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EXECUTIVE BRIEFING

The signal processing challenges in radar and software-defined radio

Digital signal processing (DSP) for digital communications and software-defined radio, as well as for advanced radar systems, can be a difficult task. Getting it right can involve not only the technical expertise necessary to understand the complexities of communications and radar processing, but also the experience of partnering with the companies with the domain knowledge for specific software-defined radio and radar applications. As different as software-defined radio and radar might sound, they also have similarities. Understanding floating-point processing, fast A/D conversion, and how to architect out the system bottlenecks are key ingredients to success.

Programmable radar and adaptive electronic warfare take center stage

The new breed of radar and EW can sense the RF environment and adapt itself in nanoseconds for the best possible performance, which is placing new demands on digital signal processing and digital conversion technology.

by **JOHN KELLER**

TODAY'S ELECTRONIC BATTLEFIELD is more complex and deadly than ever-particularly when it comes to electronic surveillance and electronic warfare. Modern radar systems have the ability to reach out and touch the environments in which they operate, detect and characterize sources of electronic noise such as RF jamming or co-location antenna interference, and adapt the radar's performance to compensate.

This kind of technology is called digitally programmable or adaptive radar. The idea is for modern radar digital signal processing (DSP) to sense and compensate for jamming and interference quickly, adapt its transmit/receive modes, and continue with the radar system's primary mission-be it military air traffic control, detecting and characterizing potential targets, or keeping a close watch for approaching threats.

The emerging ability for radar and EW systems to adapt rapidly to their environments is creating an electronic cat-and-mouse game that plays out at ever-increasing speed, as radar systems seek to adapt more quickly than the EW systems that oppose them, and likewise as EW systems seek to jam ever more quickly adaptable radar.

"It's so time-critical to follow signals that are continually adapting," points out Denis Smetana, product marketing manager for field-programmable gate array (FPGA) products at high-performance embedded computing (HPEC) specialist Curtiss-Wright Controls Defense Solutions in Ashburn Va.

Digitally programmable radar

RF and microwave technology that uses agile waveforms for security and anti-jam capability isn't new. The U.S. Single-Channel Ground and Airborne Radio System (SINCGARS), for example, has been using this approach since the 1980s to foil jamming and attempts to eavesdrop on important military voice conversations and data transmissions.

The way it works is the system's transmitter and receiver rapidly hop among a predetermined set of frequencies in a set sequence. The idea is that such a fast-moving target is extremely difficult to jam or intercept. Only those with a key to the frequency dance can participate on that radio network.

Now extend that concept to radar. A frequency-agile radar signal dancing among many different frequencies not only is difficult to detect, but it also is difficult to jam or spoof. An adversary trying to jam it often is faced with jamming a wide swath of the RF spectrum. Not only does this take a lot of power, but it also has the potential to deny the adversary parts of the RF spectrum he's trying to use himself. Sometimes broadband jamming simply isn't worth it.

Now take the notion of a frequency-agile radar one step further to digitally programmable adaptive radar. This type of system takes a more active approach to foiling attempts to spoof or jam it, by using a type of built-in electronic intelligence (ELINT) subsystem. This adaptive radar listens for RF emissions in its vicinity with potential to disrupt it, and automatically adjusts its operations to compensate-whether that involves finding unaffected frequencies or using other methods to defeat jamming and other kinds of RF noise.

This ability to reach out and touch its environment and to move quickly to compensate is not limited only to radar. Tomorrow's military radio communications also may have similar capabilities in future systems known as cognitive radio.

"Cognitive radio is a catchall for many things, like bandwidth exploitation," explains Rodger Hosking, vice president of embedded computing provider Pentek Inc. in Upper Saddle River, N.J. "This is where a system could find the frequencies that are not being used, or are not being jammed on the sending and receiving end, to send a clear signal. A minute later, it might do the same thing to evade the jamming and maintain a reliable radio link."

Modern radar systems can sense their operating environments and adapt quickly to electronic jamming and other kinds of RF interference.

This cognitive quality in adaptive radar works on the same principle. "If you are talking about radar, you have a similar kind of adaptive capability," Hosking says. Compounding the problem is the growing complexity of radar and radar signal processing. Today's radar technology is being asked not only to detect targets, but also to characterize them as large or small, friendly or hostile, and sometimes even provide radar images of the target.

"We need radar with the sensitivity to detect targets with much smaller radar cross sections than we had in the Cold War, and radars at sea must work in high sea states," says Paul Monticciolo, chief technology officer of digital signal processing expert Mercury Systems in Chelmsford, Mass. Such complexity poses the need for extremely advanced digital technologies on the radar as well as the EW side.

Adaptive EW

Put yourself in the shoes of an electronic warfare expert trying to defeat digitally programmable radar. He would need some kind of ability to sense how the radar is adapting, use algorithms that anticipate how the radar is behaving, and then transmit jamming signals fast enough to keep up with the radar's movements.

It's a cat-and-mouse game that radar and EW technicians have been playing since radar and EW were invented, yet the rules of the game today are moving more quickly than ever.

