaces like PCIe, Serial RapidIO, and Infiniband. Sophisticated memory controllers for the fastest SDRAMs support read/write data rates up to 1.6 GHz. With these diverse, high-performance capabilities, FPGAs deliver complete acquisition, processing, and interfacing subsystems ideally suited for EW and radar systems that require fast I/O, low latency, and computational intensity." (Figure 1.)

Easing FPGA development

Experts at Annapolis Micro Systems have enhanced their CoreFire Next Design Suite development product with a new tool called Open Project Builder. "It enables users to have more flexibility when developing code for FPGAs by allowing them to choose to develop code in CoreFire with or without VHDL," Donaldson says. "Developing in CoreFire without VHDL is faster, but many users still choose to work in VHDL due to processes they already have in place. With Open Project Builder, they now can develop in VHDL too and then port it to other hardware. Open Project Builder also enables the use of FPGA IP from other sources such as OpenCL and comes with a board support package for all Annapolis Wildstar boards. The CoreFire tool is included with the Annapolis hardware. There is no longer a separate price for it."

The CoreFire Next Design Suite is a dataflow-based development system that enables FPGA programming on Annapolis Micro Systems motherboards, I/O cards, and mezzanine cards, according to the company. It supplies user-made connections between programming modules, or cores, and manages multiple domain requirements automatically. The development suite does not require hardware design languages as the user creates dataflow diagrams by dragging and dropping cores, or building blocks, from the libraries and connecting their ports.

Retrofitting

Many older EW systems are custom solutions based on closed architectures that did not lend themselves to smooth tech refreshes. These systems – once quite capable of meeting traditional EW threats – now face an adversary that can adapt quickly. These new capacities call for systems based on industry standards and open architectures to enable quick capability upgrades. Two examples of this type of a retrofit leveraging VITA standards were performed by Mercury Systems and 4DSP (Austin, Texas).

VME SIGINT upgrade

"A big challenge for EW processing suppliers such as Mercury is to provide this advanced EW processing on older platforms," Graves says. "We did that recently by deploying a new, open architecture, VME-based product – the 6U DCM-2RT-VXS Transceiver – to go into an older SIGINT system as part of a retrofit for a quick reaction capability on naval platforms that are encountering adversarial threats not seen before. The upgrade gives that system the ability to adapt and change to the threats. By utilizing advanced scheduling algorithms, the multifunctional capabilities I mentioned earlier could be achieved. (Figure 2.)

"The system we upgraded was not an open system, so we went in and replaced the custom solution with an open system interface that could work with the older RF requirements. It had the capability to handle these threats from an RF perspective, but it needed a boost in processing power.

"By retrofitting these older custom solutions with open architectures, you can reduce the total life cycle cost of the systems," Graves continues. "The openness enables future tech refreshes that do not have huge cost or integration burdens. There is an OpenRFM equivalent in development where we've taken what we've done in VME and scaled that over to VPX. It is still early in the development cycle, but I can say it will rely on FPGA functionality via Xilinx Virtex 7 FPGAs. We are using Xilinx, as our customer's existing algorithm was developed in an older Xilinx family."

Figure 1 | The Onyx Virtex-7 Software Radio Module from Pentek for extremely wideband signal applications is based on the Xilinx Virtex 7 family and can digitize signal bandwidths up to 1,500 MHz.

VPX and the airborne EW pod

"Engineers at 4DSP were tasked with designing a processing solution for an EW platform that had to fit in an airborne pod that would provide attack protection and support," says Richard Ary, Vice President of Sales at 4DSP. "The requirements called for intense signal-processing capability in a small form factor. We came up with a solution, VPX167, that had enhanced computing power with an RF front end, a downconverter, and a digital mechanism for transporting data to an FPGA then converting it back out again and applying the appropriate algorithm."

4DSP then took the algorithm to the lab system, shrunk it, and placed it on the pod, Ary continues. "The 3U single-board computer (SBC) in the lab was the same 3U SBC for the pod. Using FMC, which by its nature is a small form factor, made it easy to go from a lab environment to a deployable system. The secret sauce is the modular backplane, FlexVPX. We essentially break the backplane in half to connect it with the cable in a 3U VPX form factor. It was the only way to fit the solution into the pod. The other key component in the solution is the multigigahertz wideband transceiver, made by PMI, which is mounted on a VPX module that fits in 3U VPX slot.

"FlexVPX, originally developed at the U.S. Naval Research Laboratory under

Figure 2 | The DCM-2RT-VXS Transceiver from Mercury Systems is scalable from 3U to 6U for electronic warfare systems.

the sponsorship of the Navy's Office of Naval Research, enabled an elongated form factor in a condensed space," Ary says. "The integrated LRU also created a significant weight savings, replacing four boxes with one to drop the weight from 160 to 40 pounds which helped maintain the weight requirements for aircraft.

"We took advantage of various VITA standards to minimize development time while maintaining the same level of performance. This started out as a custom design that leveraged open architectures and COTS standards so that it can be easily upgraded for tech refreshes down the road. The solution is conduction-cooled and is FPGA-agnostic. While this was designed for one particular FPGA family, there is nothing stopping the end user from using another brand if they wish," adds Ary.

OpenVPX across the globe

OpenVPX for EW applications is not only a trend in the U.S., as companies in Europe and Africa are also leveraging the standard for EW signal processing.

ApisSys engineers in Archamps, France, have designed the modular AF209, which is based on the VITA 57 FPGA Mezzanine Card standard for EW applications. It comes with a single-channel 12-bit DAC that is capable of as much as 4.5 Gsps. The AF209 DAC channel is AC-coupled with an output bandwidth wider than seven GHz for a signal of -3 dBm (450 mVpp). It is also fully supported on ApisSys 3U VPX FPGA processing engines. (Figure 3.)

In South Africa, experts at Parsec are offering the VF36x family of FPGA-based 3U OpenVPX modules that leverage

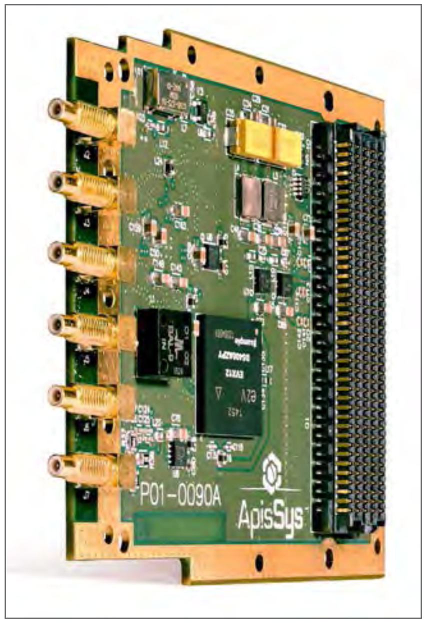
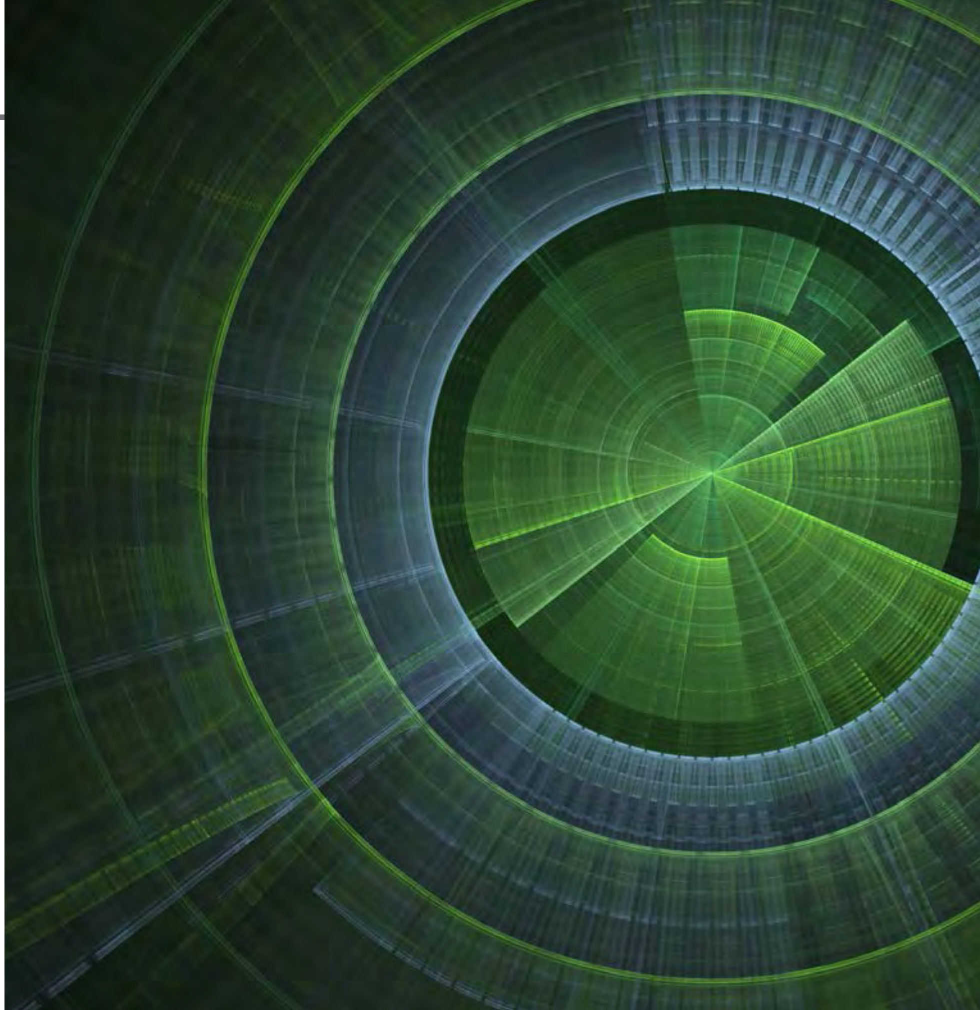


