ASSOCIATION OF OLD CROWS
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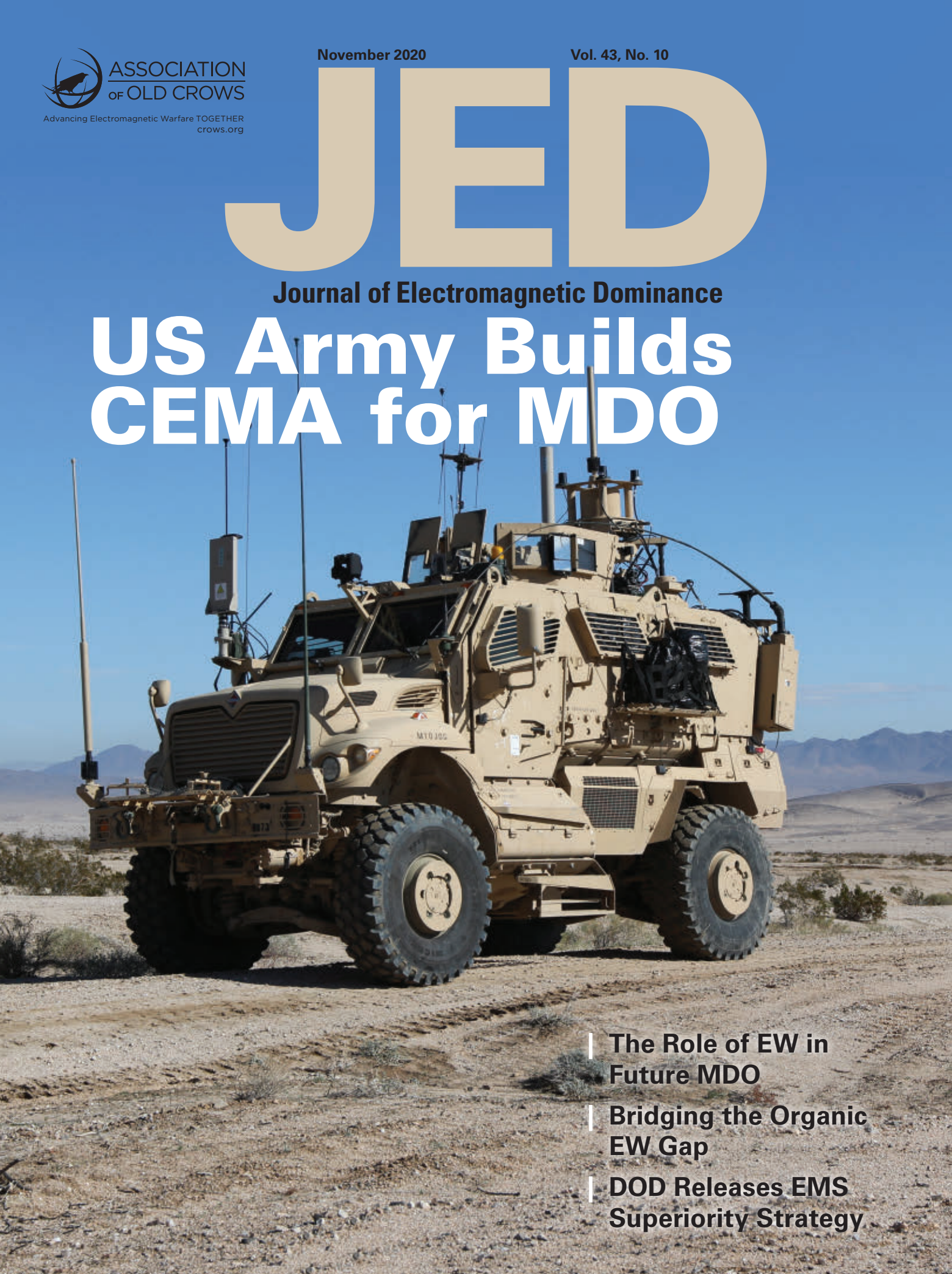
November 2020 Vol. 43, No. 10

