

JED

Journal of Electromagnetic Dominance

What CMOSS Means to the US Army



- | Interview:
**Rich Sorelle,
Abaco Systems**
- | EW 101:
EP for Satellites
- | 2021 AOC
Member Guide

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JED

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Journal of Electromagnetic Dominance

March 2021 • Volume 44, Issue 3

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How the Services are Approaching CMOSS

By John Haystead



The US Army has been working with the Sensor Open Systems Architecture industry consortium to develop the C5/ISR Modular Open Suite of Standards (CMOSS). This will be incorporated into new Army EW and SIGINT systems, such as the Terrestrial Layer System (TLS). It may eventually find its way into upgrade programs for legacy EW systems, such as the VROD (shown above).

US ARMY

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US Navy Petty Officer 3rd Class Irene Cabradilla, aviation ordnanceman assigned to the Scorpions of Electronic Attack Squadron 132 (VAQ-132) at Naval Air Station Whidbey Island, Washington, kicks out the wheel chocks of an EA-18G Growler during Red Flag 21-1 at Nellis Air Force Base, NV, on January 25.

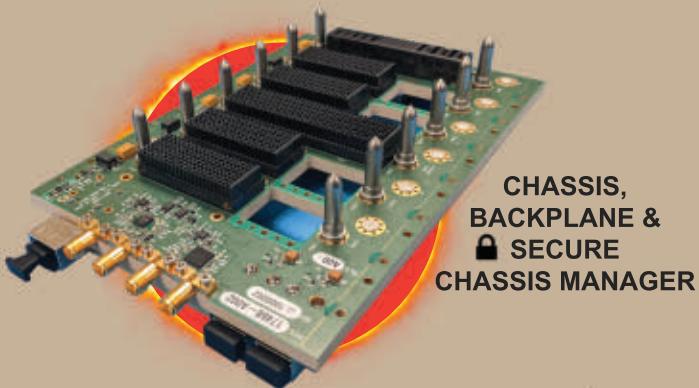
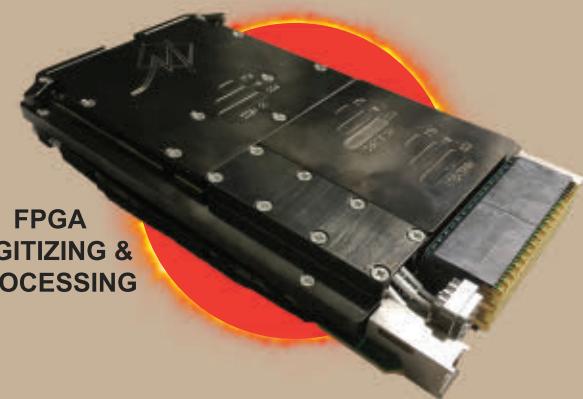
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UP TO STANDARD

This month's JED includes an excellent cover story by John Haystead about the US Army's effort to embrace hardware and software standards for its electronics systems. His article focuses on the System of Systems Architecture (SOSA), which the Army is pursuing under the C5ISR/EW Modular Open Suite of Standards (CMOSS) moniker. Previous DOD standardization efforts include the Future Airborne Capability Environment (FACE), which established avionics software standards, and the Vehicular Integration for C4ISR/EW Interoperability (VICTORY) standard that enabled the Army to develop interfaces for the various sensor systems on a ground vehicle, thereby reducing the number of keyboards and displays, share sensor and PNT data between these systems, and ultimately to reduce the size, weight, power and cost (SWAP-C) of the vehicle's electronic sensor suites.

The SOSA/CMOSS efforts establish a new embedded computing standard for EW and SIGINT sensors, which enables the Army (and other Services) to more easily replace and re-use the signal processing modules at the of these systems. SOSA erodes the "vendor lock" and allows the Army and its systems developers to select the best embedded computing boards and modules from a wider pool of manufacturers whose products meet the standard. It also lowers system lifecycle cost by enabling more competition from among the embedded computing manufacturers.

One advantage SOSA and other DOD standards efforts have behind them is robust industry consortiums that agree to develop and follow technical standards in close coordination with the Services. Without enough buy-in from lots of companies, open standards like SOSA would look great on paper but would fail to deliver in terms of operational advantage in the real world.

Aside from lower cost, what else do these new technology standards do for the DOD? In the case of SOSA, for example, EW and SIGINT systems developers can insert new embedded computing technology into a system much more rapidly than in the past. This goes hand-in-hand with the DOD's strategy to employ faster acquisition vehicles, such as middle-tier acquisition (rapid prototyping and rapid fielding) and Other Transaction Authority (OTA) schemes. Together, these two factors enable the DOD to access and field the latest EW and SIGINT technologies under timelines that match the pace of new radar and communications technologies they must sense and defeat.

The DOD began to embrace commercial-off-the-shelf (COTS) embedded computing technologies in 1994. Since that time, open standards have been a missing piece of the DOD's COTS strategy. You and I benefit from open standards every time we buy a new laptop computer or smartphone, or when we install a new OS that allows us to buy third-party apps for them. These open standards give us rapid access to the latest technologies. Unlike the DOD, however, you and I do not have to overcome an acquisition culture that was established during World War II. By embracing open hardware and software standards, the DOD is much closer to achieving the true benefits of COTS. As our cover story explains, SOSA is a major milestone on that journey. – *J. Knowles*

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Journal of Electromagnetic Dominance
is published for the AOC by

NAYLOR
ASSOCIATION SOLUTIONS

1430 Spring Hill Road, 6th Floor
McLean, VA 22102
Tel (800) 369-6220
www.naylor.com

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Editorial: The articles and editorials appearing in this magazine do not represent an official AOC position, except for the official notices printed in the "Association News" section or unless specifically identified as an AOC position.

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Calendar Conferences & Courses

MARCH

AOC Program Manager Briefing

Session 7

March 2
1300-1500 EST
www.crows.org

Advanced Radar

March 8-12
Swindon, UK
www.cranfield.ac.uk

AOC Virtual Series Webinar: Cyber Electromagnetic Activities and Signals Intelligence: a Command and Control framework

March 11
1400-1500 EST
www.crows.org

MILIPOL Qatar 2021

Conference: March 15-17

Doha, Qatar

<https://en.milipolqatar.com>

Aircraft Survivability

March 15-19
Swindon, UK
www.cranfield.ac.uk

AOC Program Manager Briefing Session 8

March 16
1300-1500 EST
www.crows.org

AUSA Global Force Next – Virtual Conference:

March 16-18
Huntsville, AL
www.usa.org

Dixie Crow Symposium 45

Conference: March 21-24
Warner Robins, GA
www.dixiecrowsymposium.com

AOC Professional Development Live Web Course: RF Theory for ES Operations

March 22-26
www.crows.org

Advanced Sensor Data Processing

March 22-26
Swindon, UK
www.cranfield.ac.uk

Counter IED

March 22-26
Swindon, UK
www.cranfield.ac.uk

Infrared/Visible Signature Suppression

Atlanta, GA
March 23-26
www.pe.gatech.edu

AOC Virtual Series Webinar: The Year in Review – GPS/PNT Disruptions and Improvements

March 25
1400-1500 EST
www.crows.org

Radar Warning Receivers

Fundamentals

Online
March 30-31
www.pe.gatech.edu

Counter-UAS Winter Summit – Virtual Conference:

March 31 – April 2

www.idga.org

APRIL

AOC Professional Development Live Web Course: Fundamental Principles of Electronic Warfare

April 5-28
www.crows.org

Basic RF Electronic Warfare Concepts

Atlanta, GA
April 6-8
www.pe.gatech.edu

Infrared Technology and Applications – Open Access

Atlanta, GA
April 6-9
www.pe.gatech.edu

LAAD Security

Conference: April 6-9
Rio de Janeiro, Brazil
www.laadsecurity.com.br

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Calendar Conferences & Courses *cont'd.*

AOC Virtual Series Webinar: Fast Switching Synthesizers for Emerging EW Systems

April 8
1400-1500 EST
www.crows.org

AOC Virtual Series Webinar: All in a Spin About Reticle-Based Seekers

April 11
1400-1500 EST
www.crows.org

2.0 EMS Virtual Summit

Conference: April 13
www.crows.org

Electronic Warfare Data Analysis

Atlanta, GA
April 19-22
www.pe.gatech.edu

Threat Radar Systems

Atlanta, GA
April 19-23
www.pe.gatech.edu

2021 Army Aviation Mission Solutions Summit (AAAA)

Conference: April 21-23
Nashville, TN
www.quad-a.org

AOC Virtual Series Webinar: All in a Spin about Reticle-Based Seekers

April 22
1400-1500 EST
www.crows.org

MAY

Cyber Warfare/EW Convergence

Atlanta, GA
May 3-5
www.pe.gatech.edu

AOC Professional Development Live Web Course: Advanced Principles of Electronic Warfare

May 3-26
www.crows.org

Modeling and Simulation of Phased-Array Antennas

Online
May 4-6
www.pe.gatech.edu

Radar Warning Receiver System Design and Analysis

Atlanta, GA
May 4-6
www.pe.gatech.edu

AOC Virtual Series Webinar: AI Guided Spectrum Operations

May 6
1400-1500 EST
www.crows.org

EW Capability Gaps and Enabling Technologies 2021

Conference: May 11-13
Crane, IN
www.crows.org

2021 Special Operations Forces Industry Conference (SOFIC)

Conference: May 17-21
Tampa, FL
www.sofic.org

Military Electronic Warfare

May 17-21
Swindon, UK
www.cranfield.ac.uk

AOC Virtual Series Webinar: 5G for Non-Terrestrial Networks

May 20
1400-1500 EST
www.crows.org

Cyber Electromagnetic Activity (CEMA) 2021

Conference: May 25-27
Belcamp, MD
www.crows.org

JUNE

EW Live

Tartu, Estonia
June 14-16
www.tangentlink.com 

AOC events are noted in red. For more info or to register, visit crows.org. Items in blue denote AOC Chapter events.

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SPEAKERS INCLUDE

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Commander, US Pacific Fleet (invited)



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Director of EW, OSD, OUSD
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President's Message



THOUGHTS ON ELECTROMAGNETIC PROTECTION (EP)

I had the distinct honor and privilege during the last week of January of participating in a Spectrum Dominance Panel sponsored by the Potomac Officers Club with Undersecretary Ellen Purdy (Director, Emerging Capabilities & Prototyping Initiatives & Analysis, OUSD (R&E)), David Tremper (Director of EW, Platforms & Weapons Portfolio Management (P&WPM), OUSD (A&S)), and Melinda Tourangeau (Executive Director, Reginald Victor Jones Institute) and then to moderate the AOC Leadership Discussions session with Gen Charles Q. Brown Jr., CSAF. Throughout these discussions, one recurring EMS theme was the need to ensure that we are addressing Electromagnetic Protection (EP) when looking to achieve Spectrum Superiority.

When we look at EMS Operations (EMSO) we may forget how intertwined the Spectrum is and that commercial and civilian systems and assets reside alongside military systems and are subject to the same challenges of operating in congested and contested spectrum. Are we designing and implementing the needed and proper capabilities to deal with challenges of operating in the spectrum, for military and commercial systems that use or are impacted by RF.

From *The History of EW Vol. I*, by Alfred Price, we know the first documented use of jamming or interference was in September 1901 during the America's Cup. American Wireless Telephone and Telegraph, who did not get the contract to report on the races, realized they could transmit "real time" status using dashes; they used one 10 second dash when *Columbia* (the American yacht) was leading, two 10-second dashes when *Shamrock II* (the British yacht) was leading; and three 10-second dashes when the yachts were even. It was simple, but effective and the 10-second dashes interfered with the transmissions from the contracted companies. Those other companies assumed that they would have spectrum to operate freely.

As I watch the current America's Cup currently going on in New Zealand, the EWO in me thinks, what if I had a capability that could interfere or control the systems onboard one of these new AC-75 racing yachts. The AC-75 yacht has a typical hull, but has foils on the port and starboard sides that enable the yachts to lift up and "fly" on one foil, at three times the wind speed. They have complex communication, electrical and hydraulic systems that enable steering, foil deployment and retraction, sail trimming and wind/weather analysis. What if I could signal one of the yachts and interfere at a critical moment or to actually control their foils? What protections have their engineers and teams built into these yachts and systems to keep them safe from their competitors or someone with ulterior motives? In today's technologically advanced world, what EP are we building into automobiles, ships, aircraft, spacecraft, robotics, etc.? Are we still assuming that we will have the ability to operate freely within the EMS?