Figure 3 | The AF209 from ApisSys is based on the VITA 57 FMC standard.

Altera's FPGA Stratix V family and Texas Instruments KeyStone DSP in a single system. Its VITA57.1 FMC provides custom I/O and a PCI Express switch for scaling multiple boards. The Parsec product can be air- or conduction-cooled. **MES**



Countering "backdoor" threats with ADS-B and AIS-enhanced radar/video surveillance

By Andrew J. Haylett

Countering the growing "backdoor" threat posed by terrorists, smugglers, pirates, and political activists at military air and naval bases, airports, and ports requires sophisticated multisensor surveillance systems to ensure that incursions are rapidly detected and actioned. A hybrid approach that brings together conventional radar systems with high-resolution video imaging sensors, radar, and video trackers – incorporating Automatic Dependent Surveillance – Broadcast (ADS-B) and Automatic Identification System (AIS) transponder technology to filter out authorized targets – can deliver the high-accuracy threat detection needed even in adverse climatic conditions and poor visibility.

A typical secured site presents multiple challenges to the deployment of an effective surveillance and security system. The layout of the site may mean that certain locations are hidden from the view of a given sensor, resulting in a security vulnerability unless steps are taken to improve coverage. Differentiation between real threats and legitimate movements, both outside and within the site, is essential to avoid real incursions becoming "lost in the noise." Moreover, these threats may take multiple forms – unauthorized individuals/insurgents, vehicles or vessels, or airborne objects including small malicious drones may all represent real incursions; a surveillance system needs to provide early detection of all anticipated threat types.

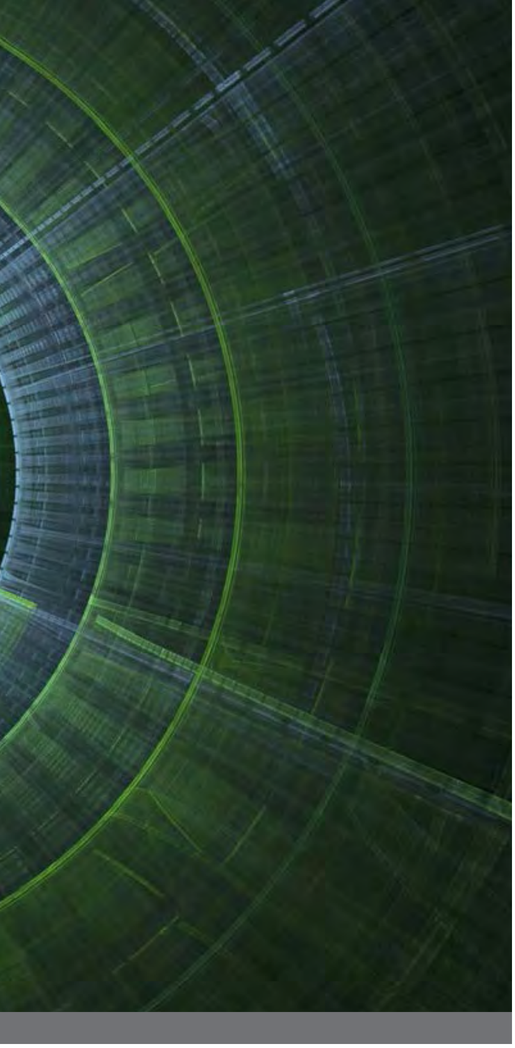
Multiple radar and video sensors

Primary radar has a long-established role in detecting objects at a distance, with moving target indication (MTI) further enhancing the radar's ability to differentiate targets from stationary objects and clutter. A typical radar can be configured to operate at longer range for early detection of distant objects or at shorter range, allowing more accurate determination of the object's characteristics such as size and shape.

Multiple radars can be combined to protect a given location, with the dual benefits of enhanced detection capability and a measure of redundancy. A process known as track fusion is able to combine reports from multiple radar trackers to form merged high-confidence tracks.

Cameras are the other essential component of a comprehensive surveillance system, providing high-definition video up to 1920 by 1080 resolution with optical zoom to 30 times or beyond. Such sensors are capable of identifying very small targets at a significant distance and providing a high level of detail, and their ability to identify object type and behavior is correspondingly enhanced.

"Daylight" camera sensors (those operating in the normal visible spectrum) are typically complemented by thermal sensors, whose ability to view the heat signature



of even very small objects such as individuals or an unmanned aerial vehicle (UAV) is an invaluable asset in surveillance solutions. Thermal sensors are not just useful at night; they also have a clear advantage over daylight sensors where visibility is limited for other reasons such as fog or smoke. Modern uncooled microbolometer-based thermal cameras offer a good compromise between performance and cost, and with higher resolution now widely available (typically 640 by 480 pixels), detection of individuals at a range of more than 2 km (approximately 1.24 miles) is possible.

Unlike a radar system, where the entire 360-degree field of view is typically scanned every second or two, cameras are normally aimed in a specific direction, with a field of view corresponding to the selected optical zoom. Any surveillance system needs to ensure that its cameras are pointed at the object of interest – the potential threat. Surveillance cameras can normally be steered using a PTZ (pan/tilt/zoom) interface implementing a standard protocol such as Pelco-D.

However, the challenge lies in automatically steering the camera towards the correct target, whether under operator guidance or in response to a newly detected threat. The radar system can detect the range of a target to within a few meters, and the target's bearing and approximate size can be determined with a resolution depending upon the radar's beam width, pulse repetition frequency (PRF), and rotation rate.

Armed with this information, the surveillance system can steer the camera towards a known target, using the target range for focusing, the target size for field of view/zoom, and the target bearing for steering, a process known as slew-to-cue.

Once the target is within the camera's field of view, advanced video-tracking algorithms can be used to lock the camera onto the selected target. Video tracking is significantly more accurate than radar tracking, due to the higher update rate (at least 30 frames per second) and superior resolution of the sensors. It involves frame-by-frame analysis of the target's presentation and velocity, together with a model of the camera's inertial properties when being steered, to predict and follow the target's movement and maintain it within the video frame. Figure 1 shows a typical system block diagram.

Filtering out ADS-B and AIS transponder data

The challenge of distinguishing real threats from legitimate movements remains. Two principal techniques can be employed: First, specific geographical areas within and outside the perimeter of the protected site can be defined, and radar-based tracking within those areas can be suppressed or enabled, enabling sensitive (alarm zone) or nonsensitive areas to be defined. Movement in nonsensitive areas can be ignored, while detection of new targets in alarm zones can initiate automatic slew-to-cue, video tracking, and operator alerts.

Secondly, the availability of secondary data from transponders fitted to many aircraft and marine vessels can be exploited to eliminate or identify nominally "friendly" targets identified by the radar system. Automatic Dependent Surveillance – Broadcast (ADS-B) transponders, which use GPS data to broadcast precise exact location and identity, are already fitted to many commercial aircraft.