JED

Journal of Electromagnetic Dominance

US Army Builds CEMA for MDO



- The Role of EW in Future MDO
- Bridging the Organic EW Gap
- DOD Releases EMS Superiority Strategy

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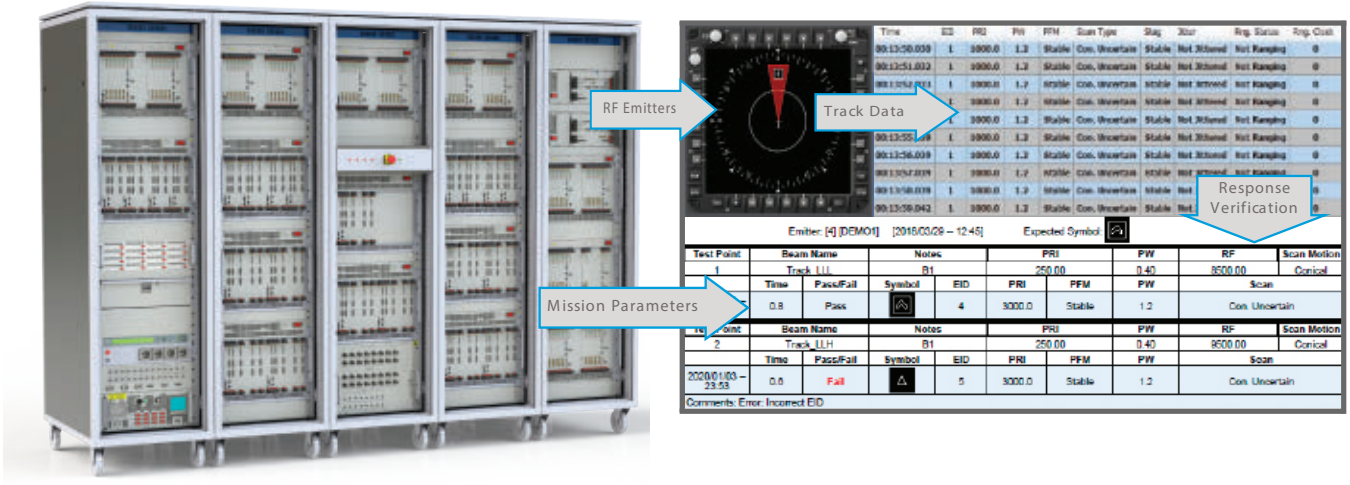

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The Big Thing in RFSoC is Here.

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Pentek's Model 6001 FPGA board lets you quickly develop and deploy RFSoC technology, while optimizing your system for SWaP.

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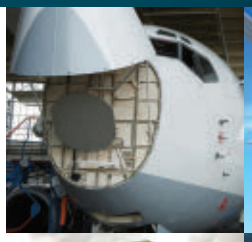
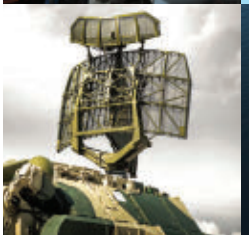
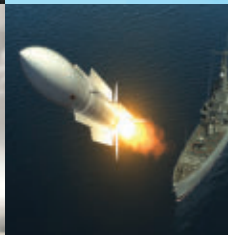
- **Navigator® Design Suite** BSP and FPGA design kit for seamless integration with Xilinx Vivado®

All this plus FREE lifetime applications support!







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THE NETWORK

As the EMS Operations (EMSO) Community looks ahead at the 2020s, one of the major trends we will see over the decade is the way EW systems will interface with information networks. By networking, I don't simply mean connecting a small number of EW platforms together over a distributed high-speed network so that they can share information with each other in real time. I also mean large numbers of EW systems feeding information to and pulling information from the major battle networks, such as the Army's TITAN, so that mission commanders can see, understand and maneuver forces within the EM Operating Environment (EMOE). Achieving this goal has been a long journey for EW.