Lastly, our "AOC Discussions" on EMSO Leadership, concludes with Air Chief Marshal Sir Stuart Peach, Chairman of the NATO Military Committee, on March 3rd. These have been outstanding opportunities to hear from our senior leaders, and I hope you have been able to enjoy their insights. – Glenn "Powder" Carlson



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FEATURED LIVE COURSES



RF Theory for ES Operations

Dr. Patrick Ford

Tuesdays & Thursdays

1:00 - 4:00 PM ET | March 22 - 26, 2021

This course will also provide a survey of propagation modeling techniques and an update on modern RF operating trends.



Advanced Principles of Electronic Warfare

Dave Adamy

Mondays & Wednesdays

1:00 - 4:00 PM ET | May 3 - 26, 2021

This Advanced Electronic Warfare course has eight three hour sessions. It is designed for individuals who have completed a fundamental EW course or have significant experience in the field.



Aircraft Radar Cross Section Engineering

Renan Richter

Mondays, Wednesdays & Fridays

1:00 - 4:00 PM ET | July 12 - 30, 2021

This course introduces students to Radar Cross Section (RCS) engineering and its basics fundamentals inside the modern EW context. Stealth technology will be addressed by presenting current challenges and future perspectives.



Introduction to Satellite Communications (Satcom)

Dr. Patrick Ford

Mondays & Wednesdays

1:00 - 4:00 PM ET | September 1 - 22, 2021

This course will cover the core material required for participants to understand and discuss basic Satcom theory and operations.



Fundamental Principles of Electronic Warfare

Dave Adamy

Mondays & Wednesdays

1:00 - 4:00 PM ET | April 5 - 28, 2021

This is an introductory Electronic Warfare course in eight three hour sessions. It provides insight into the whole electronic warfare field at the systems and operational level.



C4ISR Requirements, Principles, and Systems

Dr. Clayton Stewart

Mondays & Wednesdays

1:00 - 4:00 PM ET | June 7 - 30, 2021

This 24 hour web based course delivers a thorough overview promoting an understanding and building a successful Command, Control, Communications, Computers, Intelligence, Surveillance, Reconnaissance (C4ISR) architecture.



Direct Energy Weapons

Kyle Davidson

Mondays & Wednesdays

1:00 - 4:00 PM ET | August 2 - 18, 2021

This course introduces students to the fundamentals of Direct Energy Weapons (DEW) across the electromagnetic spectrum. The goal is to provide an understanding of the operation of laser and high-power microwave DEWs in military applications, including their design trade-offs, and target effects.



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SOSA
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30
YEARS

FRANCE PURSUES COMMON SIGINT SUITE

Last month, the French MOD's procurement agency, Direction générale de l'armement (DGA), announced that it has tapped Thales and Airbus to jointly develop new tactical signals intelligence (SIGINT) systems to upgrade the French armed forces' signals monitoring, direction finding and spectrum analysis capabilities, collectively known as renseignement d'origine électromagnétique (ROEM). The 10-year contract, awarded in late December, will equip France's air, land and naval forces with common SIGINT sensor "building blocks" that can be configured for various aircraft, ground vehicles and naval vessels and further tailored for theater and mission requirements. While the new system will enable French SIGINT capabilities to keep pace with modern communications and radar signals, the provision of common SIGINT modules is intended to simplify the

training of SIGINT operators and optimize through-life support.

The tactical SIGINT recapitalization will upgrade the electronic warfare capabilities of front-line units, providing a set of high-performance portable or vehicle-mounted assets compatible with the latest communications technologies. The new system to monitor and localize enemy communications will support tactical maneuvers in the theatre of operations, equipping vehicles of the French Army's 54th Signals Regiment (SCORPION program) together with French Navy warships and Atlantique 2 maritime patrol aircraft. The DGA said the first order, worth about €160 million, is scheduled to provide the initial capability in 2023 and full capability by the end of 2025.

Thales will leverage SIGINT expertise accrued from a number of legacy programs. These include COHORTE

(the current land-based tactical SIGINT system), MINREM (the French Navy's SIGINT suite aboard the *Dupuy de Lôme*), ARCHANGE (new-generation SIGINT suite to be installed on Dassault Falcon 8X aircraft) and CLOVIS (the strategic inter-governmental communications localization project). Thales will also build on its capabilities in end-to-end communications, radio communications and communications security.

Airbus will provide its expertise in strategic ELINT systems, drawing on its experience on programs such as RAMSES (strategic radio and satellite communications information system) and PARADOS (radio signal acquisition sensor). These systems are currently in operational service with the three armed services and France's defense intelligence agency (Direction du Renseignement Militaire). – R. Scott

LEIDOS UNDER CONTRACT TO AFRL FOR TAAP-DEW COUNTERMEASURES TECHNIQUES RESEARCH

The Air Force Research Laboratory (AFRL) has awarded Leidos (Reston, VA) a \$68.6 million indefinite-delivery/indefinite-quantity (IDIQ) contract with cost-plus-fixed-fee task orders to pursue innovative research and development to design expendable (ordnance) and directed-energy (signal) countermeasure concepts and techniques development for aircraft self-protection against both electro-optical (EO) and EO/radio frequency (RF) threats.

The five-year Threat Assessment and Aircraft Protection Defensive Electronic Warfare (TAAP-DEW) program contract is intended to investigate novel technologies and techniques applicable to both the EO and multi-spectrum EO/RF domains. Managed by the AFRL's Sensors Directorate, the program will encompass threat exploitation; modeling, simulation and analysis; hardware testing; counter-

measure technique and technology design; and field testing activities.

Intended to identify and mature technologies to defeat an evolving anti-air missile threat, the TAAP-DEW program forms part of AFRL's wider Multi-Spectrum Defensive Electronic Warfare (MSDEW) effort. MSDEW is intended to develop sensors and systems to meet needs for improved joint lethality in contested environments, the ability to strike diverse targets inside adversary air and missile defense networks, and to support a force which can deploy, survive, operate, maneuver and regenerate in all domains while under attack. – R. Scott

GENERAL ATOMICS FLIGHT TESTS MQ-9 SELF-PROTECTION POD

General Atomics Aeronautical Systems, Inc. (GA-ASI) has completed flight testing of a newly developed self-protection pod on an MQ-9 unmanned air system.

The test, conducted at the Yuma Proving Grounds, AZ, was designed to demonstrate automated threat warn-

ing and countermeasures deployment to improve MQ-9 survivability in contested environments. The US Air Force has lost several MQ-9s over the past few years, and some were believed to be shot down by enemy air defense systems, including an SA-6 in Yemen and a Pantsir-S1 in Libya.

Work on the self-protection pod was executed as part of a Cooperative Research and Development Agreement (CRADA) with US Special Operations Command with support from the Air National Guard (ANG), the US Navy, and industry partners Raytheon Intelligence & Space, BAE Systems, Leonardo, Leonardo DRS, and Terma North America.

According to GA-ASI, the self-protection pod leverages mature (TRL 9) aircraft survivability equipment (ASE) to provide full-spectrum awareness and countermeasures for the MQ-9 platform. In 2017, GA-ASI supported a joint demonstration effort in which a podded Raytheon's AN/ALR-69A(V) radar warning receiver (RWR) was used to provide

News

situation awareness and to pass emitter targeting information to radar and EO/IR sensors on the Predator.

The latest tests took this concept a step further and focused on demonstrating a self-protection capability. The self-protection pod, mounted underneath the MQ-9's fuselage, integrated an ANL-69A(V), as well as a Leonardo DRS AN/AQ-45 Distributed Aperture Infrared Countermeasure (DAIRC) system utilizing a single sensor for both two-color infrared (IR) missile warning and wide field-of-view gimbal for threat countermeasures. Also integrated into the system was BAE Systems' ALE-47 countermeasures dispenser system, which was capable of dispensing flares to defeat IR-guided threats and Leonardo's Brite-Cloud DRFM-based expendable active decoy against RF-guided threats. Terma's AN/ALQ-213 EW Management System coordinated the various threat warning and dispensing systems in order to optimize the countermeasures response.

According to GA-ASI, during testing at Yuma, the MQ-9's self-protection pod was able to successfully track RF and IR missile threats, deploy countermeasures and provide real-time threat awareness and protection against simulated RF and IR threat emitters. – R.Scott

IN BRIEF

The US Army Research Lab (Adelphi, MD) announced that it has developed a quantum spectrum analyzer that uses a Rydberg sensor to sample the spectrum from zero frequency to 20 GHz. According to a news release from the Lab, "The Rydberg sensor uses laser beams to create highly-excited Rydberg atoms directly above a microwave circuit, to boost and hone in on the portion of the spectrum being measured. The Rydberg atoms are sensitive to the circuit's voltage, enabling the device to be used as a sensitive probe for the wide range of signals in the RF spectrum." Dr. Kevin Cox, a researcher at the US Army Combat Capabilities Development Command, now known as DEVCOM, Army Research Laboratory, explained why this is an important achievement. "All previous demonstrations of Rydberg atomic sensors have only been able to sense small and specific regions of the RF spectrum, but our

sensor now operates continuously over a wide frequency range for the first time." He added, "This is a really important step toward proving that quantum sensors can provide a new, and dominant, set of capabilities for our Soldiers, who are operating in an increasingly complex electro-magnetic battlespace." Program officials expect that this and other quantum sensor technologies could eventually be used across many electromagnetic warfare, spectrum awareness and communications applications.

The Multispectral Sensing and Detection Division (RYM) of the Air Force Research Lab's Sensors Directorate (Wright-Patterson AFB, OH) has issued a Broad Agency Announcement (BAA FA8650-21-S-1180) for a new effort named Multi-Spectral Sensing Technologies Research and Development (MUSTER). Under this BAA, the Multispectral Sensing and Detection Division will fund research and development efforts across 15 technology areas, including RF sensor systems for situational awareness and targeting; ultra-sensitive receivers for SIGINT applications; novel EO/IR hardware and algorithms to detect low-signal targets in noisy and heavily cluttered environments; fully adaptive radar that exploits "all available degrees-of-freedom on transmit and receive in order to maximize target detection, tracking and classification performance;" and advanced digital multifunction arrays. AFRL has not issued any specific calls under this BAA yet, but it is expected to do so in the coming months. The overall value of the BAA is \$99 million over at least five years, with awards ranging from \$100,000 to \$10 million. The technical point of contact is Stephen Fernandez, AFRL/RYMF Project Engineer/Program Manager, +1 (937) 713-8976, e-mail stephen.fernandez.2@us.af.mil.

The US Air Force's Electronic Combat International Security Assistance Program (ECISAP) (Robins AFB, GA) has awarded a \$7.2 million contract to **Textron Systems** (Hunt Valley, MD) for flightline EW test equipment for Foreign Military Sales (FMS) customers. The company will manufacture new AN/USM-670/670A Joint Services Electronic

Combat Systems Tester (JSECST) and Model 527 Radar Signal Simulator test equipment, which will provide end-to-end testing of aircraft EW systems. The systems will be used by five FMS customer nations.

L3Harris Technologies (Salt Lake City, UT) and **Raytheon** (Tewksbury, MA) were awarded contracts from the Defense Advanced Research Project Agency (DARPA) (Arlington, VA) to develop interference mitigation technologies under the Wideband Adaptive RF Protection (WARP) program. DARPA awarded a \$7.2 million contract to L3Harris, and Raytheon received a pair of contracts totaling \$10.1 million. The WARP program aims to develop wideband tunable filters and analog signal cancellers that selectively attenuate externally-generated RF interference (such as jamming), as well as self-generated interference, to protect wideband digital radios from saturation. The tunable filters will continuously sense the EM environment and adapt to maintain the receiver's dynamic range without decreasing signal sensitivity or bandwidth. The awards cover early phases of the program, which is valued at \$40 million.