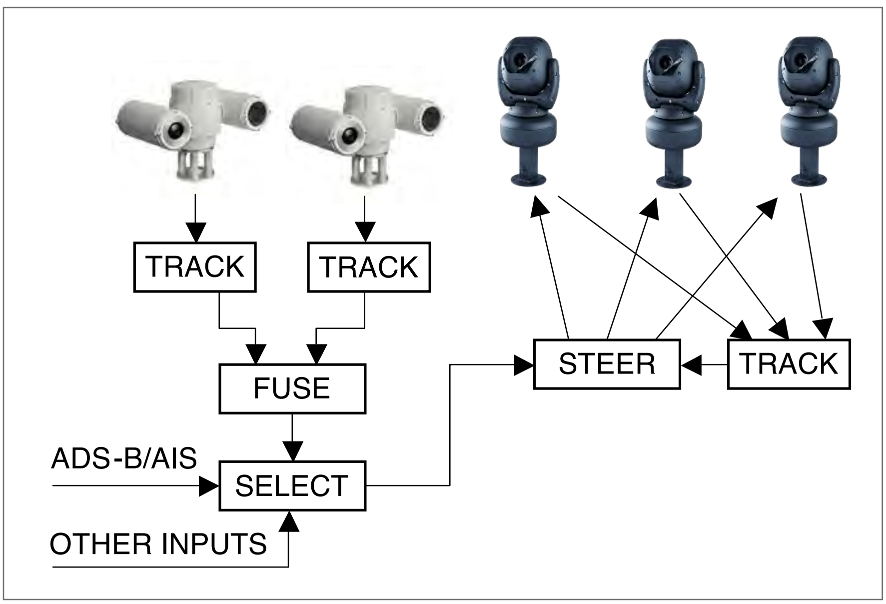


Figure 1 | A hybrid surveillance system uses radar together with video for high-accuracy threat detection.

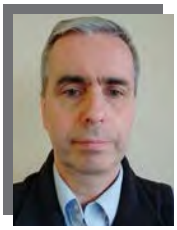
While primarily designed for air traffic control, increasing numbers of military aircraft will be ADS-B-capable in the future. Although such aircraft will normally permit the air crew to disable ADS-B transmission for security reasons, the presence of ADS-B can still be used to eliminate false positives when the surveillance system is equipped to receive ADS-B messages, since track reports can be correlated with ADS-B responses and "friendly" tracks eliminated. Ground vehicles may also be fitted with transponders, allowing effective reclassification of ground-based as well as airborne threats. The marine equivalent of ADS-B, Automatic Identification System (AIS), can be used when the protected site is, for example, a harbor or naval military base.

An example of a surveillance solution that integrates this multisensor data is Cambridge Pixel's VSD software application. Running on any embedded or industrial computing platform, VSD accepts primary video from one or more radar systems via an analog or network interface, initiating and maintaining tracks from these video streams and providing a fusion capability to link targets detected from multiple radars.

It also accepts camera video from multiple sensors, using conventional analog video or H.264-compressed video over a network, and steers the cameras towards targets reported by the fusion process. Support for AIS/ADS-B transponder input and user-defined alarm zones provides for automatic elimination and reporting of potential threats.

Map underlays with overlaid primary radar display and symbology present the operator with an overall view of camera and radar location and detected targets (Figure 2), with camera video displayed in separate full-size or picture-in-picture windows. The application can also be used to implement remote unmanned-surveillance installations, supporting full target reporting and camera control interfaces to manned headquarters over a wide area link (WAN) or uplink.

With ever-increasing security concerns notably from "backdoor" threats, air and naval bases and other military installations can benefit from hybrid multi-sensor systems that incorporate ADS-B and AIS transponder technology into the enhanced radar/video surveillance solution. With their ability to resolve small objects at significant distances, such surveillance systems offer repeatable, round-the-clock performance combined with ease of integration and a fully scalable architecture. **MES**



Andrew Haylett, *principal engineer at Cambridge Pixel, has worked in the fields of radar and video processing and display for more than twenty years. He holds a degree in Electronic Engineering from the University of Southampton in the U.K. Andrew can be reached at andrew.haylett@cambridgepixel.com.*

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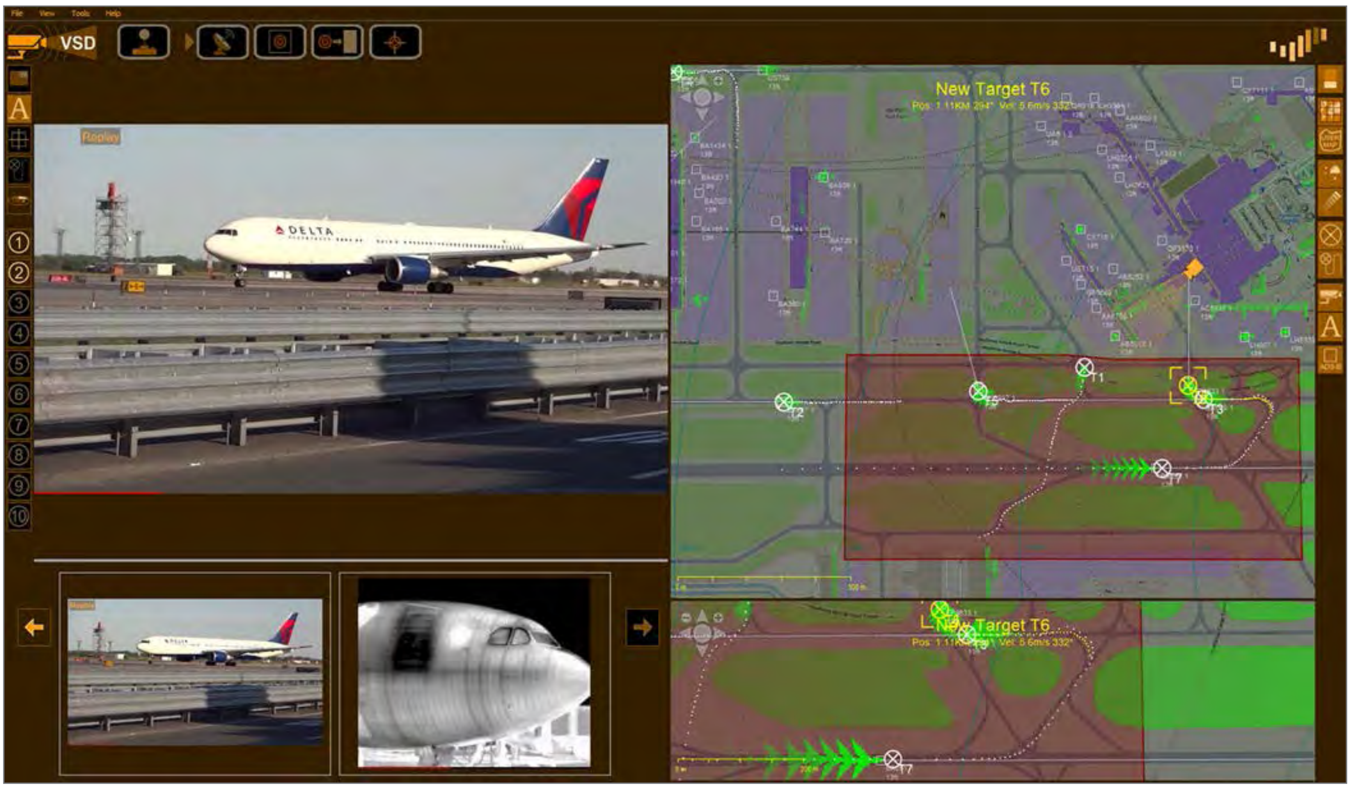

Figure 2 | The radar portion of the VSD display provides a geographic overview of the situation, showing all of the available radar videos, tracks, and secondary data, overlaid on a clear tiled map, while the camera video portion displays video from the currently selected camera, optionally with another camera video shown as picture-in-picture.

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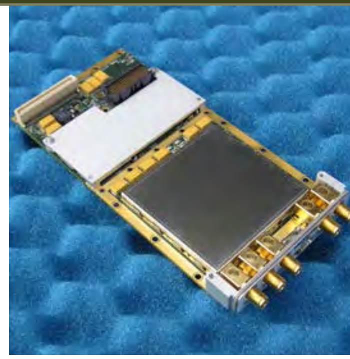

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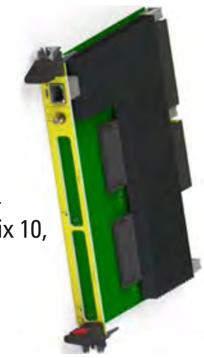

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SIGNAL PROCESSING IN RADAR, SONAR, AND ELECTRONIC WARFARE

Future enhancements to airborne AESA radar systems will leverage GaN technology. Photo courtesy of U.S. Air Force.

Solid-state technology suitable for radar applications

By Scott Behan

New radar systems have increasingly utilized active electronically scanned arrays (AESAs) for their radiating and receiving functionality. AESAs offer several desirable features compared with other radar implementations, including jam resistance, frequency agility, graceful degradation, and use for other applications such as communications, electronic self-protect (ESP), or electronic attack (EA).