"If you are a countermeasure and try to defeat a radar pulse, you could look to see what frequency the enemy radar is using and tune the power of a jamming signal to defeat that frequency," says Pentek's Hosking.

In the future, the complexities of these technologies will continue to increase. "The integrated closed-loop system is where things may be going in the future," says Mercury's Monticciolo. "That is, taking some action based on that signal, and then send out a waveform to defeat the enemy that is trying to do something to me."

The key enabling technologies for the most advanced adaptable radar and EW systems today include extremely fast analog-to-digital (A/D) converters and digital-to-analog (D/A) converters, digital processors, and high-speed digital interconnects.

Enabling technologies

Among the most crucial technologies are A/D and D/A converters. These are the devices that sit between the transceiver antennas and digital signal processing. Nanoseconds count when it comes to A/D and D/A converters, because no matter how fast the processors are, they can't perform at top levels if they don't get input and output from digital conversion in a timely manner.

One of the fastest available D/A converters, introduced in March, is the TDAC-25 from Tektronix Component Solutions in Beaverton, Ore. The 10-bit D/A converter is packaged as an application-specific integrated circuit (ASIC) and offers performance of 25 gigasamples per second.

Tektronix, a well-known manufacturer of RF test and measurement equipment like spectrum analyzers and oscilloscopes, capitalized on its experience in high-speed test equipment to craft the new device. Company officials say the TDAC-25 aims at next-generation embedded systems in such areas as defense, commercial aerospace, medical, and coherent optical communications. This device is at the heart of the Tektronix AWG70000 arbitrary waveform generator.

A Navy petty officer works on the Electronic Warfare module aboard a deployed aircraft carrier.

The TDAC-25 has dynamic ranges to -80 dBc narrowband and -60 dBc wideband, and in RF- based applications it supports direct-generation of wideband signals, reducing complexity through the elimination of D/A converter arrays and frequency conversion blocks.

The TDAC-25 already has been designed into two next-generation systems under development, including the CHAMP-WB-DRFM 6U Virtex-7 VPX module from Curtiss-Wright Controls Defense Solutions. Of particular interest in defense applications is the device's low-latency where it can deliver the fast response needed for electronic warfare systems, Tektronix officials say.

The Curtiss-Wright CHAMP-WB-DRFM leverages Tektronix digital converter technology developed for the test and measurement world, Curtiss-Wright officials say. The board set incorporates this leading-edge technology in an open standards format that is much easier to integrate into deployable systems.

The board provides two to three times the level of performance for applications that require wideband capability and low latency in defense and aerospace such as DRFM, EW, signal intelligence (SIGINT), and electronic counter measures (ECM), and in commercial applications such as direct RF digitization, ground-penetrating radar (GPR), and coherent optical applications.

"Now, in terms of latency, in sampling a signal you no longer have to pass data from an FPGA to another to get out," says Curtiss-Wright's Smetana. "It allows us to cut tens of nanoseconds for each pass." For adaptive radar and EW, the value

Design and development tools for adaptive radar and EW systems

Designers of modern adaptive radar and electronic warfare systems are learning some of the best ways to blend field-programmable gate arrays (FPGAs), general-purpose graphics processing units (GPGPUs), and general-purpose processors, but much of the most difficult design work involves algorithms.

That's where design and development tools libraries like those from The MathWorks in Natick, Mass., can come into play.

"Algorithms and logic do the tuning and updating of the digital signal processing," says Jon Friedman, aerospace and defense marketing manager at The MathWorks. "Any intelligent system is only as intelligent as what you train it on, so it's critical to have the environment to do that."

One product from The MathWorks is the Phased Array System toolbox, with monostatic and multistatic radar capabilities, including point targets, free-space propagation, clutter models, and barrage jamming.

"Radar is in the RF spectrum, and once you have your algorithms, you need a good model of the RF elements," Friedman says. The company also provides the SimRF simulation product that enables designers to model active and possible RF components like amplifiers, mixers, and transformers. "It gives you the building blocks so you can model the RF components of a system," he says.

of next-generation digital converters like the TDAC-25 cannot be overstated. "These chips are the special sauce," says Eran Strod, systems srchitect at Curtiss-Wright.

FPGA processing

In terms of digital signal processing for adaptive radar and EW, the field-programmable gate array (FPGA) is king, designers say. The reason is the FPGA's ability to process quickly changing information, but also its ability to be to be reprogrammed on the fly to adapt to changing operating conditions.

"The FPGA concept of partial reconfiguration now can change an algorithm while the FPGA is running," Smetana says. "We need to figure out what do I reconfigure, and when do I reconfigure it."

The fast and predictable performance of FPGAs-as opposed to general-purpose graphics processing units

DARPA electronic warfare project to counter programmable adaptive radar

Six U.S. research organizations have been chosen to participate in a military electronic warfare (EW) project to find ways to detect and counter digitally programmable radar systems that have unknown behaviors and agile waveform characteristics.

