July 2021 Vol. 44, No. 7

JED

Journal of Electromagnetic Dominance

Training for the AEA Mission

- Technology Survey: COMINT and Comms ESM Receivers
- News: US Army Focuses on Next Level of EW
- EW 101: 5G Modulation

A Quantic Company

- Amplifiers - Solid State
- Attenuators - Variable/ Programmable
- Bi-Phase Modulators
- Couplers (Quadrature, 180, Directional)
- Detectors - RF / Microwave
- Filters & Switched Filter Banks
- Form, Fit, Functional Products & Services
- Frequency Converters
- Frequency Sources
- Frequency Discriminators & IFM
- Frequency Synthesizers
- Gain & Loss Equalizers
- Integrated MIC/MMIC Assemblies (IMAs)
- IQ Vector Modulators
- Limiters - RF / Microwave
- Log Amps
- Miscellaneous Products
- Monopulse Comparators
- Multifunction Integrated Assemblies (IMAs)
- Phase Shifters & Bi-Phase Modulators
- Power Dividers/Combiners (Passive & Active)
- Pulse Modulators - SPST
- Rack & Chassis Mount Products
- Receiver Front Ends & Transceivers
- Single Side Band Modulators
- SMT & QFN Products
- Switch Matrices
- Switch Filter Banks
- Switches - Solid-State
- Systems - Radar Sense & Avoid
- Systems - Fly Eye Radar
- Threshold Detectors
- USB Products

Planar Monolithics Industries

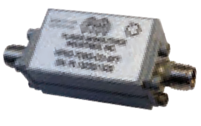
Broadband High-Pass Filters up to 40 GHz

PMI offers the highest quality Broadband High-Pass Filters for commercial, industrial and military applications up to 40 GHz. Features include low passband insertion loss, small package size, and rugged construction. While there are many standard models to select from, PMI can design and build to your specifications. More available at: https://www.pmi-rf.com/categories/high-pass-filters

HP0R3G-18G-CD-SFF
HP0R5G-18G-CD-SFF
HP-118-CD-SFF

HP2G-1780-CD-SS

HP2G-1780-CD-SS-OPT2200



HP8G-7D8G-CD-SFF

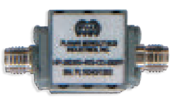
PMI Model No.	Passband (GHz)	Passband Insertion Loss	Rejection	Configuration Size (Inches) Connectors
HP0R3G-18G-CD-SFF https://www.pmi-rf.com/product-details/hp0r3g-18g-cd-sff	0.3 - 18	2.0 dB Typ	45 dB Typ @ 0.01 GHz	1.00" x 0.71" x 0.32" SMA (F) Removable
HP0R5G-18G-CD-SFF https://www.pmi-rf.com/product-details/hp0r5g-18g-cd-sff	0.5 - 18	0.5 GHz: 5 dB Max 1-16 GHz: 2 dB Max 18-16 GHz: 3 dB Max	40 dB Min @ 0.3 GHz	1.00" x 0.71" x 0.32" SMA (F) Removable
HP-118-CD-SFF https://www.pmi-rf.com/product-details/hp-118-cd-sff	1 - 18	1 GHz: 4 dB Max 2-18 GHz: 2 dB Max	60 dB Min @ 0.5 GHz	1.00" x 0.71" x 0.32" SMA (F) Removable
HP2G-1780-CD-SS https://www.pmi-rf.com/product-details/hp2g-1780-cd-ss	2 - 18	0.5 dB Typ	80 dBc @ 0.87 GHz	0.75" x 0.75" x 0.50" SMA (F) Removable
HP2G-1780-CD-SS-OPT2200 https://www.pmi-rf.com/product-details/hp2g-1780-cd-ss-opt2200	2.5 - 18	0.5 dB Typ 1 dB Max	80 dB Min @ 0.87 GHz 30 dB Min @ 1.7 GHz	0.75" x 0.75" x 0.50" SMA (F)
HPF-4G18G-CD-SFF https://www.pmi-rf.com/product-details/hpf-4g18g-cd-sff	6 - 18	1.5 dB Max	60 dB 1 - 2 GHz	1.43" x 0.79" x 0.50" SMA (F)
HP8G-7D8G-CD-SFF https://www.pmi-rf.com/product-details/hp8g-7d8g-cd-sff	8 - 22	1.5 dB Max	35 dB Typ @ 7.5 GHz, 50 dB Min @ 5.6 GHz	1.15" x 0.70" x 0.50" SMA (F)
HP10G-9D7-CD-292FF https://www.pmi-rf.com/product-details/hp10g-9d7-cd-292ff	10 - 27	1.5 dB Max	40 dBc @ 7 GHz	0.65" x 0.65" x 0.50" 2.92mm (F)
HPF18G-DC15G https://www.pmi-rf.com/product-details/hpf18g-dc15g	18 - 26.5	1.5 dB Max	60 dB DC - 15 GHz	0.64" x 0.58" x 0.38" 2.92mm (F)
HP20G-19D5G-CD-292FF https://www.pmi-rf.com/product-details/hp20g-19d5g-cd-292ff	20 - 40	1.5 dB Max	54 dBc @ 14.5 GHz	0.614" x 0.50" x 0.56" 2.92mm (F)
HP-26D5G-40G-CD-292FF https://www.pmi-rf.com/product-details/hp-26d5g-40g-cd-292ff	26.5 - 40	2.0 dB Max	54 dBc Min @ 20 GHz	0.65" x 0.65" x 0.50" 2.92mm (F)

HPF-4G18G-CD-SFF

HP10G-9D7-CD-292FF

HPF18G-DC15G

HP20G-19D5G-CD-292FF



HP-26D5G-40G-CD-292FF

West Coast Operation:
4921 Robert J. Mathews Pkwy, Suite 1
El Dorado Hills, CA 95762 USA
Tel: 916-542-1401, Fax: 916-265-2597

East Coast Operation:
7311-F Grove Road
Frederick, MD 21704 USA
Tel: 301-662-5019, Fax: 301-662-1731

sales@pmi-rf.com • www.pmi-rf.com

ISO9001-2015 REGISTERED

Ultra Specialist RF has delivered **proven solutions** for the most demanding RF applications worldwide **for decades.**

The reason our customers trust us is **simple.**

Our solutions are developed with a **relentless** focus on **innovation, quality and performance.**

When the **mission depends on it**, select Ultra Specialist RF.

Explore our portfolio of solutions at **ultra.group/intelligence-communications**

Missile Flight Instrumentation | Radio Frequency Microwave | Electronic Warfare (EW) test systems | Tactical Radio Frequency

ULTRA

Intelligence & Communications
ultra.group

Ultra Herley and Ultra EWST have combined to form Ultra Specialist RF.

JED
Journal of Electromagnetic Dominance

CONTENTS

July 2021 • Volume 44, Issue 7

18 Cover Story

Learning to Growl – Training for the AEA Mission
By John Haystead

Developing and sustaining the EA-18G is a challenge, but the biggest investment is training the people who fly it and fight with it. US NAVY

14 News

- US ARMY FOCUSES ON NEXT LEVEL OF ELECTRONIC WARFARE
- UK OUTLINES PLANS FOR ARDENT WOLF MARITIME CESM
- CONGRESS PUSHING DOD TO PRIORITIZE EMS SUPERIORITY
- US ARMY ANNOUNCES PLANS FOR CYBERQUEST 2022
- HUNGARIAN ARMY ORDERS STRIKESHIELD APS FOR LYNX IFVS

Features

25 Technology Survey: COMINT and Communications ESM Receivers
By Barry Manz

The USAFE-AFAFRICA Warfare Center Detachment 3, Polygone, became the 19th Electronic Warfare Squadron May 11. US Air Force Lt Col Jesse Palchick, 19th Electronic Warfare Squadron commander (holding flag on right), assumed command of the new squadron. The squadron activation process has been in development since 2019, and was initiated to provide more resources as the organization grows. Last month, the 19th EWS supported Exercise Arctic Challenge 21 alongside Norway, Germany and Sweden.
SENIOR AIRMAN TAYLOR D. SLATER, US AIR FORCE

Departments

6 The View from Here
8 Conferences and Courses Calendar
12 President's Message
42 EW 101
46 AOC News
48 AOC Industry and Institute/University Members
49 Index of Advertisers
50 *JED* QuickLook

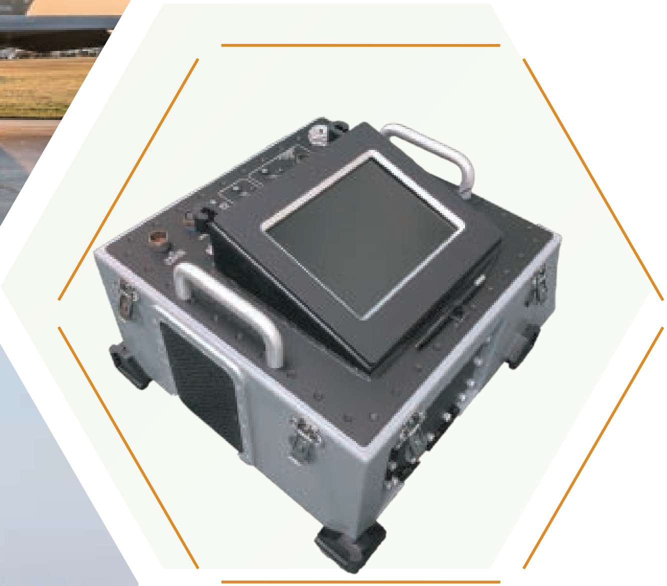
COVER PHOTO COURTESY OF US NAVY

RAPID, REPEATABLE CABLE TESTING

RADIO FREQUENCY CABLE TESTER

- Measurements
  - Insertion Loss (IL)
  - Voltage Standing Wave Radio (VSWR)
  - Distance to Fault (DTF)
  - Phase Matching
- Ruggedized, portable analysis tool
- Verifies performance of installed cables

ORDERED FOR THE F-35



TEXTRON Systems

TextronSystems.com

TRAINING FOR TOMORROW

This month, *JED* is looking at how the Navy trains its EA-18G air crews for the airborne electronic attack (AEA) mission. Our cover story, written by John Haystead, complements an earlier *JED* piece John wrote about the US Navy's AEA Weapons School, known as HAVOC. (See "US Navy's HAVOC Hones AEA Expertise," January 2021, p. 18.) While the HAVOC article looked at the top tier of AEA training (i.e., train the trainer), this month's article takes a wider view of how the Navy develops and trains its Growler crews. I hope you enjoy this story as much as I did. *JED* is going to focus a lot more on Electromagnetic Spectrum Operations (EMSO) training in the coming years because this is going to be one of the most dynamic areas for the US and many other countries over the next decade.

Training, including EW training, hasn't really changed very much since the Cold War. We educate and train a weapons system operator; we then assign that operator to a unit that trains them on specific pieces of equipment and to work as part of a unit; and then we occasionally gather some of these units to train in a large Joint or coalition exercise somewhere.

Over the last decade, however, our EW concepts have evolved to become part of EMSO; the technologies we use to conduct EW and EMSO are changing; and the way EMSO connects other systems and operators in the battlespace is also rapidly changing. At the same time, the need to understand EMSO is spreading to just about every soldier, airman, sailor and Marine. There's just no way our traditional approach to EW training is going to work in this environment.

Back in the 1990s, the DOD was focused on eliminating the Cold War-era intelligence system stovepipes so that commanders could make faster and better decisions. The goal was for a mission commander to see various sources of intelligence in real-time, such as SIGINT from a Guardrail System and the radar feeds (SAR and MTI) from a Joint Stars, as well as the EO/IR sensor data coming in from an Airborne Reconnaissance Low and the HUMINT coming in from units on the ground. While the DOD did manage to begin the process of eliminating its intelligence stovepipes, the intelligence collectors and analysts (as well as the mission commanders) were becoming overwhelmed with intelligence, because they had never trained for so much information coming in so quickly from so many different sources. The Army's response to this problem was to develop the Intelligence and Electronic Warfare Tactical Proficiency Trainer (IEWTPT), which it still uses today.

Today, we are exploring Artificial Intelligence (AI) and Machine Learning (ML) to see how these technologies can help EMS operators make quicker and better decisions – not necessarily "in the loop" so much as "on the loop." Whether it is in the cockpit of an EA-18G or an Electromagnetic Battle Management (EMBM) system operating across a vast battlespace, technology will help, but only as much as we humans are trained (in new ways) to use and exploit it. – *J. Knowles*

JED

Journal of Electromagnetic Dominance

EDITORIAL STAFF
Editor: John Knowles
Publisher: John Bacon
Senior Editor: John Haystead
Managing Editor: Hope Swedeen
Technical Editor: Barry Manz
Threat Systems Editor: Doug Richardson
Contributing Writers:
Dave Adamy, Luca Peruzzi, Richard Scott, Dr. David Stoudt, and Andrew White
Proofreaders: Ken Janssens, Shauna Keedian
Sales Manager: Tabitha Jenkins
Sales Adminstrator: Amanda Glass

PRODUCTION STAFF
Layout & Design: Barry Senyk
Advertising Art: Elaine Connell
Contact the Editor: (978) 509-1450, JEDeditor@naylor.com
Contact the Sales Manager:
(800) 369-6220 or tjenkins@naylor.com
Subscription Information:
Please contact Glorianne O'Neilin at (703) 549-1600 or e-mail oneilin@crows.org.

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

COVER PHOTO COURTESY OF US NAVY
PUBLISHED JUNE 2021/JED-M0721/2538

JULY

Principles of Modern Radar
July 12-16
Las Vegas, NV
www.pe.gatech.edu

AOC Professional Development Live Web Course: Aircraft RCS Engineering – Historical Perspective, Basic Principles, and Stealth Technology
July 12-30
www.crows.org

Signals Intelligence (SIGINT) Fundamentals
July 13-14
Las Vegas, NV
www.pe.gatech.edu

Farnborough Air Show Connect 2021 Virtual Conference: July 13-15
www.farnboroughairshow.com

Radar Warning Receiver System Design and Analysis
July 13-15
Atlanta, GA
www.pe.gatech.edu

AOC Virtual Series Webinar: Introduction to Satellite Communications (SATCOM)
July 15
1400-1500 EST
www.crows.org

AUVSI Unmanned Systems Defense Phase II Virtual Conference: July 27-29
www.auvsi.org

Basic RF Electronic Warfare Concepts
July 27-29
Las Vegas, NV
www.pe.gatech.edu

AOC Virtual Series Webinar: Electromagnetic Pulse (EMP): Science, Strategy, Politics
July 29
1400-1500 EST
www.crows.org

AUGUST

Navy League Sea-Air-Space Conference: August 1-4
National Harbor, MD
www.seaairspace.org

AOC Professional Development Live Web Course: Direct Energy Weapons
August 2-18
www.crows.org

AOC Virtual Series Webinar: Quick Searches for Emitters in an RWR
August 5
1400-1500 EST
www.crows.org

AOC Virtual Series Webinar: Standards and Applications in Defense Video
August 12
1400-1500 EST
www.crows.org

Directed Infrared Countermeasures: Technology, Modeling, and Testing
August 17-19
Atlanta, GA
www.pe.gatech.edu

Radar Cross Section Reduction
August 23-25
Atlanta, GA
www.pe.gatech.edu

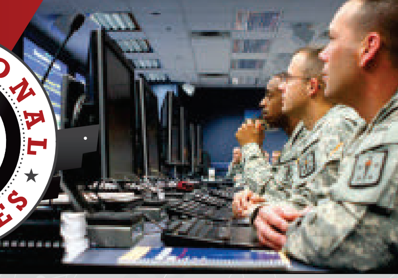
36th Space Symposium Conference: August 23-26
Colorado Springs, CO
www.spacesymposium.org

Electronic Warfare Data Analysis – Online
August 23-26
www.pe.gatech.edu

AOC Virtual Series Webinar: Introduction to Digital Signal Processing for Electronic Warfare
August 26
1400-1500 EST
www.crows.org

continued on page 10

FEATURED LIVE COURSES



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.

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.

Introduction to Satellite Communications (Satcom)

Dr. Patrick Ford

Mondays, Wednesdays & Fridays

1:00 – 5:00 PM ET | December 6 – 10, 2021

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

= Web Course, no travel required!

58th AOC INTERNATIONAL SYMPOSIUM & CONVENTION

WASHINGTON D.C.

Fundamental Principles of Electronic Warfare

Dave Adamy

Friday & Saturday

08:00 AM – 5:00 PM EST | December 3 – 4, 2021

Machine Learning for Electronic Warfare

Kyle Davidson

Friday & Saturday

08:00 AM – 5:00 PM EST | December 3 – 4, 2021

FOR COURSE LISTINGS AND MORE VISIT **CROWS.ORG**

Calendar *Conferences & Courses* *cont'd.*

Counter UAS Summit 2021 Virtual Conference:
August 30 - September 2
www.idga.org

Modeling and Simulation of Phased-Array Antennas – Online
August 31 – September 2
www.pe.gatech.edu

SEPTEMBER

MSPO 2021
Conference: September 7-10
Kielce, Poland
www.targikielce.pl

AOC Virtual Series Webinar: Radar Ambiguities
September 9
1400-1500 EST
www.crows.org

Test and Evaluation of RF Systems – Online
September 14-16
www.pe.gatech.edu

DSEI
Conference: September 14-17
London, UK
www.dsei.co.uk

AOC Virtual Series Webinar: US Loses First Global Space War to Russians
September 16
1400-1500 EST
www.crows.org

AFA 2021 Air, Space and Cyberspace Conference: September 20-22
National Harbor, MD
www.afa.org

Modern Day Marine Conference: September 21-23
Quantico, VA
www.marinemilitaryexpos.com

Infrared Technology and Applications – Open Access
September 21-24
Atlanta, GA
www.pe.gatech.edu

AOC Virtual Series Webinar: Bandits at Three O'Clock! The RAF's Chain Home Radar and British Strategic Success
September 23
1400-1500 EST
www.crows.org

2021 EW Live
Conference: September 28-30
Tartu, Estonia
www.electronic-warfare-live.com

OCTOBER

AOC Virtual Series Webinar: 5G for Critical Communications
October 7
1400-1500 EST
www.crows.org

Airborne EW System Integration
October 19-21
Atlanta, GA
www.pe.gatech.edu

Electromagnetic Materials and Measurements: RAM, Radome, & RAS
October 19-21
Atlanta, GA
www.pe.gatech.edu

Precision Strike Technology Symposium (PSTS-21)
Conference: October 19-21
Laurel, MD
www.ndia.org

Seoul ADEX 2021
Conference: October 19-24
Seoul, ROK
www.seouladex.com

AOC Virtual Series Webinar: Eliminating the Pain of Transitioning EW Systems from Lab Tests to Field Tests
October 21
1400-1500 EST
www.crows.org

DEPS DE Systems Symposium
Conference: October 25-29
Washington, DC
www.deps.org

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

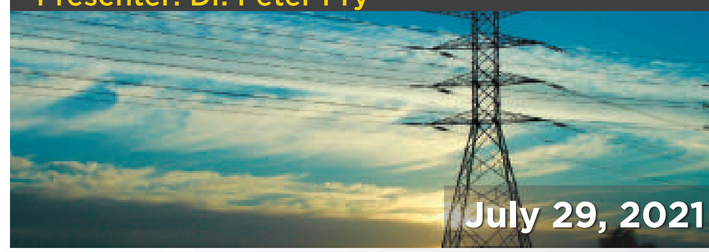
AOC Virtual Series Webinars

AOC VIRTUAL SERIES

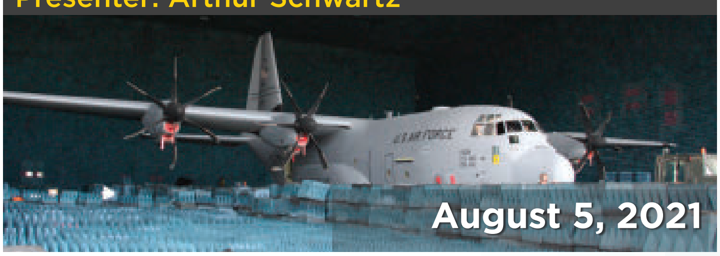
AOC Virtual Series has been a tremendous asset providing the AOC's audience with learning, advocacy, and the exchange of information. Register today to hear from subject-matter experts on all things EW!