Legacy systems developed prior to the AESA evolution often require a single or a few high-power transmitters feeding passive or semi-active arrays or antenna structures. These transmitters have often been vacuum electronic devices (VEDs) such as traveling wave tube amplifiers (TWTAs), klystrons, magnetrons, or crossfield amplifiers, having been the only available technologies to achieve the required high levels of RF or microwave power at a sufficiently high operating efficiency.

Recently, the confluence of high-power gallium nitride (GaN) monolithic microwave integrated circuit (MMIC) technology in concert with novel broadband, low-loss power combining methods has enabled solid-state alternatives to these high power vacuum devices. GaN MMICs can be implemented in an amplifier platform to achieve power levels from hundreds of watts to greater than 1,000 watts. Several of these high-power modules can then be combined into a transmitter configuration incorporating power supplies, command and control circuitry, and thermal management to achieve power levels in the tens of kilowatts. (Figure 1.)

The ability to replace legacy VED transmitters with solid-state replacements potentially results in incidental enhancement of some characteristics of the radar system, and, perhaps more importantly, improves the reliability and availability of the systems.

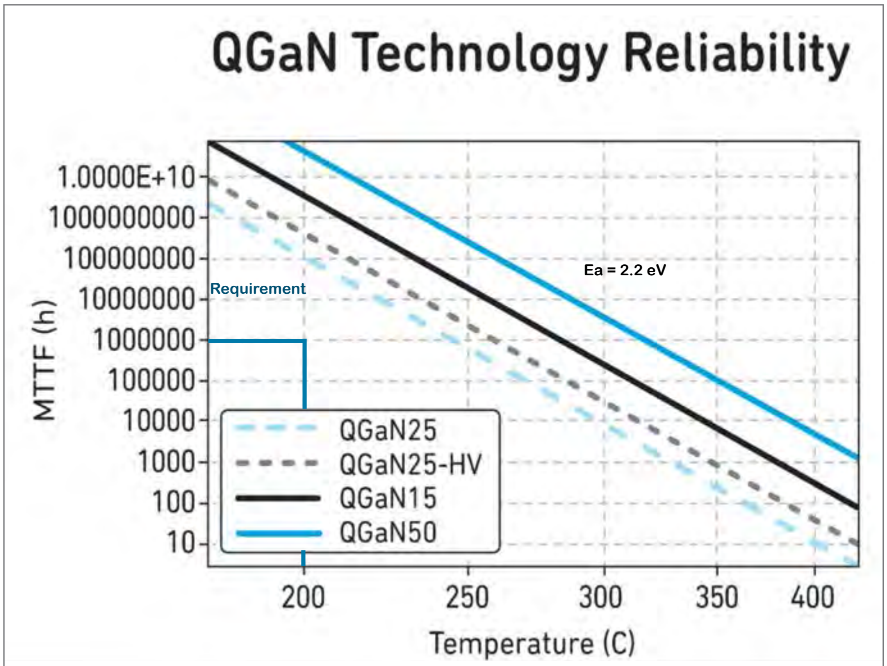
VEDs and their associated high-voltage power supplies often suffer from short lifetimes, varying from as few as several hundred hours to ten thousand hours for relatively benign environments. GaN semiconductor MMICs, on the other hand, exhibit mean-time-to-failure of greater than 10 million hours at junction temperatures of 200 °C. In addition to the relatively short lifespans, VEDs are prone to gassing up and may need to be operated periodically to maintain their functionality. Solid-state amplifiers can effectively exist indefinitely in an unpowered state, yet be ready to perform instantly.

The structure of the high-power modules, because they combine several devices to achieve their composite power output, has an inherent graceful degradation characteristic. The failure of a single device in a single amplifier of this type typically results in less than 0.7 dB loss of power, with approximately 0.7 dB additional reduction for each subsequent device removed from service. In a typical very-high-power application, with several GaN MMIC amplifiers, the transmitter performance acts very similar to an AESA in that a single device failure has a generally inconsequential

effect on overall performance and power. (Figure 2.)

The solid-state transmitter also is found to output generally less thermal noise and fewer spurious signals than a vacuum device. Broadband TWTAs are particularly notorious for their ability to output substantial power as harmonic content when operating at their full-rated capacity, in some cases putting out as much or more power at the second harmonic than is realized at the fundamental frequency of interest. Intermodulation characteristics are often equally poor. Comparatively, the typical harmonic content of the solid-state amplifier is usually more than 15 dB below the primary signal. This significantly better performance enables output filtering requirements and associated power handling requirements to be reduced, with associated cost and performance benefits.

THE ABILITY TO REPLACE LEGACY VED TRANSMITTERS WITH SOLID-STATE REPLACEMENTS POTENTIALLY RESULTS IN INCIDENTAL ENHANCEMENT OF SOME CHARACTERISTICS OF THE RADAR SYSTEM, AND, PERHAPS MORE IMPORTANTLY, IMPROVES THE RELIABILITY AND AVAILABILITY OF THE SYSTEMS.



- Parametric failure is defined as a 10% reduction in Idmax
- QGaN50 parametric failure is shown here at a 3.5% reduction in Idmax

Figure 1 | GaN lifetime vs. junction temperature.

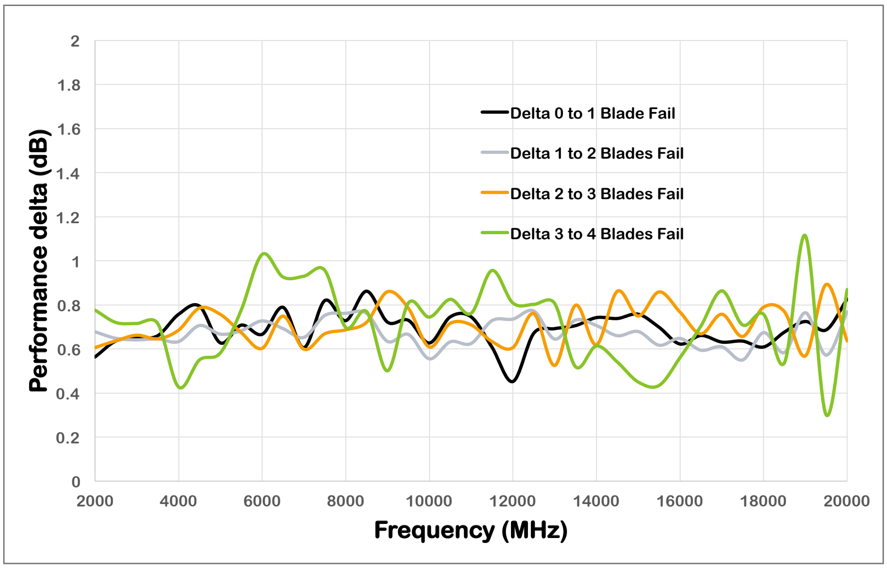


Figure 2 | Comparative degraded performance of a 16-blade amplifier.

VEDs typically operate from very-high-voltage power supplies, generally anywhere from a minimum of several hundred volts to more than 10 kilovolts. This operating range presents significant challenges to the power supply implementation as well as a potential personnel safety hazard should exposure to the supply voltages occur. Because a GaN-based device typically operates at much lower voltage, between 20 and 48 volts DC, the power supplies operating at these voltages offer significant size, weight, operating life, and cost savings.

Critics of solid-state solutions often point out apparent deficiencies of the technology with respect to its efficiency when compared with a VED, correctly asserting that in some applications, VED-based power amplifiers can achieve efficiencies close to 70 percent. Historically, solid-state high-power amplification was only able to be achieved by circuits combining very large number of gallium arsenide (GaAs)-based amplifiers. The circuit-combining methods often resulted in diminishing returns as accommodations for phase and amplitude matched paths over increased bandwidth and device numbers resulted in ever higher losses following the amplifiers. These losses directly degraded both the output power availability and effective operating efficiency of the amplifier. High-efficiency GaN devices are now capable of power levels of >100 watts from a single device, which can be combined with a low-loss combiner structure with less than 0.5 dB of loss.

While parametric performance for the application is a requirement that either technology must meet to be accepted for use, the opportunity for volume manufacturing capacity and associated cost reduction, along with significant design reuse offers yet another compelling reason to replace legacy VED transmitters. The structure of these devices is inherently broadband, and can be populated with devices that operate across all, some, or just a tiny portion of its frequency coverage. This enables leverage of the myriad of GaN MMIC devices that are commercially available.