The BAE Systems Electronic Systems segment in Merrimack, N.H., and Systems and Technology Research (STR) in Woburn, Mass., are the latest to join the Adaptive Radar Countermeasures (ARC) program of the U.S. Defense Advanced Research Projects Agency (DARPA) in Arlington, Va.

Last month, BAE Systems won a $36.7 million DARPA contract and STR won a $7.1 million contract to participate in the ARC program. Also last month, DARPA ARC contracts went to Science Applications International Corp. (SAIC) in McLean, Va., worth $31.5 million, and to Vadum Inc. in Raleigh, N.C., worth $4.1 million.

In February, Helios Remote Sensing Systems Inc. in Rome, N.Y., won a $2.9 million DARPA ARC contract, and the Michigan Tech Research Institute (MTRI) in Ann Arbor, Mich., won an $8 million DARPA ARC contract.

The DARPA ARC program seeks to develop EW capability to counter hostile adaptive radar systems based on their over-the-air signals. The program aims to counter enemy radar that senses its environment and automatically adapts to attempts to jam it.

Today's airborne EW systems are proficient at identifying analog radar systems that operate on fixed frequencies. Once they identify a hostile radar system, EW aircraft can apply a preprogrammed countermeasure technique.

The job of identifying modern digitally programmable radar variants using agile waveforms is becoming more difficult. The six ARC contractors will work to enable systems to generate effective countermeasures automatically against new, unknown, or ambiguous radar signals in near real time.

Radar and EW experts at the six companies will develop new processing techniques and algorithms that characterize enemy radar systems, jam them electronically, and assess the effectiveness of the applied countermeasures.

The goal of the DARPA ARC program is to develop ways to counter adaptive radar threats quickly based on over-the-air observable signals.

Cryptologic technicians monitor electronic emissions in the electronic warfare module aboard the Nimitz-class aircraft carrier USS Ronald Reagan.

Cryptologic technicians monitor electronic emissions in the electronic warfare module aboard the Nimitz-class aircraft carrier USS Ronald Reagan.

Threats of particular interest include ground-to-air and air-to-air phased array radars capable of performing several different functions, such as surveillance, cued target acquisition, tracking, non-cooperative target identification, and missile tracking. These kinds of radar systems are agile in beam steering, waveform, coding, and pulse repetition interval.

Key challenges to the ARC contractors are how to isolate signals clearly amid hostile, friendly, and neutral signals; figuring out the threat the signal poses; and jamming the signal.

Today's airborne electronic warfare (EW) systems match enemy radar signals and determine appropriate countermeasures based a list of known threats, but are limited when enemy signals are ambiguous or not on the list.

Modern enemy radar systems, however, are becoming digitally programmable with unknown behaviors and agile waveform, so identifying and jamming them is becoming increasingly difficult.

Things will get worse in the future as radars develop the ability to sense their environment and adapt their transmission characteristics and pulse processing algorithms to defeat attempts to jam them.

The objective of the six companies involved in the ARC program is to enable EW systems to generate effective countermeasures automatically against new, unknown, or ambiguous radar signals as they are encountered.

The organizations will try to develop new processing techniques and algorithms to counter adaptive radar threats through real-time analysis of the threat's over-the-air observable properties and behaviors.

The program will develop a closed-loop system with signal analysis and characterization, countermeasure synthesis, and countermeasure effectiveness assessment. The system not only will be able to learn automatically to counter new radar threats, but also will enable human operators to command and receive feedback from the system.

DARPA officials say that software algorithms the ARC contractors develop under the ARC program most likely will be used in existing or planned EW systems.

The ARC program should be able to isolate agile unknown radar threats in dense, complex electromagnetic environments with friendly, hostile and neutral RF emitters; counter these new radar threats; provide real-time feedback on countermeasure effectiveness; counter several threats at once; support single-platform or distributed, multi-platform operations; support autonomous and human-in-the-loop operation; and use a standards-based, modular, open and extensible software architecture. The system also should be able to store and download new knowledge and countermeasures for post-mission analysis.

The ARC program is a five-year effort. The first 30 months focuses on algorithm development and component level testing; the second 18 months focuses on systems development; and the remaining two years is for building a real-time ARC prototype.

(GPGPUs) or general-purpose processors like the Intel Core i7-is what makes them so attractive to today's radar and EW systems designers.

"FPGAs are the only type of programmable computing device with very low latency and predictable response," says Dan Veenstra, product manager of sensor processing platforms at GE Intelligent Platforms on Ottawa.

Veenstra describes a kind of radar spoofing EW that quickly samples a radar system's characteristics such that the EW system can manipulate return signals to make targets look like some things they're not. "You can actively transmit a reflection of your own design, so instead of one aircraft, you can look like a squadron of aircraft," he says.

The enabling technology challenges of such a capability are major challenges. "We need to have enough dynamic range on the A/D converters, and need to read memory in and out at a very high rate," Veenstra says. "You read in the receive signature, and you need to read out of that memory many repeated versions with the desired characteristics. You need the FPGAs to do the echo modification; the aircraft creates its own radar echo, but you want artificial echoes. You need to get that reflection out of memory and over the air as quickly as possible to make it look realistic. That is the high level of what our customers are trying to implement."