In the wake of the Gulf War and throughout the 1990s, the DOD invested tremendous energy and dollars into developing a new generation of distributed tactical information networks as part of a larger Network-Centric Warfare (NCW) concept. A few of these early battle networks were robust enough to enable signals intelligence (SIGINT) platforms to share emitter data between them in real- or near-real time. SIGINT platforms, though few in number, could provide valuable emitter information to mission commanders who wanted to see into the EMOE. EW systems were another story. While there were many, many EW sensors in the battlespace, they were not designed to present information beyond the cockpit display or the shipboard operator's console. Most of these EW systems, being designed for self-protection applications, did not have a lot of high-quality information to share on a network, even in aggregate. As a result, there was little demand to share EW information across a network.

The upshot is that for most of the past 30 years, while other types of sensor systems, such as radars, EO/IR targeting systems, SIGINT and IMINT sensors, etc., have connected to the major battle networks, EW systems have lagged far behind. This meant that mission commanders could only gain a partial picture of the EMOE. While the mission commander suffered, so did EW because it was perceived as only being relevant to self-protection and specific missions, such as Airborne Electronic Attack.

As EW systems have become more capable, especially with the wider availability of digital receiver technology over the past 15 years, this has helped to solve the EW information quality issue. While a typical RWR in the 1990s would cover 2-18 GHz, today's radar ESM systems typically span 0.5-40 GHz. And we now have many more airborne and ground-based EW sensors covering the 20-MHz to 6-GHz range, as well. In aggregate, today's EW systems have the ability to provide the largest picture of what is happening across very active portions of the EMS.

At the same time that EW systems have improved, the DOD has been working to solve the problem of moving EW data around quickly on its emerging battle networks. We are indeed entering a new era in which EW can support a real-time picture of the EMOE for mission commanders. This is long overdue, and it's probably going to be as significant for EW as it is for the warfighter. – *J. Knowles*

JED
Journal of Electromagnetic Dominance

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Calendar *Conferences & Courses*

We have combined *JED*'s courses and conferences calendars in an effort to provide readers with the most comprehensive list of upcoming EW, SIGINT and related EMSO learning opportunities and events. Conferences will be denoted next to event dates; all calendar listings not labeled as a conference will be courses or webinars.

Due to the disruptions caused by COVID-19, some event organizers have chosen to change the dates and/or venues of their events and courses. Please check the organizers Web site or contact the event or course provider to receive the latest details.

NOVEMBER

Radar Principles
November 2-6
Swindon, UK
www.cranfield.ac.uk

Test and Evaluation of RF Systems – Online
November 3-5
www.pe.gatech.edu

AOC Virtual Series Webinar: High Power RF/HPM Directed Energy Weapons
November 5
1400-1500 EST
www.crows.org

2020 DE Systems Virtual Symposium
Conference: November 16-19
www.deps.org

Communications Principles
November 16-20
Swindon, UK
www.cranfield.ac.uk

Communications Systems
November 30 – December 4
Swindon, UK
www.cranfield.ac.uk

Survivability
November 30 – December 4
Swindon, UK
www.cranfield.ac.uk

vIITSEC – Virtual Event
Conference: November 30 – December 4
www.viitsec.org

DECEMBER

EWONLINE: 13th Electronic Warfare Symposium
Conference: December 1-2
www.cranfield.ac.uk

SIGINT Fundamentals – Online
December 1-3
www.pe.gatech.edu

AOC Professional Development Live Web Course: RF Theory for ES Operations
December 6-7
www.crows.org

JANUARY

European Microwave Week 2020
Conference: January 10-15
Jaarbeurs Utrecht, the Netherlands
www.eumwa.org

Electro-Optic and Infrared Systems 2
January 11-15
Swindon, UK
www.cranfield.ac.uk

Surface Navy Association 33rd Annual National Symposium
Conference: January 12-14
Arlington, VA
www.navysna.org

AOC Virtual Series Webinar: An Overview of IADS (Integrated Air Defense Systems)
January 14
1400-1500 EST
www.crows.org