Introduction to Satellite Communications (SATCOM)
Presenter: Dr. Patrick Ford

Electromagnetic Pulse (EMP): Science, Strategy, Politics
Presenter: Dr. Peter Pry



Quick Searches for Emitters in an RWR
Presenter: Arthur Schwartz

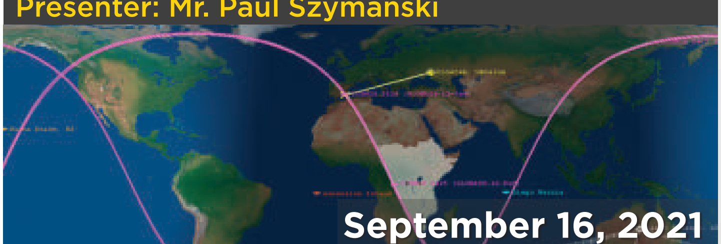


Standards and Applications in Defense Video
Presenter: Kevin Mitchell

Introduction to Digital Signal Processing for Electronic Warfare
Presenter: Dr. Clayton Stewart

Radar Ambiguities - Knowing if a target is coming or going
Presenter: Dr. Warren Du Plessis

United States Loses First Global Space War to Russians
Presenter: Mr. Paul Szymanski



Bandits at Three O'Clock! The RAF's Chain Home Radar and British Strategic Success
Presenter: Dr. Clayton Stewart

For more upcoming AOC Virtual Series Webinars, visit crows.org

ASSOCIATION OF OLD CROWS

YOUNG CROWS

As we approach July Fourth, Independence Day for the United States, I think of the young patriots that took on the quest for independence and the desire to build a new nation. These individuals were passionate about their endeavor and the creation of the United States. I believe that AOC needs to look to our young Crows for the future, to embrace new ideas, and to help us "seasoned" Crows discover and adopt new ideas on Spectrum. Young Crows working across industry, government, and academia can help our community approach Spectrum in a new way and embrace how it links our military, civilian, and commercial sectors together.

I want to set a goal for AOC to increase our young Crow membership and involvement. I am challenging myself, the current Board of Directors and Governors, Chapters, Chapter Boards, and AOC Membership to reach out and recruit young Crows and to make sure they have more opportunities to get involved, develop and lead new ideas on how to grow our organization and increase our global reach. I strongly believe in mentorship because it creates an opportunity for new and old members to learn and grow. When I mentor someone, I get just as much out of the experience (if not more) as the mentee. These are wonderful opportunities for knowledge transfer and to listen to future ideas and help put them into play. In support of this endeavor, AOC is currently developing an interactive mentor tool that will help align and support mentors, such as senior scientists, engineers, experts, and managers, with interested individuals or groups of young Crows.

As we begin summer (in the northern hemisphere), I also want to encourage folks to take vacations/holidays, refresh, relax, recharge and enjoy life and family, especially as we continue to navigating through the COVID-19 Pandemic. I took a week off in June at our camp and spent time on the boat on Lake Winnipesaukee. I disconnected from work and drastically reduced my electronic connect time to the world; it was a much-needed break. Disconnecting from the Spectrum was not easy for me to do, as I enjoy my connections and networks. But separating from the network can also be beneficial and refreshing and allow for new and fresh ideas.

I have now had the opportunity to attend three in-person events, and I am looking forward to the fall and additional opportunities to see our AOC members at events. We are pushing up the throttles to execute our 58th Annual AOC International Symposium & Convention, November 30 – December 2, 2021 in Washington, DC. The theme is "All-Domain Operations, Integrating Effects Across the Spectrum." We also have our elections starting soon, and I challenge each of you to make sure that you vote and that you encourage other members to vote. This is your opportunity to pick the future leadership of AOC.

– Glenn "Powder" Carlson

EW Analysis, Planning & Rehearsal

BATTLESPACE SIMULATIONS, INC.

Electronic Warfare Analysis, Planning and Rehearsal with BSI's MACE and ARMOR

BSI's MACE and ARMOR combine to offer an unparalleled capability for EW analysis, planning and rehearsal. MACE for simulating highly contested battlespaces down to pulse-level fidelity. ARMOR for visualization of the EW environment, including real-time radar beam/scan activity, dynamic 3D radar cross section visualization, weapon engagement zones and more. Don't settle – contact BSI for more information.

Battlespace Simulations, Inc.
"Don't Settle"

www.bssim.com sales@bssim.com
www.youtube.com/user/BattlespaceSims

US ARMY FOCUSES ON NEXT-LEVEL OF INFORMATION WARFARE

Speaking at AOC's "CEMA 2021" May virtual conference, focused on "joint, multi-domain, high-intensity conflict through the use of Cyber Electromagnetic Activity (CEMA) capabilities," LTG Stephen G. Fogarty, Commanding General, Army Cyber Command, declared the Army has come a long way in its thinking and implementation of information warfare (IW). Noting that the Service is no longer just working to rebuild its once-neglected EW capabilities to catch up with our adversaries, Fogarty said that having learned major lessons regarding the application and importance of IW from multiple modern conflicts, such as Russia's annexation of the Crimea in the Ukraine and the Azerbaijan/Armenia war, today's focus is squarely on multi-domain/all-domain operations and complete IW dominance. "Our capabilities are not the individual soldier, but their ability to bring the entire power of the US military to bear at their location on the battlefield – the ability to connect our forces, provide effective command and control, persistent ISR, long-range precision fires, just-in-time logistics, medivac – everything a modern Army needs."

Going further, Fogarty pointed out that "our adversaries also recognize this, and that they must be able to attack our network fabric, which they will do through a combination of cyber attacks and attacks in the Spectrum. This is critically important to understand. We're well beyond just having to fight our way through Spectrum congestion, primarily from our own fratricide, to dealing with a very-much contested Electromagnetic Spectrum Environment. We must use, and fully understand, the role that all of our resources play to succeed. This is where 'decision-dominance' comes in."

Fogarty emphasized that he's not just referring to situational awareness but rather situational understanding. "A commander must have the ability to sense, understand, decide, act, and assess faster and more effectively than our adversary. We have a lot of sensors deployed on the network and connected to people on the ground, and they are all vulnerable to disruption, so our ability to understand what is happening in the environment, and at a high-level of fidelity at all times, is critically important."

Noting that "the EW community cannot, and should not, be expected to succeed in this alone," Fogarty described EW as being a form of maneuver and a form of fires. "The ability to integrate all of our resources effectively is the key to success. We can't have different information from different sources provided to commanders. Our focus is on the need-for-speed, and confusion causes a loss of speed. If we are to provide decision dominance for our commanders, we have to effectively integrate all of our capabilities." – *J. Haystead*

UK Outlines Plans for Ardent Wolf Maritime CESM

The UK Ministry of Defence (MOD) is looking to procure a new maritime communications electronic support measures (CESM) capability to replace the Hammerhead CESM suite currently fitted to Royal Navy (RN) Type 23 frigates.

Given the project name "Ardent Wolf," the new contract is planned to cover the delivery, installation and in-service support of a CESM system founded on a readily available COTS product already at a high Technical Readiness Level.

RN Type 23 frigates are currently fitted with the Hammerhead CESM system supplied by Babcock in partnership with Boeing-owned Argon ST. According to an MoD tender notice published in late May, Ardent Wolf will utilize the extant CESM infrastructure on the Type 23 frigates, with the contract expected to deliver a minimum of seven COTS-based systems. The full scope of the requirement includes equipment installation/embodiment, repair and maintenance, spares provisioning, calibration, system and design safety, contractor logistics support, training, security accreditation, capability resilience, reliability, documentation management, and possible solution updates and upgrades.

Due to the security aspects of the requirement, the Ardent Wolf competition is limited to UK prime contractors only. An Invitation to Negotiate is planned for issue to up to six shortlisted bidders in September, with a contract award scheduled for April 2022. The contract is expected to last six years from the date of award.

In April, Babcock received a £1.3 million Hammerhead Life Extension (HHLE) contract to sustain the existing CESM equipment in service. Under the HHLE contract, awarded by Defence Equipment and Support's Joint Electronic Surveillance delivery team, the system will now remain in service through to a revised out-of-service date of March 2025. – *R. Scott*

Congress Pushing DOD to Prioritize EMS Superiority

US military and government officials have been increasingly outspoken about the fact that the US has not just lost, but has given up, much of its advantage in the Electromagnetic Spectrum (EMS). While there has been a push to reinvest in EMS superiority across the Services, the progress that has been made is owed in a large part to congressional efforts to force change within the DOD, according to Rep. Don Bacon (NE 2), House Armed Services Committee, Subcommittee on Tactical Air and Land Forces, who spoke on a panel hosted by the Hudson Institute in May, "The US Military and Electromagnetic Spectrum Superiority."

If progress is to continue, Bacon says Congress must maintain its pressure on the Joint Staff and the Services, focusing on three key objectives: identifying issues inherent to the way the DOD understands and prioritizes EW, implementing a clear chain of command within an EW-specific office, and creating a "hardwired" funding and acquisitions process specific to EW.

To his first point, Bacon said, "There is no doubt we had EW dominance in the '80s and '90s, totally dominating in [Operation] Desert Storm, for example." However, when there was no longer a perceived threat on the horizon, EW was defunded and received little attention.

In the meantime, according to Bacon, both the Chinese and Russian militaries took note of the US military's successes within the EMS. "They were building up their capabilities while we were walking away because we felt confident," Bacon said.

Rep. Jim Langevin (RI 2), House Armed Services Committee, Subcommittee Chair on Cyber, Innovative Technologies, and Information Systems (CITI), affirmed Bacon's remarks, saying, "We have to recognize that our enemies and adversaries have absolutely invested in these asymmetric technologies that undermine our advantage."

Perhaps the crux of the EW challenge, according to Bacon, lies in how the EMS is understood. "I was in favor of making the Electromagnetic Spectrum a separate domain," Bacon said. "I frankly think that is scientifically accurate. It is a physical domain. Without control of the EMS, you can have the best aircraft, the best ships, the best tanks...and if you can't talk, you can't get radar, you can't use GPS, these systems are easily defeated."

According to Bacon, the DOD may be hesitant to define the EMS as a warfighting domain out of budgetary concerns. Creating offices and funding pipelines specific to EMSO might require "more money to fix the problem" than is practicable within the DOD's budget. However, Bacon said choosing not to address the EMS as a domain because it's not in the budget – or out of fear of a separate EMS "Service" being proposed – could be what's hindering progress. "I think we're denying there's a problem if you don't acknowledge the EMS as a domain," he said.

Bacon's second objective is to ensure a team of people at the DOD is responsible for EMS strategy and implementation. "Somebody in the Pentagon needs to know they own EW," Bacon said.

This point was echoed by Langevin, who said that if a clear EW command structure isn't in place, "the current [EMS Superiority] Strategy is going to end up like the 2013 and the 2017 EMS Strategies."

"I'm bound and determined that that's not going to happen," he continued. "We're going to get it right this time."

The third objective, the "hardwired funding process for EW," is essential to maintaining an "enterprise view of

EW," according to Bacon. EMSO must be treated as a separate function in terms of acquisitions, rather than part of larger acquisition efforts, if it is to receive the funding it needs. "If it's embedded in tons of other funding lines, you can't really have an enterprise view."

Expanding on this point, Langevin said the focus of EW funding must "move away from hardware-centric systems" and shift to more flexible, software-centric, networked systems that are adaptable and upgradeable when new threats are identified. Langevin said he would push the DOD toward a software-centric acquisitions approach, which could help mitigate the DOD's budgetary inefficiencies where EW is concerned.

Overall, both Langevin and Bacon view pressure from Congress as an important forcing function in attaining EMS superiority, particularly through these three objectives. "If Congress is not pushing this area, the Pentagon will not deliver," Bacon said. "There's a lot of analysis and studies at the Pentagon; I want to start seeing action and start working diligently to close this gap with a plan," he continued. "We've got to stop studying at some point and start acting – start executing." – *H. Swedeen*

US Army Announces Plans for CyberQuest 2022

The Cyber Battle Lab at Army Futures Command (Huntsville, AL) has issued a Broad Agency Announcement (BAA) inviting industry and academia, as well as other government organizations, to "… showcase their emerging cyber, electronic warfare, intelligence, and networking technologies at Cyber Quest 2022." The annual event, which will be held for the seventh time, will be conducted in March 2022 at Fort Gordon, GA, in partnership with the Army Expeditionary Warrior Experiment (AEWE) 2022 at Fort Benning, GA.

CyberQuest 2022 will focus on "the integration of network, cyberspace and electronic warfare capabilities into a CEMA cell's output within a Brigade's or Echelon Above Brigade's Tactical Operations Center undertaking Multi-Domain Operations. It looks to provide the CEMA cell with the ability to provide commanders with non-kinetic options to defeat threats while protecting their own capabilities," according to the BAA.

The Cyber Battle Lab is seeking proposals in several technology focus areas: 1) Electromagnetic Warfare; 2) networks and services; 3) tactical radio; 4) cyberspace operations; 5) intelligence applications (Intel Apps); and 6) Military Information Support Operations (MISO).

In the Electromagnetic Warfare (EW) focus area, the Cyber Battle Lab is seeking "organic, integrated EW capabilities to assist in creation of windows of advantage and multiple dilemmas in support of Multi-Domain Operations," according to the BAA materials. Among the EW capabilities the Army wants to test is a long endurance (>12 hours) UAS flying in a "follow-the-leader" orbit above a ground vehicle using cooperative TDOA for geolocation against a target signals of interest at long range. In this area, the Army also wants to evaluate alternative TDOA time synchronization approaches for geolocation and test the ability to sense and locate aerial and ground targets via bistatic radar. Finally, the Army wants to demonstrate experimental C5ISR/EW Modular Open Suite of Standards (CMOSS) and PHOTON-compatible capabilities to inform future EW programs.

Another area if interest within the EW topic is the Army's Terrestrial Layer Systems – Echelons Above Brigade (TLS-EAB). At CyberQuest 2022, the Army wants to evaluate technologies that can support its upcoming TLS-EAB program. These include using terrestrial DF angle-of-arrival data to cue non-kinetic responses at long range and high-gain beam-formed electromagnetic attack against aerial signals of interest at long range. The Army also wants to assess operational and technical characteristics (receiver sensitivity, transmitter power) required for a defensive electronic attack (DEA) capability to protect ground assets from adversary threats (SSMs/UAS/RF-Proximity Fuzes) at each echelon and to test the minimum RF engagement range to create an adequate miss angle for RF or PNT guided threats.

The tactical radio focus area will look at several capabilities, including Low Earth Orbit (LEO) / Medium Earth Orbit (MEO) constellations that provide ruggedized, mobile, beyond line of sight (BLOS) communications capabilities with increased bandwidth and low latency. The BAA said, "desired system characteristics include: high throughput with low latency; low EMS signature; spectrum efficiency; and reduced Size, Weight, and Power-Cost (SWaP-C). Ground terminals should be scalable with common components to support users at the tactical edge to division command posts and above." In addition, the Army wants to evaluate resilient network transport capabilities, such as advanced networking waveforms and dynamic spectrum access, that enable soldiers to access reliable information in contested and congested environments. Lastly, this area will look at solutions that converge capabilities using a standards-based solution, such as CMOSS and CMOSS Mounted Form Factor (CMFF).

The cyberspace focus area concentrates on enabling Offensive Cyber Operations (OCO) expeditionary forces to support Multi-Domain Operations, including "exploiting technologies," predictive analysis and machine learning. A related area addresses Cyber (CEMA) situational awareness that allows tactical commanders to ingest, correlate, analyze and display relevant cyberspace data into useful, actionable warfighter information. This includes: integration of cyberspace threat intelligence data sources; integration of EW data sources; displaying Blue Order of Battle (e.g. EW forces, CPTs, etc.); integration Gray Space data sources; and displaying lower and upper Tactical Internet (TI) infrastructure (i.e., network topology with geolocation).

CyberQuest will drive requirements definition, inform rapid acquisition initiatives and support acquisition risk reduction activities in support of the Army's goal to be MDO capable by 2028. – *JED Staff*

Hungarian Army Orders StrikeShield APS for Lynx IFVs

Rheinmetall Protection Systems GmbH (Bonn, Germany) is to equip Hungary's new fleet of Lynx infantry fighting vehicles (IFV) with its StrikeShield hardkill active protection system (APS) in a deal worth over €140 million.

StrikeShield is designed to provide protection from shaped-charge warhead threats, such as rockets or missiles, by neutralizing incoming projectiles before they strike the platform itself. It adopts a distributed system architecture, with sensors and countermeasures integrated into the contours of the vehicle.

Hungary ordered a fleet of over 200 Lynx KF41 IFVs from Rheinmetall in September 2020. The StrikeShield APS will be mechanically integrated into hybrid armor tiles on the vehicle. Instead of conventional passive add-on armor modules, the platform will feature spaced passive armor tiles that incorporate the components of the APS between an outer ply and inner tiles mounted on the vehicle's hull. Rheinmetall contends that this hybrid approach provides an improved capability to counter new effects and threats, such as residual energy from a disabled rocket hitting the vehicle and deflagrating. – *R. Scott*

IN BRIEF

Saab has been contracted by Panavia Aircraft GmbH to upgrade the radar warning equipment (RWE) fitted to Tornado aircraft operated by the Luftwaffe.