BAE Systems Hägglunds AB (Örnsköldsvik, Sweden) has awarded an \$82 million contract to Elbit subsidiary **IMI Systems** (Ramat Hasharon, Israel) to supply the company's Iron Fist active protection system (APS), as well as Commander Open Architecture Panoramic Sights on Royal Netherlands Army (RNLA) CV90 armored combat vehicles. After studying the integration of an APS systems beginning in 2015, the RNLA and BAE announced their selection the Iron Fist APS in September 2019. In a separate development, the German Government announced that has approved the acquisition of an undisclosed number of Trophy APSs from Rafael Advanced Defense Systems for the Bundeswehr's Leopard 2A6 tanks. Several more European countries are expected to announce APS decisions for their ground combat vehicles over the coming year.

Gen Kenneth McKenzie, USMC, Commander of US Central Command (CENTCOM) gave the keynote address at

the Middle East Institute's MEI-CENTCOM Annual Conference last month. He told the audience that small unmanned aerial systems (i.e., commercial drones) are a pervasive threat in the CENTCOM AOR. "These systems are inexpensive, easy to modify and weaponize, and easy to proliferate," he said. "The growing threat posed by these systems, coupled with our lack of dependable network capabilities to counter them, is the most concerning tactical development since the rise of the improvised explosive device in Iraq. Right now, we're on the wrong side of the cost imposition curve because this technology favors the attacker, not the defender. But, we're working very hard to fix this and flatten the curve. We have a variety of systems in the field already, and I know that it has the direct attention of leaders in the Department of Defense and the Army, the executive agent for counter UAS. Those are all steps in the right direction. But it worries me because I think what we're seeing is the emergence of a new component of warfare, part of a system-of-systems, and how we work our way through this challenge will be closely watched by our competitors and our adversaries."

The US Air Force's Air Combat Command (Langley, VA) is planning to award a sole-source modification to CRFS to upgrade to the Spectrum Monitoring System at Joint Base Langley-Eustis (JBLE). The Command is also considering a follow-on acquisition for the ACC Enterprise Spectrum Monitoring Solution, which would see Spectrum Monitoring Systems installed at as many as 13 ACC bases. The first of these additional systems would be installed at Seymour-Johnson AFB and Shaw AFB. Last month, ACC released a Request for Information for this effort. Responses were due February 19. The contracting point of contact is Shantia Allen, (757) 225-4341, e-mail shantia.allen@us.af.mil.

The US Army is soliciting proposals for same frequency while simultaneously transmitting and receiving (SF STAR) technology that can be incorporated into commercial software defined radios (SDRs). Issued through a Small Business Innovative Research (SBIR) Broad Agency

Announcement (BAA), the Army is seeking "...four prototypes adapted from commercial off the shelf (COTS) software defined radios (SDR's) capable of operating in the same frequency while simultaneously transmitting and receiving (i.e., SF-STAR) voice and data from external sources and capable of performing network operations in congested, contested and denied environments," according to the solicitation. Additionally, the Army is "...looking for solutions of suppressing friendly interference, whether co-located

in the same platform, or, in the general presence of other potential interfering sources while performing SF-STAR." The Solicitation Number is W50RAJ-20-S-0001_SBIR_BAA_A214-002. Proposals are due by March 24.

BAE Systems (Nashua, NH) has received an \$81.3 million contract option to supply additional 1,512 radio frequency countermeasures systems (including approximately 500 ALE-70 decoys) for F-35 Lot 12 production. The contract covers

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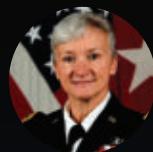


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the US Navy, US Marine Corps and US Air Force, as well as international F-35 users. Work is scheduled for completion in March 2024. In related program news, Lockheed Martin received a \$64.1 contract option for Digital Channelized Receiver/Techniques Generator and Tuner Insertion program technology for the F-35. The upgrades will support the transition to the Lot 15 Block 4 configuration for US Air Force in international customers.

The **Air Force Research Lab's Directed Energy Directorate** (Kirtland AFB, NM) has issued an Advanced Research Announcement for its upcoming Directed Energy Technology Experimentation Research (DETER) effort. Under DETER, the Directorate is seeking white papers and proposals across several topics areas. These include: 1) directed energy sources (laser sources and high-power electromagnetic sources); 2) acquisition tracking pointing (ATP), beam control and atmospheric compensation systems; 3) DE weapons, component/subsystem prototype risk reduction, fabrication/purchase, assembly, integration and testing; 4) DE effects testing; 5) modeling, simulation and analysis; and 6) wargaming. The ARA Number is FA9451-21-S-0001, and it will remain open to proposals through February 2022. In addition to the white papers, AFRL may issue calls for specific requirements. The contracting point of contact is Lisa Pendragon, e-mail afrl.deterара@us.af.mil.

The US Navy has announced plans to award sole source contracts in FY2022 to **Argon ST** (a Boeing Company) and **Sierra Nevada Corp.** (SNC) to produce additional Multi-Intelligence Sensor Development (MISD) Common Chassis units. The companies will produce up to five variants of the Common Chassis for Naval Air Systems Command's Maritime Patrol and Reconnaissance Aircraft Program Office (PMA-290). In addition, the Navy plans to award sole source follow-on production contracts to Argon ST for MISD Low Band Sensor Suites and to SNC for MISD High Band Sensor Suites. The companies have been delivering hardware and software for the Common Chassis program for several years. The Common Chassis was developed

in multiple variants for the US Navy's P-8A, EP-3, MQ-4, Naval Undersea Warfare Center (NUWC), Naval Information Warfare Center (NIWC) and the US Army's EMARSS aircraft.

Northrop Grumman received a \$330 million contract option from the US Navy's Naval Sea Systems Command (NAVSEA) to manufacture Joint Counter Radio-Controlled Improvised Explosive Device Electronic Warfare Increment One Block One (JCREW IICB1) dismounted and

mounted systems. The contract also covers mounted auxiliary kits, operational level spares, depot level spares and engineering support services. Approximately \$116.5 million of the contract will be used to produce systems for the Australian Defence Force. In November 2019, the Australian Government, acting through FMS channels, requested to purchase 850 JCREW IICB1 systems (533 vehicle mounted and 317 dismounted) for \$245 million. This contract covers a portion of that request. ↗

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Rich Sorelle, CEO, Abaco Systems

Rich Sorelle is an industry leader who has spent most of his career in electronic warfare (EW). He started as an engineer at Grumman Aerospace, where he worked on various Navy aircraft programs, including the EA-6B Prowler. After Grumman, he took a position at ITT Industries, where he would spend the next 20 years focusing on EW systems. When ITT Industries spun off their defense business to become Exelis, Sorelle's duties evolved from engineering and program management to executive management. In 2012, he was named President of Exelis Electronic Systems and managed the company's EW business during its acquisition by Harris. After retiring from Harris in 2015, he became a board member in an investment group that had acquired Abaco from GE in 2015. Sorelle was named CEO of Abaco in 2017, and he has shaped the embedded computing company to additionally focus on opportunities in the EW and signals intelligence (SIGINT) markets.

John Knowles spoke with Rich Sorelle about his career and his plans for Abaco.

JED

Please tell me about your first job as an engineer and how your career brought you to Abaco.

Rich Sorelle

My first job in engineering was modeling the entire Texas Instruments microcircuit product line. In 1982 and 1983, it was a yellow, hard-covered data book, and that contained all of the Texas Instruments products. It gave me a really great view of both hardware functionality and software because I had to use the software to model the hardware. That functionality in software was used as software models in one of the first functional design and test capabilities. This type of software modeling was new to the industry, and it taught me about microcircuits at an early age.

I worked at Grumman Aerospace for 13 years, where I helped support five production airplanes for the Navy while also earning my engineering degree. It was an easy transition for me from manufacturing into design engineering. My background in manufacturing was very helpful because I understood as a design engineer what manufacturing needs in order to be successful. I went into program man-

agement from engineering. I spent a lot of time with customers, but I also spent a lot of time working with different functions in the company; it's almost like being an orchestra conductor to make progress on complex projects and programs. The various departments must work together to produce the product. This includes everything from understanding the requirements up front to understanding the project schedule, technical specifications and cost.

After Grumman, I went to ITT, where I spent 20 years working primarily in EW. I retired from ITT/Exelis in 2015 and in 2017 joined an investment firm, where I was asked by those investors to lead Abaco. Abaco is a carve-out from GE, which had a long history in embedded computing that goes back to Radstone Technology over 40 years. At Abaco, I formed a new leadership team, and we have introduced new products that have allowed us to open significant new opportunities, primarily in the EW and SIGINT markets, with first-to-market disruptive technologies.

JED

What are some of the valuable career lessons you have learned on your

journey from an entry-level engineering position to your current role as President and CEO of Abaco?

Rich Sorelle

I learned that if you treat people with respect, if you tell them the truth, if you listen to them and give them a vision of a shared future, they give you their best effort. I learned that there is no substitution for good engineering talent. This is especially true in EW because it's a very difficult undertaking with both hardware and software.

The other thing that's really important is the need to accelerate growth by continuing to develop new products, especially ones that allow you to move into near-adjacent markets to accelerate growth. For example, when I first arrived at Abaco, I looked around with an understanding of where the EW world was headed, having spent 30 years in that market. We invested heavily in the RF System-on-a-Chip (RFSoC) from Xilinx, and in 2018, we released the first to market product. We used that disruptive technology to move into the EW and SIGINT market, where Abaco hadn't had a presence before. We are now growing over 15% a year on the top line and even more than that on the bottom line.

JED

In terms of the defense market that Abaco serves, what do you think are some of the most significant challenges you will need to address over the next five years?

Rich Sorelle

The defense market is our primary vertical. We do about 85% of our work for the defense market. The other 15% is primarily for commercial aviation, as well as industrial applications, such as oil and gas drilling. In terms of challenges, the first is the worldwide autonomous initiative, which require massive amount of data processing, onboard computing and digital signal processing. Autonomous capabilities blanket both defense and commercial markets and require additional levels of certification to ensure safe and secure operation, whether that's unmanned

air systems (UAS) or autonomous ground vehicles similar to what Google, Ford, GM and Tesla are working on. We provide significant computing capabilities for those types of autonomous platforms. In addition, the autonomous programs include some degree of artificial intelligence and machine learning. Solutions for these platforms are typically constrained in terms of size, weight and power (SWAP) – and cost. Abaco is very good at ruggedizing the best and newest processing capabilities designed to align to the SOSA™ technical standard, which allow our customers to quickly and effectively upgrade their systems with new technology.

Another opportunity for rugged embedded computing is in the hypersonic arena. Those platforms need ruggedized embedded hardware that perform way above the current norms for temperature, shock and vibration, altitude, and acceleration. These platforms will require the next level of performance to meet their computing and processing needs.

JED

As the DOD moves toward embracing Sensor Open Systems Architecture (SOSA) standards, how is Abaco responding to this?

Rich Sorelle

Over three years ago, we realized the importance of the emerging SOSA initiatives and the benefits it would bring. When we think about the US Army having a suite of open architecture standards and we think about the C5ISR Modular Open Suite of Standards (CMOSS), it's really about enabling the sharing of hardware and software components. It prevents vendor lock, which has been a DOD objective for the past 20 years. It also allows smaller companies, like Abaco, to pursue a larger number of opportunities by offering the best technology.

At Abaco, we spend more than 10% of our revenue on R&D. Customers choose us because we stay closer to the state of the art of processing. If someone comes to me (as a prime) and says, "I developed, at my own cost, the best single board computer that's out there,

using the best gaming processor that's out there, with the best RFSoC that's out there, and spent \$30 million dollars of my own money doing it," you get attention. Our customers can have all this and can ride their domain specific software on our hardware. This allows our customers the ability to start their hardware/software integration earlier than ever before. Today, Abaco has a very comprehensive portfolio of solutions designed to align to the SOSA standard. For example, we launched our IPN254, a multiprocessor solution aligned with the SOSA standard, which incorporates the latest Intel Xeon CPU with NVIDIA's Quadro RTX GPU and a Xilinx Zynq Ultrascale FPGA on a 3U Open VPX board which is aligned with the SOSA standard. Our roadmap includes over twenty products that are designed to align with the SOSA standard; twelve are currently scheduled for release in 2021.

JED

How do you want to position Abaco in the defense market going forward?

Rich Sorelle

Our vision is to be the leading supplier of ruggedized advanced 3U and 6U VPX boards and systems for system-level mission computing. Our portfolio provides end-to-end offerings for the entire sensor-to-shooter chain, which includes digital signal processing, graphics processing and networks. So, it's about interoperability and interchangeability in a full-up board sets to help speed our customer's system integration.