While they are not able to replace every application where vacuum devices prevail, solid-state alternatives can be considered where practicable for increasingly high-power microwave signal amplification. **MES**

Scott Behan *is senior marketing manager with Qorvo's High Power RF Systems group. He has more than 30 years of experience in high-power amplifier design and applications, holds several patents and pending patents in high-power microwave amplifier circuits, and possesses a broad knowledge of related systems and subsystem implementation. He earned a BSEE from Worcester Polytechnic Institute and has published several articles on microwave amplifiers and associated applications. Scott Behan can be reached at scott.behan@qorvo.com.*

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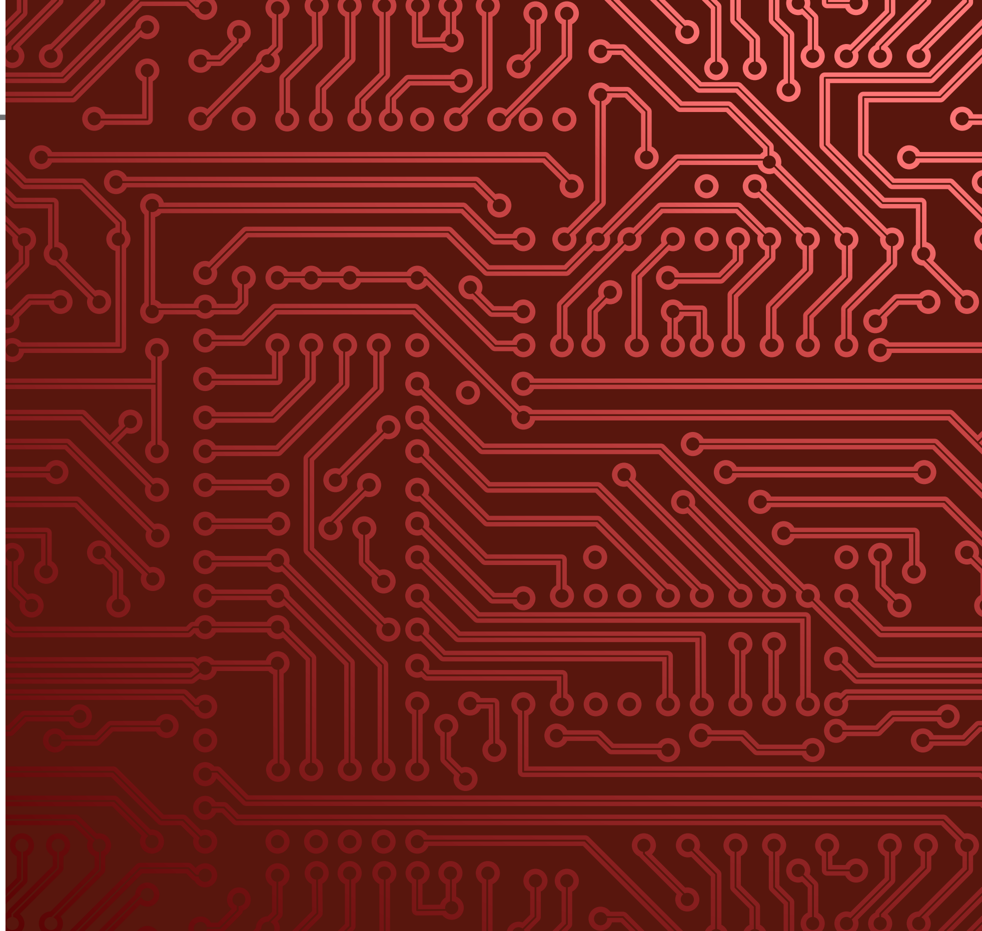


Xeon-D and 3U VPX combine for cognitive EW

By Marc Couture

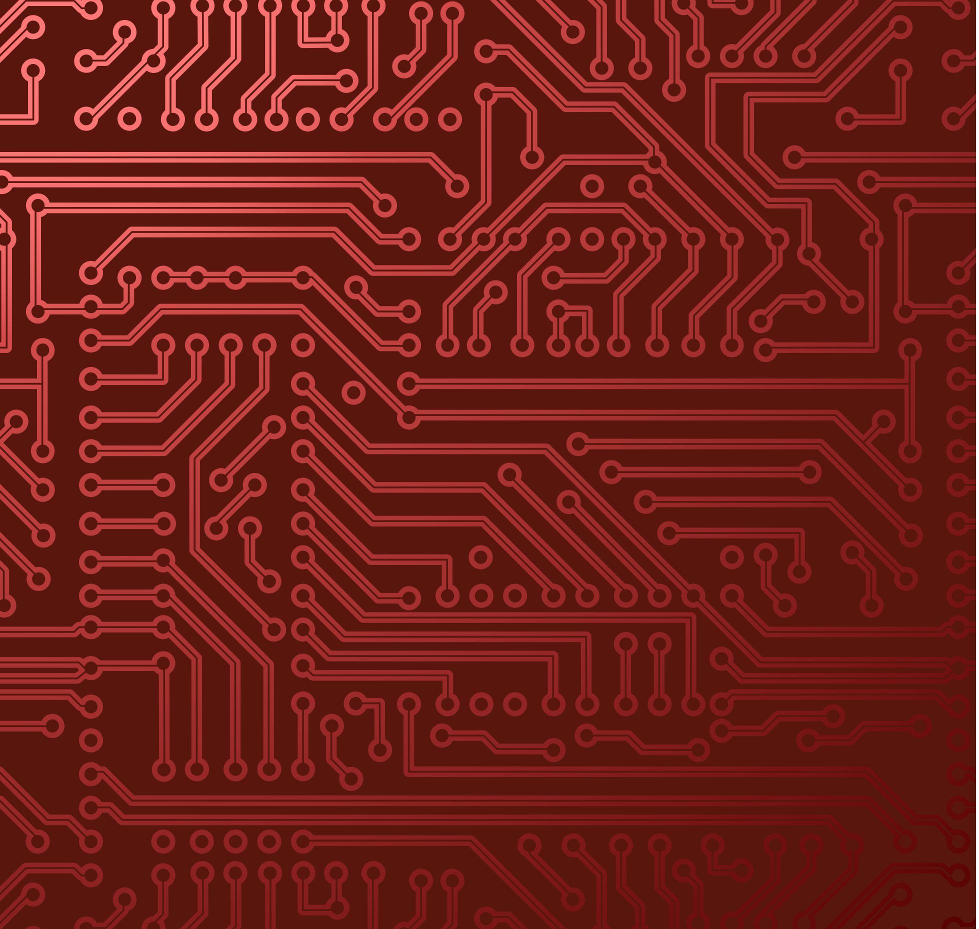
Intel's new Xeon D system-on-chip (SoC) is making large numbers of x86 processing cores readily available for embedded defense applications. With an architecture designed to support math-intensive processing and very-high-bandwidth data transfers, the Xeon D enables advanced cognitive electronic warfare (EW) applications to operate in small size, weight, and power (SWaP)-constrained platforms.

Unlike conventional radar systems, new software-defined digitally programmable radars are able to generate previously unencountered waveforms that do not match known waveforms and pulse trains already on an EW system's pulse descriptor word (PDW) list. The PDW typically contains all the collected data for a specific pulse, including time of arrival (TOA); angle; pulse width, power, and frequency (superhet); or frequency band. In order to defeat never-before-seen waveforms, system designers are developing a new generation of cognitive EW systems that are able to quickly adapt to changes in the radio frequency (RF) environment and almost instantly make decisions about how to respond to unfamiliar threats.

These cognitive EW systems are well served by the recent introduction of new multicore Intel Xeon processor D (Xeon D) devices that deliver the greater thermal range performance required by SWaP-constrained EW pod environments. Cognitive EW systems built with these new devices promise to provide an alternative to today's EW systems, which are typically implemented with field-programmable gate array (FPGA)-based system-level architectures. While FPGA-centric EW systems that implement digital radio frequency memory (DRFM) and other EW techniques in firmware via VHDL and Verilog are sufficient for intercepting and prosecuting known waveforms and pulse trains on the PDW list, they lack the dynamic flexibility needed to counter new waveforms generated on the fly by sophisticated adversaries using digitally programmable radar.

The role of FPGAs in cognitive EW

That's not to say that FPGAs don't play an important role in these new cognitive EW systems. Unlike general-purpose processors, FPGAs are very good at sophisticated highly parallelized, high-throughput DRFM techniques such as range gate pull-off. FPGAs, however, are not very good at making decisions and dynamically changing their own architecture, which is key to cognitive EW. One approach for implementing deployable embedded cognitive EW is to couple a cluster of general-purpose Intel x86 cores – such as the eight, 12, or 16 cores available on a Xeon D – with large FPGAs. In this type of heterogeneous system architecture, the FPGA provides the high-speed parallelization while the Xeon D provides the required real-time supercomputer-class analytic and metadata processing. The decision-making speed of the system's Xeon D cores and the processing performance of the FPGA work in concert to enable the system to respond to unknown waveforms by synthesizing a mix of responses to quickly create the best defense against the new threat. This response may include the partial or complete reconfiguration of the FPGA, depending on the findings of the Xeon D. The extremely low-latency decision-making capability of the



PREVIOUSLY, X86-BASED GENERAL-PURPOSE PROCESSORS HAVE SERVED IN EW SYSTEMS, BUT USUALLY ONLY TO PROVIDE SYSTEM MANAGEMENT AND TO HANDLE THE MAN-MACHINE INTERFACE. THE EXPANDED MULTICORE ARCHITECTURE OF THE XEON D ENABLES THE DEVICES TO SERVE AS ACTIVE PARTICIPANTS IN THE PROSECUTION OF RF EMITTER STACKS.

x86 cores actually enables the cognitive EW system to select the proper set or mix of signal-manipulation techniques to adapt to the threat while in-theater.