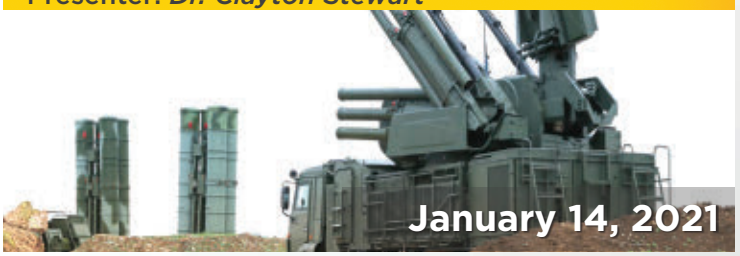
continued on page 10

AOC Virtual Series Webinars

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!

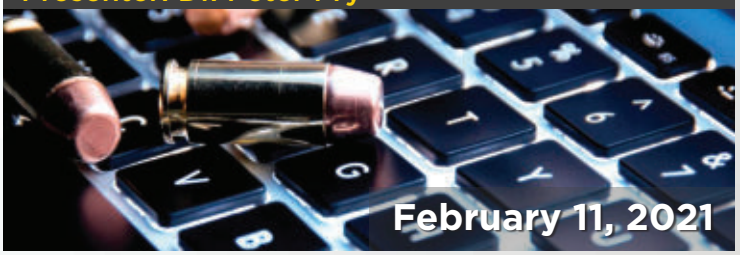
High Power Radio Frequency/Microwave DE Weapons
Presenter: John T. Tatum

An Overview of IADS (Integrated Air Defense Systems)
Presenter: *Dr. Clayton Stewart*

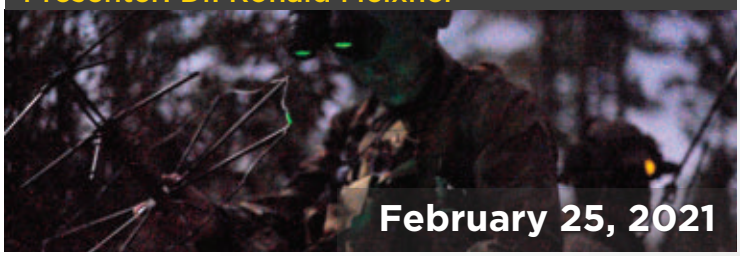


When Crows Break Codes
Presenter: Mr. John Kolm

From Sarissa To Cyber Warfare
Presenter: Dr. Peter Pry



HF meets Big Data – Intercept in an era of HF Renaissance
Presenter: Dr. Ronald Meixner



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

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

Fast Switching Synthesizers for Emerging EW Systems
Presenter: Uri Yaniv

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

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Fundamentals of Radar Signal Processing
January 25-28
Atlanta, GA
www.pe.gatech.edu

TechNet Augusta
Conference: January 25-28
Augusta, GA
www.afcea.org

DEPS Joint Conference on T&E Support to Prototyping and Experimentation
Conference: January 27-30
Albuquerque, NM
www.deps.org

AOC Virtual Series Webinar: When Crows Break Codes
January 28
1400-1500 EST
www.crows.org

FEBRUARY

Radar Electronic Warfare
February 1-5
Swindon, UK
www.cranfield.ac.uk

Modern Threats: Surface-to-Air Missile Systems Conference 2021
Conference: February 2-4
Redstone Arsenal, AL
www.crows.org

Aero India 2021
Conference: February 3-7
Bengaluru, India
www.aeroindia.gov.in

AOC Virtual Series Webinar: From Sarissa to Cyber Warfare
February 11
1400-1500 EST
www.crows.org

IDEX 2021
Conference: February 21-25
Abu Dhabi, UAE
www.idexuae.ae

Communications Electronic Warfare
February 22-26
Swindon, UK
www.cranfield.ac.uk

AFA Aerospace Warfare Symposium
Conference: February 24-26
Orlando, FL
www.afa.org

AOC Virtual Series Webinar: HF Meets Big Data – Intercept in an Era of HF Renaissance
February 25
1400-1500 EST
www.crows.org