JED

How is Abaco addressing the demand for more AI/ML in EW, SIGINT and other defense electronics systems?

Rich Sorelle

We are seeing a huge interest, of course, in deploying AI and ML in EW and SIGINT systems to help identify and act upon novel waveforms without any human interaction. On the hardware front, we are deploying boards and systems based on the general purpose processors that are available

today – GPGPUs that the gaming community uses, FPGAs that are extremely large and that have the room and capability for different AI applications. We've been working with some partner companies to port their AI accelerated signal classifiers to our hardware, and that's been very beneficial. We can specialize in the hardware portion, which allows the freedom to our Tier 1 systems customers who have the significant domain knowledge in EW, as well as AI or machine learning algorithms, to be able to port their algorithms on to our hardware. That's really our strategy.

JED

Lastly, how do you recruit and develop the talent that you want at Abaco?

Rich Sorelle

We are always looking for top talent. Most of the young engineers that we bring in are paired up with one of our senior engineers at the outset, to serve as a mentors. We have also created a completely technical career path, which is not something that companies our size usually do. Not all scientists or engineers are interested in pursuing a management role, so our company offers two paths to our engineers. One is a management path, and one is a technical fellow or chief scientist role, which is equivalent to a VP in most companies.

We also have an early career technical talent intern and co-op program. We select students and, where possible, we keep the students beyond the traditional 12-month work-study process. More often than not, we offer them full-time employment well before their graduation. So that's how we get some of our new talent.

We are spending a lot of time and a lot of R&D on new products, and that is driving 20 to 30 new designs per year. This really attracts some of the best engineers because they like working on the latest technology that's available from our silicon partners, like Intel, NVIDIA and Xilinx. In our case, it is 6 to 18 months for design, and then they will move on to a new one, which is a really exciting pace for many of them. 

Army SOSA/CMOSS Stays Interoperable and Upgrades

By John Haystead

Since pretty much the beginning of the electronics revolution, all the military Services have struggled mightily to keep up with the pace of technology advancement and a constantly evolving enemy threat. Until recently, it has seemed to be largely an insurmountable task without an affordable solution in sight. Although open systems and open system architectures have long been touted as the only possibly successful approach, actual implementation of such pathways have been slow in coming. Today, that is changing, with the Army, in particular, charging ahead with a detailed and mandated new approach to designing, developing and fielding new and upgraded capabilities through open architectures.

The C5ISR/EW Modular Open Suite of Standards (CMOSS) is the Army's open system solution for embedded electronic system interoperability and reusability. Based on, and aligned with, the industry/government Sensor Open Systems Architecture (SOSA) consortium's open standards "to enable, enhance and accelerate the deployment of affordable, capable, interoperable sensor systems," CMOSS standards will be implemented in systems across the Army for all manner of applications.

CMOSS was started in 2013 by the Army's Combat Capabilities Development Command (DEVCOM) Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR) Center, formerly CERDEC. As emphasized by Ben Peddicord, Chief of the Intel Technology Architecture Branch of the C5ISR Intelligence and Information Warfare Directorate (I2WD), the first important point to note about CMOSS is that it's not a single standard but a suite of standards, covering everything from hardware form factors and interfaces for embedded computing, to cards and interfaces for RF resources, network connectivity, and all of the software frameworks that drive a host of new capabilities. As such, it incorporates a number of standards including the Vehicular Integration for C4ISR/EW Interoperability (VICTORY) standard, OpenVPX backplane standard and the Modular Open RF Architecture (MORA) standard, as well as a number of software

Colonel Finch says, "We're already seeing industry do some really interesting things with these 3U cards, for example placing multiple capabilities on the same card."

frameworks such as REDHAWK, the Software Communications Architecture (SCA), Photon, and the Future Airborne Capability Environment (FACE).

Jason Dirner, Architecture Team Leader in the Intel Technology Architecture Branch of C5ISR I2WD, is also a member of the SOSA Steering Committee. He adds that, the profiles being used in CMOSS are aligned with the profiles used in SOSA, as well as the profiles being used by the Navy as part of their Hardware Open System Technology (HOST) standard. The HOST standard development was launched by the Naval Air Systems Command (NAVAIR) in 2014, and is being used in the integrated core processor (ICP) of the F-35, as well as its panoramic cockpit display electronic unit (PCDEU). Says Peddicord, "We have had a strong partnership with the Navy since the start of the CMOSS effort. In fact, the Navy funded a lot of the initial S&T to develop these standards that we call CMOSS." The Navy, as well as the Air Force, is also represented on the SOSA steering committee. SOSA was actually initiated by the Air Force's Life Cycle Management Center (AFLCMC) (Wright-Patterson AFB, OH) in 2015. Says Dirner, "The goal has always been to get to the point where you can take the same board, whether a single-board computer or transceiver and use it across all three Services in order to get the reuse and economies of scale."

A SUITE OF STANDARDS

In terms of hardware, CMOSS is built upon the OpenVPX VITA 65 standards, as well as some of the other VITA standards for certain hardware interfaces. It supports both 3U and 6U form factors plugging into a common ruggedized chassis known as the CMOSS Mounted Form Factor (CMFF). Peddicord notes that the majority of users are focusing on the 3U format. CMOSS also includes infrastructure support and profiles for items such as power supplies, internet switches, and Precision Navigation and Timing (PNT). As described by Peddicord, "In terms of general purpose payloads, we have one preferred profile that is suitable for embedded computing, including things such as processors, DSPs and FPGAs, and one for RF transceiver cards. The same slot is able to support either application simultaneously. Another kind of general-purpose slot would be most commonly used for an I/O intensive single-board computer, which is particularly useful when you have a lot of legacy platform I/O that you need to interface to."

CMOSS also supports multiple software frameworks to provide reusability and portability of applications. This includes REDHAWK, which is a framework for Software Defined Radio (SDR) designed to support the development, deployment and management of real-time software radio applications that can

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be seamlessly deployed on a single computer or multiple network-enabled computers. The Software Communications Architecture (SCA) is an open architecture framework that defines a standard way for radios to instantiate, configure and manage waveform applications running on their platform and separating the waveform software from the underlying hardware platform.

The Future Airborne Capability Environment (FACE) is the open avionics standard for making military computing operations more robust, interoperable, portable and secure. Similarly, Photon is a common software framework already in use on some Army vehicles to provide portability of operations with use on many more platforms expected.

As stated by Peddicord, "We're not requiring a specific software framework for all applications. So, while we're making sure to provide explicit support and developing support for these portable reusable applications, we're also allowing for the use of other frameworks as necessary. Also, we have some important software-defined interfaces, particularly for RF devices that fall under MORA that provide standardized ways to access RF resources on a platform. Within SOSA, there's a working group dedicated to software interfaces, and we're participating in that – trying to evolve and grow and deepen support for software interfaces."

Besides hardware and software interoperability, another pillar of CMOSS and SOSA is network interoperability. Says Dirner, "With CMOSS, we've adopted the Vehicular Integration for C4ISR/EW Interoperability (VICTORY) standard that provides network-based interoperability using share services, such as Time and Position. That standardizes how services can be discovered, monitored, managed over a network, and how data such as PNT can be shared. MORA, which provides a standardized way to access and control RF resources, was developed as an extension to VICTORY for those network-based interfaces."

CMOSS MANAGEMENT

As explained by Peddicord, the Army worked with the Navy, Air Force and industry to establish SOSA for the long-term management and development of the standards that would be utilized within CMOSS and to make them sustainable over the long haul. "But, although we transitioned our standards and specifications from S&T development to the SOSA Consortium," he said, "we retained the CMOSS name, as it provides us the flexibility to meet and address Army program office requirements and timelines that a consortium cannot necessarily guarantee."

The specific CMOSS implementations of SOSA standards are managed by the CMOSS board of directors, which was estab-

lished last year. In addition to the DEVCOM C5ISR Center and Program Executive Office Electronic Warfare & Sensors (PEO IEW&S), the board includes senior leaders from: Program Executive Office Command, Control, Communications – Tactical (PEO C3T); PEO Ground Combat Systems (PEO GCS); PEO Soldier; PEO Combat Support and Combat Service Support (PEO CS&CSS); Network Cross Functional Team (N-CFT); Assured Positioning, Navigation and Timing/Space Cross Functional Team (APNT/S CFT); US Army Communications – Electronics Command (CECOM); and Army Test and Evaluation Command (ATEC).

Under the CMOSS BOD are two working-level Integrated Project Teams (IPTs) that execute strategy for the board and manage the CMOSS standards to ensure that the alignment between CMOSS and SOSA is maintained going forward.

Peddicord says there are multiple ways to evaluate and measure the progress of CMOSS acceptance and implementation, "but I would say, we have had for many years multiple demonstrations of capability implemented using CMOSS standards, and demonstrating real live interoperability on relevant applications within the environment. We also participate in events like the Tri-Service Open Architecture Integration Demonstration (TSOAID), where we show interoperability between standards-based implementations from all three Services."

Other metrics include the acceptance and release of standards by the standards bodies that govern them, such as VITA and VICTORY. Peddicord says, however, that he believes the most important metric is the participation and implementation by industry and their use of the standards without government funding. "This is what we're starting to see a lot of, with a rapidly growing catalogue and library of both hardware and software products which implement and offer the support for the standards. This makes it easy now for vendors and pro-

Says Jason Dirner, "The goal has always been to get to the point where you can take the same board, whether a single-board computer or transceiver and use it across all three Services in order to get the reuse and economies of scale."

gram offices to build solutions that are standards based. When you see vendors spending their own money, using their own IR&D and their own product development money, that is the strongest metric of successful progress."

CMOSS IMPLEMENTATION

In terms of the current state of CMOSS implementation in the Army, Peddicord observes there are a number of programs that have explicit requirements for CMOSS with a newly approved requirement for CMOSS Mounted Form Factor (CMFF) through a Futures Command Abbreviated Capabilities Development Document (ACDD). The system incorporates mission command, communications and PNT, as well as EW. Peddicord says an office of primary responsibility has not yet been assigned for it, but "there are a number of program offices that have to work together to make it work – PM Tactical Radio, PM I2S, PM PNT, and PM EW&C. We're currently working with all of them in planning for that implementation."

Perhaps not surprisingly, the Army's PM Electronic Warfare & Cyber (PM EW&C) within PEO IEW&S has taken a clear lead in the Army's CMOSS implementation initiative with currently four Programs Of Record (POR) requiring its use. As described by COL Kevin Finch, EW&C Project Manager, "If you go back and look at a lot of the EW and SIGINT systems that we've fielded over the years, you'll see that we ended up having an end-of-life projected way out into the future. At the same time, however, we were basically asking the vendors for a black box, so inevitably we ended up facing obsolescence or proprietary elements of

Ben Peddicord explains, "We also have a very wide swath of industry participation, including both prime contractors and COTS suppliers, represented within SOSA in developing and agreeing to the standards. They all have a voice, and we've essentially had unanimity in the selection of the standards and interfaces that we control."

the system that inhibited our ability to pace the threat. This framework, that we loosely refer to as CMOSS, is the key for us to be able to overcome this. It allows us to have a software backbone with hardware as a commodity. So, as technology improves, we can simply switch out those hardware elements." From his point of view, Colonel Finch says he doesn't view success as fielding a system able to meet today's requirements. "It's about being able to effectively upgrade these systems to meet the needs of those we will face 8-9 years from now and to provide seamless interoperability between systems."

Colonel Finch reiterates Ben Peddicord's point of emphasis that CMOSS is a suite of standards, and that there isn't necessarily one overall Army standard. "You may need different parts of SOSA/CMOSS standards depending on what you're doing," explained Colonel Finch. As such, PM EW&C's approach was to gather their engineers together to sort through all of the various standards available through CMOSS, and narrow them down to what is called the EW&C CMOSS standard. This in-

corporates the VICTORY, MORA, and 3U OpenVPX hardware elements of CMOSS, as well as software frameworks such as REDHAWK and Photon. PM EW&C signed a policy memorandum in 2019 that defined the EW&C CMOSS subset to achieve and ensure platform interoperability.