The Xeon D expansion

During the last five to ten years, while FPGAs have dominated EW system development, Intel processors were limited to a maximum of four cores. Previously, x86-based general-purpose processors have served in EW systems, but usually only to provide system management and to handle the man-machine interface. The expanded multicore architecture of the Xeon D enables the devices to serve as active participants in the prosecution of RF emitter stacks. In addition, the recent introduction of these processors in ball grid array (BGA) packages gives EW system designers access to a rugged processor that can provide four, 12, or 16 cores in the same power footprint as the earlier four-core devices. One advantage of the BGA packaging is that the device's entire bottom surface can be used for interconnection pins, which is necessary for high-bandwidth operations. Moreover, each of the Xeon D cores is supplemented by a powerful AVX2 SIMD engine to deliver enough processing power to execute complex decision-making and high-bandwidth DSP math (Figure 1).

With the large number of cores at their disposal, designers can flexibly partition and dedicate sets of cores to different EW techniques and dynamically allocate processor resources. The Xeon D, with its multiple closely-linked x86 cores and math engines, is designed to support math-intensive processing and very high bandwidth data transfers and can truly be considered a "mobile server."

Although there are other processing devices that are capable of delivering higher FLOPS performance, Xeon D delivers an average of 0.5 TFLOPS, depending on the specific chip SKU, in a manageable 35 W to 45 W package. In comparison, power requirements for larger Xeons and GPUs range from 75 W to 100 W and higher, making them extremely

Figure 1 | The Intel Xeon processor D-1500 product family features 8-/12-/16-core versions with enhanced performance at low power, suitable for use on rugged open-architecture modules designed for deployment in extremely compute-intensive EW and command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) aerospace and defense applications in harsh environments.

difficult to cool even with VITA 48 REDI techniques. Since the Xeon D is a compact SoC, commercial off-the shelf (COTS) vendors can create SWaP-optimized VPX modules that provide enough space to include a 25 W XMC mezzanine. To complete the system, wideband analog-to-digital converters (ADCs) and digital-to-analog converters (DACs), used as microwave IF receivers or even RF tuners and for the digitization of interferometry for jamming, can be integrated onto an XMC mezzanine module that fits above the Xeon D in a one-inch pitch. This setup means that the FPGA and digitizers can be placed in extremely close proximity to the multiple x86 cores on a 3U module, which can improve overall performance and significantly lower latency.

3U VPX for SWaP-optimized cognitive EW

The 3U VPX form factor provides a useful way to deploy new Xeon D/FPGA-based card sets into next-generation cognitive EW pods. What makes the device an especially good fit for SWaP-constrained applications is the fact that, unlike larger and hotter commercial Xeon devices and Core i7s processors, Xeon D eliminates the need for a separate "Southbridge" platform controller hub. Xeon D is actually a single SoC. The serial ATA (SATA)

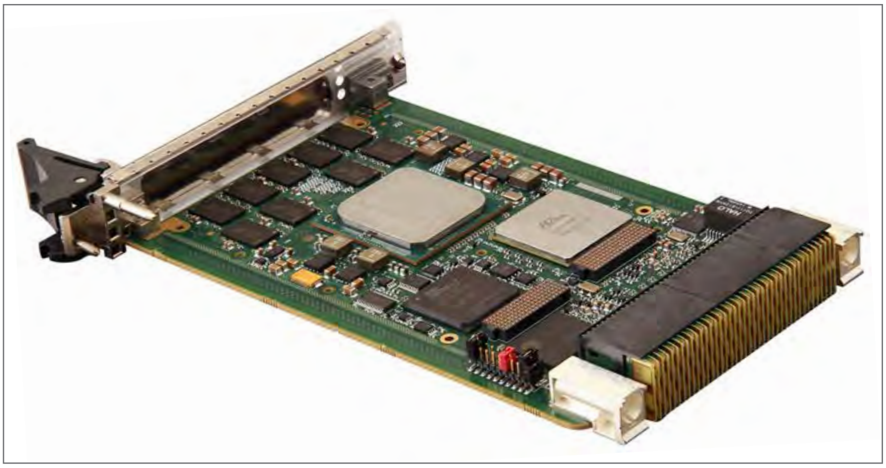


Figure 2 | Curtiss-Wright's 3U OpenVPX CHAMP-XD1 is a SWaP-optimized DSP engine module that leverages the performance specs of Intel's Xeon processor D architecture for EW applications.

interface and general-purpose I/O functionality used in laptops and servers has been subsumed into the device, making it suitable for use on small-form-factor conduction-cooled 3U modules where real estate is limited. In rugged deployed applications, larger land grid array (LGA)-packaged Xeon processors require special – even exotic – cooling techniques that may not be appropriate for many programs since they add risk and undesirable costs. In contrast, the more affordable Xeon D, with its greater operating range, is able to use standard cooling envelopes and techniques

A new 3U VPX Xeon D solution

An example of a Xeon D-based 3U VPX module is the Curtiss-Wright CHAMP-XD1 card, a DSP engine module for use in very compute-intensive High Performance Embedded Computing (HPEC) applications (Figure 2). This open-architecture module features high-speed DDR4 memory and bandwidth along the OpenVPX data, expansion, and control planes. It has XMC card expansion and the choice of one Gigabit or 10 Gigabit Ethernet (GbE) interfaces along the control plane. **MES**

***Marc Couture** is the Senior Product Manager for Intel, PowerPC, and GPGPU based digital signal processors in the ISR Solutions group at Curtiss-Wright. He has worked in the embedded COTS industry for over two decades, having specialized in High Performance Embedded Computing and RF/microwave technologies. Marc is a graduate of the University of Massachusetts Dartmouth with a Master of Science in Electrical Engineering. Readers may reach him at mcouture@curtisswright.com.*

Curtiss-Wright
www.curtisswrightds.com

RF tiptoes into the embedded world

By Lorne Graves

OPINION

"There are no rules here, we are trying to accomplish something."
– Thomas Edison

This quote from the famed inventor succinctly stated one of the two reasons why microwave subsystems – integrated microwave assemblies (IMAs) – employed in defense systems have never conformed to open standards such as OpenVPX. The second reason is that the U.S. Department of Defense (DoD) never required such conformation, until recently. Designers of board-level embedded products that adhere to specific, fixed form factors and electrical specifications might consider such a scenario chaotic, even ridiculous. To provide some perspective about why it's taken 70 years for the defense industry to tiptoe into open standards, we need to look at both the technology and the DoD.

As engineers designing defense embedded systems know, digital and microwave technology have little in common. Digital systems are designed around highly integrated semiconductor-based components such as central processing units (CPUs), field-programmable gate arrays (FPGAs), general processing units (GPUs), digital signal processors (DSPs), and systems-on-chip (SoCs). The key tasks for the designer are to – within the confines proscribed by a standard form factor – make all these devices work together, program them, deliver as much input/output as possible, and deal with the issues of thermal management and power consumption.

In contrast, while microwave design engineers face some of the aforementioned challenges, they additionally face those unique to this microwave technology as well, the latter dictated by the fundamental nature of "fields and waves." That is, as wavelength (and thus component size) decreases as frequency increases, subsystems that operate at 500 MHz, for example, are inherently larger than those operating at higher frequencies. Therefore, designing a UHF system to fit in a small, invariable form factor is a challenge that cannot easily be achieved. Digital devices do not suffer from this problem: While FPGAs may get larger with increases in performance, they do not get three times larger. Although microwave subsystems for defense applications typically operate between 1 and 26 GHz where component size is reduced, some components do not get that much smaller.