EW Releasability and Export Control Workshop
Conference: February 2021 (TBD)
Washington, DC
www.crows.org

MARCH

AFCEA West Conference and Exhibition
Conference: March 2-3
San Diego, CA
www.westconference.org

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

AOC Virtual Series Webinar: Cyber Electromagnetic Activities and Signals Intelligence: a Command and Control Framework
March 11
1400-1500 EST
www.crows.org

MILIPOL Qatar 2021
Conference: March 15-17
Doha, Qatar
https://en.milipolqatar.com

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

FEATURED LIVE COURSES

RF Theory for ES Operations

Dr. Patrick Ford

Tuesdays & Thursdays
Times TBD | December 8 - 10, 2020
This course will also provide a survey of propagation modeling techniques and an update on modern RF operating trends.

Fundamental Principles of Electronic Warfare

Dave Adamy

Mondays & Wednesdays
13:00 – 16:00 EDT | April 5 – 28, 2021
This is an introductory Electronic Warfare course in eight three hour sessions. It provides insight into the whole electronic warfare field at the systems and operational level.

Advanced Principles of Electronic Warfare

Dave Adamy

Mondays & Wednesdays
13:00 – 16:00 EDT | May 3 – 26, 2021
This Advanced Electronic Warfare course has eight three hour sessions. It is designed for individuals who have completed a fundamental EW course or have significant experience in the field.

C4ISR Requirements, Principles, and Systems

Dr. Clayton Stewart

Mondays & Wednesdays
13:00 – 16:00 EDT | June 7 – 30, 2021
This 24 hour web based course delivers a thorough overview promoting an understanding and building a successful Command, Control, Communications, Computers, Intelligence, Surveillance, Reconnaissance (C4ISR) architecture.

Aircraft Radar Cross Section Engineering

Renan Richter

Mondays, Wednesdays & Fridays
13:00 – 16:00 EDT | 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.

Navigation Warfare & PNT

Kyle Davidson

Mondays & Wednesdays
13:00 – 16:00 EDT | August 2 – 18, 2021
This course introduces students to the fundamentals of navigation warfare in the modern hostile electromagnetic spectrum. The course commences with an overview of navigation systems, focussing on integrated navigation systems that use a variety of sensors to track the platform's position, such as inertial navigation and the Global Positioning System.

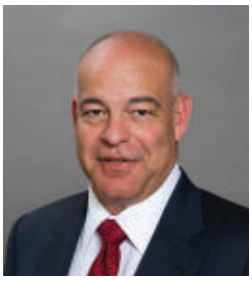
Introduction to Satellite Communications (Satcom)

Dr. Patrick Ford

Mondays & Wednesdays
13:00 – 16:00 EDT | September 1 – 22, 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!

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



THANK YOU

As I wind down my tenure as AOC President, I want to say what a pleasure it has been to serve our community. We have accomplished so much over the past two years, and I was fortunate to work with an excellent Board of Directors and a wonderful and innovative AOC staff.

If there has been a common theme for the AOC during the past two years, it has been "change." Our community is driven by changes around us, and at the same time, we have helped to shape and drive some of this change ourselves. Our traditional Electronic Warfare terminology is giving way to a new Electromagnetic Warfare lexicon. Regardless of the term we use, EW is now more firmly entrenched within the larger concept of EMS Operations (EMSO). We are also tackling some of the larger issues that have prevented our community's growth in the past. We now have more senior leaders among our ranks, and some of them are managing EMSO organizations that did not exist two years ago.

Just as our EMS community is evolving and adapting to a changing security environment, the professional organization that serves our community is also evolving and adapting. We have certainly helped to shape the EW and EMSO conversations that our military and government leaders are discussing today. This process began several years ago, and it will continue for many more years. But I think we have been effective, through our conferences, symposia and webinars, as well as our publications, at keeping the EMSO and EM Domain conversation going strong. Cultural change can be extremely difficult, and one thing that I am particularly proud of is that we have not been afraid to adapt our thinking when this was required.