Colonel Finch describes EW&C CMOSS in terms of four main layers. The OpenVPX backplane layer of EW&C CMOSS defines only the use of the 3U form factor – dropping the 6U variant. Cards developed by third-party vendors according to the OpenVPX standard will be compatible with slots in the CMOSS chassis. But, depending on the application, backplane pinouts must also be correct and comply with a defined coaxial pin assignment for coherent operation across payloads (see **Figure 1**). Colonel Finch says "We're already seeing industry do some really interesting things with these 3U cards, for example placing multiple capabilities on the same card."

The MORA standard interfaces allow for low-latency sharing of resources and also allow for efficient handling of analog-to-digital conversion. As stated

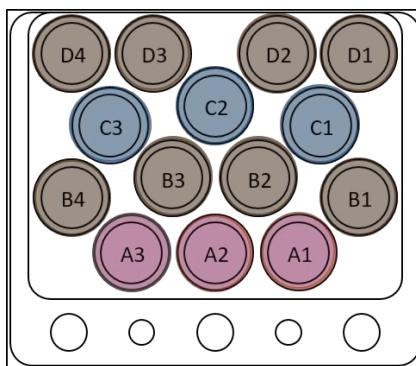


Fig. 1a: Payload 14 Position SMPM looking at front side of backplane

US ARMY

| Module Type | Channel 67.3C SMPM Designation | | | | | | | |
|------------------|--------------------------------|-----|-----|-----|-----|-----|-----|-----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 Channel Module | B1 | N/A |
| 2 Channel Module | B1 | B4 | N/A | N/A | N/A | N/A | N/A | N/A |
| 3 Channel Module | B1 | B4 | D1 | N/A | N/A | N/A | N/A | N/A |
| 4 Channel Module | B1 | B4 | D1 | D4 | N/A | N/A | N/A | N/A |
| 5 Channel Module | B1 | B4 | D1 | D4 | B2 | N/A | N/A | N/A |
| 6 Channel Module | B1 | B4 | D1 | D4 | B2 | B3 | N/A | N/A |
| 7 Channel Module | B1 | B4 | D1 | D4 | B2 | B3 | D2 | N/A |
| 8 Channel Module | B1 | B4 | D1 | D4 | B2 | B3 | D2 | D3 |

Fig. 1b: Six (6) User Defined pins (A1, A2, A3, C1, C2, C3) for coherent operation across payloads (e.g., local oscillator distribution)

US ARMY

in the EW&C CMOSS standard document, “MORA decomposes monolithic radio systems into high-level devices with well-defined functions and interfaces. Devices include Software Defined Radios (SDRs), RF Conditioning and Distribution (RDC) and Radioheads (RHDs). Signal resources, such as amplifiers, antennas, filters, switches, etc., as well as processing resources, must comply with defined MORA specifications.”

At the application layer level, the Photon software framework is currently being implemented or planned as the software backbone for the vast majority of EW and offensive cyber systems, particularly those performing a heavy level of signal processing.

Colonel Finch points to the communications layer as “the place where the magic really happens. There’s the VICTORY standard, which is really the vehicle plumbing piece and allows you to share PNT data. But, getting the data from Point A to Point B and being able to run on the tactical radio networks is critical to making sure that we have synchronization of capabilities on the battlefield through the Joint Capabilities Integration and Development System (JCIDS). At the Brigade or Division Tactical Operations Center (TOC), if you can’t effectively command and control your components on the battlefield and provide situational awareness in real time, you’re really missing what these capabilities are all about. The JCIDS 4.2 is a very important piece, and we also have a common data messaging format optimized for cyber/electronic warfare known as AppCEMA.”

FOUR PROGRAMS OF RECORD

Among the four PM-EW&C programs of record (PORs) currently implementing EW&C CMOSS is the Multi-Function Electronic Warfare-Air Large (MFEW-AL), which provides Brigade Combat Team (BCT) Commanders with an organic airborne offensive EW capability. Developed by Lockheed Martin, the single self-contained EW pod is mounted on a General Atomics MQ-1C Gray Eagle Unmanned Aircraft System (UAS). Based on a Software-Defined Radio (SDR)/Digital Radio Frequency Memory (DRFM) architecture, MFEW-AL processes both

“The big difference between having ‘a standard’ and a collaborative standard is having that open dialogue with industry. We’re not doing this in a vacuum. As commercial standards evolve, we can make the changes to the SOSA standard as well.”

– Colonel Finch

pre-programmed signal characteristic and real-time battlefield information.

Colonel Finch says, “Beginning in the fourth quarter of 2018, MFEW-AL was really the first program to implement the new standards with an actual CMOSS chassis out of the lab and operating in a relevant environment. Now we’re building Engineering Manufacturing Development (EMD) pods as we speak and look to go to test early in FY2022.”

TERRESTRIAL LAYER SYSTEM BRIGADE COMBAT TEAM (TLS-BCT)

The Terrestrial Layer System (TLS) is the Army’s next-generation tactical vehicle based system that delivers an integrated suite of signals intelligence, EW and offensive cyber capabilities for the Joint All Domain Operational (JADO) force. When fielded, TLS will be assigned to the Multi-functional Platoon and the EW Platoon organic to the Military Intelligence (MI) Company (MICO) in the Brigade Combat Team (BCT). As per the program description,

“It is intended to provide critical situational awareness of the enemy through detection, identification, location, exploitation, and disruption of enemy signals of interest.”

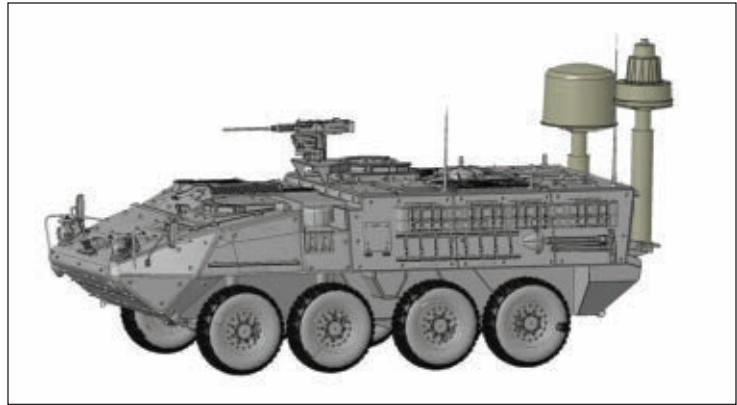
The TLS-BCT program was started in FY20, and according to Finch, is currently past CDR for the B-kit of which the CMOSS chassis is a part. “It will be going out to Ft. Huachuca (AZ) in the second quarter of this year to demonstrate capabilities.” A First Unit Equipped (FUE) date is planned for FY22. In September, the Army said it was developing a larger variant of the TLS for Division-level units. Known as TLS-Echelon Above Brigade (EAB), the Army wants to field this system by the end of 2023.

Tactical Cyber Equipment (TCE)

Tactical Cyber Equipment (TCE) is a portfolio of systems for the 915th Cyber Warfare Battalion (CWB) to deny, degrade, disrupt, destroy or manipulate threats in support of tactical Cyber-Electromagnetic Activities (CEMA) operations. The back-packable TCE provides



The MFEW-Air Large pod will give Army Brigade Combat Teams a much-needed airborne EW capability.
LOCKHEED MARTIN



The Terrestrial Layer System is currently in development with competing solutions from Lockheed Martin (left) and Boeing's DRT Inc. (right).

LOCKHEED MARTIN AND DRT

configurable spectrum survey and CEMA effects at the tactical edge through swapable capability cards integrated with EW&C CMOSS-compliant platforms, such as the TCE CMOSS Chassis (TCE-CC), MFEW-AL, and TLS. Says Colonel Finch, although the TCE is a man-portable system, operators will also be able to swap out their interoperable application cards with other CMOSS chassis aboard vehicles, such as the TLS, when greater power/range is needed. "We just had a Critical Design Review (CDR) and should

have some early prototypes of the chassis in the late summer."

The fourth POR is a classified CMOSS card to provide an offensive cyber capability. As observed by Colonel Finch, platforms such as the TLS must be able to integrate such capabilities. Being developed by CACI (Arlington, VA), Colonel Finch notes that "this effort, involving a third-party vendor, is an excellent example of the benefits of CMOSS. We didn't team these guys up, but their card will be able to utilize and integrate with the

standard OpenVPX backplane chassis. This is going to be a big milestone, really proving out CMOSS." At the time of our discussion with him in January, Colonel Finch expected to get a prototype of the card in February, with testing beginning in the fourth quarter of 2021.

BALANCING TRADEOFFS

Although CMOSS is clearly providing great benefits, I2WD's Peddicord points out that "standards and modular open systems don't come for free. By defini-



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tion, when you define and control interfaces, you constrain, to some extent at least, the solutions that are offered. We have certainly been aware of that and have been very successful in only defining interfaces that we have a really strong clear-government-use case for and where the cost-benefit ratio is good. Sometimes people have a misconception regarding how restrictive the standards actually are when, in fact, we've left the maximum amount of flexibility possible. We also have a very wide swath of industry participation, including both prime contractors and COTS suppliers, represented within SOSA in developing and agreeing to the standards. They all have a voice, and we've essentially had unanimity in the selection of the standards and interfaces that we control."

Adds Dirner, "While we're certainly extremely careful to not preclude systems from meeting operational requirements or stifling innovation within industry, it's also important to remember that one of the benefits of CMOSS, and something we constantly strive for, is not just providing an open architecture, but a common open architecture – common not only within the CMOSS ecosystem, but across the community and other complementary standards like SOSA and HOST. In order to get that commonality, you inherently have to start restricting options so that you have the ability to share and reuse capabilities across programs and Services. Ultimately, that's what is going to allow us as a community to be able to rapidly adapt to a new requirement or new threat, and to be able to hopefully leverage an existing capability, regardless of who developed it, and rapidly integrate it into a system to provide that capability to the soldier."

Colonel Finch agrees, pointing out that "The big difference between having 'a standard' and a collaborative standard is having that open dialogue with industry. We're not doing this in a vacuum. As commercial standards evolve, we can make the changes to the SOSA standard as well." Colonel Finch also notes that "by providing an open-standard environment, and not providing capabilities in a proprietary format, we're also lowering the entry barrier for smaller, third-party companies to participate."

Peddicord sums up his view of the benefits of CMOSS by recalling that, "Coming into the Army as an engineer, I saw lots of exciting technology solutions that could be brought to bear to improve our fighting capabilities and protect our soldiers, but I was very frustrated with the timeline for development and fielding. Sometimes, by the time it actually got there, it was no longer even relevant, leading to a lot of obsolete technology in the hands of soldiers.

"CMOSS and other modular open system approaches, if they are actu-

ally meaningfully done, if they are sufficiently clear and defined to provide the access we need, will enable us to much more rapidly update, upgrade, and incrementally change and adapt our solutions. Ultimately, it's really an important aspect of our ability to maintain parity with adversaries in a world where a lot of the most important technology is now commercially developed and where defense R&D budgets are not sufficient to allow us to be the leaders in many technologies." 