Microwave engineers also cannot draw from a set of highly integrated devices, like FPGAs, that can perform many functions in a small space. The closest this technology gets to such integration is the monolithic microwave integrated circuit (MMIC) that combines gallium arsenide, gallium nitride, or silicon germanium transistors with tiny components to produce amplification, mixing, and switching, for example. IMAs also must use discrete passive and active components on the circuit board, all of which are connected via etched transmission lines such as microstrip or coplanar waveguide, the length and other dimensions of which are critical. The higher the frequency, the more difficult it becomes to combine all of these circuit elements while maintaining precise matching to 50 ohms, very low insertion loss, and a variety of other essential performance parameters. In short, designing microwave subsystems that must always conform to some declared form factor is exceptionally difficult, and subsystems designed to transmit substantial amounts of power make integrating them into standard form factors like Open VPX even more challenging, and at higher power levels practically impossible.

That said, it's reasonable to ask how, then, do smartphones transmit and receive data from 700 MHz to 2.6 GHz over the carrier's network, Wi-Fi, and near field communications (NFC), and receive GPS and possibly FM broadcast signals – all in a package a quarter-inch thick, four inches wide, and five inches high? First, smartphones operate at extremely low power levels and take advantage of SoCs that combine virtually every baseband, DSP, control, and many other functions in a single device. Secondly, the DoD system requirements far exceed those of the commercial market in terms of ruggedness, operating temperature, and an array of other requirements not required by the consumer market. Finally, unlike defense systems, smartphones and tablets must conform to a specified form factor dictated by the end user. In other words, someone (in this case, the user) required it.

In comparison, for the entire history of the microwave industry, the DoD has challenged microwave designers with creating subsystems with performance at or in some cases beyond the state of the art – and were just happy to get something that works, even at high cost. Requiring the microwave subsystem to conform to a 3U or 6U form factor was not even on the table. In other words (as previously stated), "There are no rules here, we are attempting to accomplish something." As a result, almost every microwave subsystem is unique, designed for a specific system and platform, not the least bit modular, created by the team of designers within a specific company often using proprietary techniques, and extremely difficult to modify once designed and fabricated.

Now, after 70 years of stasis, the DoD is not simply suggesting but in fact mandating that future defense systems be designed according to Modular Open System Architecture (MOSA) principles, with specific attention being paid to "… modular designs with loose coupling and high cohesion." This mandate is also being reinforced under the latest Better Buying Power 3.0 Implementation Guidance Memorandum issued by Frank Kendall, undersecretary of defense, in April 2015. Under the DoD's mandate, the Army, Navy, and Air Force each are working to achieve this goal, not only for embedded digital systems, but also for radio frequency (RF) systems.

Mercury Systems is a pioneer in this effort, as it introduced the OpenRFM architecture initiative for RF subsystems in

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October 2014. It remains – more than a year later – the only such proposal from either the embedded systems or microwave technology domains focused on standardizing various aspects of RF and microwave subsystems. In proposing OpenRFM, Mercury's goal was not to be the sole manufacturer of such systems but rather to provide a roadmap for others as well, in order to make OpenRFM (or a modified version of it) a recognized standard that supports the DoD's MOSA principles. The path toward realization of this goal is paved with challenges but the end result will be well worth the effort. **MES**

***Lorne Graves** is a Technical Director with Mercury Systems.*

UAV autopilot simulation has 3-D option

Aimed at unmanned aerial vehicles (UAVs), MicroPilot's True Hardware in the Loop (trueHWIL²) offers integrators and researchers a UAV autopilot simulator. This form of simulation reads information from the serial port or CAN, introducing inaccuracies while on autopilot in-flight. It electronically simulates all sensor outputs using digital to analog converters, signal conditioning, and pulse-width modulation (PWM) interface boards enabling users to replicate the conditions of the UAVs' experience in-flight. The company says that 3-D visualization of flights is available using third-party products, such as X-Plane. The parameters of the simulation can be monitored from a remote PC and it includes full electrical simulation of all autopilot sensors.

TrueHWIL² has the option of using MathWork's MATLAB as a simulation and programming environment. This model is built using Simulink and MATLAB's language programming, which is then compiled and sent to the xPC target computer with installed input and output hardware. This acquisition hardware is connected to the autopilot and reads its outputs and simulates its inputs. TrueHWIL² includes all required MATLAB libraries and block sets for fixed-wing and rotary-wing airframes. It also comes with a precompiled MATLAB simulator for users who choose not to purchase MATLAB, Simulink, or Simulink Coder.

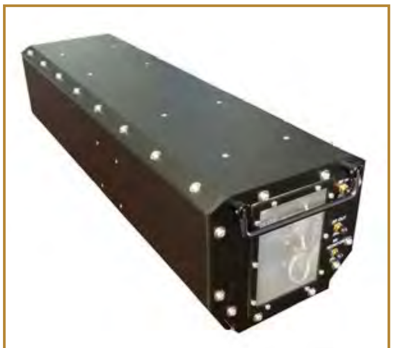
MicroPilot | www.micropilot.com | www.mil-embedded.com/p373249

Sensor fusion delivers navigation to UAV applications

KVH engineers developed the GEO-FOG 3D inertial navigation system (INS), which is based on the company's Fiber Optic Gyro (FOG)-based 1750 inertial measurement unit (IMU). The device has three KVH DSP-1750 gyros and is integrated with three low-noise microelectromechanical system (MEMS) accelerometers, three axes of magnetometers, a pressure sensor, and an option of a single- or dual-antenna global navigation satellite system (GNSS) receiver. The GEO-FOG 3D INS uses sensor fusion to deliver navigation to applications in unmanned systems on land, sea, and air. The system has performance monitoring and instability protections to ensure stable and reliable data for use in extreme environments.

Engineers designed the embedded GNSS receiver to support all the current and future satellite navigation systems, including GPS, GLONASS, GALILEO, and BeiDou. The GEO-FOG 3D north-seeking algorithm runs continuously while the INS is operating, and is not affected by velocity or angular motion. This feature means that the GEO-FOG 3D and GEO-FOG 3D Dual provide accurate heading in environments in which magnetometers and GNSS-heading cannot be used. The embedded Trimble GNSS receiver includes Receiver Autonomous Integrity Monitoring (RAIM) to assess the integrity of satellite signals. The GEO-FOG 3D INS also contains a built-in backup MEMS IMU providing inertial data collection in the event of a primary IMU failure.

KVH | www.kvh.com | www.mil-embedded.com/p373250



Seven-slot system with integrated single board computer

Engineers at 4DSP designed the VPX167 as a 3U-based VPX system with as many as seven slots that is VPX standard (VITA 46) compliant. It offers modular architecture in a small and ruggedized form factor suitable for most electronic warfare (EW) applications. A single-board computer will typically act as the control and communication hub and connect to multiple peripheral cards. Subsystems with the following components and capabilities are possible: RF up-and-down conversion, switched filter banks, analog-to-digital, digital-to-analog, FPGA, and DSP capabilities.

The VPX167 cuts down integration time with a flexible architecture that relies on commercial-off-the-shelf (COTS) modules. It can host a variety of COTS-based systems that are a combination of custom RF systems, COTS processing cards, and custom, reconfigurable firmware. Operating temperatures for the system range between -40° C to +70° C and it is MIL-STD 810-compliant for shock and vibration, and EMI compliant for MIL-STD 461C. Additional features include high-speed external digital communication using 10 Gb or 1 Gb Ethernet, high-speed interslot communication using PCIe, and a ruggedized, conduction-cooled enclosure designed to perform in harsh military environments.

4DSP | www.4dsp.com | www.mil-embedded.com/p373251

Process/record/playback ultrawideband signals

D-TA offers the System-95, which gives users direct processing, recording, and playback of ultrawideband signals. The system includes the DTA-9500 – which occupies 1U rack space – and the DTA-5000 redundant array of independent disks (RAID) server with as many as 23 TB solid-state drive (SSD) storage. A smaller 1U server is also available for single-channel recording at 1.8 gigabytes/sec. The system comes integrated and tested; no user development is required for recording and playback. The included graphical user interface (GUI) software is intended for systems control and operation.

System-95 has two options for digitizing: It digitizes either one input signal at up to a 3.6 GHz sample rate or two input signals at 1.8 GHz sample rate each. The ADC 12-bit resolution system also includes one 12-bit DAC capable of operating at a rate of up to 4 GHz. Onboard FPGAs provide different options for processing IF signals. Various DDC cores are offered for 1 GHz and 1.2 GHz intermediate frequency (IF) signals, with BWs up to 500 MHz and 160 MHz IF signal with bandwidth up to 100 MHz. The output is complex baseband data. The DTA-5000 RAID server is a dual six-core RAID server with record/playback software engine capable of recording and playing back at up 4 gigabytes/sec.