Systems designers also are looking at new generations of smart FPGAs with embedded microprocessors not only to increase performance, but also to shrink electronic components in the interests of saving size, weight, and power (SWAP), Veenstra says.

"The main advances, other than shrinking the die and getting power down, is the addition of embedded processors," Veenstra says. "ARM is the most popular in the FPGAs to make the devices more autonomous. It gives you two functions in slot because you don't need the separate CPU to make the decision of what and when to run in the operating system."

One of the most promising embedded processing technologies from GE Intelligent Platforms for adaptive radar and EW is the SPR870A 3U VPX wideband digital receiver/exciter module, which packs a lot of capability into a small package for applications such as unmanned aerial vehicles (UAVs), Veenstra says.

Pentek engineers are designing company signal processing boards and subsystems to be as flexible and applicable to as wide a range of end products as possible, Hosking says. "Of all our products that use FPGAs and that use digital upconverters, A/Ds, and D/As, the person who is using these boards can program the frequencies with 32 bits of resolution so they are tunable across the range of frequencies they can receive."

"We provide products that work in radar, data acquisition, telemetry, and medical imaging that need different frequencies and different bandwidths," Hosking says. "Our products are highly configurable across the control interface."

Hosking also sings the praises of FPGAs for their configurability in radar and EW applications. "We use a technology called Gate Express that allows the system to reconfigure the FPGA at runtime without rebooting," he says. "A user may need to adapt to a different application; one kind of radar might need one kind of FPGA, and a different radar another."

Despite the obvious advantages of FPGAs in modern radar and EW applications, some processors could benefit from blending FPGAs, GPGPUs, and general-purpose processors, points out Mercury's Monticciolo.

"A designer may use FPGAs as the interface between the A/D converter in the radar, and use that to do some smart beamforming," Hosking says. "He may use GPUs to do some radar signal processing like pulse compression and Doppler filtering. Then he might use Intel processors to track the signal and determine the appropriate waveforms to counter it."

JOHN KELLER is Editor-in-Chief of Military & Aerospace Electronics.

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SDR and cognitive radio: the new horizons of military communications

Software-defined radio is opening up a whole new way for warfighters to send and receive voice, data, and imagery in Internet-like fashion, and is pointing the way to a new generation of combat radios that could be considered tactical cell phones.

by **JOHN KELLER**

PREVIOUS GENERATIONS OF soldiers who struggled with interference-laden combat radios, which offered no guarantees of getting important messages through, might be amazed at what modern military radios offer to the warfighter.

Military radio communications has progressed light years beyond those crackly sounding, two-handed walkie-talkies that we see in old movies. Military wireless communications on the battlefield today increasingly consists of software-defined radio (SDR), which not only can adapt to a wide variety of communications protocols to enhance

General Dynamics AN/PRC-154 Rifleman Radios enable soldiers on the battlefield to have secure, mobile voice, video, and data communications capabilities that are similar to those available through commercial cellular networks. (Photo courtesy JPEO JTRS.)

interoperability among different military services and allied forces, as well as among military and civil authorities, but also could be the basis of a future wireless tactical Internet for the battlefield designed to connect computers and provide cell phone-like connectivity.

The latest military radio communications go far beyond simple voice and data. Modern combat radios are starting to offer a variety of functions that take place in the background without the user's intervention or knowledge. Military radios today can act as communications repeaters and network-control devices to facilitate voice and data networking on the move. In the future, each radio on the battlefield might act as a secure, wireless node to provide Internet connectivity to rugged handheld devices, such as smartphones, electronic tablets, and laptop computers.

Tomorrow's combat radios will offer even a broader variety of functions that are transparent to the user. While today's radios also are repeaters and network-control devices, tomorrow's radios will be able to offer chemical, biological, and nuclear agent detection and mapping, situational awareness of where friendlies and enemies are located, data on the availability of artillery fire support, and the ability to call in air strikes faster than ever before.

Anticipated future developments in combat radios also are expected to augment software-defined radio technology with an approach experts call cognitive radio. This will offer the ability for radios to sample the surrounding environment, determine where interference and electronic warfare jamming are blocking certain frequencies, and automatically choose the best frequencies on which to communicate and set up an ad-hoc network on the fly to make best use of those clear frequencies.

What is software-defined radio?

Lots of definitions of software-defined radio exist. The consensus industry definition, according to the Wireless Innovation Forum in Phoenix, is a radio in which some or all of the physical layer functions are software-defined. If that sounds a little fuzzy, essentially SDR technology involves blending computers and radios. While legacy military radios have been designed in hardware with specific and limited functionality, SDR implements radio functionality in software, similarly to how a PC carries out word processing, Web browsing, database management, games, and other functions as computer programs that run on top of software operating systems, such as Windows and Linux.