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DTA-100M50G-30-CD-1



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|--|-----------------------|---------------|------------------------|-----------------------|-----------------|----------------------------------|
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|--|-----------------------|------------------|--|----------|---|--|
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| PMI Model No. | Frequency Range (GHz) | Insertion Loss (dB Typ) | Isolation (dB Typ) | Switching Speed (Typ) | Power Supply | Configuration Size (Inches) Connectors |
|--|-----------------------|-------------------------|--------------------|-----------------------|----------------------------------|---|
| P2T-100M50G-100-T | 0.1 - 50 | | | 50 ns | +5 V @ 100 mA -5 V @ 100 mA | SP2T, Absorptive 1.0" x 0.75" x 0.4" 2.4mm (F) |
| P2T-100M52G-100-T | 0.1 - 52 | 6 | 100 | 50 ns | +5 V @ 100 mA -5 V @ 100 mA | |
| P2T-100M56G-100-T | 0.1 - 56 | | | | | |
| P4T-100M50G-100-T-RD | 0.1 - 50 | | | | +5 V @ 154 mA -5 V @ 135 mA | |
| P4T-100M52G-100-T-RD | 0.1 - 52 | 7 | 100 | 50 ns | +5 V @ 200 mA -5 V @ 200 mA | SP4T, Absorptive 1.25" x 1.25" x 0.4" 2.4mm (F) |
| P4T-100M53G-100-T-RD | 0.1 - 53 | | | | +5 V @ 200 mA -5 V @ 200 mA | |
| P8T-100M50G-90-T-RD | 0.1 - 50 | 9 | 90 | 50 ns | +5 V @ 400 mA -5 V @ 300 mA | SP8T, Absorptive 1.6" x 1.68" x 0.4" 2.4mm (F) |
| P8T-100M54G-90-T-RD | 0.1 - 54 | | | | | |
| P16T-100M50G-100-T-DEC | 0.1 - 50 | | | 100 ns | +5 V @ 700 mA -5 V @ 680 mA | SP16T, Absorptive 8.0" x 3.0" x 0.67" 2.4mm (F) |
| P16T-100M52G-100-T-DEC | 0.1 - 52 | 12.5 | 100 | | +5 V @ 1100 mA -12 V @ 720 mA | |



P8T-100M50G-90-T-RD



P8T-100M54G-90-T-RD



P16T-100M50G-100-T-DEC



P16T-100M52G-100-T-DEC

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MBDA is a missiles and missile systems world-class leader offering comprehensive product range, incorporating today's most advanced technologies and concepts - Exocet anti-ship missile, Marte, Scalp/Storm Shadow, SPEAR, MICA-NG, Meteor BVRAAM, CAMM, Aster anti-ballistic missile. MBDA France is also uniquely positioned to advise, develop and supply a range of countermeasures equipment capable of protecting aircraft and helicopter from air-to-air and surface-to-air threats. These equipment include both detection and decoy systems, DAS controllers and provide sensors fusion and threat assessment within Rafale SPECTRA DAS system. Our range of countermeasures comprises DDM-NG - DEDALE - ECLAIR M - ELIPS - SAPHIR M - SAPHIR 400 - Active decoy.

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Since 1995, MC Countermeasures Inc. (MCCM) has offered high quality products and services designed specifically for Radar EW applications. Applications range from lab-based development to EW training to operational deployment covering land, sea and air roles. Our hardware products are in service worldwide and include: noise and DRFM-based radar jammers, radar target generators (RTG), radar signal

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MDSI

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Meggitt Baltimore has over 50 years of experience specializing in design, development, and production of radomes and antennas for use in Electronic Warfare (EW), Communication, Navigation, and Identification (CNI) applications. The site is specialized in producing products for various military aircraft, land, UUV/shipboard platforms.

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Meggitt specializes in airborne pods, countermeasure deployment systems, radomes, air data systems, flight deck displays and life support systems for aircraft and helicopters.

Meggitt is known for battle-proven intelligent air data systems and compact

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Founded in 2011, Northeast Information Discovery Inc. (NEID) is a woman-owned engineering firm providing (R&D) services, building hardware and software systems for electronic warfare and offensive RF/cyberspace operations. Reach Dan Meyer at DMeyer@neidinc.com.

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PLATH GmbH is a German company specialising in military radio monitoring and radiolocation, active internationally and with headquarters in Hamburg.

The company specialises in communication intelligence for tactical (COMMS ESM) and strategic applications (COMINT). With its products and systems, and in association with various subsidiaries, PLATH GmbH covers the entire process chain for communication intelligence, from sensor systems to analysis and the evaluation of mass data.

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QuantiTech, Inc., founded in 1991, is a Defense and Space industry company headquartered in Huntsville, Alabama with 700+ employees. We deliver superior technical, program, and technology services and solutions to our Government and Commercial Customers in core capabilities: Systems Engineering & Integration; Logistics Engineering; Intelligence and Cybersecurity; Test & Evaluation; Safety & Facilities Engineering, and Business and Program Management. QuantiTech's leadership team has 30+ years of experience executing highly technical and complex programs, delivering on-time and within-budget Prime contract performance across our entire Customer base.

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RADA Technologies, LLC (RADA USA), a subsidiary of Israel-based RADA Electronic Industries Ltd, is a defense electronics company specializing in the production and sales of All-Threat, Air Surveillance radars. RADA USA was established in 2018 to serve the U.S. defense and aerospace markets.

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Research Associates of Syracuse (RAS), founded in 1986, is a small business in Rome, NY. RAS analyzes, models, develops, and tests software and firmware for Electronic Warfare (EW) subsystems, signal detection, measurement, identification, and direction-finding applications. Ongoing efforts include cognitive reasoning and machine learning applications of multi-agile emitters in contested and congested electromagnetic environments. We have in-depth experience in digital receivers, system equalization, intentional and unintentional modulation recognition, and specific emitter tracking (e.g. Combat

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Signal Hound designs and manufactures affordable, compact PC-connected RF spectrum analyzers. They achieved this milestone beginning with their first USB-powered spectrum analyzer in 2010. Since then, Signal Hound has regularly added free software upgrades and innovative new models, like their latest product, the SM200C – a 10 GbE-connected real-time spectrum analyzer and remote monitoring receiver well-suited for applications in cellular, military, aerospace, and TSCM. Comparable with RF analyzers up to 7x their cost, Signal Hound devices provide unrivaled value. All Signal Hound products are proudly designed and built in the USA.

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Space EW – Part 28

Electronic Protection of Satellite Links

By Dave Adamy

Satellite links are vulnerable to intercept, jamming and spoofing. Therefore, it is important to protect those links from hostile activity.

INTERCEPT

Intercepting a link means the data-link signal is received by someone other than the intended receiver. Sometimes the hostile receiver operator may just be interested in learning the signal “externals,” such as transmission frequency, modulation, emitter location, encryption approach, or timing issues. Collecting these signal externals is called electromagnetic support (ES – formerly called electronic warfare support).

However, sometimes the intention of the hostile receiver is to recover the “internals” of the signals – that is, the information they carry. Collecting these signal internals is called communications intelligence (COMINT).

Intercept can be prevented by the same techniques described below for protection against jamming. Also, encrypting the signals can prevent the recovery of signal internals.

SPOOFING

If false command signals are transmitted to a satellite and accepted as valid, they can cause the satellite or its payload to perform functions that compromise the proper operation of the system. In some cases, they can disable the satellite, change its orbit or end its mission. These vulnerabilities can be addressed via authentication measures or by the techniques described below to overcome jamming.

LINK JAMMING

Since satellite links are typically digital, jamming them can involve creating bit errors or preventing the link from syn-

chronizing. Links must carry their information in serial format, so it is necessary to synchronize the receiver with the transmitter in order to recover the information. If it is practical to prevent synchronization, jamming can be very efficient. However, the synchronization of all but a few commercial links can be expect-

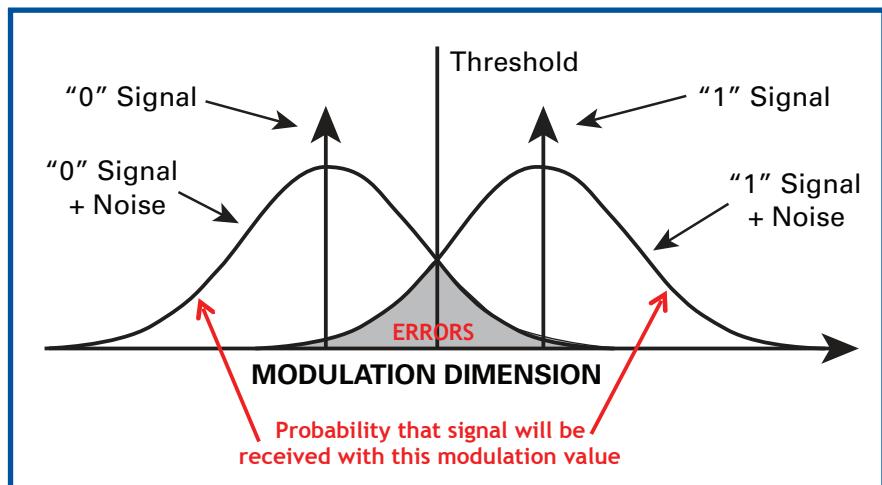


Fig. 1: Ones and zeros in digital signals are recovered by determining which side of a threshold they occur in the received signal. The signal + noise envelope is the probability that a one or zero will be received at that point in the modulation dimension. Bit errors occur when the noise takes the signal to the wrong side of the threshold.

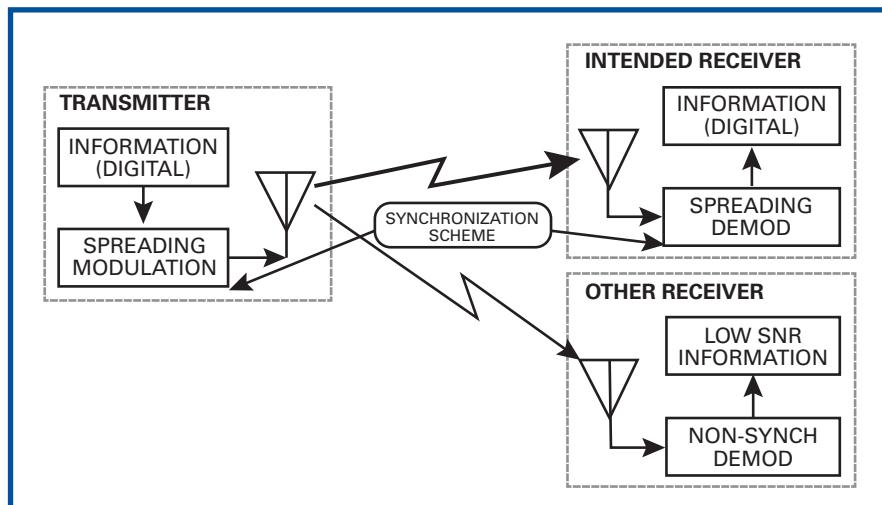


Fig. 2: Communication electronic protection prevents unauthorized receivers from receiving protected signals. There are several types of spreading modulation. The most common for satellite links are frequency hopping or direct-sequence spread spectrum.

ed to be very robust. Therefore, it is most practical to jam the link by causing it to generate large numbers of bit errors.

Digital bits cannot be directly transmitted; they must first be modulated onto radio frequency carriers with ones and zeros differentiated by frequency, amplitude or (most frequently) phase.

Bit errors are transmitted “ones” that are received as “zeros” or vice versa. There is a relationship between the pre-detection signal-to-noise ratio in the received signal and the percentage of bit errors that are output. This ratio depends on the modulation scheme used. The relationship between the modulation and bit errors is illustrated in **Figure 1**. As a general rule, if the bit-error rate is about 25%, communication cannot take place. This bit-error rate must be present in every syllable of voice communication or in every sub-frame of digital data. A generally used criteria for creation of enough bit errors to stop communication is that the pre-detection jamming to signal ratio (J/S) be at least unity (i.e., 0 dB).

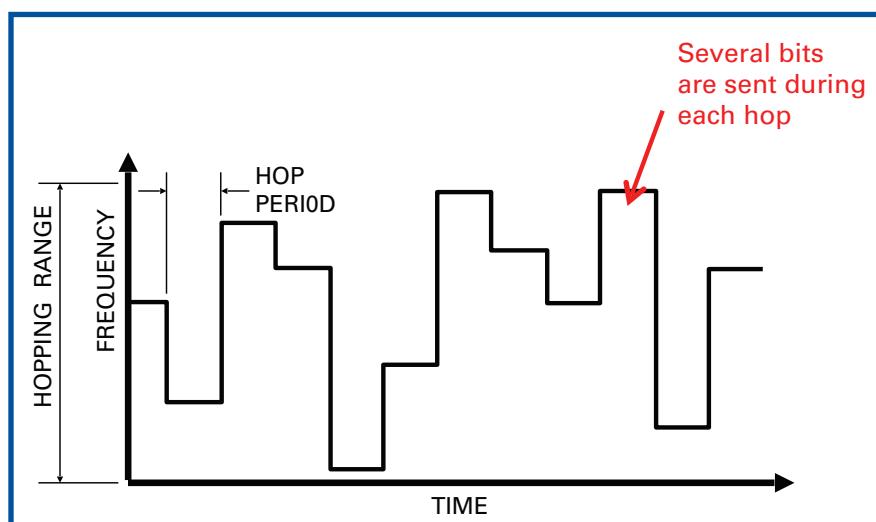


Fig. 3: A frequency-hopped signal changes frequency after several bits are sent.