It is difficult to plan for change because, by its nature, we do not know what the future will bring. But as the new year began, I don't think it was possible for any organization to anticipate the changes brought about by the COVID-19 pandemic over the past 8 months. If you had asked me to imagine a period in which our AOC Community would not be able to gather in person, hold any sort of meeting or teach courses in classrooms, I would have been unable to envision how the AOC could continue to remain relevant. But our AOC team responded to the pandemic with new ideas, such as our first Virtual EMS Summit in May and our CEMAlite virtual conference in September and by launching a government affairs newsletter that delivers news and insights when meetings and forums on Capitol Hill are not viable. I think if you take a look on the AOC Website and scroll through our past events from this year, you'll see that our Webinar program has grown with interesting new topics, and our professional development courses continue to be offered in a virtual format.

I am certainly proud of what we have achieved, and I am proud to have been a small part of it. On behalf of the AOC staff and board, thank you for your support. – *Muddy Watters*

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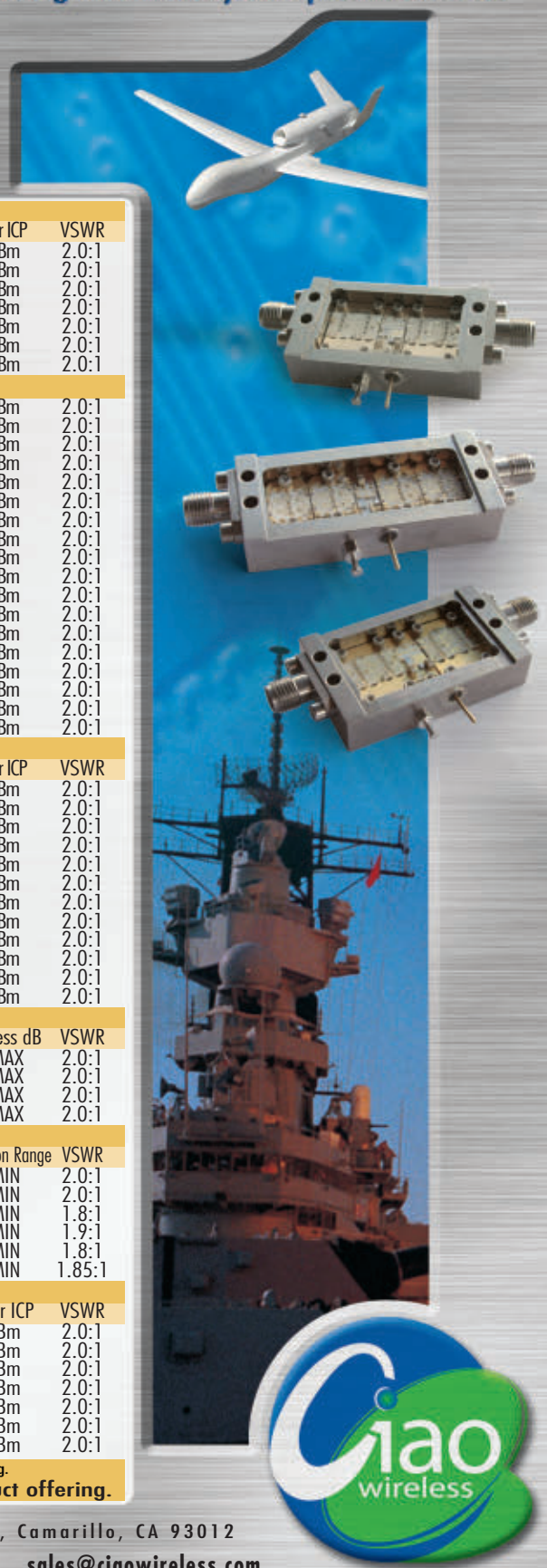

OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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DOD ISSUES EMS SUPERIORITY STRATEGY, ROADMAP AND IMPLEMENTATION PLAN TO FOLLOW

The DOD released a new Electromagnetic Spectrum (EMS) Superiority Strategy document on October 2, outlining five strategy goals intended to address EMS operations (EMSO) challenges and to prepare the Services to achieve and maintain a strategic, tactical, operational and technological advantage in the EMS.