Continuing the PC analogy, the software programs in SDR technology that determine functionality—such as frequency range, security, frequency-hop scheme, and other factors necessary to be interoperable with other radios—are called waveforms. The SDR operating system, meanwhile, which is standard for U.S. military software-defined radio systems, is called the open-systems Software Communications Architecture (SCA). SCA relies on CORBA and POSIX operating systems to coordinate different SDR waveform software modules.

"The waveform is protocol by which information will be transmitted from one place to the other, and at the other end, the information will be extracted," says Lewis Johnston, vice president of advanced programs at Thales Communications Inc. in Clarksburg, Md. "It's where the features and functions of the radio are software-reprogrammable, extending down to the radio's modulation and demodulation. Encryption is part of the waveform, so there is a whole series of steps in processing from where you speak or put data into the radio, and how it comes out the other side."

For the U.S. military, and increasingly for allied militaries throughout the world, the program driving software-defined radio development and deployment is the Joint Tactical Radio System, or JTRS. Even though some radio manufacturers may not be formally part of the JTRS program, those companies can participate in U.S. military SDR procurements, as long as their offerings comply with JTRS policies, software, and design approaches, and have testing and approval from JTRS officials.

"The key innovation in software-defined radio is that, just as you load Microsoft Word on your computer, you can load SINCGARS on your radio," explains Eric Whitehill, chief engineer at the ITT Corp. Communications and Force Protection Systems segment in Fort Wayne, Ind. ITT is among the builders of the Single-Channel Ground and Airborne Radio System (SINCGARS), a legacy military radio that ITT engineers are upgrading for SDR capability.

"The next day you decide you might need different radio properties, but would like to have some data capability," White goes on. "You could use another waveform, such as the soldier radio waveform that combines voice and data, reliability, and a nice data pipe for voice, images, video, and data. Software-defined radio is the ability to load waveforms and repurpose a hardware device to do many different functions."

Benefits of SDR

So what does software programmability bring to the table for military radio communications? The list of SDR benefits is long, but some of the most important are interoperability with new and legacy radio systems; ability to squeeze a staggering amount of radio capability in a very small package; and the ability to implement networking tasks on each radio that run transparently to the user.

Software-defined radio technology in the future could help enable embedded radios in other soldier-worn systems for future capabilities in situational awareness, chemical agent detection, and even electronic warfare.

"SDR lets a user program the radio for multiple frequency ranges," explains Bob Haag, vice president and general manager of communications products at Rockwell Collins in Cedar Rapids Iowa. "I can do all that in one radio now, whereas in the past, I would have needed multiple radios. SDR lets soldiers, vehicles, and aircraft come together and do their jobs better on the battlefield, such that we can move data so we know where our allies are and can get situational awareness of the battlefield."

Situational awareness often is touted as one of the most promising aspects of SDR, and what enables this capability is the ability of SDR to form wireless data networks on the fly. Say, for example, that each infantryman has a software-defined radio with an embedded global positioning system (GPS) sensor. That collection of radios has the capability to place the locations of each soldier on the network, and broadcast a picture to everyone in the area of where everyone is.

Perhaps a soldier's vital signs are measured and transmitted onto the network. In that way, commanders could get a quick picture of who in their units is dead, wounded, in some other kind of stress, or fully operational.

Perhaps the most important aspect of SDR technology is its ability to accept systems upgrades through software programming, which ex- pends the lifecycles of radio systems and enables users to adapt quickly to new capabilities, challenges, and threats. "We are able now to upgrade our radio products downstream and preserve the radio's lifecycle for the users. That's where we are today," says Mark Turner, engineering director of software and information assurance at the Harris Corp. RF Communications Division in Rochester, N.Y.

History of SDR

Interoperability also is a huge advantage of SDR technology, and historically has been one of the primary drivers of SDR development and deployment for military forces. "At one time, we had 200 radios in the DOD [U.S. Department of Defense] inventory, and none of them talked to each other," points out Byron Tarver technical director for the radio business of General Dynamics C4 Systems in Scottsdale, Ariz. "With the pace of battle and the need for the U.S. Army to talk to the Marines and the Air Force, it became imperative to have interoperability."

Software and computers were key to the transition to software-defined radio. "Legacy radios were purpose-built RF devices that used RF frequencies. Computing technology was the natural evolution that turned radios into computers with RF front ends," says Kurt Grigg, director of marketing for communications products at

The venerable Single-Channel Ground and Airborne Radio System (SINCGARS) from ITT is undergoing upgrades to give the radio SDR capability.

Rockwell Collins. "It is a computer running this processing, or waveform, that enables networking and data sharing, with the RF front end transmitting and receiving the data. It has a lot of processing horsepower behind it."

Efforts, moreover, have been worth it. "We've come a long way," Tarver says. "We have demonstrated software-defined radios in the military and commercial sector, of taking a radio platform and programming it to do different protocols, or waveforms. The processing capabilities, versatility, and power of SDR have been demonstrated in real time."

Enabling technologies

Embedded computing is the primary enabling technology behind software-defined radio, and as embedded computing has evolved, so has SDR technology. Digital signal processing (DSP), field-programmable gate arrays (FPGAs), general-purpose processors, and software design and development tools all lend themselves to software-defined radio, and enable SDR technology to improve on roughly similar trajectories.