Valued at approximately SEK400 million ($48.2 million), the contract covers the supply of new digital components to increase processing power and resolve obsolescence in the RWE equipment. Saab will carry out the work at its sites in Nuremberg, Germany, and Järfälla, Sweden, with deliveries to take place between 2021 and 2025.

An initial order for the RWE for Germany's Tornado strike aircraft was awarded to Saab in 1999. A series production contract followed in 2005.

Thales (Limours, France) delivered its first Sea Fire radar to the Lorient shipyard for integration on the French Navy's *Amiral Ronarc'h* frigate, the first of five Defence and Intervention Frigates (FDI) planned by the French Navy to replace its *LaFayette*-Class frigates. The delivery marks an important milestone in the Sea Fire program, which the company has been developing over the past seven years. The multifunction four-panel AESA radar will perform simultaneous air and sea search functions over hundreds of square kilometers covering 360-degrees in azimuth and 90-degrees in elevation.

Mercury Systems (Andover, MA) announced that it has acquired **Pentek Systems, Inc.** (Upper Saddle River, NJ) for $65 million in cash. Pentek makes software designed radio (SDR) and data acquisition boards, as well as other DSP-based products for the EW, SIGINT and radar markets. The acquisition will strengthen Mercury's embedded computing portfolio and provide it with more application-ready solutions. One of Pentek's main competitors, Abaco Systems, was acquired by Ametek in March.

Northrop Grumman (Baltimore, MD) has delivered the AN/SLQ-32(V)7 Surface Electronic Warfare Improvement Program (SEWIP) Block 3 Engineering and Development Model (EDM) to the US Navy for land-based testing. The SEWIP Block 3 EDM will undergo testing at Naval Sea Systems Command's Surface Combat Systems Center in Wallops Island, VA.

The **US Air Force's 772d Test Squadron, 412th EW Group** (Edwards, AFB, CA) has requested information from industry for a program to incrementally upgrade the Combat Electromagnetic Environment Simulator (CEESIM) and Next Generation Electronic Warfare Environment Generator (NEWEG) simulation systems at its Benefield Anechoic Facility (BAF). Known as the CEESIM and NEWEG Development and Upgrades (CENDUP) program, the effort primarily entails evolutionary Improvement & Modernization (I&M) upgrades to the CEESIM and NEWEG RF threat simulation systems at the BAF. These upgrades will be managed under a single CENDUP contract that will run for five years. According to a Statement of Work, "The CENDUP effort will support the research and development (R&D) and procurement of capability enhancements to the BAF test environment specific to the CEESIM and NEWEG threat simulators, mainly focused, but not limited to the RF generation components of the systems." The contracting point of contact is Rebecca Snider, +1 (661) 277-8452, e-mail rebecca.snyder.1@us.af.mil.

The **Strategic & Spectrum Missions Advanced Resilient Trusted Systems (S2MARTS)** consortium, acting on behalf of the Office of Naval Research (Arlington, VA), has issued a Request for Solutions (RFS) for a "prototype subminiature radio frequency (RF) signal processing payload subsystem for integration into a maritime system of expendable unmanned systems." Known as the Neptune Payload Prototype effort, the RFS states that ONR "requires component technologies that are available for integration to satisfy ONR's payload requirement include currently available integrated wideband RF transceiver chipsets, Field Programmable Gate Array (FPGA), RF Application Specific Integrated Circuit (RF ASIC), Radio Frequency System-on-Chip (RFSoC), and high-performance microcontrollers." In terms of performance, the objective is to develop a payload that tunes and receives and transmits signals from A-J band, with a minimum instantaneous bandwidth per receive/transmit channel of 55 MHz threshold and an objective of greater than 400 MHz. The payload will be configured to fit into a 2.875-in. (dia.) cylinder that is between 4 and 8 inches long. The objective weight is 300 g, although it could be as high as 1 kg. Available power will come from the host platform and provide up to 137 hrs of battery life at 49W. The expendable unmanned system that will house the Neptune Payload Prototype will be developed/evolved in parallel by the Navy. With an anticipated budget of $6.7 million over five years, the Neptune project will be managed by the Naval Surface Warfare Center, Crane Division (Crane, IN), Electromagnetic Warfare and Science and Technology (S&T) Division, Code WXV. The program anticipates multiple awards. This opportunity is only available to S2MARTS consortium members. More details are available at https://s2marts.org. The point of contact is Joseph Johnson, +1 (812) 854-5965, joseph.m.johnson5@navy.mil.

Learning to Growl – Train

By John Haystead

US NAVY

For the US Navy, the job of performing airborne electronic attack (AEA), including the suppression of sophisticated integrated enemy air defense systems (IADS), very much begins and ends with the EA-18G "Growler" aircraft. The Growler is the Navy's primary tactical jamming aircraft tasked with performing offensive suppression of an adversary's use of the electromagnetic spectrum (EMS) – primarily radars and the communications networks that link them together within an IADS.

Though extremely capable, the aircraft does not fly or operate itself, however, and not surprisingly, training aircrews to fly and operate the Growler is an extremely complex task – involving continuous, evolving, and multi-level training levels; advanced training schools; and training and tactics program development processes.

The primary responsibility for training Growler aviators and electronic warfare officers (EWOs) falls to the Commander Electronic Attack Wing, US Pacific Fleet (COMVAQWINGPAC) (CVWP), NAS Whidbey Island, WA. In fact, CVWP is in charge of all Navy EA-18G Growler Electronic Attack (EA) fleet squadrons, responsible for maintenance, material and operational readiness support, as well as everyday administrative functions. Supporting the Commander, Naval Air Forces (COMNAVAIRFOR) and combatant commander tasking worldwide, the Wing also provides EW tactical and technical development leadership and expertise.

There are currently twelve operational Growler squadrons at Whidbey and one operational squadron, VAQ-141 "Shadowhawks," permanently forward-deployed to the Western Pacific on board USS *Ronald Reagan* (CVN 76), home ported in Japan. Each Growler squadron typically has four aircraft assigned and averages 30 officers and 170 enlisted personnel. VAQ squadrons deploy in support of both East and West Coast air wings and aircraft carriers, as well as to various land-based Joint facilities.

CAPT Dave Harris, Deputy Commodore, Electronic Attack Wing, CVWP, says "Although the EA Wing carries a 'Pacific-Fleet' denotation in its name, it actually handles the manning, training and equipping functions for all US Navy Growler squadrons, regardless of their coast or carrier deployment location, forward deployed naval force (FDNF), several test squadrons, or as part of the VAQ-129 'Vikings' Fleet Replacement Squadron (FRS) permanently based at Whidbey Island. Though the 'immediate superior-in-charge' of carrier-deployed squadrons is the carrier's air wing commander (CAG), the CVWP still maintains responsibility for their manning, training and equipping before deployment to the carrier. CVWP is also the operational

ing for the AEA Mission

commander of the six Growler squadrons designated as Expeditionary squadrons, which can be deployed to air bases and fields around the world in support of the Joint Force. In total, on any given day, we are tasked with having 97 mission-capable Growlers deployable around the world."

VAQ-129 VIKINGS

The VAQ-129 FRS at Whidbey is charged with the initial training or retraining of all EA-18G air crews providing different levels of tactical training. Says Harris, "When you're brand new out of flight school and going through VAQ-129 for the first time, you're essentially getting your Level 1 Growler qualification, the focus being on airmanship and rudimentary tactics." It takes about a year to get through that initial training, but Harris explains, "VAQ-129 is one of those things that you go through repeatedly, because any time you are outside of a cockpit for more than a year, you go back through for some form of refresher training."

As described by CDR Warren Van Allen, VAQ-129 Commanding Officer, "As a fleet replacement squadron, we provide the VAQ fleet with combat-ready replacement aircrew. As such, we're charged with training all EA-18G aviators and developing standard operating procedures for the maintenance and operation of the aircraft, as well as teaching the basics of electronic attack." The squadron currently manages the training of roughly 75 students at a time through a challenging syllabus including airborne electronic attack, air-to-air counter tactics, and carrier qualification.

Van Allen says they technically have 57 assigned aircraft, but on its flight side, they maintain 29-30 aircraft to support their production flight schedule. The other aircraft are more in community-level scheduled maintenance phases. "On the flight side, we'll call it 27 aircraft, we have a student body right now of about 70 officers who are aircrew in training with roughly 28 instructor pilots and the same number of instructor EWOs. The huge lift is the maintenance and administrative effort, where we have roughly 450 enlisted personnel and nominally about 200 contract maintenance personnel who mostly support scheduled maintenance and flight-line troubleshooting. All together it's a team of about 800 personnel putting out on average about 30 FRS aircrews (30 pilots and 30 EWOs) US Navy Category 1 right out of flight school. Although the main job is the production of those flight school students who just got their wings and come here to learn how to fly the Growler. We also train guys coming back to the community after a Joint tour where they haven't been flying, and putting them through a refresher syllabus."

As described by Commander Van Allen, although not all of their instructor pilots and EWOs are Growler Tactics Instructor (GTI)-level personnel, (See *JED* January 2021, "US Navy's HAVOC Hones AEA Expertise"), they usually do have at least one GTI pilot and a GTI EWO on the staff. "Sometimes we have more than that, but our primary trainers are guys that are finishing their first junior officer tour in the fleet that come back here to instruct at the FRS. They are all fully-qualified and high-performing aircrew, and we truly get the cream-of-the-crop out of the fleet."

Aside from the pilot-unique "stick-and-throttle mechanics" of actually physically maneuvering the aircraft, Commander Van Allen emphasizes that the Growler training syllabus is identical for both pilot and EWO members of the aircrew. "In addition, the EWOs much also be versed in air-to-air mechanics since any portion of the airborne electronic attack mission can be performed from either cockpit location. So, while they are not actually moving the aircraft, the EWOS do need to know when to move it, and how it moves, in order to work together efficiently as an aircrew."

LEVEL ONE TRAINING SYLLABUS

According Van Allen, "As a broad-brush description, the syllabus is broken up into phases, with all phases fundamental to flying the EA-18G. At any given time, all phases are active and right now, we have about six classes in training.

"The first phase is the transition, or aircraft familiarization, phase which includes formation flying, and using the aircraft's radar to conduct intercept – known as all-weather intercepts (AWIs). From there, we have some latitude on where they go next based on class flow. One option is the AEA-1 mission-function phase where they go through the 'button-push mechanics' of how to make the machine do AEA. It also includes air-to-air counter tactics or (ACT) which is our air-to-air phase."

Captain Harris notes that, "The addition of the air-to-air component is one of the great positive changes resulting from the switch from the EA-6B Prowlers to the Growler. We now have this defensive and limited offensive air-to-air capability. It means we can get closer to the enemy and still do our mission, because we can now protect ourselves and any other members of the Joint force from enemy air-to-air threats, making us more effective. So a significant portion of the syllabus is dedicated to performing beyond-visual-range air-to-air tactics, as well as within-visual-range tactics (commonly known as dogfighting)."

Says Commander Van Allen, "Again, although at VAQ-129, this is basic-level stuff, training to fairly simplistic scenarios, but we do start with beyond-visual-range tactics to gain knowledge of the advanced tactics used at the fleet, then to within-visual-range ACT syllabus, which includes Basic Fighter Maneuvers (BFM) – both offensive and defensive, high-aspect BFM, unusual merges, and dissimilar aircraft. Here we try to get support from the adversary squadrons at Key West or at Fallon (NAS). The AEA-2 syllabus combines all of those elements of AEA-1 with higher-level mission planning, culminating with a full tactical scenario in which they will start out on an AEA mission, transition to some air-to-air threat – engaging and attriting that threat, and then resetting back to an AEA mindset."

Then, says Commander Van Allen, "based on the availability of an aircraft carrier, we may interrupt an advanced class and prepare them for carrier qualification (CQ), which is separate from the rest of the syllabus. Ideally, we put the CQ phase at the end of the syllabus, but quite frequently it is taken out of order."

TRAINING TOOLS AND RESOURCES

VAQ-129 training involves both the use of simulators, as well as flight training. According to Commander Van Allen, each phase of its training includes several hours of guided academic instruction, as well as several hours of computer-based instruction that students work through at their own pace. There are also several hours of simulator events and several flight events for each phase.

"The majority of our flight training takes place at Whidbey," says Commander Van Allen. "Here, we use our own aircraft in the adversarial role and are also able to virtually replicate some threat aircraft. Our near-peer and higher-fidelity threat training takes place by and large in the simulators. Some of the advanced technologies just cannot yet be replicated on the training range. The students also get quite an in-depth education through the mission planning aspects of their guided academic classes."

Captain Harris also points out that VAQ-129 was one of the first FRS or operational squadrons throughout the Navy to utilize the "Link-16 Inject-to-Live" capability. "With Link 16 Inject-to-Live, we could simulate enemy threats via Link 16, which would allow us to dedicate a lot more of our resources to actual student flights as opposed to red-air flights, and it's been a really big force multiplier. The reason that it came about was just to make us more efficient. We were being tasked with creating a large number of students and historically what we would do was send out students in two different jets with instructors and then launch other Growlers to simulate enemy air forces and be essentially training aids where they would get simulated firings etc. Great, but not producing students, just being a simulated target for a missile."

The squadron now also has the Pacific Northwest EW Range for intensive training in AEA against integrated air defense systems (IADS). As described by Captain Harris, "Stood up a few years ago, the Pacific Northwest EW Range, located out on the Olympic coastline, really gives the ability to VAQ-129 or fleet squadrons to train at a high level locally."

The range equipment consists of a fixed emitter site and three mobile emitter vans that send out signals that Growler aircrews need to detect and identify to complete basic to intermediate Airborne Electronic Attack training. Says Captain Harris, "The range has really allowed us to train locally in the area without going down to Fallon NAS or to Nellis AFB. It allows us to do some really good (medium-end) training, simulating some of the enemy IADS that we would come up against, right here out of Whidbey. We train through a broad range of missions – that can be from counter-insurgency or counter-terrorist operations, but also for the high-end fight and the near-peer adversary. We have always trained for it, but definitely a renewed focus on it now. We're really trying to stand up resources to better help us simulate the enemy threat and do a better job of training to it." Commander Van Allen added, "Over the past few years, it has become a very robust EW training range for the VAQ community providing some pretty high-fidelity training."

Flight training also takes place at NAS Fallon and at NAS Key West. Located near the southern tip of the Florida Keys, NAS Key West is home to the Navy Reserve Squadron (VFC-111) "Sun Downers," which is a professional adversary squadron flying F-5 Tiger II aircraft. "We use them for our air-to-air syllabus, and usually about twice a year, we will detach to Key West," says Commander Van Allen. In total, he says, "The time it takes VAQ-129 to train a Category 1 (CAT 1) officer who has just completed flight school – on paper, takes about 47 weeks. But in reality, with weather, etc. it takes about 53 weeks to get a CAT 1 student through."

Following basic VAQ-129 training, aircrews are then assigned to a fleet squadron where they will continue their training through the Electronic Attack Weapons School (EAWS) at Whidbey. Here, they begin their Level 2 syllabus to become essentially a combat-capable aircrew. They then work on their Level 3 syllabus which is where they can become a mission commander in time of war or any type of training mission where they could be in command of three to four Growler aircraft performing a specific VAQ or EA-18G mission.

Level 4 addresses training as a Suppression of Enemy Air Defense (SEAD) mission commander, which means they can coordinate with other SEAD assets, such as Air Force F-16s and EC-130/EC-37 Compass Call aircraft, as well as other F-18s within the air wing carrying HARMS or AARGMs. As a SEAD commander, they are in charge of an individual SEAD package, which would have several types of aircraft and other assets besides Growlers. Level 5 is Growler Tactics Instructor (GTI) qualification or HAVOC is the highest level of Growler training given at the Navy's Airborne Electronic Attack Weapons School (AEAWS), part of the Naval Aviation Warfare Development Command (NAWDC) at NAS Fallon. (See "US Navy's HAVOC Hones AEA Expertise," *JED,* January 2021, p. 18 for more on HAVOC.)

ELECTRONIC ATTACK WEAPONS SCHOOL (EAWS)

The Electronic Attack Weapons School (EAWS) at Whidbey provides comprehensive, formal training to EA-18G Growler aircrew and extensive weapons-related training to EA-18G ordnance and maintenance personnel. The school acts as the central repository for all EA-18G tactical matters. It is responsible for providing a graduate-level curriculum that prepares EA-18G squadrons for deployment around the world. Flight-side training support is continually provided to squadrons, locally or deployed.

EAWS is the community manager for the EA-18G Weapons and Tactics Program used in the training of Growler aircrew and for the Electronic Warfare Advanced Readiness Program (EWARP). As described by Captain Harris, "EAWS is all Level 5 tactics instructors, training up all the squadrons to make sure they are all at the correct tactical level before they go on deployment. It's really a significant difference from VAQ-129 which is focused on lower-level training, safe flight, and basic tactics, while the EAWS is more of a certification of a squadron that they are meeting tactical thresholds before deployment. As opposed to VAQ-129, EAWS is more akin to HAVOC and is our schoolhouse for developing advanced tactics and training procedures as well as working with the entire air wing at Fallon NAS. The EAWS works for the Commodore relative to man, train and equip, and is one of our key cogs in making sure that the squadrons are properly trained before they head out the door for deployment. They do advanced tactical training here at Whidbey, but are more focused on the squadrons, as opposed to HAVOC which is more focused on tactics development and creating individual Growler Tactics Instructors (GTIs).” Additionally, the EAWS serves as experts and stewards to the Joint and Coalition Forces, Industry, Advanced Think Tanks, Special Projects Offices and the Acquisition World.

As described by EAWS Commanding Officer CDR Jeremy Nuttall, “While the primary job of HAVOC is to create the graduate-level (PhD) in airborne electronic attack instructors that will not only teach at the Airborne Electronic Attack Weapon School (AEAWS) at Fallon, but continue the pipeline of pumping out instructors both there as well at the EAWS, we take all of the tactical recommendations that they provide and apply them to the fleet as aircrews prepare for deployment. We’re constantly in touch with our partners at Fallon to make sure we’re putting out the latest and greatest information to the fleet through standardized implementation of the Growler Weapons and Tactics Program (GWTP) and the Electronic Warfare Advanced Readiness Program (EWARP).”

As described by Commander Nuttall, “Once trainees complete their Level One VAQ-129 FRS training and are assigned to a deployable squadron, that squadron could either already be deployed or one that just returned from deployment or anywhere in between. In any case, however, they will be expected to show up at their squadron ready to start executing their Level Two Growler Weapons and Tactics Program (GWTP) syllabus and working toward mission qualifications. Although EAWS owns and executes the GWTP program, if a squadron is deployed, that training program will actually be conducted by a GTI-level instructor that is assigned as a training officer for each individual squadron.”

In contrast, all EWARP training is done at Whidbey depending on when a squadron is actually assigned to Whidbey according to its training workup schedule. As Commander Nuttall says, depending on when an aircrew first shows up at their assigned squadron, and depending on where that squadron is in its workup schedule, the first time they may actually come to EAWS is when they come to begin their EWARP syllabus.