D-TA | www.d-ta.com | www.mil-embedded.com/p373252

EMI/RFI filters target midrange power inverters

Manufacturers of electromagnetic interference (EMI) and radio frequency interference (RFI) power line filters, Astrodyne TDI, offer the RP328 family series with screw-type, touch-proof terminals. This single stage, three-phase power-line filter targets low to midrange power inverters as well as other chassis-mounted applications that require high insertion loss performance in a compact mechanical form factor. Astrodyne TDI's RP328 filters have a current rating up to 180A and are rated at 480 VAC at 50/60/400 Hz. The RP328 filter series offers a range of line-to-ground (Y) capacitance values, resulting in thousands of possible configurations.

The RP328 series can be used with three-phase variable frequency drives (VFD) and inverter-based systems that require a small mounting footprint. It is also available with threaded stud-type terminals. Other options, such as wire leads, are available upon request. The filters' ambient temperature ranges from -25 to +50 °C, with a climatic category of 25/100/21. The filters have also passed through UR, CSA, EN60939 safety approvals.

Astrodyne | www.astrodynetdi.com | www.mil-embedded.com/p373253

PC/104 OneBank carrier for SoC modules

Sundance's EMC²-DP is a PCIe/104 OneBank Carrier for a Trenz-compatible system-on-chip (SoC) module and has expansion room for a VITA57.1 FMC LPC I/O board. It also has I/O pins, using a 100-way Samtec RazorBeam connector system. The add-on board, called Sundance External Interface Connector (SEIC), contains LEDs, RS232, USB2.0, HDMI, 1 Gb Ethernet, and SATA. The SEIC is customizable for individual applications and bespoke connectors.

The PCIe/104 OneBank design enables the EMC²-DP to be added to rugged installations for various commercial, medical, industrial, and military uses. The main component of the EMC2-DP is the system-on-module (SoM)-based module, with additional versions including the Zynq SoC, configuration device, Ethernet PHY, and all necessary power-supply components. Another feature is the use of an expansion board to the PCIe/104 form factor. This expansion board and SEIC module contains most of the I/O connectors and – in some cases – interface circuitry as well. The SEIC module is connected to the main board using a 100-pin Samtec high-density connector similar to that used for the SoM module.

Sundance | www.sundance.com | www.mil-embedded.com/p373254

Electronic warfare school

By John McHale, Editorial Director

Wouldn't it have been fun in college if you could have dropped your basic philosophy or English course for a beginning track on electronic warfare (EW), studying basic concepts such as electronic attack, jamming equations, laser radars, and anti-radiation missiles? Now you can get those basics in a four-day course offered by the Maple Leaf Chapter of the Association of Old Crows (AOC), Carleton University in Ottawa, Ontario, and the AOC headquarters in Washington – and you don't even have to be an engineer.

The first course, "Fundamental Principles of Electronic Warfare Course," took place recently, January 18-21. According to a PDF on the curriculum, it provided "insight into the whole electronic warfare field at the systems and operational level." Materials provided to the students said that the course was able to "avoid deep mathematical coverage, explaining all concepts in practical physical terms."

Very little math = good news for journalists and politicians who want to give EW a try.

The course focused on the fundamental principles of electronic warfare and was not an advanced-level EW course, but rather an introductory one, says Tuhin Das, president of the Maple Leaf AOC, business operations manager for D-TA Systems in Ottawa, and spokesperson for the course.

"Attendees ranged from current Canadian military personnel as well as industry engineers and technicians – both with current EW expertise and those new to the field," he says. "It is also attractive to nonengineers, such as business development managers like myself, who want to understand more about the technology and market from which they earn their living."

The instructor for the first course was Dave Adamy, who has more than 40 years of experience as a systems engineer and program technical director. He holds a MSEE in Communications Theory and has published ten books.

The AOC – Maple Leaf Chapter, in partnership with Carleton University's Department of Electronics and its Faculty of Engineering and Design, developed the pilot program under which the course is offered. The goal of this program is to reach out to Canadian EW talent and offer them a suite of Canadian-based EW courses at a much lower cost with the added university certification. Carleton University offered a "Certificate of Attendance" to those who attended the January course, which was signed by the Dean of Carleton's Faculty of Engineering and Design.

The course is an evolution of the work begun by Das at his company, D-TA, along with its chairman and founder, Dipak Roy, aimed at inspiring young Canadian engineers to pursue careers in EW through the Maple Leaf AOC chapter and Carleton.

Roy started the Dipak and Tara Roy Advanced Sensor Processing Laboratory several years ago at Carleton, intended to help build Canadian EW defense capabilities, Das says. "Now we are taking that one step further in the relationship with the Maple Leaf AOC chapter to provide members with courses run by instructors such as Adamy and providing them with access to the sensor-processing lab. We are encouraging Canadian companies and military personnel to come into the lab and bring their equipment to experiment and test and help train operators." For more on the formation of the Maple Leaf AOC chapter, visit http://mil-embedded.com/guest-blogs/inspiring-electronic-warfare-careers-in-canada/.

The first course was completely full. "It was cold outside and still it sold out," Das says. "This bodes well for future courses, as it shows the demand for education on this topic is strong. We are fairly confident there will be at least one more course in 2016, possibly as early as April."

Roy, Das, and their fellow AOC members are exploring other topics for future courses. Additional subjects under consideration for coverage include advanced EW, essentials of 21st-century EW, and EW components, as well as potential courses focused on the business aspects of EW, he says. "We are looking into distance learning as well."

"Based on the success of the first course we are discussing with Carleton the formation of a certification program that will include a combination of all these courses," Das says. "It can really help build Canadian EW capability."

This was the first time any course like this was held in Canada; Canada's defense personnel saved thousands of dollars in travel costs by having the course hosted in-country, he adds.

While the course has not yet been offered to the U.S. market, there are financial advantages to hosting the course in Canada, since the U.S. dollar is currently equal to about $1.42 Canadian, Das says. If a U.S. resident were to take this course, they would save about 40 percent right off the bat, he adds.

A course like this would be attractive to U.S. industry engineers as well as military personnel, but – based on current U.S. export regulations – it likely would have to be held in the U.S. Regardless, the concept is timely as the defense industry looks to compete for talent with better-paying commercial-technology engineering jobs. Any amount of education and positive marketing will help. For information on future courses, contact sales@CanadianCrows.org.

ADVERTISER INFORMATION

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3	**Annapolis Micro Systems, Inc.** – WILDSTAR OpenVPX Ecosystem
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CONNECTING WITH MIL EMBEDDED

By Mil-Embedded.com Editorial Staff

CHARITY

Operation Delta Dog

Each month in this section the editorial staff of *Military Embedded Systems* will highlight a different charity that benefits military veterans and their families. We are honored to cover the technology that protects those who protect us every day. To back that up, our parent company – OpenSystems Media – will make a donation to every charity we showcase on this page.

This month we are featuring Operation Delta Dog, a mostly volunteer organization founded in 2013 in Massachusetts, that rescues homeless dogs and trains them to work as service dogs for veterans who are suffering from traumatic brain injury (TBI), post-traumatic stress disorder (PTSD), and related challenges. Veterans are able to receive a service dog through Operation Delta Dog at no cost.

The founders of the 501(c)3 organization saw the epidemic rise of veterans who served their country and then came home suffering from TBI and PTSD; at the same time, they saw shelters overflowing with animals looking for a home. They decided to tackle both of these problems at the same time: helping veterans through their time of need and finding a home for abandoned animals.

Service animals have been found to help treat depression, reduce stress, and manage the panic attacks associated with PTSD and TBI. Trainers find canine candidates from shelters and breed-rescue groups and train them – using positive-reinforcement methods – for a new life filled with purpose and affection. The veterans can participate in training without leaving their jobs or families and find relief with their canine companions from their symptoms and challenges.

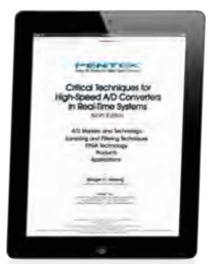
According to the organization, it takes roughly $10,000 to train each veteran and dog team. All training sessions take place in donated venues to keep costs down.

For more information, visit http://www.operationdeltadog.org.

WHITE PAPER

Critical techniques for high-speed A/D converters in real-time systems

By Rodger Hosking, Pentek



The two primary characteristics of analog-to-digital converters (ADCs) are the rate of conversion or sampling rate, expressed in samples per second; and the accuracy of each digital sample expressed as the number of binary bits or decimal digits per sample. Sampling rates vary tremendously between applications: A digital medical thermometer may deliver samples to update the readout once every five seconds, while a high-speed wideband radar may produce two billion samples per second.

This white paper will focus primarily on ADCs with sampling rates higher than 100 MHz. It will review sampling techniques, examine field-programmable gate array (FPGA) technology, and present the latest high-speed products and applications based on them.

Read the white paper: http://mil-embedded.com/white-papers/white-ad-converters-real-time-systems/

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