"To run our waveforms, our SDR technology has had to progress," says Rockwell Collins' Haag. "Our software-defined radios have become more capable and less power hungry, as the basic technology components became more powerful and cost-effective. We needed to host the software-defined part of the radio in a reasonable-sized package. Otherwise, our radios would be the size of refrigerators."

Advances in software-design tools, automated software code generation, and real-time software compilers also have contributed greatly to the progress of SDR technology. "The way the software is developed has progressed a lot over the last 10 years," Haag says. "Efficient software is critical to run on smaller, yet more powerful microprocessors in software-defined radios."

Rockwell Collins is giving the legacy AN/ARC-210 airborne radio SDR upgrades, which should add capability for Navy and Air Force combat aircraft.

The process of writing software today "takes longer than we would like," says Thales' Johnston. "There are tools to enable you to develop software quicker, and check for software defects. We have software development tools today to do automated testing of software, and that look for loops and software practices."

Also playing a big role in the evolution of software-defined radio is battery technology, Johnston points out. "Our batteries are about 1.5 inches by 3 inches by 3 inches, and we try to provide eight to 10 hours of mission life, of transmit/receive, per battery charge. We want chemistries that can provide more capacity in that size of package. We have gone from NiCad to nickel-metal-hydride to lithium-ion batteries, which now is the state of the practical art," Johnston continues. "We have moved from 4.8 amp-hour to 5.8 amp-hour capacities by changing the kinds of cells that are in the package."

The future of SDR

So where do we go from here? On the power side, future developments in fuel-cell technology undoubtedly will play a part in future software-defined radio. "The next step would be fuel cells and we might, in the next five years, see soldier-worn, fuel-cell systems in some sort of power pack that will power several items. Fuel cells embedded in the radios, however, might take until the 10-year time frame," Johnston says.

The sizes of software-defined radios also are expected to shrink on a similar path to embedded computing. "We are seeing the transition and evolution of the capabilities we have in our manpack radios down into the smaller-packaged radios and personal radios," says Harris' Turner. "Our AN/PRC-152A [soldier radio] now has wideband capability, and can do the kind of wideband networking that our manpack radio can do. As form factors shrink, we can get more and more capability in our radios, and that has really enabled our wideband capability."

In addition, military communications systems designers will consider embedding software-defined radio capability into other systems as SDR technology continues to become smaller in size, lighter in weight, and more stingy in power consumption. "We're already seeing a melding of technologies and capabilities," says Rockwell Collins' Grigg. "We could see wrist-mounted or helmet-mounted technology where the radio and display capability are merged."

Likewise, Rockwell Collins is upgrading its venerable AN/ARC-210 airborne radio with SDR technology—a process that should increase the radio's capability, and leave room in the chassis for far more functions than the radio can do today. "It is growing to become a networking software-defined radio. So, what is next?" Haag asks. "Now that I have a computer in my radio, I might find new ways of massaging the data."

New uses for software-defined radio are high on the U.S. Army's list of priorities, says General Dynamics' Tarver. "This is fairly new technology, and trying to understand how these networks will behave in terrain in the field is non-trivial," he says. "We're also looking at tying all the pieces together on the battlefield, and looking at command and control links for the robots, as well as for extracting sensor data. What better way would there be than for a soldier to access and extract that information to get a total picture of the battlefield?"

In addition, researchers are investigating embedding capability in software-defined radio sets to perform electronic warfare, signals intelligence, and even detecting chemical, biological, and radioactive agents on the battlefield, all without the radio user's involvement. "We now have to figure out the priorities and how we will use these systems," Tarver says.

Beyond SDR: cognitive radio

Looking beyond software-defined radio, experts say the next step is a smart, computer-controlled radio that in real time is able to sample the RF environment, locate vacant, interference-free frequencies, and establish communications links automatically. This concept is called cognitive radio, which should be even more computer-intensive than SDR, experts say.

"Cognitive radio is the next thing," says ITT's Whitehill. "It has intelligence to know what the right thing to do is, like listening to the environment and determining if frequencies are jammed, and to make use of other frequencies." Still, this kind of radio communications technology primarily will be in the future.

"It's a little before its time," says Rockwell Collins' Grigg. "We will see this exploited first in the commercial domain. In DOD, you deploy your radio systems with rigorous spectrum management. The concept of cognitive radio says if I

Handheld software-defined radio technology from Thales Communications can aid communications interoperability among U.S. and allied forces.

have a congested spectrum, I can sense the spectrum, use areas of the spectrum in real time, and find a channel not being used. Today's tactics and logistics of the Army don't allow that.

Among the military challenges of cognitive radio are not simply finding unused frequencies, but determining how to rank each radio message or data transmission in importance, to find a way for the highest-priority radio and data traffic to get through first, and to enable lower-priority traffic to wait in line, he says.

JOHN KELLER is Editor-in-Chief of Military & Aerospace Electronics.