HIGH VELOCITY TRAINING

Roughly three years ago, EAWS launched a new approach to more rapidly and efficiently prepare EA-18G aircrews for their mission. Known as “High Velocity Training,” Commander Nuttall explains, “In general it’s an approach to training and education particularly for aircrews that is being implemented across the fleet.” Based on concepts in the book by Steven Spear entitled, *The High*

US NAVY

Velocity Edge as well as those presented in *Thinking Fast and Slow,* by Daniel Kahneman, who writes on behavioral science and particularly on different types of thinking, such as instinctive behavior vs. consideration of possible alternative approaches before acting, more along the lines of the Observe-Orient-Decide-Act (OODA) Loop process.

"From this we created our EWARP syllabus in two different ways," says Commander Nuttall. "In System 1, we apply what we call 'skills and drills' – doing the same thing over and over again – if you see something, you react. For example, normally as we're doing an Advanced Readiness Program (ARP), we'll focus one day on Electronic Support (ES) which is one of, if not the most important, thing we have to do in executing the AEA mission. Then, as we go through, we also amp up the intensity until the mechanization of how we do that is engrained in someone. The next day we'll do the same process but expanding the drill to include Electronic Attack (EA), so ES recognition followed by EA response. We do this through the whole scope of things that we do including the firing of an ARM or a comms EA mission. We don't just have guys sit through a lecture and then put them right into a simulator to execute. Instead we'll put them through a lecture and then do a 'table talk' to describe what to expect and what to do. We run through 10-15 examples of how they're going to execute, and then review responses and correct where necessary before moving on to the simulator. Once in the simulator, the pace and complexity is gradually sped up, starting with a single emitter every twenty seconds or so and ramping up to new emitters every five to ten seconds. The approach has really improved the executability of the mission."

System 2 of the EWARP syllabus is more focused on the logical, calculated, and conscious decisions that need to be made, depending on the total environment. Says Commander Nuttall, "This is where we get beyond knowing how to react when you see something to an actual 'type of scrimmage' environment, where you evaluate all of what you are seeing and develop a skillset to determine what really matters and what needs to be addressed first in terms of priority – refining that tactical decision making."

In addition to Navy personnel, EAWS also has a US Air Force representative who, as noted by Commander Nuttall, "is very helpful to us particularly as we have the Joint Expeditionary Squadron mission as well."

JOINT FORCE EXPEDITIONARY SQUADRONS

In addition to the Navy's carrier-based Growler squadrons, there are also a number of land-based Joint-Force expeditionary EA-18G Growler Squadrons. Currently, there are six expeditionary squadrons with aircrews that include both Navy and Air Force pilots and EWOs. Historically, they have also included a number of Royal Australian Air Force (RAAF) aircrews and maintainers. The five operational expeditionary squadrons are VAQ-131 Lancers, VAQ-132 Scorpions, VAQ-134 Garudas, VAQ-135 Black Ravens, and VAQ-138 Yellow Jackets. The reserve VAQ squadron is VAQ-209 "Star Warriors."

In fact, the US Air Force is a major component of the Joint Airborne Electronic Attack Program, and its aircrews follow the same Growler training program as Navy aircrews at both VAQ-129 and EAWS. The Air Force's 390th "Wild Boars" Electronic Combat Squadron (ECS) is the parent command for all US Air Force personnel stationed at NAS Whidbey Island, WA. It is attached to the 366th Fighter Wing at Mountain Home Air Force Base, ID. 390th ECS airmen both fly the EA-18G Growler, as well as provide logistical expertise in support of the Joint Airborne Electronic Attack Program.

Lt Col David Davidson, USAF, Commanding Officer of the 390th ECS, says the Joint AEA Program is relatively new, with Air Force pilots just starting flying the Growler in the fall of 2017. On average, they have between 30-36 aviators (about five pilots and 24-27 EWOs). Usually pilots come straight out of pilot training and EWOs come straight out of Combat System Officer (CSO) training in Pensacola, FL. "We get a couple of brand new guys a year from Pensacola. Once they complete their Growler training here, they are attached to one of the Joint expeditionary squadrons. Following that tour, they usually go on to flying Air Force F-15Es."

In addition to those straight out of school, the 390th also trains other experienced EWOs (second or third assignment) from the F-15E, B-1, B-52 and RC-135 Mission Designation Series (MDS) communities. These aviators come to Whidbey to train on the Growler, are attached to an expeditionary squadron assignment, and then return to their previous MDS, unless they are selected for a school or staff assignment.

Says Colonel Davidson, "Currently there are 42 members in the squadron, including officers, enlisted personnel, and one civilian. One part of the squadron, which is not standard for an operational squadron, is a three-man air transportation team whose job it is to do all the Outside Contiguous United State (OCONUS) movement and logistics for the [Navy's] six expeditionary squadrons. They're a small Logistics Readiness Squadron (LRS) in and of themselves, and a huge piece of what we do. The Navy doesn't have an indigenous team for their expeditionary squadrons, so all of the expeditionary squadrons have 390th members attached to them."

Although, currently, 390th personnel deploy exclusively with the expeditionary Growler squadrons and not to Navy aircraft carriers, they participate in both VAQ-129 as well as EAWS training just as the Navy personnel do. After Initial training at VAQ-129, and once qualified to fly the Growler, they will go to their expeditionary squadrons.

Colonel Davidson says, "All of the guys with the expeditionary squadrons will train with EAWS when they start ramping up for deployment. At that point, the entire squadron will go through the EAWS's EWARP training to strengthen their knowledge in all the different mission areas for deployment."

Although the Air Force no longer has a dedicated AEA platform other than the EC-130 and advanced capabilities on 5th Generation fighters, such as the F-22 and F-35, Colonel Davidson says, "One of the primary objectives for the 390th aircrews and the Joint Electronic Attack program is to take Growler experience in AEA and EMS superiority back to their Air Force MDSs and spread that knowledge through those units – to get them into communities that really don't have any EW training (i.e., single-seat squadrons including the F-22 and F-35) – to help fill the Air Force's gap in inherent AEA mission sets. In terms of EMS superiority, this is one of the ways that the Air Force has been trying to bring knowledge back to the Air Force and continue to grow EMS knowledge and align with what the Air Force Chief is trying to do."

As Commander Van Allen of VAQ-129 says, "As you look at the training continuum of the EA-18G, including the HAVOC piece and now the FRS piece, it's important to understand the coordination and communication that has to happen amongst the community as pilots and EWOs move about from the carriers, to the different training ranges and schools to ensure that it remains a continuous learning, training, and operational thread that provides a huge benefit across the board."

And, as noted by Captain Harris, "We're very unique in being the only Joint tactical airborne electronic attack asset in the Joint Force. We work extremely closely with both the Air Force and with the RAAF, who are both huge force multipliers – which is really a limited, high-demand, but low-density asset in the Growler." Although current Growler training does not yet encompass the Next Generation Jammer (NGJ), Captain Harris, says that "NGJ will be such a key enabler to the high-end fight, we expect to be training on it soon. It is primarily in the test squadrons right now, and it is well in process of developmental and operational testing, and we are yearly awaiting the day it makes it to us here at Whidbey and deployment to the fleet."

TECHNOLOGY SURVEY

A SAMPLING OF COMINT AND COMMUNICATIONS ESM RECEIVERS

By Barry Manz

This month, *JED* is surveying communications intelligence (COMINT) and communications electronic support measures (comms ESM) receivers. Traditionally, COMINT has involved collecting the information *within* a message (signals internals) as well as the information *about* a message (signals externals), such as signals type, frequency, duration, emitter location, etc. This was more or less an arrangement of convenience, because the personnel and units who were collecting and recording the signals internals where also capturing the external signal parameters as part of the intelligence process. Before high-data-rate battlefield networks became available, tactical forces relied on intelligence units to collect COMINT and share tactical information (emitter type, location, etc.) about communications emitters in their mission area. However, the tactical commander did not have much control over this process. The message internals had to be handled separately by intelligence analysts, and the relatively small number of COMINT assets were typically tasked and controlled by higher-echelon commanders. For the tactical commander of the past, this meant he would receive a less detailed enemy comms picture than desired and that information would usually be slower to arrive than if he had control of his own comms ESM assets.

Two things have changed over the past two decades. Tactical forces are now connected over more robust data networks, which means lower-echelon units can share information more easily. Secondly, as these data networks began to emerge, these lower echelon forces could operate their own sensor nodes (including comms ESM systems) and share the information with the mission commander quickly. These innovations are helping drive today's need for smaller comms ESM systems that can be integrated onto tactical UAVs or "ride along" on whatever tactical platforms (tanks, APCs, small boats, etc.) are operating in a local area of interest. The point is that the tactical commander can now see – with more precision and timeliness – what is happening in communications signal environment where his or her forces are operating. This trend is driving greater interest in comms ESM systems, while the demand for COMINT systems also remains strong. It is not a coincidence that this is *JED*'s largest technology survey, with more than 50 companies responding.

This month's survey covers COMINT and comms ESM receivers operating across the HF, VHF, UHF and SHF bands. The number of communications systems operating in these frequencies has grown as military forces have become more networked and as commercial users' appetites for greater connectivity continue to grow. These trends create dense and complex signal environments, even at the local level, which in turn require high-performance COMINT and comms ESM systems to monitor them.

In the survey table that follows, the first column indicates the unit or model number, followed in the next column by the type of receiver its uses. The next two columns describe the receiver's operating frequency range and its instantaneous bandwidth. The following two columns address typical installed sensitivity and total dynamic range. These indicate how the receiver performs against low-power signals and in noisy environments. The types of modulations the receiver can handle are defined in the next column. The following column describes if the system can perform direction finding. During the Cold War, DF systems were typically separate from COMINT systems. Today, however, there are fewer discrete communications direction-finding systems, because this function is built into many (but not all) COMINT and comms ESM systems. The next column indicates how many channels the receiver provides, which gives an indication about how many signals can be monitored and processed at any time. The remaining columns describes the unit's power requirements, size, which types of weapons platforms it is designed for, and weight.

Next month, our technology survey will look at EW and SIGINT antennas.

COMINT AND COMMS ESM RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	DYNAMIC RANGE	MOD TYPES
ASELSAN; Ankara, Turkey; +90-312-592-10-00; www.aselsan.com.tr						
MEERKAT - V/UHF Pocket Receiver	Superhet/Digital	20 MHz - 6 GHz	80 MHz	-105 dBm (12.5 kHz FFT Res.)	125 dB	AM, FM, CW, LSB, USB
BAE Systems; Richardson, TX, USA; +1 972-699-8580; www.baesystems.com						
RXR6322/ RXR6422	Superhet/digital	0.1 MHz - 6 GHz	10, 40 or 80 MHz	-114 dBm (25 kHz)	144 dB (AGC) >80 dBc Single Tone SFDR across entire tune range with tone at -1 dBFS.	Pre-D, AM, FM, CW, SSB
Boger Electronics; Baden-Württemberg, Germany; +49 7525 923820; www.boger-electronics.com						
AFAS-18000	Digital monitoring receiver	10 kHz - 18 GHz	10 MHz, 2 MHz for I/Q streaming	-120 dBm with 10 dB S/N	115 dB	AM, FM, USB, LSB, I/Q; automatic classification of PSK (2-16), OQPSK, FSK, OFDM
Chemring Technology Solutions; Romsey, Hampshire, UK; +44 1794 833000; www.chemring.co.uk						
MCDWR16I	Direct digitisation SDR	100 kHz - 30 MHz	4 independent freq. channels, each ≤ 1.25 MHz	NF: 12 dB	>113 dB instantaneous (3 kHz BW, 0dB SNR, no AGC)	AM, LSB, USB, FM, CW, IQ
Chordell Systems; Adelaide, Australia; +61753484; www.chordell.com.au						
WOLVERINE	Digital	500 MHz - 30.5 GHz	30 GHz	CRLB +0.2dB typ	155 dB typ.	All, voluntary and involuntary
CommsAudit; Cheltenham, UK; +44 1242 253131; www.commsaudit.com						
CA7851	Dual conversion, superhet	20 MHz - 6 GHz	100 MHz digitized bandwidth (full stare)	NF: 8 dB typ.	Single-tone, inst. spurious-free dynamic range (in normal mode): 65 dB typ., 60 dB min. (20-120 MHz); 80 dB typ., 70 dB min. (120 MHz - 6 GHz)	VITA49 I/Q output to external demod/decode resources
CA7852	Dual conversion Superhet	20 MHz - 6 GHz	2 x 100 MHz digitized bandwidth (full stare) - channels are phase coherent	NF: 7 dB typ.	Single-tone, inst. SFDR 65 dB typ. (20-120 MHz); 85 dB typ. (120 MHz - 6 GHz)	VITA49 I/Q output to external demod/decode resources
CA7814	Direct Digitization	9 kHz - 32 MHz	32 MHz (full band)	NF: 8 dB typ.	Single-tone, inst. SFDR 97 dB min. (above 2 MHz)	VITA49 I/Q output to external demod/decode resources
CRFS Inc.; Chantilly, VA, USA; +1 571-321-5470; www.crfs.com						
RFeye® Node 40-8 / Node 50-8 / Node 100-8	Superhet	9 kHz - 8 GHz	40-8: Up to 40 MHz; 50-8: Up to 50 MHz; 100-8: Up to 100 MHz	Typ. noise figures: 5.5 - 9 dB from 9 kHz - 8 GHz	120 dB	CW, AM, FM, SSB, DSB, LSB, USB, PM, Noise, ASK-n, BPSK, MSK, FSK, PSK-n, OPSK, QAM-n, V.29-n, IQ
RFeye® Node 100-18	Superhet	9 kHz - 18 GHz	Up to 100 MHz	Typ. noise figures: 8.5 - 13 dB from 9 kHz - 18 GHz	120 dB	CW, AM, FM, SSB, DSB, LSB, USB, PM, Noise, ASK-n, BPSK, MSK, FSK, PSK-n, OPSK, QAM-n, V.29-n, IQ
RFeye® Node 100-40	Superhet	9 kHz - 40 GHz	Up to 100 MHz	Typ. noise figures: 8.5 - 16 dB from 9 kHz - 40 GHz	120 dB	CW, AM, FM, SSB, DSB, LSB, USB, PM, Noise, ASK-n, BPSK, MSK, FSK, PSK-n, OPSK, QAM-n, V.29-n, IQ
D-TA Systems; Ottawa, Ontario, Canada; +1 613-745-8713; www.d-ta.com						
RFvision-Broadview	Superhet	1 MHz - 8 GHz	80 MHz IBW (10 kHz - 80 MHz, DDC selectable Op BW)	(-) 82 dBm at Full 80 MHz BW	(-) 75 dBc worst case SFDR	Std Analog & Digital
RFvision1-Supermini	Superhet	1 MHz - 8 GHz	80 MHz IBW (10 kHz - 80 MHz, DDC selectable Op BW)	(-) 82 dBm at full 80 MHz BW	(-) 75 dBc worst case SFDR	Std Analog & Digital
DTA-2300	Direct sampling HF transceiver	1-40 MHz	40 MHz IBW (5 kHz - 40 MHz, DDC selectable Op BW)	(-93) dBm at full 40 MHz BW	(-) 90 dBc worst case SFDR	Std Analog & Digital

SUPPORT DF	CHANNELS	POWER (W)	SIZE (HxWxL in/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
*	1	*	80 x 35 x 140 mm	Man-pack, air, shp, grd-mob	0.6 kg	WB surveillance/monitoring operations; Digital spectrum, NB I/Q, audio stream outputs; DDR channel for demodulation and I/Q data.
Amplitude and phase interferometry (N-channel and Commutated Baseline) DF. TDOA and FDOA geolocation.	2 RF channels and 32 Independent DDR channels.	72 W max 45 W min depending upon user FPGA use.	3U VPX - 1-in. pitch or 0.975 H x 3.95 -in. W x 8.25” L “brick” style form factor.	Air, grd-mob, grd-fix, shp, sub, LEO space	1.4 lbs	VITA 65 OpenVPX with VITA 67.2 Blind-mate RF connectors. VITA 49.2 Radio Transport over PCI-E and 10 GigE. Phase coherent across multiple modules. High-sensitivity, low phase noise.
Supports third party DF	Configurable (up to 4 RX-channels per processing unit)	Config. dep.	Config. dep.	Air, grd-fix, grd-mob, shp	Config. dep.	Digital monitoring receiver with analog scanning rf-frontend; BO-35 wideband receivers.
Super-resolution, N channel coherent	≤9 expandable to ≤18 (dual-unit configuration) and higher (multi-device configuration)	35 W	2U x 19-in. rack	Grd-fix	5.25 kg	Multi-site networking for simultaneous position fixing.
FDOA, TDOA, PDOA	1 or 4	15 kW	52 x 22 x 40 in.	Grd, ship, air, sub	200 kg	COMINT, ELINT, ESM - any RF emission.
Yes. TOA, TDOA, FDOA, Super Resolution	Up to 128 DDC channels	28 W typ.	41 x 145 x 241 mm (half 1U)	Air, grd-fix, grd-mob, shp, sub	2.2 kg	13-band sub-octave pre-selector; low-noise, high dynamic range; on-board DSP/FPGA; low phase noise; precision timestamps for JICD-compliant applications.
Yes. Designed for 2-channel sequenced interferometry DF in single reciever	Up to 128 DDC channels	70 W typ.	41 x 165 x 270 mm (half 1U)	Air, grd-fix, grd-mob, shp, sub, UAV	2.8 kg	Compact design for portable 2-channel DF applications; incorporated into systems qualified to DO-160G; low-noise, high dynamic range; on-board DSP/FPGA; low phase noise; precision timestamps for JICD-compliant applications.
Yes - various options	Up to 128 DDC channels	40 W max	145 x 41 x 260 mm (half 1U)	Air, grd-fix, grd-mob, shp, sub	1.5 kg	Full-band digitisation; 1 million point FFT; super-low noise figure for SIGINT; superior image rejection to improve P(intercept); integrated RF limiters and RF pre-selection; precision timestamps for JICD-compliant applications.
AOA, POA, TDOA	1 channel. 40-8: 4 switchable full BW inputs; 50-8/100-8: 3 switchable full BW inputs	25 W typ.	40-8: 74 x 200 x 130 mm; 50-8/100-8: 74 x 200 x 192 mm	Air, grd-fix, grd-mob, shp, sub	40-8: 2.1 kg; 50-8/100-8: 2.4 kg	40-8: Receiver phase noise: ≤-107 dBc/Hz @ 20kHz offset at 1GHz input. 50-8/100-8: Receiver phase noise: ≤-130 dBc/Hz @ 20kHz offset at 1GHz input.
AOA, POA, TDOA	1 channel w/ 3 switchable full BW inputs	40 W typ.	74 x 200 x 192 mm	Air, grd-fix, grd-mob, shp, sub	2.4 kg	Receiver phase noise: ≤-126 dBc/Hz @ 20kHz offset at 1GHz input.
AOA, POA, TDOA	1 channel w/ 3 switchable full BW inputs	50 W typ.	74 x 200 x 192 mm	Air, grd-fix, grd-mob, shp, sub	2.8 kg	Receiver phase noise: ≤-126 dBc/Hz @ 20kHz offset at 1GHz input.
Multi-channel phase coherent	Up to 16 Rx and Tx in any combination	25 W/ch	1U - 3U Rack mount (number of channels dep.) or custom	Air, shp, grd-mob	15 kg max for rack-mount	Open-architecture and configurable solution can incorporate third party processing software.
2-channel mono-pulse	1 Rx & 1 Tx or 2 Rx or 2 Tx	250 W	Portable 3/4 ATR	Air, shp, grd-mob	8 kg	Built-in recording and processing of both channels at full 80 MHz BW.
Multi-channel phase coherent	4 Rx & 8Tx / card	60 W/card	7.5 x 7 in. card	Air, shp, grd-mob	0.5 kg/card	Any number of channels can be configured for HF communications or HF radar applications. Each card provides 2 x 10 GbE networks for data transfer.