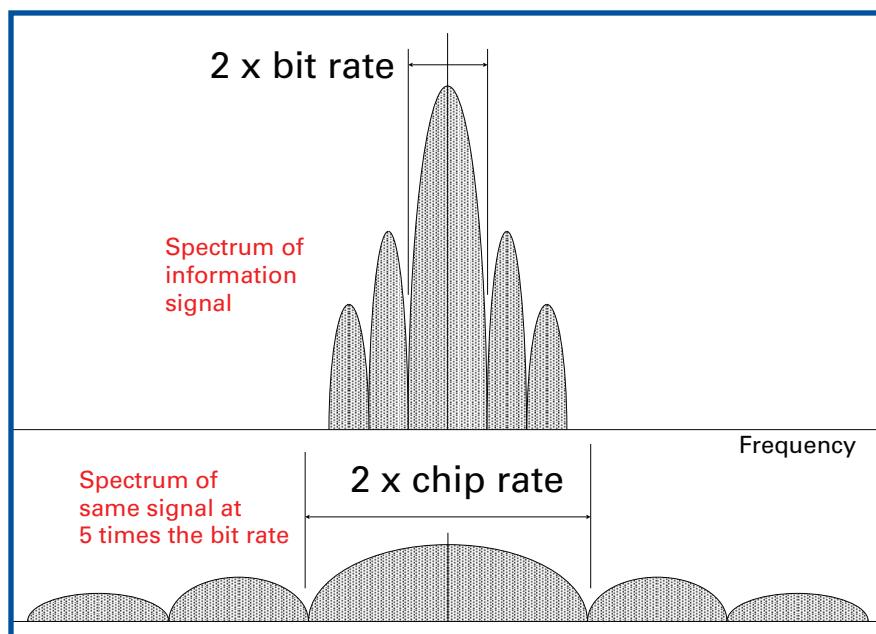


Fig. 4: Frequency spreading vs. bit rate. “Chips” are bits used to spread the signal; “bits” carry the information.

There are several ways to protect against the creation of bit errors by jamming; these include error correction codes, majority encoding and spectrum spreading. Error correction codes add extra bits to each block of digital data that allow the receiver to detect and correct the errors detected up to some maximum error percentage. Since these extra bits require greater signal bandwidth, they will make the receiver less sensitive and thus require stronger link signals. Majority encoding involves repeating data blocks several times and comparing the received blocks before selecting the block with the maximum correlation. This, again, requires extra signal bandwidth.

The most common way to protect satellite links is by spectrum spreading. This involves adding a secondary modulation to a digital signal so that it is transmitted over a wider bandwidth. When the spread signal is received by an authorized receiver, the spreading code is removed so the correct original modulation is processed. Unauthorized receivers will not be able to remove the spreading code as shown in **Figure 2**.

There are two common spreading approaches used in satellite links: Frequency Hopping (FH) and Direct Sequence Spread Spectrum (DSSS). Either or both can be used to protect links.

FREQUENCY HOPPING

As shown in **Figure 3**, FH involves changing frequency after each block of many bits. This is a very mature approach and is widely used. FH allows very wide frequency spreading. However, it is the easiest spreading scheme to defeat using modern software-driven techniques.

DIRECT SEQUENCE SPREAD SPECTRUM

DSSS involves applying a second digital modulation that has a significantly higher bit rate. As shown in **Figure 4**, the transmitted power is spread over a wider spectrum by the ratio of the increase in the modulation bit rate. This figure represents an under-exaggeration in that the spreading modulation is only five times as fast as the information carrying modulation. In general, the signal is spread by an order of a hundred or a thousand.

WHAT'S NEXT

Next month, we will start a new EW101 series focusing on the EW impact on 5G cellular signals for military applications. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.

IN MEMORY OF BRADLEY DAVID FARNSWORTH

**By Nicole K. Zaretski,
President,
AOC Garden State Chapter**



The Association of Old Crows Garden State Chapter is deeply saddened to announce the sudden passing of its beloved member, Bradley David Farnsworth, age 36, on January 29, 2021 following complications with a heart condition. He was the son of Brian D. Farnsworth of East Liverpool, Ohio and of Lyneah Breskvar Huff of Apollo Beach, Florida.

Bradley worked for CACI LGS Labs in Florham Park, NJ, was a brilliant engineer and a great human being. He was a very active member of the AOC and continually demonstrated his unwavering dedication to the EW community. He was selfless in all he did. Bradley volunteered to provide technical presentations at the AOC national and local levels. He was especially focused on the chapter's STEM outreach and scholarship programs. He always found time in an already full schedule to support the Jersey Shore Junior Science Symposium (JSJSS) as a judge, believing it is key to not just the AOC's mission but our nation's future. He also was a member of the chapter's scholarship committee and was committed to ensuring the AOC recognized and rewarded qualified

and deserving candidates at the university level.

Bradley was raised in East Liverpool, Ohio, the first 18 years of his life. He was also a member of the St. John Lutheran Church in East Liverpool. He was the valedictorian of his graduating class at East Liverpool High School. He moved to Cleveland, Ohio, for college at Case Western Reserve University, where he graduated with a bachelor's degree in electrical engineering and was valedictorian of his class. He was awarded the President's Award for being the outstanding graduating student. He also attended Case Western Reserve for his master's degree in electrical engineering, where he was valedictorian once again. Bradley was also a judge and mentor for the ION Mini Urban Challenge, which is a national competition in which high school students design robotic cars.

After graduation, Bradley settled in New Jersey for the last 5 years and has worked with several large corporations dealing with signal processing and telecommunications. He is the owner of 11 patents and is the author of 11 publications. At CACI LGS Labs, he was the director of the Technology Center in Wireless Solutions. Most recently, he was just appointed to the Board of Directors of ENSCO.

Bradley loved life and all the people he met along the way. He was a role model for all and lived his life with all his might in everything he did. A true scholar and a noble gentleman, Bradley will be sorely missed by all who were fortunate enough to meet him.

If you would like to join in making a lasting tribute to Bradley, the family has established the Bradley Farnsworth Fund for Undergraduate Research at Case School of Engineering. You can read more about Bradley's achievements and involvement with his alma mater at www.givecampus.com/bg8kya, where there is also a guide for supporting this fund in his memory.

AOC ACCEPTING SCHOLARSHIP APPLICATIONS

AOC Raytheon STEM Student of the Year Scholarship

Two \$12,500 scholarships will be awarded in May 2021 to one male and one female student studying in the fields of engineering or engineering technology and interested in working in the Aerospace and Defense Industry. These scholarships are funded by a generous \$25,000 donation from Raytheon Intelligence & Space. Scholarship applications are due by April 30, 2021. crows.org/scholarship program.

US Army Cyber Corps Warrant Officer Scholarship Program

The Cyber Corps Warrant Officer Scholarship was established by the Laurie Buckhout Foundation August 2020 under the AOC Education Foundation (AEF) and registered as a Non-Profit status under 501(c)(3) of the Internal Revenue Code. The Cyber Corps Warrant Officers Scholarship Foundation is a non-profit organization dedicated to providing support to US Army Cyber Corps (i.e., 170A, 170B, and 170D) warrant officers by providing them with financial assistance in gaining various levels of formal higher education. Awards range from \$1,500 to \$3,000. To qualify, applicants must be a CW3 or under, demonstrate excellent promotion potential, be in the Cyber Warfare or Electronic Warfare (EW) workforce (i.e., 170A, 170B, and 170D), have a minimum of two years left on active duty, and be eligible and accepted to attend a Masters or PhD program. Applications are due by March 31, 2021. crows.org/USA_WO_Scholarship.

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AOC Virtual Series has been a tremendous asset providing the AOC's audience with learning, advocacy, and the exchange of information. Register today to hear from subject-matter experts on all things EW!



Cyber Electromagnetic Activities and Signals Intelligence: a Command and Control framework
Presenter: Claudio Santo Malavenda



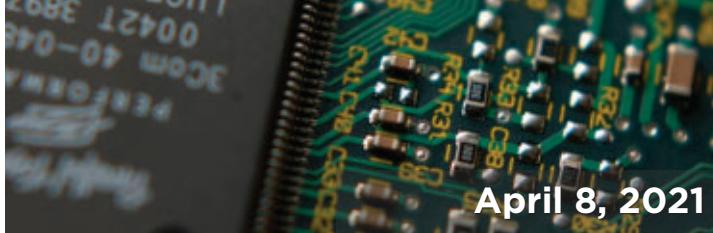
March 11, 2021

The Year in Review - GPS/PNT Disruptions and Improvements
Presenter: Dana Goward



March 25, 2021

Fast Switching Synthesizers for Emerging EW Systems
Presenter: Uri Yaniv



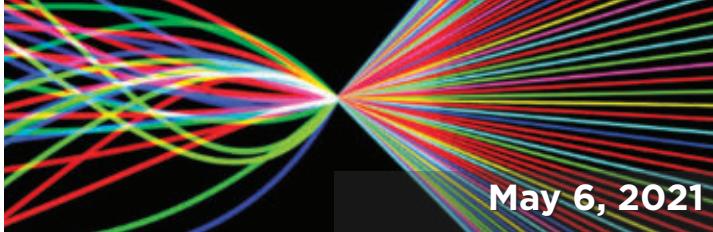
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Reticile Based Seekers
Presenter: Dr. Warren Du Plessis



April 22, 2021

AI Guided Spectrum Operations
Presenter: Nicholas Ortyl



May 6, 2021

5G for Non-Terrestrial Networks
Presenter: Reiner Stuhlfauth



May 20, 2021

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Presenter: Philip Gresock



May 27, 2021

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Associate Director, Engineering and Technical
Management Directorate, Robins Air Force
Sustainment Center



GUEST SPEAKER
Emily L. Jay,
Director of Contracting, Air Force
Sustainment Center, Robins AFB

SCHEDULE OF EVENTS

SUNDAY, MARCH 21

Registration
Hospitality Suite – Open Nightly

Best Western Plus Executive Residency, Warner Robins, Georgia
Best Western Plus Executive Residency, Warner Robins, Georgia

5:00 PM-8:00 PM
5:00 PM-8:00 PM

MONDAY, MARCH 22

Registration/Lunch
Spring Golf Tourney

Southern Landings Golf Course, Warner Robins, Georgia
Southern Landings Golf Course, Warner Robins, Georgia

11:30 AM-12:55 PM
1:00 PM Tee Time

TUESDAY, MARCH 23

Registration
Plenary Session/Keynote Speaker
Exhibits Open
Exhibitor Reception

Century of Flight Hangar, Museum of Aviation
Century of Flight Hangar, Museum of Aviation
Century of Flight Hangar, Museum of Aviation
Century of Flight Hangar, Museum of Aviation

7:30 AM-6:00 PM
8:00 AM-11:00 AM
10:00 AM-7:00 PM
5:00 PM-7:00 PM

WEDNESDAY, MARCH 24

Registration
Exhibits Open
Crows N.E.S.T.
Banquet

Century of Flight Hangar, Museum of Aviation
Century of Flight Hangar, Museum of Aviation
VIRTUAL EVENT
Nugteren Exhibit Hangar, Museum of Aviation

9:00 AM-2:00 PM
9:45 AM-3:00 PM

Cocktails – 5:30 PM-6:30 PM
Dinner – 6:30 PM-8:30 PM

**WELCOME TO DIXIE
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Our Symposium Committee, Dixie Crow Chapter President, Adam Delestowicz, and the Chapter Directors cordially invite you to join us for all the exciting events described here. Thank you in advance for your support of this important electronic warfare/information operations trade show.

Sincerely, Lisa Frugè-Cirilli, Chair | lisa.fruge@baesystems.com

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N.E.S.T.
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Already in progress: The Dixie Crow Chapter's approach to our 7th Annual Crows N.E.S.T. will be focused on providing monetary donations to surrounding schools to supplement the teacher's STEM classroom planning. (Unfortunately, there will be NO student STEM event during our Symposium as in years past.) However, we will still provide all participating schools' students with t-shirts displaying Industry logos and names of our Dixie Crow Chapter Education Foundation Donors! We greatly appreciate your support educating our "Leaders of Tomorrow!"

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Note from the EWA conference: "The Electronic Warfare and Avionics System program office (AFLCMC/WNY) is the sole sponsor of the EWA Technical Conference, which will be deferred to March 2022." Government sponsorship of the Dixie Crow Symposium 45 is not implied.