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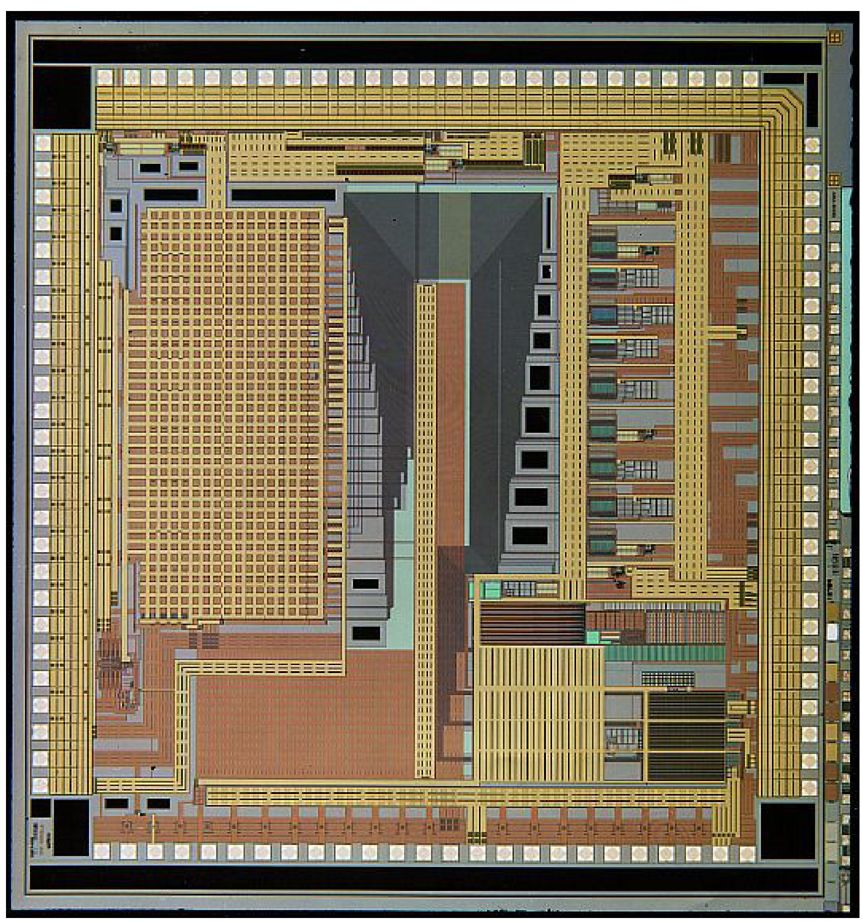
DARPA considers ASIC-based signal processing for the toughest EW and communications problems

by **JOHN KELLER**

ARLINGTON, VA., U.S. military researchers are considering a program to develop new kinds of digital signal processing (DSP) based on application-specific integrated circuit (ASIC) technology for advanced sensors for aircraft and space, as well as for the next generations of military communications systems and electronic warfare (EW).

Scientists at the Defense Advanced Research Projects Agency (DARPA) in Arlington, Va., are reaching out to defense companies to find out if the kinds of signal-processing technologies they envision already exist in industry or on the drawing board.



DARPA officials last week released a request for information (DARPA-SN-14-19) for the Signal Processing Co-Processor for Sensors, Communications program, which seeks to develop a co-processor that can serve a variety of military signal processing electromagnetic functions for military programs. The RFI is on behalf of the DARPA Strategic Technology Office (STO).

Advanced defense systems require a combination of programmability and throughput, DARPA officials explain. While field-programmable gate arrays (FPGAs), are programmable, they are larger, slower and much less power efficient then application specific integrated circuits (ASICs).

JOHN KELLER is Editor-in-Chief of Military & Aerospace Electronics.

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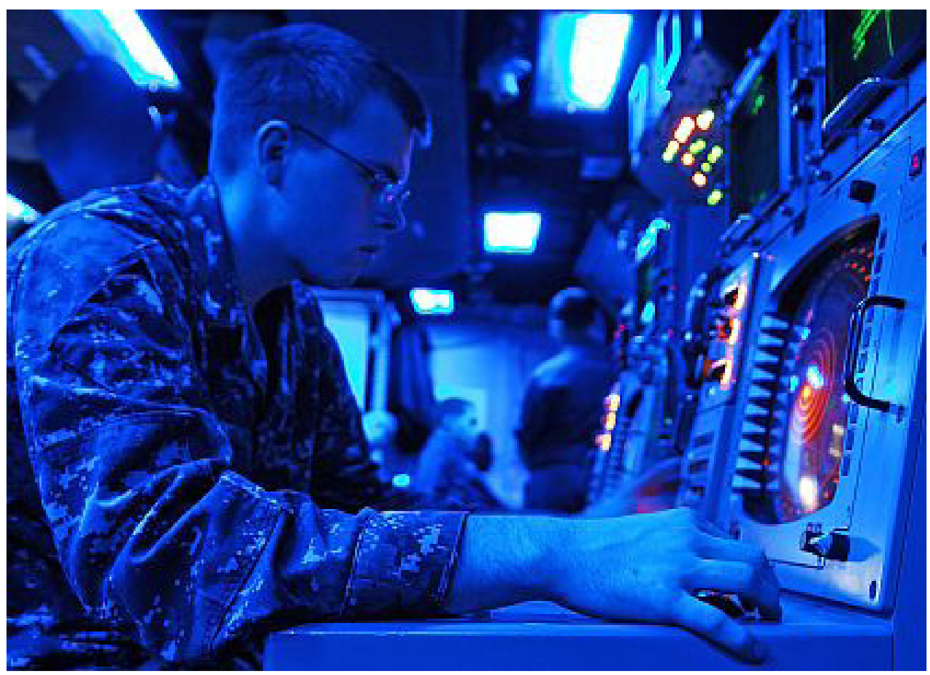
Air Force releases solicitation for radar initiative to improve target tracking and imaging