COMINT AND COMMS ESM RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	DYNAMIC RANGE	MOD TYPES
Digital Receiver Technology Inc., a Boeing Company; Germantown, MD, USA; +1 301-9160-5554; www.drti.com						
120xC/1183C	Digital	0.2 MHz - 6.5 GHz	*	*	*	DSP demodulation, application specific AM, FM, CW, USB, LSB
Elbit Systems EW and SIGINT – Elisra; Holon, Israel; +1-972-3-5577278; www.elisra.com						
TSR 2300	Superhet	20 MHz - 6 GHz	Analog: 50 MHz; Dig: 40 MHz, 20 MHz and 10 MHz	10 kHz: -105 dBm; 50 kHz: -98 dBm; 100 kHz: -95 dBm; 300 kHz: -90 dBm	120 dB	AM, FM, ISB, USB, SSB and CW
Elettronica; Rome, Italy; +39 06 41541; www.elt-roma.com						
ELT 332 DF/ COMINT	Digital receiver	30-3000 MHz	≤ 80 MHz for DF; 1, 5, 20, 40 MHz for monitoring	- 110 dBm	110 dB	AM,FM, USB, LSB; ASK2 / Morse; 2-4 FSK, M-FSK; 2-4-8 PSK and variants (OQPSK, pi/4 QPSK); QAM 16-32-64; MSK, GMSK; OFDM
Elta Systems Ltd; Ashdod, Israel; +972-8-857-2312; www.elta.co.il						
ELK-7065VU	*	VHF/UHF	*	*	*	*
Enablia S.R.L.; Rome, Italy; www.enablia.com						
TitanSDR	Direct sampling software radio	0.009-32 MHz	312.5, 625, 937.5, 1250, 1562.5, 1875, 2187.5 kHz	-116 dBm (0.34 μV) SSB at S+N/ N=10dB, 15MHz, 2.4 kHz BW	>108 dB (SFDR)	USB, LSB, AM, NBFM, CW, eUSB, eLSB, FSK, IQ
Epiq Solutions; Rolling Meadows, IL, USA; +1 847-598-0218; www.epiqsolutions.com						
VPX400	SDR transceiver	1 MHz - 6 GHz	Up to 800 MHz	<8 dB typical noise figure	75 dB SFDR typical	GMSK, QPSK, OFDM, others
The Espy Corporation; Austin, Texas, USA; +1 512-261-1016; www.espy.com						
teamSENTINEL V/UHF	Superhet with SDR dig. channelizer	20 MHz - 6 GHz	128, 256, 384, 512, 640, 678, 896 1024 MHz	-105 dBm	>75 dB	AM, FM, CW, SSB, IQ, and others
FEI-Elcom Tech, Inc.; Northvale, NJ, USA; +1 201-767-8030; https://fei-elcomtech.com						
SIR-3200-40/80	Superhet, IF sampling SDR	20 MHz - 3 GHz	40 MHz/80MHz	-103 dBm	20 kHz/90 dB	AM, FM, PM, SSB, IQ
GEW Technologies; Pretoria,South Africa; +27 12 421 6216; www.gew.co.za						
MRR8001C Wideband and Monitor Receiver	Superhet, SDR	500 kHz - 9 GHz	Up to 80 MHz	-125 dBm, mode dep	Up to 140 dB	SSB, CW, AM, FM, dig IO
GRX6000 Wideband HF Receiver	SDR	9 kHz - 30 MHz	Up to 30MHz	-135 dBm	Up to 120 dB	SSB, CW, AM, dig IO
MRD7090CE Wideband Direction Finder	Superhet, SDR	8 kHz - 9GHz	Up to 80 MHz	*	*	DF on all modulation types. Dig IO of 80 MHz available
Herrick Technology Laboratories, Inc.; Germantown, MD, USA; +1 301-972-2037; www.herricktechlabs.com						
HTLv SOSA Aligned Multi-Channel VPX Sensor System	RX/TX, superhet, SDR	2 MHz - 20 GHz, 44 GHz with frequency extender	80 MHz or 2 GHz per channel	*	*	FA, PTT, dPTT Radar: Pulse, LPI
HTLw	RX/TX, superhet, SDR	20 MHz - 20 GHz, 44 GHz with frequency extender	1 GHz per channel	*	*	Radar: Pulse, LPI
HTLx	RX/TX, superhet, SDR	2.0 MHz - 18 GHz, 44 GHz with frequency extender	80 MHz per channel	*	*	FA, PTT, dPTT Radar: Pulse, LPI
Horizon Technologies; London, UK; +(44) 2036 089996; www.horizontechnologies.eu						
Flying Fish 3rd Generation (SD)	*	L-Band	*	*	*	Thuraya, Inmarsat, IsatPhone Pro

SUPPORT DF	CHANNELS	POWER (W)	SIZE (HxWxL in/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
Compatable with DRT DF sub-systems	12C - 816 half-duplex (32 channels per WPM3); 1183C 336 half-duplex (32 channels per WPM3)	12C - 1143 W; 1183C - 650W	12C - 4U 19-in. rack mount chassis; 1183C 7 in. H x 13 in. W x 11.5 in. D	Air, grd-manpack, grd-mob, grd-fix, shp, sub	12C - 70 lbs; 1183C 45 lbs	Mult. slots that can be config. to any combination of turners, processsors; comes w/ DF antenna options.
Amplitude, phase interferometer, time of arrival	1 - 7	60 W	14 x 19 x 23.5 in.	Air, grd, shp, sub	*	*
Correlative interferometry	5 DF channels	≤ 1 kW per channel according to specific servers configuration	1/2 ATR for DPU, 74 x 76 x 127 mm for RFU, DFMA/SM, monitoring, WS and servers according to specific installations	Ship	250-300 kg, according to specific installations	COMINT functions integrated through GFE, third parties and proprietary modules.
Yes	*	*	100 x 170 x 260 (rcvr unit)	Air	*	UAS-based COMINT system; uses Vector Sensor Antenna to geolocate VHF/UHF emitters, measuring elevation and azimuth conucrrently.
No	Wideband channels: 4; narrowband channels: 40	15 W	5.2 cm x 24.3 cm x 14.5 cm	Grd-fix	3.2 kg	*
All channels phase coherent capable, multi-card sync capable	4 RX, 4 TX	11 W typ. for tuner	100 x 24 x 160 mm	3U VPX SOSA aligned	*	Integrated FPGAs, quad-core processor, pre-select filtering. SOSA aligned with SLT3-PAY-1F1U1S1S1U1U2F1H-14.6.11-4 profile (options available). Integrated MORA support or development kit available.
Correlative interferometer DF, TDOA and FDOA, JCID 4.2 Node-compliant	4, 8, 12, 16	From 500 W	From 4U, 19-in. rack	Air, grd-fix, grd-mob, shp, sub	From 60 lb	Built-in wideband recording (from 7-hours to multiple days), multiple SDR NB receivers, and support for multi-sensor operations and networks.
Common synth LO	2 - 4	120 W	19 in. , 2U	Air, grd, shp	*	*
High speed interface to DFs available	1 WB plus 32 NB	< 100 W	2U x 19 in. x 440 mm	Grd-fix, grd-mob, shp	< 16 kg	*
*	One	< 80 W	19 in. x 1U x 490 mm depth	Grd-fix, grd-mob, shp	<10 kg	*
Corrolative interferometric DF and TDOA modes	Independant demodulation channel built in	< 250W	4U x 19 in. x 380 mm depth	Grd-fix, grd-mob, shp	<40 kg	*
Yes	11 slot: 2-16 channels	11 slot system: 1500 W max	11 slot Chassis: 10.5 x 15 x 18 in.; 3U VPX modules; 19 slot available	Air, grd-mob, grd-fix	Fully Loaded Chassis : 70 lb; Mod: 2 lb	SIGINT, ELINT and EW capabilities: spectrum analytics, DF, tracking, PDW, LPI detection, geolocation and transmit.
Yes	4	120 W typ.	2.06 x 4 x 8.0 in. (H x W x D)	Air, grd-mob, grd-fix	4 lb	ELINT capabilities: spectrum analytics, DF, PDW, LPI detection.
Yes	4	80 W typ.	1.6 x 3.5 x 8.0 in. (H x W x D)	Air, grd-mob, grd-fix	2.9 lb	SIGINT, ELINT and EW capabilities: spectrum analytics, DF, tracking, PDW, LPI detection, geolocation and transmit.
*	64	AC PSU External: 90V - 264VAC; DC PSU Internal 28V	392 x 371 x 240 mm	Air	16 kg	Analyzes Thuraya, IsatPhone Pro traffic simultaneously.

COMINT AND COMMS ESM RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	DYNAMIC RANGE	MOD TYPES
Indra Sistemas, S.A.; Madrid, Spain; +34-916-271-162; www.indra.es						
IN/TSD-1000	Preselected superhet wideband dig.; direct sampling HF	20 MHz - 6 GHz	80 MHz (30 MHz in HF)	-105 dBm (-112 dBm in HF)	120 dB	IQ data
Innovationszentrum für Telekommunikation (IZT); Erlangen, Bavaria, Germany; +49-9131-9162-0; www.izt-labs.de						
IZT R3000: R3030/R3040; R3301; R3410/ R3411	Dual-conversion superhet	9 kHz - 18 GHz	25 MHz	-120 dBm (SNR=10 dB; BW=2 kHz)	170 dB (AGC)	FM, AM, USB, LSB, I/Q
IZT R5000: R5010; R5040; R5060; R5070	Dual-conversion superhet	9 kHz - 18 GHz	60, 80, 120 MHz	-120 dBm (SNR=10 dB; BW=2 kHz)	170 dB (AGC)	*
IZT R5506/R5509	Interferometric digital DF	R5506: 1 MHz - 6 GHz; R5509: 20-520 MHz	R5506: 60 MHz; R5509: 40 MHz	*	*	*
iRF - Intelligent RF Solutions; Sparks, MD, USA; +1 443-595-8510; www.irf-solutions.com						
iUR-7400/ UltraRail	Superhet, search/set-on receiver	20 MHz - 18 GHz	500 MHz/1 GHz	100 dB @1 MHz	60 dB, STSFDR	Contact factory
Jordan Electronic Logistics Support; Amman, Jordan; +96 279 667 9716; www.jels-tech.com						
Signal Sniper	Channelized w/ dig receiver	50 MHz - 6GHz	50 MHz	-100 dBm @ 10 MHz BW	60 dB	AM, FM, PM, DSB, SSB, NBFM
L3Harris - TRL Technology; Tewkesbury, Gloucestershire, UK; +44 1684 278700; www.L3Harris.com						
SMARTSCAN MEWS	Superhet	2 MHz - 3 GHz	40 MHz	*	*	AM, FM, SSB and CW
L3Harris Technologies; Melbourne, FL, USA; +1 903-455-3450; www.L3Harris.com						
Rio Niño	*	100 kHz - 6 GHz	320 MHz (4 x 80 MHz per receiver)	-115.5 dBm 3dB SNR at 500 MHz with 30 KHz DDC BW	75.3 dB at 500 MHz	AM, FM, SSB, FSK, BPSK, QPSK, OQPSK/SQPSK, QAM and MSK
Leonardo DRS; Germantown, MD, USA; +1 301-948-7550; www.leonardodrs.com/SignalSolutions						
Vesper SI-9173/ SI-9172	Superhet	3 MHz - 6.2 GHz	Selectable bandwidths: 100, 30, 15 MHz	13 dB NF, -122 dBm sensitivity @ 10 kHz BW	88 dBc SFDR in a 10-kHz BW	VITA 49 packetized digital IF via Aurora transport protocal
LS telcom AG; Lichtenau, Germany; +49-7227-9535-600; www.lstelcom.com						
LS OBSERVER PPU 318w	Superhet/digital	9 kHz - 18 GHz	Up to 40 MHz	*	*	AM, FM, CW, LSB, USB, DSB; further types available.
Midwest Microwave Solutions Inc.; Hiawatha, IA, USA; +1 319-393-4055; www.mms-rf.com						
MSDD-6640	Dual channel scanning superhet with digitizer	30 MHz - 6 GHz	40 MHz	*	*	*
Motorola Solutions; Schaumburg, IL, USA; ATInfo@motorolasolutions.com; www.motorolasolutions.com/appliedtechnology						
OVERLORD	SDR	Rx/Tx: 70 MHz - 6 GHz	Rx: 56 MHz, Tx: 40 MHz per channel	<6 dB noise figure typ.w	60 dB SFDR typ.	DSP demodulation, application specific (CW, AM, FM, BPSK, FSK, GMSK, PSK-n, QPSK, QAM-n, OFDM, others)
VENGEANCE	DDR, SDR	Rx: 2 MHz - 30 GHz, Tx: 2 MHz - 27 GHz	Rx/Tx: 1 GHz per channel	<8 dB noise figure typ.	72 dB SFDR typ.	DSP demodulation, application specific (CW, AM, FM, BPSK, FSK, GMSK, PSK-n, QPSK, QAM-n, OFDM, others)
TRICKSTER	SDR	Rx: 2 MHz - 30 GHz, Tx: 2 MHz - 27 GHz (w/ MCM)	Rx: 56 MHz, Tx: 40 MHz per channel	<6 dB noise figure typ.	60 dB SFDR typ.	DSP demodulation, application specific (CW, AM, FM, BPSK, FSK, GMSK, PSK-n, QPSK, QAM-n, OFDM, others)
Novator Solutions; Stockholm, Sweden, +46 8 622 63 50; www.novatorsolutions.com						
HUGIN 2000 - V/U/SHF Multichannel Receiver	Superhet, Vector Signal Analyzer	20 MHz - 3.6/14/26.5 GHz	2 x 50/200 MHz	20-100 MHz -155 dBm/Hz; 100 MHz-1.7 GHz -157 dBm/Hz	V/UHF: 119 db	AM, FM,CW, SSB, WFM, I/Q (no demodulation)

SUPPORT DF	CHANNELS	POWER (W)	SIZE (HxWxL in/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
Correlative interferometry (Watson-Watt in HF)	3; up to 8	600 W	19 in. x 6U x 640 mm	Air, grd-mob, shp	47 kg	Fix frequency, frequency hoppers and DSSS signals pre-classification HF.
Correlative interferometer, Watson-Watt, TDOA	1	43 -160 W, model dep.	model dep.	Grd-mob, grd-fix, shp, sub	R3040: 11 kg R3040: 12 kg R3301: 17 kg R3410: ~6.8 kg R3411: 4.5-4.9 kg	Rack-based or rugged/mob.; multiple DDCs; high linearity; 1 Gbit Ethernet interface.
TDOA	1	R5010/R5040: 70-150 W R5060/R5070: 50 W	R5010: 1U x 19 in. x 560 mm; R5040: 306 x 85 x 532 mm; R5060: 42 x 219 x 380 mm; R5070: 96 x 283 x 348 mm	Grd-mob, grd-fix, shp, sub	R5040: 12 kg R5060: 5 kg R5070: 8 kg	Rack-based or rugged/mob.; multiple DDCs; high linearity; 10 Gbit Ethernet interface.
Super Resolution DF, Correlative interferometer, TDOA	R5506: 5+1; R5509: 9	200-250 W	*	Grd-mob, grd-fix, shp, sub	Model dep.	High linearity; 2 x 10 Gbit Ethernet interface; directly mounted on antenna mast.
Yes	4, expandable to 8	40 W	3U VPX, brick	Air, grd-fix, shp, sub	2 lb	High density microwave receiver w/ superior phase noise, signal fidelity.
No	4	*	40 x 40 x 12 cm	Grd-mob	*	Support automatic jamming system.
Correlative interferometry	3	44 W	14 x 24 x 29 cm	Grd-mob	*	*
Commutated DF/ advanced geo engine and precision geo (JICD 4.2)	4	180 W	9 x 5.7 x 8.5 in.	Air, grd, shp	15 lb	Four channel COMINT receiver; open architecture and sized for multiple operators.
N-channel coherent or full independent tuning	Up to 8 Rx & 1 Tx/ Up to 4 Rx & 1 Tx	111 W/50 W	6U VPX/3U VPX	*	4.5 lb	Highly configurable with multiple channels. CMOSS/ SOSA aligned.
Yes	Dual-receiver option available (monitoring sweep mode + DF in parallel)	*	42 x 25 x 56 cm	Grd-mob, grd-fix, shp, sub	20 kg	Fully integrated portable COMINT system; automatic DF; co-channel signal resolution;TDOA geolocation (min. 3 receivers needed).
*	4	*	3.75 x 7 x 2.4 in.	Air, grd, shp, sub	*	50 MSPS I/Q streaming, 300 µsec tune time, four complete receivers.
FDOA, TOA	8 Rx, 8 Tx	160 W total (max)	10.8 x 19.2 x 2.1 in. RU	Air, grd-fix, grd-mob	11.75 lb	Four independent SDRs with integrated processors, FPGAs, GPS, 1GbE switch, phase-coherent sampling. EW/ISR Capabilities.
FDOA, TOA	8 Rx, 8 Tx	120 W total (max)	9.88 x 7.50 x 2.64 in.	Air, grd-fix, grd-mob	7.0 lb	Xilinx RFSoC, 1/10/100GbE, NVMe, GPS, phase-coherent sampling, independently tunable channels, future support of 5G, VITA49, and OpenCPI framework.
FDOA, TOA	8 RX, 8 TX	SDR Module: 15 W typ. / 25 W max (application dep.)	SDR Module: 8.1 x 4.75 x 1.5 in.; MCM: 8.0 x 4.75 x 1.2 in. typ.	UAS (Group 1-5), MAV, HAB, sub, shp, grd-fix, grd-mob	SDR Module: 1.2 lb; MCM: <1 lb typ.	Modular payload system with high performance SDR. Flexible mission support via field swapable Mission-Capability-Module (MCM) and antenna.
TDOA via third party	2 RF channels 2048; independent DDR channels	340-530 W (Unit total, config. dep.)	19-in. rackmount 4U (17.71 x 44.55 x 46.36 cm)	Air, grd-fix, shp, sub	22.3-26.5 kg (config. dep.)	Built-in server, Digital Spectrum, Independent NB configuration during run-time, I/Q or demod channel independent.