JED, Journal of Electromagnetic Dominance (ISSN 0192-429X), is published monthly by Naylor, LLC, for the Association of Old Crows, 1001 N. Fairfax St., Suite 300, Alexandria, VA 22314.

Periodicals postage paid at Alexandria, VA, and additional mailing offices. Subscriptions: *JED, Journal of Electromagnetic Dominance*, is sent to AOC members and subscribers only. Subscription rates for paid subscribers are \$160 per year in the US, \$240 per year elsewhere; single copies and back issues (if available) \$12 each in the US; \$25 elsewhere.

POSTMASTER:

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JED, Journal of Electromagnetic Dominance
c/o Association of Old Crows
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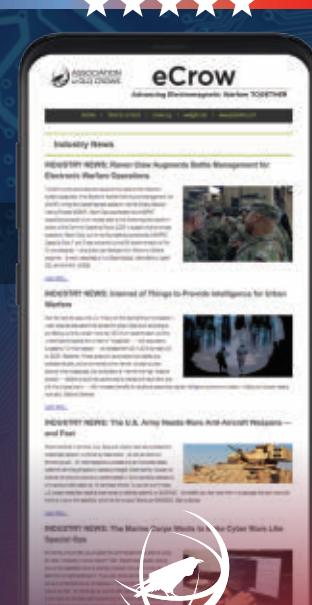
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OCTAVE BAND LOW NOISE AMPLIFIERS

| Model No. | Freq (GHz) | Gain (dB) | MIN | Noise Figure (dB) | Power-out @ P1-dB | 3rd Order ICP | VSWR |
|-------------|------------|-----------|---------|-------------------|-------------------|---------------|-------|
| CA01-2110 | 0.5-1.0 | 28 | 1.0 MAX | 0.7 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA12-2110 | 1.0-2.0 | 30 | 1.0 MAX | 0.7 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA24-2111 | 2.0-4.0 | 29 | 1.1 MAX | 0.95 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA48-2111 | 4.0-8.0 | 29 | 1.3 MAX | 1.0 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA812-3111 | 8.0-12.0 | 27 | 1.6 MAX | 1.4 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA1218-4111 | 12.0-18.0 | 25 | 1.9 MAX | 1.7 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA1826-2110 | 18.0-26.5 | 32 | 3.0 MAX | 2.5 TYP | +10 MIN | +20 dBm | 2.0:1 |

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

| Model No. | Freq (GHz) | Gain (dB) | MIN | Noise Figure (dB) | Power-out @ P1-dB | 3rd Order ICP | VSWR |
|-------------|--------------|-----------|---------|-------------------|-------------------|---------------|-------|
| CA01-2111 | 0.4 - 0.5 | 28 | 0.6 MAX | 0.4 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA01-2113 | 0.8 - 1.0 | 28 | 0.6 MAX | 0.4 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA12-3117 | 1.2 - 1.6 | 25 | 0.6 MAX | 0.4 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA23-3111 | 2.2 - 2.4 | 30 | 0.6 MAX | 0.45 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA23-3116 | 2.7 - 2.9 | 29 | 0.7 MAX | 0.5 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA34-2110 | 3.7 - 4.2 | 28 | 1.0 MAX | 0.5 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA56-3110 | 5.4 - 5.9 | 40 | 1.0 MAX | 0.5 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA78-4110 | 7.25 - 7.75 | 32 | 1.2 MAX | 1.0 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA910-3110 | 9.0 - 10.6 | 25 | 1.4 MAX | 1.2 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA1315-3110 | 13.75 - 15.4 | 25 | 1.6 MAX | 1.4 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA12-3114 | 1.35 - 1.85 | 30 | 4.0 MAX | 3.0 TYP | +33 MIN | +41 dBm | 2.0:1 |
| CA34-6116 | 3.1 - 3.5 | 40 | 4.5 MAX | 3.5 TYP | +35 MIN | +43 dBm | 2.0:1 |
| CA56-6114 | 5.9 - 6.4 | 30 | 5.0 MAX | 4.0 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA812-6115 | 8.0 - 12.0 | 30 | 4.5 MAX | 3.5 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA812-6116 | 8.0 - 12.0 | 30 | 5.0 MAX | 4.0 TYP | +33 MIN | +41 dBm | 2.0:1 |
| CA1213-7110 | 12.2 - 13.25 | 28 | 6.0 MAX | 5.5 TYP | +33 MIN | +42 dBm | 2.0:1 |
| CA1415-7110 | 14.0 - 15.0 | 30 | 5.0 MAX | 4.0 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA1722-4110 | 17.0 - 22.0 | 25 | 3.5 MAX | 2.8 TYP | +21 MIN | +31 dBm | 2.0:1 |

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

| Model No. | Freq (GHz) | Gain (dB) | MIN | Noise Figure (dB) | Power-out @ P1-dB | 3rd Order ICP | VSWR |
|-------------|------------|-----------|---------|-------------------|-------------------|---------------|-------|
| CA0102-3111 | 0.1-2.0 | 28 | 1.6 Max | 1.2 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA0106-3111 | 0.1-6.0 | 28 | 1.9 Max | 1.5 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA0108-3110 | 0.1-8.0 | 26 | 2.2 Max | 1.8 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA0108-4112 | 0.1-8.0 | 32 | 3.0 MAX | 1.8 TYP | +22 MIN | +32 dBm | 2.0:1 |
| CA02-3112 | 0.5-2.0 | 36 | 4.5 MAX | 2.5 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA26-3110 | 2.0-6.0 | 26 | 2.0 MAX | 1.5 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA26-4114 | 2.0-6.0 | 22 | 5.0 MAX | 3.5 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA618-4112 | 6.0-18.0 | 25 | 5.0 MAX | 3.5 TYP | +23 MIN | +33 dBm | 2.0:1 |
| CA618-6114 | 6.0-18.0 | 35 | 5.0 MAX | 3.5 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA218-4116 | 2.0-18.0 | 30 | 3.5 MAX | 2.8 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA218-4110 | 2.0-18.0 | 30 | 5.0 MAX | 3.5 TYP | +20 MIN | +30 dBm | 2.0:1 |
| CA218-4112 | 2.0-18.0 | 29 | 5.0 MAX | 3.5 TYP | +24 MIN | +34 dBm | 2.0:1 |

LIMITING AMPLIFIERS

| Model No. | Freq (GHz) | Input Dynamic Range | Output Power Range Psat | Power Flatness dB | VSWR |
|-------------|------------|---------------------|-------------------------|-------------------|-------|
| CLA24-4001 | 2.0 - 4.0 | -28 to +10 dBm | +7 to +11 dBm | +/- 1.5 MAX | 2.0:1 |
| CLA26-8001 | 2.0 - 6.0 | -50 to +20 dBm | +14 to +18 dBm | +/- 1.5 MAX | 2.0:1 |
| CLA12-5001 | 7.0 - 12.4 | -21 to +10 dBm | +14 to +19 dBm | +/- 1.5 MAX | 2.0:1 |
| CLA618-1201 | 6.0 - 18.0 | -50 to +20 dBm | +14 to +19 dBm | +/- 1.5 MAX | 2.0:1 |

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

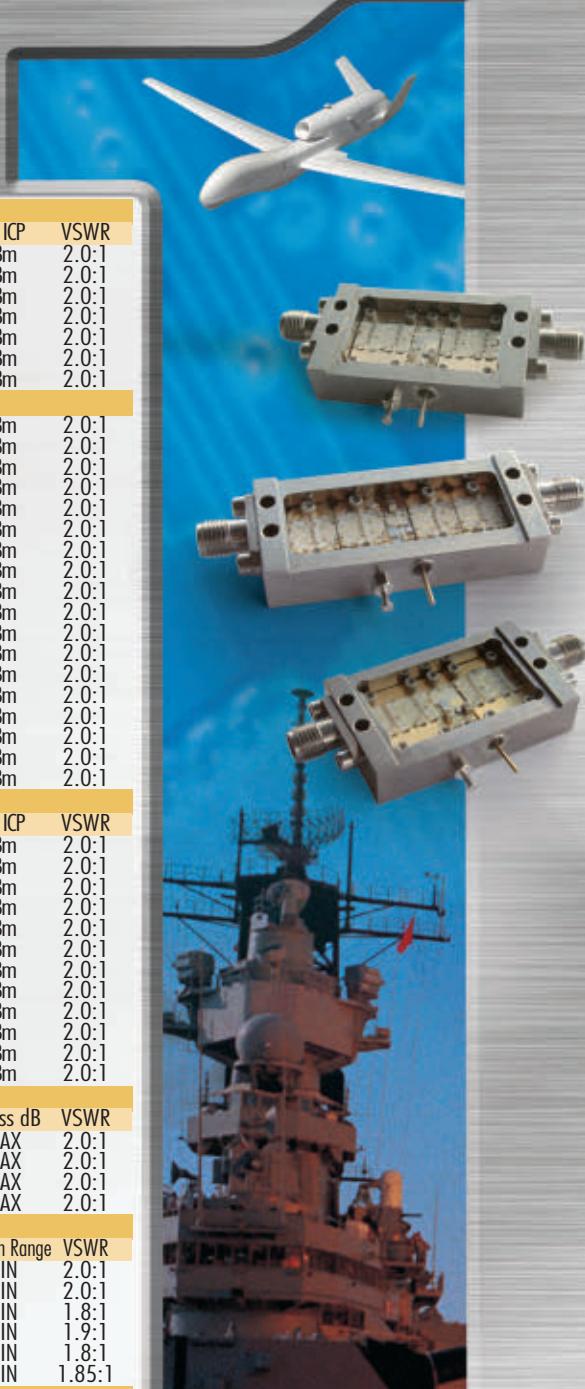
| Model No. | Freq (GHz) | Gain (dB) | MIN | Noise Figure (dB) | Power-out @ P1-dB | Gain Attenuation Range | VSWR |
|--------------|-------------|-----------|---------|-------------------|-------------------|------------------------|--------|
| CA001-2511A | 0.025-0.150 | 21 | 5.0 MAX | 3.5 TYP | +12 MIN | 30 dB MIN | 2.0:1 |
| CA05-3110A | 0.5-5.5 | 23 | 2.5 MAX | 1.5 TYP | +18 MIN | 20 dB MIN | 2.0:1 |
| CA56-3110A | 5.85-6.425 | 28 | 2.5 MAX | 1.5 TYP | +16 MIN | 22 dB MIN | 1.8:1 |
| CA612-4110A | 6.0-12.0 | 24 | 2.5 MAX | 1.5 TYP | +12 MIN | 15 dB MIN | 1.9:1 |
| CA1315-4110A | 13.75-15.4 | 25 | 2.2 MAX | 1.6 TYP | +16 MIN | 20 dB MIN | 1.8:1 |
| CA1518-4110A | 15.0-18.0 | 30 | 3.0 MAX | 2.0 TYP | +18 MIN | 20 dB MIN | 1.85:1 |

LOW FREQUENCY AMPLIFIERS

| Model No. | Freq (GHz) | Gain (dB) | MIN | Noise Figure dB | Power-out @ P1-dB | 3rd Order ICP | VSWR |
|------------|------------|-----------|---------|-----------------|-------------------|---------------|-------|
| CA001-2110 | 0.01-0.10 | 18 | 4.0 MAX | 2.2 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA001-2211 | 0.04-0.15 | 24 | 3.5 MAX | 2.2 TYP | +13 MIN | +23 dBm | 2.0:1 |
| CA001-2215 | 0.04-0.15 | 23 | 4.0 MAX | 2.2 TYP | +23 MIN | +33 dBm | 2.0:1 |
| CA001-3113 | 0.01-1.0 | 28 | 4.0 MAX | 2.8 TYP | +17 MIN | +27 dBm | 2.0:1 |
| CA002-3114 | 0.01-2.0 | 27 | 4.0 MAX | 2.8 TYP | +20 MIN | +30 dBm | 2.0:1 |
| CA003-3116 | 0.01-3.0 | 18 | 4.0 MAX | 2.8 TYP | +25 MIN | +35 dBm | 2.0:1 |
| CA004-3112 | 0.01-4.0 | 32 | 4.0 MAX | 2.8 TYP | +15 MIN | +25 dBm | 2.0:1 |

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