by **JOHN KELLER**

WRIGHT-PATTERSON AFB, OHIO. U.S. Air Force Researchers are asking industry to develop radar and electronic warfare (EW) technology that improves target detection, tracking, imaging, classification, and identification in the midst of enemy RF jamming, spoofing, and other challenging conditions.

Officials of the Air Force Research Laboratory at Wright-Patterson Air Force Base, Ohio, last week released a broad agency announcement (BAA-RQKS-2014-006) for the Contested Environment Radio Frequency Exploitation And Research (CERFER) program, which seeks to address problems of concurrent detection, tracking, imaging, classification, and identification of targets.



The CERFER program will require advances in radar subsystems, particularly in hardware, software, and algorithm solutions to detect, track, image, and identify targets within contested areas. This includes exploiting passive and active signals.

The goal of the CERFER program is to advance RF sensing hardware, software, and algorithms using spatial diversity, waveform diversity, transmit and receive adaptivity, signals of opportunity, and similar resources to enhance sensor performance.

The idea is to address problems of concurrent detection, tracking, imaging, classification, and identification of targets within contested environments with single- and distributed-sensing architectures. The project will involve developing models, hardware, software, algorithms, and techniques for active and passive sensing.

Air Force researchers primarily are interested in distributed sensing architectures; distributed active detection; distributed active and passive tracking; distributed active and passive imaging; distributed active and passive identification and classification; synthetic aperture radar (SAR) detection, tracking, imaging, and identification; and fully adaptive radar (FAR) detection, tracking, imaging, and identification.

The CERFER program will last for seven years — five years for the ordering period and two years to complete all tasks and submit the final report. Air Force officials expect to choose one contractor for the anticipated $46 million project.

For technical questions contact Air Force Maj. Jason Paul by phone at 937-528-8127, or by email at jason.paul@us.af.mil. For contracting questions contact Marcus Duff by phone at 937-255-6351, or by email at marcus.duff@us.af.mil.

More information is online at https://www.fbo.gov/spg/USAF/AFMC/AFRLWRS/BAA-RQKS-2014-006/listing.html.

JOHN KELLER is Editor-in-Chief of Military & Aerospace Electronics.

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Company Description:

Pentek is an ISO 9001:2008 certified company that has been successfully supplying COTS recording systems and boards for both the military and commercial markets. Pentek is the premier source for high-speed real-time recording systems and software, along with high-performance digital signal processing, software radio and data acquisition and I/O board-level products. Our customers enjoy the performance and flexibility afforded by our board and system-level commercial and conduction-cooled product lines and our world-class applications support.

- **Pentek has been designing and building boards for 25+ years:** We understand how embedded boards and systems are going to be used and have designed them for maximum performance, signal quality, thermal characteristics, cooling, FPGA loading, I/O to and through the boards and for channel synchronization where low phase noise is critical..
- **Digital Signal Processing (DSP) and Data Acquisition and I/O Experts:** Starting with our very first products, Pentek engineers have been helping customers solve the toughest design challenges in radar and communications systems by thoroughly understanding advanced signal theory and real-world system considerations.
- **Pentek targets the high-end of the market:** Virtually all customers push the capabilities to the max so Pentek's board designs are always optimized for maximum performance.
- **FPGAs are fully characterized:** Pentek provides detailed information on FPGA utilization and can recommend exactly which FPGA to use on each board based on how much user generated IP will be installed.
- **GateFlow FPGA Design Resources:** Allows the user to easily modify, replace and extend the standard factory installed functions in the FPGA and add user-generated IP. GateFlow is used with Xilinx ISE Foundation tools and includes a complete ISE project with VHDL source, which significantly shortens the time for end users to develop and install custom IP.
- **Technical Support:** Pentek offers free, unlimited, lifetime technical support from DSP engineers.
- **Documentation:** Pentek delivers quality documentation saving an enormous amount of development time.
- **Startup Time:** You can install and use the board immediately by using the ReadyFlow Command Line Interface and Signal Analyzer to display the data without having to do any programming. This saves development time and shortens project start up time.
- **Quality:** Pentek implements the highest quality practices in all operational phases and is committed to customer satisfaction and on-going improvement.

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