COMINT AND COMMS ESM RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	DYNAMIC RANGE	MOD TYPES
PLATH Signal Products GmbH & Co. KG, Hamburg, Germany, +49 (0) 40-237-34-0, www.plath-signalproducts.com						
Monitoring Receiver SIR 2115	Superhet	20 MHz - 3 GHz (opt. from 9 kHz -6 GHz)	80 MHz @ 1 kHz freq. resolution	MDS: -139 dBm @ 1kHz; NS: 6 dB typ.	155 dB (SFDR >= 90 dB); internal spurious < -120 dBm	AM, FM, CW, USB, LSB, ISB
QinetiQ; Farnborough, Hampshire, UK; +44 (0) 1684 894750; www.qinetiq.com						
ASX Family of COMINT/DF Systems	*	20-500 MHz	40 MHz	*	*	NFM, WFM, AM, USB, LSB, CW
Radixon Group (WiNRADiO); Melbourne, Australia; +61 3 9417 3417; www.winradio.com						
G69DDC(i/e)	Direct-sampling + Superhet	8 kHz - 8 GHz	Up to 32 MHz	MDS -128 dBm @ 10 MHz, 500 Hz BW -138 dBm @ 800 MHz, 500 Hz BW (preamp on)	105 dB up to 80 MHz, 90 dB above, preamp off	Analogue, digital
Rohde & Schwarz GmbH; Munich, Germany; +49-89-4129-0; www.rohde-schwarz.com						
R&S®DDF®550 Wideband Direction Finder	Superhet and DDR	300 kHz - 3 GHz	80 MHz	0.7-10 µV/m typ.	150 dB w/ 40 dB attn (1 dB steps)	AM, FM, PM, pulse, I/Q, USB, LSB, CW, ISB
Saab Sensor Systems Germany GmbH; Nuremberg, Germany; +49 911 47725 001; www.saab.com/de/markets/germany						
MFT-400-5	Direct Sampling and Superhet	20 MHz - 8 GHz	Up to 80 MHz	Installed sensitivity dep. on antenna and cable set; NF: < 10 dB: 20 MHz - 3 GHz < 17 dB: 3 GHz - 8 GHz	> 140 dB	IQ Output
Sagax Communications; Budapest, BP, Hungary; +36-30-172-0718; www.sagaxcommunications.com						
SRM-3000	HF: direct samplig V/UHF: IF sampling superhet monitoring and collecting digital receiver	HF: 9 KHz - 36 MHz V/UHF: 20 MHz - 3 GHz	200 KHz	-120dBm @ 10dB S/N with 1KHz resolution	124 dB	Energy detection, amplitude spectrum, bearing spectrum

SUPPORT DF	CHANNELS	POWER (W)	SIZE (HxWxL in/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
TDOA ready	1	~150 W	1 HU x 19 in. x 490 mm	Grd-fix, grd-mob, shp, sub	10 kg	Ultra fast scan with 100 GHz/s, complete IQ stream (4 x 20 MHz), 20 DDC simultaneously (inside 80 MHz BW); real-time spectrum calculation.
Yes	*	*	Varies	Air	*	Optional 20 MHz - 3 GHz coverage; AS3 for tactical UAVs and helos; AS4 for MALE and HALE UAVs; AS5 for business jets.
*	3	16 W @ 12V, 20 W PoE	166 x 97 x 59 mm (6.5 x 3.8 x 2.3 in.) external version	*	839 g (29.6 oz) external version	Ext. clock in/out.
HF: amplitude (Watson-Watt); VHF/UHF/SHF: phase (correlative interferometer)	2 receiving channels	400 W (Config. dep.)	17.6 x 42.6 x 45 cm	Air, grd-fix, grd-mob, shp, sub	18 kg (installed options dep.)	Time synchronization for triangulation networks, DF error correction, DDC signal extraction, high-resolution panorama spectrum, detection of short-time signals.
Full support of DF (Phase and Amplitude) for 5 coherent channels	5 V/U/SHF channels with up to 80 MHz instantaneous BW each	490 W	7U x 19 in. x 490 mm	Grd-fix, grd-mob, shp, sub	35 kg	Digital receiver for SDR incl. digital IF output (full IF bandwidth for all channels), all channels independently controllable (multifunctional).
Amplitude (Wattson-Watt)	4 independent RF input and 16 independent hw DDCs	<45 W	41 x 200 x 440 mm (1U half rack)	Grd-fix, grd-mob, portable	<5 kg	TCP/IP remote control and data/spectrum streaming, built-in DF processor, record and playback.

COMINT AND COMMS ESM RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	DYNAMIC RANGE	MOD TYPES
Seqtor of Denmark; Grenaa, Denmark; +45 20292280; www.Seqtor.com						
MENTOR	Direct conversion	25-3000 MHz in 10 KHz steps	100 KHz/ 500 KHz / 2 MHz /10 MHz	90 dBm	70 dB	None; RSSI Type of energy only
Silver Palm Technologies; Ijamsville, MD, USA; +1 301-874-0065; www.silverpalmtech.com						
SP-8385 SDR	Superheterodyne with SDR	20 MHz - 6 GHz	4 MHz (software definable up to 40 MHz)	-86dBm for 10db snr in 4MHz bandwidth	80 dB	AM, FM, Log
Southwest Research Institute (SwRI); San Antonio, TX, USA; +1 210-522-3493; www.swri.org						
MBS-567	Digital, superhet	0.1 MHz - 6 GHz	30-320 MHz	*	*	PSK, MSK, FSK, QAM, SSB, FM and others
Spectranetix, Inc.; Sunnyvale, CA, USA; +1 408-982-9057; www.spectranetix.com						
SX-430	Wideband SDR transceiver	1 MHz - 18 GHz	160 MHz per channel	<12 dB NF <6 GHz <15 dB NF>6 GHz	>100 dB	Software defined
TCI; Fremont, CA, USA; +1 510-687-6110; www.tcibr.com						
TCI 850 Blackbird	Hybrid superhet; channelized analog/dig rcvr	.009-8000 MHz	4 or 40 MHz (dual BW receivers)	-120 dBm @ 1 kHz BW	120 dB	DF on all modulations
Tech Comm, Inc.; Ft. Lauderdale, FL, USA; +1 954-712-7777; www.techcommdf.com						
TC-9320 COMINT/DF	SDR, digital DF processor	30 MHz - 6 GHz	22 MHz	-115dBm	120 dB	AM, FM, SSB, CW, 2500+ signal types
TC-9330VM COMMINT/DF	SDR, digital DF proceesor	30 MHz - 6 GHz	22 MHz	-115dBm	120 dB	AM, FM, SSB, CW, 2500+ signal types
TC-9332VM COMMINT/DF	SDR, digital DF proceesor	30 MHz - 6 GHz	22 MHz	-115dBm	120 dB	AM, FM, SSB, CW, 2500+ signal types
Thales SIX-GTS ; Gennevilliers, France; +33 1 46 13 20 00; www.thalesgroup.com						
TRC 6460	DF and superhet receiver	20 MHz - 3 GHz V/UHF DF; SHF opt.	40 MHz in V/UHF	-128 dBm in V/UHF	120 dB in V/UHF	DF on all modulations

SUPPORT DF	CHANNELS	POWER (W)	SIZE (HxWxL in/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
No	24 pre-programmable	0.4 W	1.28 x 3.05 x 6 in. / 3.25 x 7.74 x 15 in.	Standalone / handheld	0.5 lb / 250 g	Personal ESM system; built-in solid-state frequency recorder with GPS & real-time.
Could be added in SDR FPGA load	1	< 15W	6 x 3.5 x 1.25 in.	Air, grd-mob, grd-mob, shp	1 lb	Designed as a software definable tuner/receiver replacement for legacy systems.
DF (vector match), T/FDOA	2 to 8 (>200 simultaneous receivers)	*	2 racks, scalable to 1	Shp, sub	*	Wideband automatic detection, classification and recording; tactical or strategic operations; data mining; complex signals analysis.
Phase coherent	2 TX and 2 RX	60-100 W	3U VPX conduction cooled	Air, grd-mob, shp	1.98 lb	Full Duplex CMOSS/SOSA SDR, Multi-card Phase Coherent.
Optional Hybrid AOA/TDOA, AOA or TDOA	1-3 (plus 92 DDCs)	<200 W	7 x 19 x 20 in.	Grd-fix, grd-mob., portable	*	*
Mult. DF techniques 30 MHz - 6 GHz	2, single DF	90 W @ 12vdc	2U with 1U pull out rack for system control laptop	Air, grd-mob, grd-fix, shp	14.6 lb	4-degree DF accuracy with Tech Comm 8000 series antennas.
Mult. DF techniques 30 MHz - 6 GHz	1, single DF	35 W @ 12vdc	3/4 ATR, 7.86 x 6.75 x 15.75 in.	Air, grd-mob, grd-fix, shp	6.8 lb	4-degree DF accuracy with Tech Comm 8000 series antennas.
Mult. DF techniques 30 MHz - 6 GHz	2, single DF	70 W @ 12vdc	Full ATR	Air, grd-mob, grd-fix, shp	10.9 lb	4-degree DF accuracy with Tech Comm 8000 series antennas.
Enhenced Vector Correlation	5 or 6 DF, 1 or 2 monitoring	<475 W	9U, 19 inch	Air, grd-fix, grd-mob, shp	<45 kg	*

SURVEY KEY – COMINT AND COMMS ESM RECEIVERS

MODEL
Product name or model number

REC TYPE
Receiver type
- DDR = direct digital receiver
- DF = direction-finding
- dig = digital
- HF = high frequency
- IF = intermediate frequency
- LAN = local area network
- SDR = software-defined radio
- superhet = superheterodyne

OP FREQ
Operating frequency in kHz, MHz or GHz.

INST BW
Instantaneous bandwidth (if different from operating frequency)

TYP INST SENS
Typical Installed Sensitivity
- FFT = fast Fourier transform
- SNR = signal-to-noise ratio

DYN RANGE
Total dynamic range
- AGC = automatic gain control
- SFDR = spur-free dynamic range

MOD TYPES
Modulation types it can process
- AM = amplitude modulation
- BFSK = binary frequency shift keying
- BPSK = binary phase shift keying
- CDMA = code division multiple access
- CPM = continuous phase modulation
- CW = continuous wave
- DBPSK = differential binary phase shift keying
- DF = decision feedback
- DQPSK = differential quaternary phase shift keying
- DSBSC = double sideband-suppressed carrier
- EVDO = evolution-data optimized
- FM = frequency modulation
- FSK = frequency shift keying
- GMSK = Gaussian filtered minimum shift keying
- GSM = global system for mobile
- I/Q = in-phase/quadrature
- ISB = independent sideband
- LSB = lower sideband
- MQAM = multilevel quadrature amplitude modulation
- MSK = minimum shift keying
- OFDM = orthogonal frequency-division multiplexing
- OOK = on/off key
- OQPSK = offset quadrature phase shift keying
- PAM = pulse-amplitude modulation
- PM = phase modulation
- QAM = quadrature amplitude modulation
- QPSK = quadrature phase shift keying
- SQPSK = staggered quadrature phase shift keying
- SSB = single-sideband
- USB = upper sideband
- VSB = vestigial sideband

SUPPORT DF
Does it support DF and with what technology?
- DDC = direct digital downconversion
- FDOA = frequency difference of arrival
- LO = local oscillator
- SHF = super high frequency
- TDOA = time difference of arrival
- TOA = time of arrival

 # REC CHANNELS
Number of receiver channels (RF paths) to create a complete system

PWR (in W)
Power dissipated in Watts per channel
- AC = alternating current
- DC = direct current

SIZE (in in/cm)
Size by height x weight x length, or diameter, in inches
- ATR = air transport rack
- PCI = peripheral component interconnect
- RU = rack unit
- VME = virtual machine environment

PLATFORM
Platform
- air= airborne
- grd= ground
- grd-fix = ground-fixed
- grd-mob = ground-mobile
- shp = shipboard
- sub = submarine

WEIGHT
Weight in lb/kg

OTHER ABBREVIATIONS USED
- opt = option/optional
- dep = dependent
- config = configuration
- wband = wideband
- nband = narrowband
- < = greater than
- > = less than
- min = minimum
- max = maximum
- deg = degree
- freq = frequency
- USB = universal serial bus

** Indicates answer is classified, not releasable or no answer was given.*

AUGUST 2021 TECHNOLOGY SURVEY: BENCHTOP SPECTRUM ANALYZERS

This survey will cover benchtop spectrum analyzers used for electromagnetic warfare and signals intelligence, as well as military radar and communications applications. Please e-mail JEDEditor@naylor.com to request a survey.

SYMPOSIUM AGENDA

All-Domain Operations - Integrating Effects Across the Spectrum

The importance of electromagnetic spectrum operations cannot be over-emphasized; it empowers All-Domain Operations, an integrated and synchronized application of capabilities across all warfighting domains. Awareness and understanding of the electromagnetic spectrum, its properties, and the need to command and control effects within it are necessary to strategize thoroughly, plan, and decisively execute any mission anywhere in the world.

An advantage in the electromagnetic spectrum is foundational to successful All-Domain Operations.

Symposium Sessions

Below is a sample of some symposium sessions that are on the agenda this year. You can learn more about themes, session chairs, and agenda descriptions at **58.crows.org**

- [5G Networks] Critical Enabler or Vulnerability?
- [Air Force Spectrum Warfare Wing] Vision, Initial efforts, Integration across the Joint Force
- [EMSO] Implementing EMSO for the Future Fight
- [JADC2] The Criticality of EMS Interoperability/Compatibility
- [MBSE Digital Environment and Engineering] Enabling to Rapid Development and Fielding
- [Project Convergence 21] Linking Land, Air, Sea, Space, and Cyberspace
- [Government and Industry Perspectives] Strategic Opportunities and Emerging Technologies
- [Talent Challenges] How Space Force Is Developing Guardians To Build High-Performance Teams
- [AI and Autonomy] The Speed of Data and Decisions in the Next Fight *(brought to you by Young Crows)*

**As of June 8, 2021 – Subject to Change*

REGISTRATION INFORMATION

Registration and housing will be opening in late July.

Master Pass

The 'Master Pass' includes access to keynote sessions, access to all symposium sessions Tuesday–Thursday, access to the Welcome Reception; access to the exhibit hall, lunches and happy hours, First-Time Attendee Orientation, and access to all recorded keynote sessions and all briefings as released by the speakers. *Registration does not include access to the Program Manager Briefing Series or post-convention courses.*

	By 8/31	9/1-11/5	11/6-On-Site
Industry (Member)	$695	$795	$895
Industry (Non-Member)	$895	$995	$1095
Academia*	$445	$545	$645
Young Crows (35 and younger)*	$445	$545	$645
Government Civilian*	FREE	FREE	FREE
Military in Uniform**	FREE	FREE	FREE

*Must present proper ID for discounted price:
- Academia - faculty/staff/student ID.
- Young Crows (35 years old and younger) - photo ID with DOB.
- Government Civilian - government ID or civilian CAC card.

**Duty uniform must be worn each day. If not, a fee of $100 will be assessed.

Discounted pricing ends 8/31!

Exhibition Only Pass

This complimentary registration type provides access to the Welcome Reception, keynote sessions and the exhibit hall. *It does not allow access to all other symposium sessions, Program Manager Briefing Series or post-convention courses.*

Exhibition Only	FREE	FREE	FREE

POST-CONVENTION COURSES

Extend your convention experience by signing up for a post-convention AOC educational course. These courses are eligible for credit and taught by our subject matter experts.

Space Electronic Warfare

December 3-4, 2021

Presented by: Dave Adamy

View the schedule online at crows.org/2021Courses

Courses currently being added. Seperate registration required.

PROGRAM MANAGER BRIEFING SERIES

PROGRAM MANAGER BRIEFING SERIES
WHERE GOVERNMENT & INDUSTRY MEET

AOC is thrilled to announce the return of our Program Manager (PM) Briefing Series to this year's International Symposium and Convention. The PM Briefing Series will offer a technology interchange in a series of 45-minute sessions comprised of presentations from PM offices across the military services and audience Q&A.

During this program, exhibitors will hear directly from their government customers on the status of key programs and activities under their leadership, opportunities and milestones on the horizon, and how government and industry can strengthen collaboration.

This program is only open to 2021 exhibiting companies.

OPTIMIZE YOUR EXPOSURE

The best of the best in the world of Electromagnetic Warfare attend the Annual AOC Symposium & Convention. Have your organization stand out and make an impact. Custom sponsoring opportunities are available, no matter what the size and budget of your organization. Learn more about sponsoring and exhibiting at the show: go to 58.crows.org or contact **Sean Fitzgerald** at **fitzgerald@crows.org**.

Booth space is selling quickly! Book now! *Special opportunities for Small Businesses are available.*

#CROWS2021

ASSOCIATION OF OLD CROWS

Introducing the New AOC Podcasts

Brought to you by the Association of Old Crows

This regularly scheduled podcast, hosted by Ken Miller, AOC's Director of Advocacy and Outreach, will feature interviews, analysis, and discussions covering leading issues of the day related to electromagnetic spectrum operations (EMSO). This will include current events and news from around the world, US Congress and the annual defense budget, and military news from the US and allied countries.

We will also bring you closer to AOC events and provide a forum to dive deeper into policy issues impacting our community.

crows.org/FromtheCrowsNest

This podcast will take you on a journey throughout time and around the world to meet the inventors, the battles, and the technology that has not only shaped military operations - how we fight - but also how we live.

The History of Crows will cover some of the most important discoveries, battles, and events that shaped what we know today as electromagnetic spectrum operations. Episodes that take you deeper into our history will be added periodically.

crows.org/HistoryOfCrows

Interested In Being a Guest?

Send your ideas and recommendations to Ken Miller, Director of Advocacy and Outreach, at kmiller@crows.org. We look forward to hearing from you!

Interested In Becoming a Sponsor?

For more information and to secure your sponsorship, please contact Sean Fitzgerald, AOC's Manager of Sales and Client Operations, at fitzgerald@crows.org.

5G Communications (Part 4)

5G Modulation

By Dave Adamy

5G captures digital signals using a modulation method known as quadrature amplitude modulation (QAM), as illustrated in **Figure 1.** This figure shows 16QAM, so four information bits are passed by each transmitted baud. The states of the bauds are separated in both amplitude and phase. The receiver determines which state is closest to the received signal and outputs the corresponding bits.

As shown in **Figure 2,** the noise vector is added to the signal vector to form a signal + noise vector. The location of the end of the signal + noise vector determines which four bits will be output by the receiver – depending on which QAM state is closest to it. The fewer the number of QAM states, the more distance there is between the states and thus the more tolerant the system is to noise. If the received signal-to-noise ratio is low enough, 32QAM can be used to pass five bits per baud, 64QAM to pass six bits per baud, 128QAM to pass seven bits per baud or 256QAM to pass eight bits per baud. In each case, the separation of the states will determine the bit error rate that can be achieved at a specified signal-to-noise ratio. Thus, the higher the QAM number, the higher the received signal-to-noise ratio of the received signal must be to meet any specified bit error rate. The bit error rate is the number if incorrectly received bits divided by the total number of bits sent.

Figure 3 shows the bit error rate vs. E_b/N_o. E_b/N_o is the energy

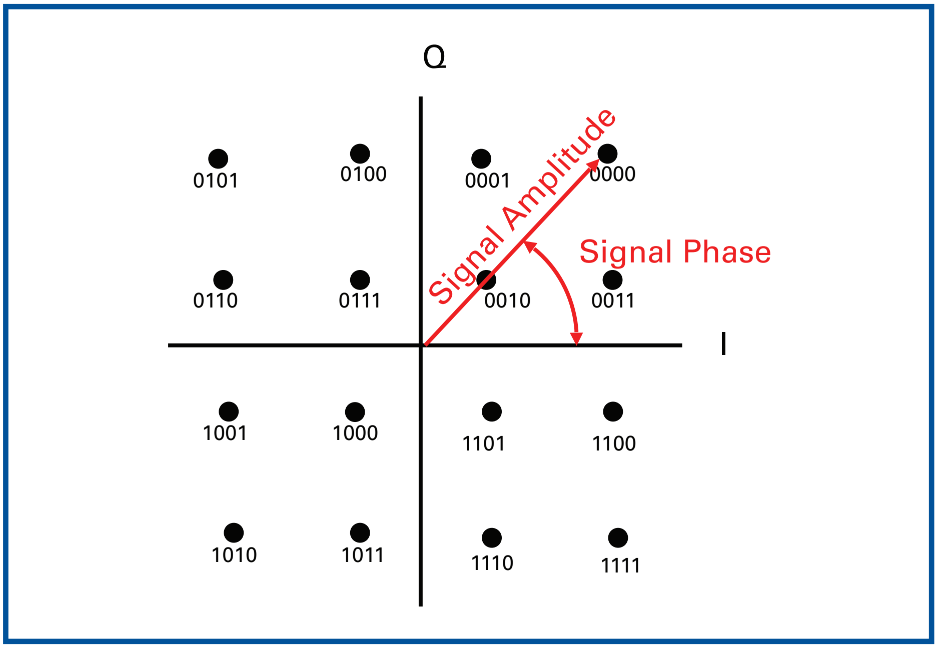


Fig. 1: QAM modulation provides multiple information bits per transmitted baud by spacing the states. The large separation between the states reduces the likelihood that a bit (either one or zero) will be received in error. This diagram illustrates a 16QAM signal which carries four information bits per transmitted baud.

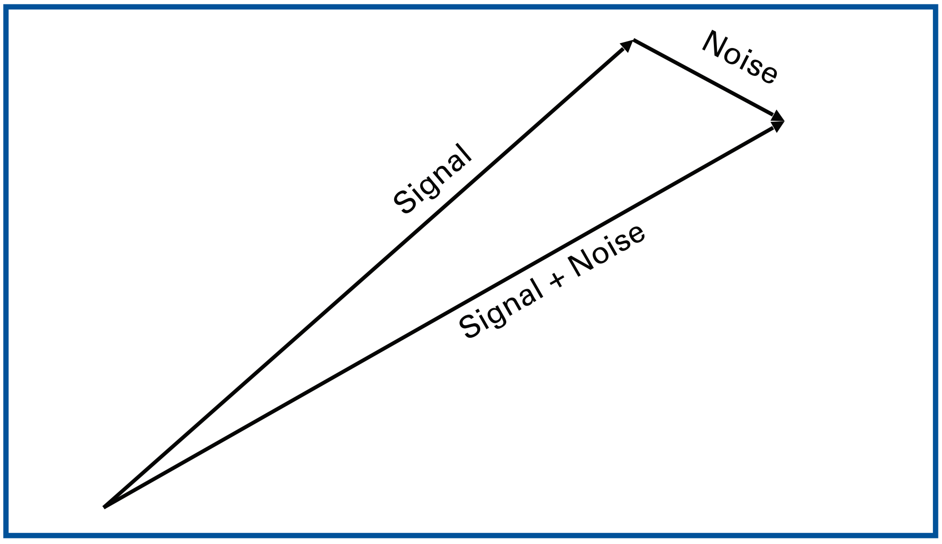


Fig. 2: This vector diagram shows the signal and noise components received by the receiving station. The separation of the states determines the percentage of bauds that will be incorrectly received (thus, the bit error rate).

per bit vs. the noise per hertz and is calculated by multiplying the predetection signal-to-noise ratio (RFSNR) by the bandwidth to bit-rate ratio. At one hertz per one bit-per-second, it is just equal to the RFSNR.

The received pre-detection signal-to-noise ratio is a function of the range from the transmitter, the operating frequency, the receiver bandwidth, and the receiver noise figure. These factors are shown in the following formulas:

The sensitivity of the receiver is the minimum signal strength that can be received in order for the receiver to do its job – which in this case is to deliver the required bit error rate.

Sensitivity is defined by the following formula:

Sens = kTB + NF + RFSNR

Where: *Sens* is the sensitivity of the receiver in dBm,
kTB is the thermal noise inside the receiver in dBm,
NF is the noise figure of the receiver in dB, and
RFSNR is the received predetection signal to noise ratio.

The received signal power is a function of the propagation model. For line-of-sight propagation, the received signal strength (out of the receiving antenna) is given by the following formula:

$$P_R = ERP_T - 32.44 - 20 \log F - 20 \log d$$

Where: P_R is the power at the output of the receiving antenna in dBm,
ERP_T is the effective radiated power out of the transmitting antenna in the direction of the receiver in dBm,
F is the signal frequency, and
d is the distance from the transmitter to the receiver in km.

If the receive power is greater than the sensitivity, the receiver will output signals with the specified bit error rate.

Each QAM signal is combined with the other signals to be transmitted as shown in **Figure 4.** Like any frequency division multiplexed signal, each input signal is converted to a different frequency. The special quality of the Orthogonal Frequency Division Multiplexing (OFDM) signal is that the frequencies are orthogonal. This means that they are statistically unrelated. The impact of orthogonality is that with proper phasing, the subcarriers can overlap each other with minimal interference. This allows efficient use of bandwidth.

As shown in **Figure 5,** the N digital channels are combined into a single radio frequency signal by an inverse Fourier transform (IFFT). This RF signal is then transmitted to another station where it is converted back into the individual digital channels by a fast Fourier transform (FFT).

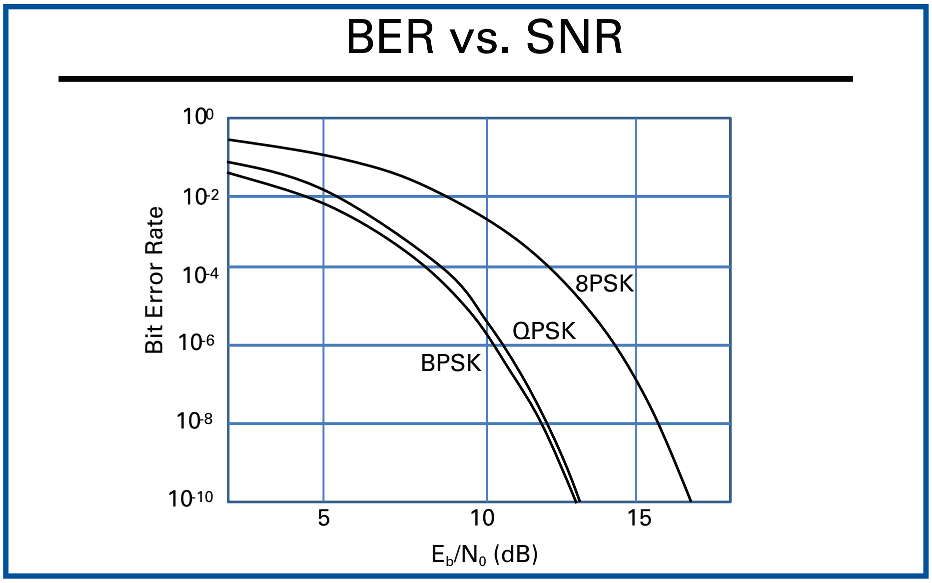


Fig. 3: *The bit error rate is a function of the E_b/N_0, which is the predetection signal-to-noise ratio increased by the bandwidth to bit rate ratio.*

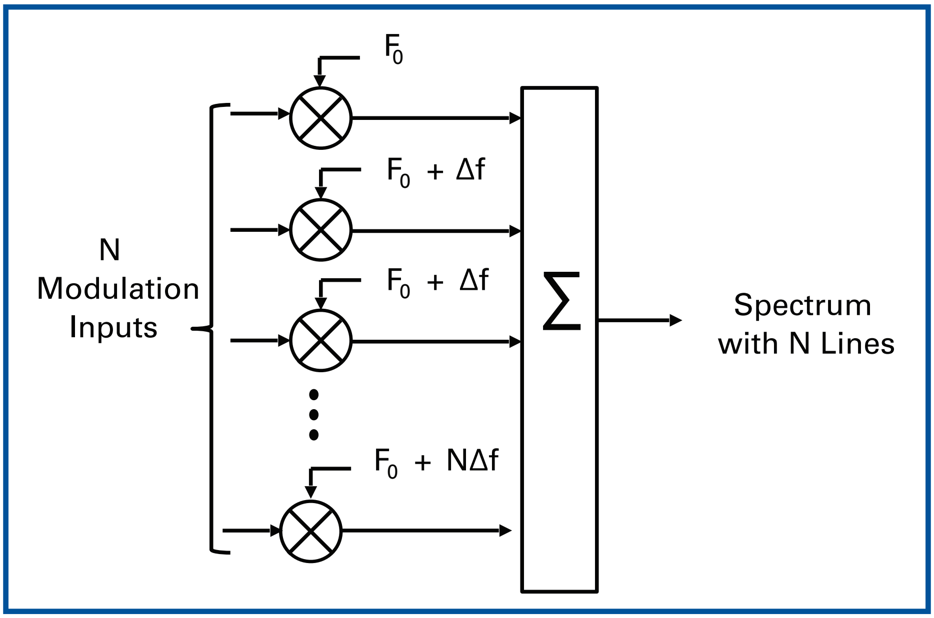


Fig. 4: *Orthogonal Frequency Division Modulation generates a signal with N orthogonal spectral lines spaced at equal frequency intervals.*

WHAT'S NEXT

Next month, we will continue our 5G discussion by focusing on military applications. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.

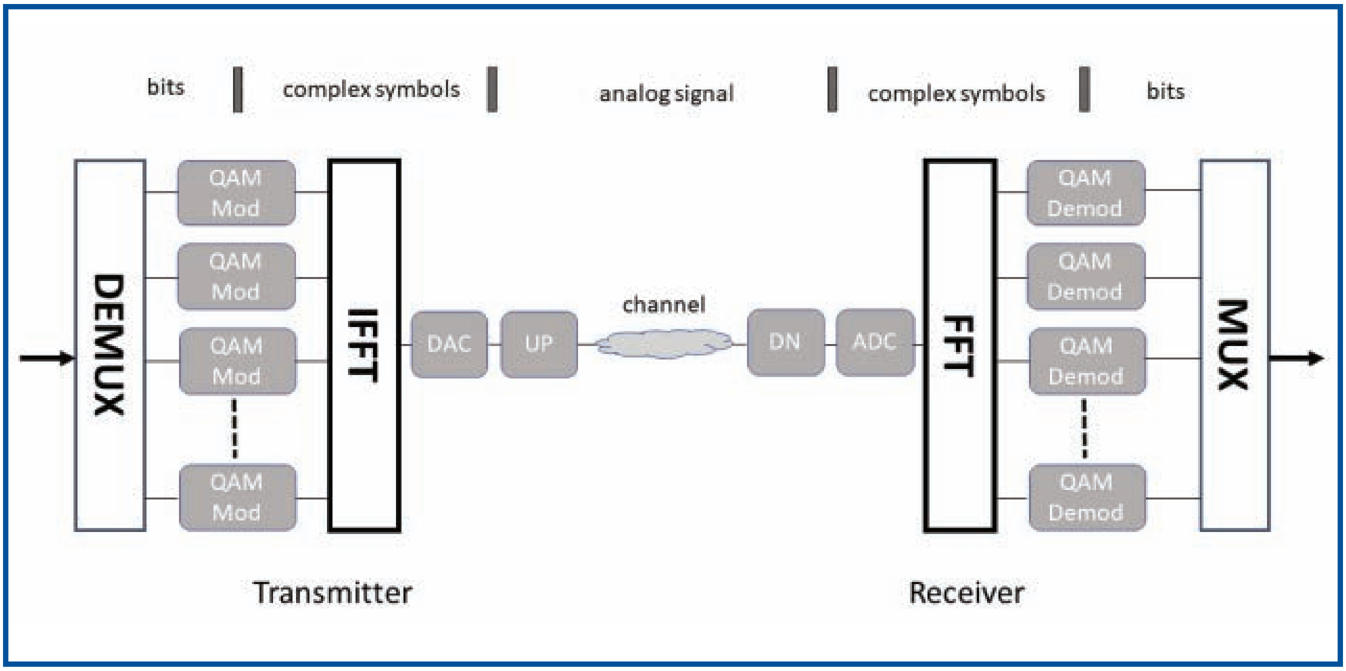


Fig. 5: *The OFDM system combines N QAM modulated digital signals into a single transmitted signal by performing an inverse fast Fourier transform. The receiver re-creates the individual digital signals by performing a fast Fourier transform.*

CORRECTION:
UPDATED FIGURES IN MAY EW 101 COLUMN

In the May 2021 issue of *JED*, the incorrect figures were printed in the EW 101 column, "5G Communication – Part 2, Millimeter-Wave Propagation." This error has been fixed in the digital edition of *JED*, and the correct figures for the May column are below.

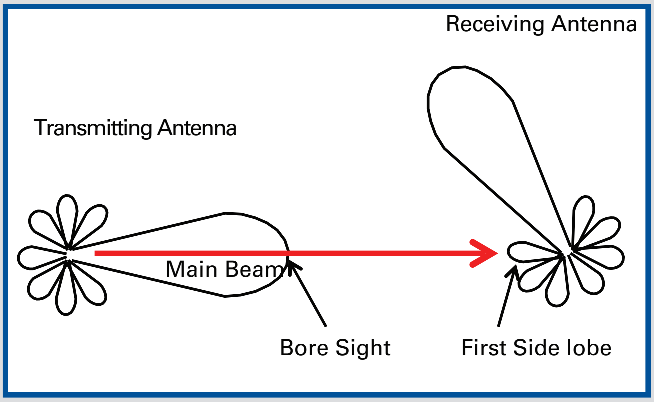


Fig. 2: *The receiving antenna is directed away from the transmitter, so the transmitted signal is received in a side lobe (in this example, it is the first sidelobe).*

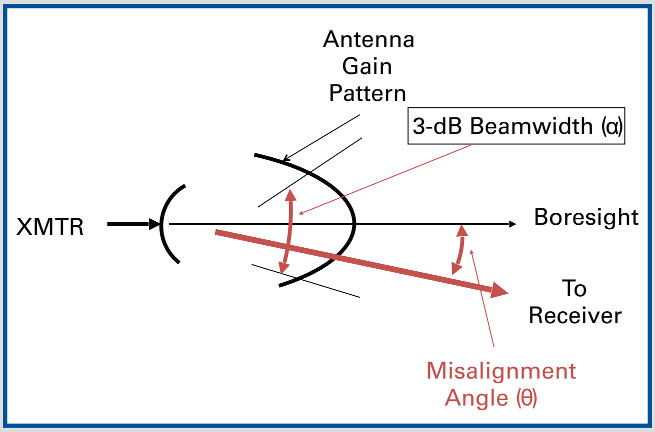


Fig. 1: *This figure shows how the reduction in gain, when an antenna is transmitting to a receiving antenna that is away from its boresight, is a function of the misalignment angle and the antenna beam width.*

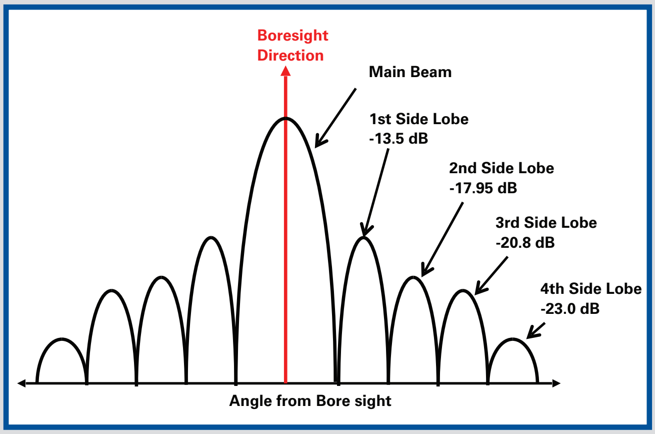


Fig. 3: *The side lobes of an antenna pattern are reduced relative to the boresight gain, and they are narrower. Note that the nulls between lobes are much narrower than the widths of the lobes.*

TOGETHER AGAIN: 45TH ANNUAL DIXIE CROW SYMPOSIUM

The Dixie Crow Chapter of AOC hosted a successful 45th Annual Symposium in Warner Robins, Georgia, at the Museum of Aviation, Robins AFB, following COVID-19 Safety Guidelines. The sold out exhibit hall offered the opportunity for vendors to emphasize the importance of Electromagnetic Spectrum Operations (EMSO), including Electronic Warfare (EW) systems and the vital role Command and Control, Intelligence, Surveillance and Reconnaissance (C2ISR) provides in protecting our warfighters on today's modern battlefield.

The Dixie Crow Symposium was the first successful in-person event in 2021 for AOC, the defense industry and Robins AFB, with 660 registered attendees. The exhibit hall was sold out, and several vendors have already pre-registered for the 46th Annual Symposium. This year's event featured 32 exhibitors and was sponsored by 26 industry partners. Thank you all for bringing this event to life, despite the challenging year we all faced in 2020.

In addition to our sponsors and exhibitors, the Dixie Crow Chapter would like to extend a heartfelt "thank you" to our members, volunteers, attendees, advisors, speakers, planning committee, AFLCMC/WNY, 78 ABW, the Museum of Aviation, *JED*, AOC and many others for believing in us and in this event! Without all of you, our success would have not been possible!

8th Annual Crows N.E.S.T. (Novel Experiments with Science & Technology)

Designed to inspire students to pursue STEM careers, the Crows N.E.S.T. typically takes place during the in-person event, providing technology demonstrations with local military, government civil service, academia, the defense industry and volunteers.

This year, we saw a need to change our approach. As such, our efforts focused on providing monetary donations to eight local schools to supplement STEM teachers' classroom budgets (Bonaire Middle, Houston County High, Huntington Middle, Northside High, Perry Middle, Sacred Heart, Veterans High and Warner Robins High). STEM students at these schools also received Crows N.E.S.T. t-shirts with all of the Dixie Crow Chapter Education Foundation industry partner logos displayed proudly on the back.

COVID-19 Guidelines

In order to adhere to COVID-19 safety guidelines, the following procedures were in place throughout the event: masks required, six feet social distancing, temperature checks, monitored attendee in and out traffic (350 capacity), dedicated entrance and exit to building and to exhibit hall floor, arrows on floor to control flow of traffic, contactless badge pick up, QR code onsite registration, individually wrapped snacks, etc. Exhibitors on the show floor were also positioned with a 10 x 10 ft. space between each of them, allowing for additional social distancing and to provide exhibitors with additional opportunity to advertise their products and services.

GARDEN STATE CHAPTER HONORS MEMBERS, ROTC SCHOLARSHIP RECIPIENTS

By Bob Perricelli, Director, AOC Garden State Chapter

On May 1, the Garden State Chapter (GSC) held its annual appreciation dinner at the Navesink Country Club in Middletown, NJ. The event honors both Rutgers University ROTC scholarship recipients and chapter members for all the work they do supporting AOC and the GSC. The dinner was attended by GSC members as well as AUSA and Quad A (AAAA) local chapter members, and the chapter also welcomed AOC President Glenn "Powder" Carlson and AOC Northeast Regional Director Myles Murphy.

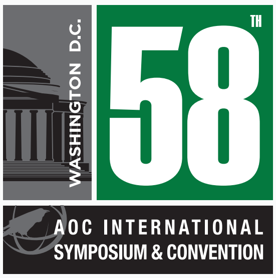
GSC President Nicole Zaretski opened the event by welcoming all, summarized GSC accomplishments in 2020 and noted winning the Chapter of the Year Award for a medium sized chapter. She also recognized three GSC recipients who received AOC National Awards in 2020: Donald Belmar, Joseph W. Kearney Pioneer Award recipient; Lawrence Rakos, AOC Technology Hall of Fame inductee; and Robert Filoramo, Certificate of Merit recipient for his long career and professional excellence supporting the Navy's IDECM program. Two strong chapter sponsors were also acknowledged; CACI international Inc. and L3Harris Technologies.

Zaretski then recognized the four Rutgers University ROTC cadets who each received $2,500 GSC AOC scholarships in 2021. Unfortunately, due to COVID-19, restrictions the awardees and their families could not attend the dinner. The following cadets were awarded scholarships and were recognized at the GSC event.

- Cadet Aaron Bender of Pennsauken, NJ, is majoring in Aerospace Engineering while building his computer language skills. Aaron wishes to fly and obtain certification in computer programming.
- Cadet Kevin Morales of Edison, NJ, is also majoring in Aerospace Engineering and hopes to be commissioned in the US Army upon graduation.
- Cadet Hayoung Park of Ridgewood, NJ, is majoring in Nursing and wishes to receive a commission in the Army Nursing Corps upon graduation.
- Cadet Owen Murphy of Red Bank, NJ, is majoring in Civil Engineering with a double minor in History and Military Science. Upon receiving his commission, he hopes to serve as an Engineering Officer with the Army Corps of Engineers.

In a moving remembrance to the late COL Sam Fuoco, who was a loyal and good friend of the GSC, Zaretski presented the COL's family with the AOC Distinguished Service Award. COL Fuoco was honored for a lifetime of selfless service to our warfighters, veterans and his country.

WHAT'S HAPPENING AT AOC IN 2021!



58th Annual AOC International Symposium & Convention

November 30 - December 2, 2021 | Washington, DC

Save the date!
58.crows.org

Product Showcase

Check out the latest product updates and announcements from our industry partners.

View the showcase at
crows.org/Product-Showcase

Podcasts

AOC has two new Podcasts, The History of Crows and From the Crows' Nest.

Subscribe at
crows.org/podcast

Focusing on leading issues of the day related to electromagnetic spectrum operations (EMSO)

Covering some of the most important discoveries, battles, and events that shaped what we know today as electromagnetic spectrum operations.

Virtual Series Webinars

Bite-sized educational sessions on a myriad of technical topics in EW.

Check out the schedule at
crows.org/Webinar_schedule

Educational Courses

Professional development for the EMS workforce through world-class courses.

Start learning at
crows.org/PDC_Schedule

Collaborative EW Symposium

March 29-31, 2022
Pt. Mugu, CA

Save the date!

EW Capability Gaps & Enabling Tech Conference

May 10-12, 2022
Crane, IN

Save the date!

Check out crows.org for up-to-date information on events, resources and products.

AOC Members

SUSTAINING

BAE Systems
Bharat Electronics Ltd
CACI International Inc.
Chemring Group PLC
Electronic Warfare Associates, Inc.
General Atomics Aeronautical Systems, Inc.
General Dynamics
Keysight Technologies
L-3 Harris
Leonardo
Perspecta
Raytheon Intelligence & Space
Rohde & Schwarz USA
Saab Sensor Systems Germany GmbH
SRC, Inc.

MILITARY UNITS

30 Cdo IX Gp RM
547 IS
57 IS/DOD
Air Command Denmark
Detachment-A 743d
Helicopter Wing 53
IWTG Norfolk
Japan Air Self-Defense Force
NASIC/AC
NIWTG SD
Zentrum Elektronischer Kampf Fliegende Waffensysteme

INSTITUTES/ UNIVERSITIES

Georgia Tech Research Institute (GTRI)
Mercer Engineering Research Center (MERC)
Riverside Research Institute
RVJ Institute

GOVERNMENT GROUPS

Australia Department of Defence DIO
DE&S
Defence Science & Technology Agency (DSTA)
DOD
Los Alamos National Lab
New Zealand Defence Technology Agency
NGA – National Geospatial-Intelligence Agency
NLR – Royal Netherlands Aerospace Centre
Swedish Defence Materiel Administration T&E Directorate (FMV T&E)

GROUPS

35 Technologies Group, Inc.
3dB Labs Inc.
3SDL Ltd.
Abaco Systems
ACE Consulting Group
Advanced Test Equipment Rentals
ALARIS Antennas
Alion Science and Technology
Allen-Vanguard
Ampex Data Systems
Analog Devices
API Technologies
ApisSys SAS
Apogee Engineering
Applied Systems Engineering, Inc.
Armtec Defense Technologies
Aselsan A.S.
Atkinson Aeronautics & Technology, Inc.
Atlanta Micro, Inc.
Avix
Babcock International Group
Base2 Engineering LLC
Battelle Memorial Institute
Beca Applied Technologies Ltd.
Black Horse Solutions, Inc.
Blue Ridge Envisioneering, Inc.
Booz Allen Hamilton, Inc.
Boyd Corporation
Cablex PTY Ltd.
CEA Technologies, Incorporated
Centauri
Centerline Technologies LLC
Clearbox Systems
Cobham Advanced Electronic Solutions
Communication Power Corporation
Communications & Power Industries LLC
Comsec LLC
Comtech PST Corporation
Crescend Technologies, LLC, Defense Solutions
CRFS Inc.
CRFS Limited
CSIR DPSS
Cubic Defense
D-TA Systems, Inc.
Daqscribe
Darkblade Systems
Dayton Development Coalition
dB Control
Decodio AG
Defense Research Associates Inc.
DEFTEC Corporation
DEWC Group
Dreamlab Technologies AG
DRONESHIELD
DRT, Inc.
Eagle Sales Corp.
ELBIT Systems of America
Elbit Systems of EW & SIGINT Elisra
ELDES S.r.l.
Elettronica S.p.A
Empower RF Systems
Epiq Solutions
ESROE Limited
Evans Capacitor Company
Galleon Embedded Computing
GFD GmbH
Gigatronics Incorporated
Hammer Defense Technologies LLC
HASCO
HawkEye360
Hegarty Research LLC
Hensoldt Sensors GmbH
Hermetic Solutions
Herrick Technology Laboratories, Inc.
Hughes
IDS International Government Services
Indra
Intelligent RF Solutions
Interface Concept
ITA International, LLC
IW Microwave Products Division
JT4, LLC
Kihomac, Inc.
Kirintec
Kranze Technology Solutions, Inc. (KTS)
Kratos General Microwave Corporation
L3Harris TRL Technology
LCR Embedded Systems
Leonardo DRS
Leonardo Electronics-US
Liteye Systems, Inc.
MarServices GmbH
Mass Consultants Ltd.
MBDA France
MC Countermeasures, Inc.
MDA
MDSI
MegaPhase LLC
Meggitt Baltimore
Meggitt Defense Systems
Meta Mission Data Ltd.
Microwave Products Group
Milpower Source, Inc.
Milso AB
Mission Microwave Technologies
The MITRE Corporation
Molex
Motorola Solutions
MRC Gigacomp
MTSI
My-Konsult
MyDefence System Integration
N-Ask Incorporated
Nagravision S.A.
NEL Frequency Controls, Inc.
Northeast Information Discovery Inc.
Northrop Grumman Defense Systems – Advanced Weapons
Novator Solutions AB
OCS America, Inc.
Parsons
Pentek
Penten
Persistent Systems, LLC
Perspecta
Phasor Innovation
Photonis Defense Inc.
Physical Optics Corporation
Plath GmbH
PredaSAR
PROCITEC GmbH
QinetiQ Target Systems
Qnion Co., Ltd.
QuantiTech
RADA Technologies LLC
RAFAEL Advanced Defense Systems Ltd.
Research Associates of Syracuse, Inc.
Rincon Research Corporation
Rohde & Schwarz GmbH & Co. KG
Rohde & Schwarz Norge AS
Roschi Rohde & Schwarz AG
Rotating Precision Mechanisms
Rowden Technologies
S2 Corporation
School of Information Operations (SOIO)
SciEngines GmbH
Scientific Research Corp.
SEA Corp.
Serpikom
Sierra Nevada Corporation
Signal Hound
Silver Palm Technologies
SimVentions
SMAG Mobile Antenna Masts GmbH
Smiths Interconnect
Spectranetix, Inc.
Spherea GmbH
Spirent Communications
SR Technologies
STEATITE
Systems & Processes Engineering Corp. (SPEC)
Tabor Electronics
TCI International, Inc.
Tech Resources, Inc.
Teledyne Technologies, Inc.
Telemus Inc.
Teleplan Globe Defence
TERMA
Tevet LLC
Textron Systems
Textron Systems Electronic Systems UK Ltd.
ThinkRF
Tinex AS
TMC Design
TMD Technologies Ltd.
Transformational Security LLC
Transhield Inc.
Trenton Systems
Trideum
TUALCOM, Inc.
Ultra Electronics - EWST
Ultra Electronics Avalon Systems
unival group GmbH
Valiant Integrated Services
Valkyrie Enterprises LLC
Verus Research
VIAVI Solutions
Vic Myers Associates
Vigilant Drone Defense Inc.
VITEC
W.L. Gore and Associates
Warrior Support Solutions LLC
WGS Systems, Inc.
X-COM Systems
ZARGES, Inc
Zentrum Elektronischer Kampf Fliegende Waffensysteme

ASSOCIATION OF OLD CROWS

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:
Send address changes to
JED, Journal of Electromagnetic Dominance
c/o Association of Old Crows
1001 N. Fairfax St., Suite 300
Alexandria, VA 22314

Subscription Information:
Glorianne O'Neilin
(703) 549-1600
oneilin@crows.org

JED Sales Offices

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

Project Manager:
Tabitha Jenkins
Direct: +1 (352) 333-3468
tjenkins@naylor.com

Project Coordinator:
Amanda Glass
Direct: +1 (352) 333-3469
aglass@naylor.com

Advertising Sales Representatives:
Shaun Greyling
Direct: +1 (352) 333-3385
sgreyling@naylor.com

Erik Henson
Direct: +1 (352) 333-3443
ehenson@naylor.com

Chris Zabel
Direct: +1 (352) 333-3420
czabel@naylor.com

NAYLOR (Canada) Inc.
200 – 1200 Portage Ave.
Winnipeg, MB R3G OT5 Canada
Toll Free (US): (800) 665-2456
Fax: +1 (204) 947-2047

Index of Advertisers

Ametek Abaco Systems .... www.abaco.com 21
ARS Products .... www.arsproducts.com 36
Battlespace Simulations, Inc. .... www.bssim.com 13
Ciao Wireless, Inc. .... www.ciaowireless.com .... Inside Back Cover
CommsAudit .... www.commsaudit.com 32
CRFS .... www.crfs.com .... Outside Back Cover
D-TA Systems Inc. .... www.d-ta.com 23
Hensoldt South Africa .... www.hensoldt.co.za 8
IZT GmbH .... www.izt-labs.de 32
Motorola Solutions .... www.motorolasolutions.com 35
Navy League of the United States .... www.SeaAirSpace.org 10
Norden Millimeter, Inc. .... www.nordengroup.com 15
Pacific Defense .... www.pacific-defense.com 34
Planar Monolithics Industries, Inc. .... www.pmi-rf.com .... Inside Front Cover
TechComm .... www.techcommdf.com 33
Tektronix .... www.tek.com/mil-gov 7
Textron Systems .... www.TextronSystems.com 5
Ultra Electronics Limited – EWST .... www. ultra.group/intelligence-communications 3

JED QuickLook

Details **Page #**

45th Annual Dixie Crow Symposium Event Recap 46
5G Communications: 5G Modulations 42
AOC CEMA 2021 Conference 14
ASELSAN, COMINT and Comms ESM Receivers 26
BAE Systems, COMINT and Comms ESM Receivers 26
Boeing, EA-18G Growler 18
Boger Electronics, COMINT and Comms ESM Receivers 26
CAPT Dave Harris, Deputy Commodore, Electronic Attack Wing, Commander Electronic Attack Wing, US Pacific Fleet (CVWP) 18
CDR Jeremy Nuttall, Commanding Officer, Electronic Attack Weapons School (EAWS) 21
CDR Warren Van Allen, Commanding Officer, VAQ-129 Electronic Attack Squadron 19
Chemring Technology Solutions, COMINT and Comms ESM Receivers 26
Chordell Systems, COMINT and Comms ESM Receivers 26
CommsAudit, COMINT and Comms ESM Receivers 26
CRFS Inc., COMINT and Comms ESM Receivers 26
Cyber Battle Lab, Army Futures Command, Cyber Quest 2022 16
Digital Receiver Technology Inc., COMINT and Comms ESM Receivers 26
D-TA Systems, COMINT and Comms ESM Receivers 26
Elbit Systems EW and SIGINT - Elisra, COMINT and Comms ESM Receivers 28
Elettronica, COMINT and Comms ESM Receivers 28
Elta Systems Ltd., COMINT and Comms ESM Receivers 28
Enablia S.R.L., COMINT and Comms ESM Receivers 28
Epiq Solutions, COMINT and Comms ESM Receivers 28
The Espy Corporation, COMINT and Comms ESM Receivers 28
FEI-Elcom Tech, Inc., COMINT and Comms ESM Receivers 28
GEW Technologies, COMINT and Comms ESM Receivers 28
Herrick Technology Laboratories, Inc., COMINT and Comms ESM Receivers 28
Horizon Technologies, COMINT and Comms ESM Receivers 28
Indra Sistemas, S.A., COMINT and Comms ESM Receivers 30
Innovationszentrum für Telekommunikation (IZT), COMINT and Comms ESM Receivers 30
iRF - Intelligent RF Solutions, COMINT and Comms ESM Receivers 30
Jordan Electronic Logistics Support, COMINT and Comms ESM Receivers 30
L3Harris - TRL Technology, COMINT and Comms ESM Receivers 30
L3Harris Technologies, COMINT and Comms ESM Receivers 30
Leonardo DRS, COMINT and Comms ESM Receivers 30
LS telcom AG, COMINT and Comms ESM Receivers 30

Details **Page #**

Lt Col David Davidson, Commanding Officer, 390th Electronic Combat Squadron 22
LTG Stephen G. Fogarty, Commanding General, Army Cyber Command 14
Mercury Systems, acquires Pentek Systems, Inc. 17
Midwest Microwave Solutions Inc., COMINT and Comms ESM Receivers 30
Motorola Solutions, COMINT and Comms ESM Receivers 30
Northrop Grumman, AN/SLQ-32(V)7 SEWIP Block 3 17
Novator Solutions, COMINT and Comms ESM Receivers 30
PLATH Signal Products GmbH & Co. KG, COMINT and Comms ESM Receivers 32
QinetiQ, COMINT and Comms ESM Receivers 32
Radixon Group (WiNRADiO), COMINT and Comms ESM Receivers 32
Rep. Don Bacon (NE 2), House Armed Services Committee, Subcommittee on Tactical Air and Land Forces 15
Rep. Jim Langevin (RI 2), House Armed Services Committee, Subcommittee Chair on Cyber, Innovative Technologies, and Information Systems (CITI) 15
Rheinmetall Protection Systems GmbH, StrikeShield APS 16
Rohde & Schwarz GmbH, COMINT and Comms ESM Receivers 32
Saab Sensor Systems Germany GmbH, COMINT and Comms ESM Receivers 32
Saab, Luftwaffe Tornado radar warning equipment (RWE) upgrade 17
Sagax Communications, COMINT and Comms ESM Receivers 32
Seqtor, COMINT and Comms ESM Receivers 34
Silver Palm Technologies, COMINT and Comms ESM Receivers 34
Southwest Research Institute (SwRI), COMINT and Comms ESM Receivers 34
Spectranetix, COMINT and Comms ESM Receivers 34
Strategic & Spectrum Missions Advanced Resilient Trusted Systems (S2MARTS) consortium, Neptune Payload Prototype effort 17
TCI, COMINT and Comms ESM Receivers 34
Tech Comm, Inc., COMINT and Comms ESM Receivers 34
Thales SIX-GTS, COMINT and Comms ESM Receivers 34
Thales, Sea Fire AESA radar for French Navy frigates 17
UK Ministry of Defence (MOD); Ardent Wolf program, Royal Navy (RN) Type 23 frigates CESM suite 14
US Air Force 772d Test Squadron, 412th EW Group; Request for Information (RFI) for Combat Electromagnetic Environment Simulator (CEESIM) and Next Generation Electronic Warfare Environment Generator (NEWEG) simulation systems upgrades 17
US Army, Terrestrial Layer System – Echelons Above Brigade (TLS-EAB) 16

Visit the *JED* Defense Electronics Resource Guide online at jed.onlinemarketbase.org.