According to the strategy document, the success and superiority of the EMS Enterprise is paramount, as, "Freedom of action in the electromagnetic spectrum, at the time, place, and parameters of our choosing, is a required precursor to the successful conduct of operations in all domains." However, "Adversary actions, commercial development, and regulatory constraints impede U.S. forces' freedom of action in the EMS," and these challenges drive "the need to develop new capabilities, new techniques, and better integration within DoD and with its partners to enhance spectrum efficiency, maximize spectrum compatibility, and ensure EMS superiority."

The DOD's strategy aims to address these challenges and ensure EMS superiority by meeting five goals.

1) Develop Superior EMS Capabilities

According to the strategy document, "In order to maintain warfighting superiority, DOD must look to revolutionary, leap-ahead technologies and capabilities to be able to compete against a range of adversaries throughout the competition continuum."

This goal will be achieved by improving existing and future EMS technologies; acquiring capabilities suitable for complex (congested, contested, and constrained) environments; leveraging commercial technologies; developing Electromagnetic Battle Management (EMBM) capabilities; and developing and fielding disruptive EMS capabilities to "create chaos for our adversaries."

2) Evolve to an Agile, Fully Integrated EMS Infrastructure

This objective includes more robust EMS data collection; making EMS data more readily and widely available through the use of "autonomous/semi-autonomous systems that use AI/machine learning and access cloud-based tools;" creating architectures and standards for all EMS systems to "enable international spectrum sharing, coalition and joint force interoperability;" and modernizing the EMS testing and training infrastructure.

3) Pursue Total Force EMS Readiness

EMS readiness encompasses training, doctrine and education, and evaluation. "Total Force EMS readiness" according to the EMS strategy, will be achieved through training all EMS workforce professionals "at the appropriate level;" incorporating EMS doctrine and activities into educational curricula; and the frequent evaluation of Force readiness via "periodic individual and unit-level training, joint force exercises, rehearsals, and wargames" that "integrate all EMS capabilities and challenges."

4) Secure Enduring Partnerships for EMS Advantage

According to the strategy document, achieving EMS superiority requires cultivating international partnerships to continue effective global operations within the EMS; ensuring EMS capabilities align with allies' capabilities and allow for collaboration using interoperable architectures; and engaging with US leadership to ensure the EMS Enterprise is a more widely recognized priority.

5) Establish Effective EMS Governance

Effective EMS governance, according to the DOD strategy, includes unifying DOD EMS Enterprise activities, which means, "Research, development, acquisition, and sustainment of future system portfolios must be synchronized across the DoD components to identify and manage spectrum risks and opportunities, avoid duplication of effort, and increase affordability."

This goal also includes developing a "continuous process improvement" (CPI) culture in order to "cultivate data-driven solutions that will ensure superiority over our adversaries and keep pace with technology and industry;" and promoting policies that support the continued cultivation of the EMS Enterprise.

The new EMS Strategy, developed by the EMSO Cross Function Team (EMSO CFT), combines two previous documents, a 2013 EMS Strategy issued by the OSD CIO and a 2017 EW Strategy from the DOD's EW Executive Committee (EW EXCOM). A Roadmap and Implementation Plan (RM/IP), which is being developed by the EMSO CFT, is expected to provide greater insight into the implementation of the strategy goals outlined in the 2020 EMS Superiority Strategy. As the Senior Designated Official (SDO) of the EMSO CFT, the Vice Chairman of the Joint Chiefs of Staff will be responsible for oversight and execution of this new EMS Superiority Strategy and the RM/IP. – *H. Swedeen*

US ARMY DISCUSSES CEMA DEVELOPMENTS

The US Army is taking concrete steps tailor its Cyber Electromagnetic Activities (CEMA) concept to support the DOD's over-arching Multi-Domain Operations (MDO) strategy, according to senior Army officials. During the AOC's CEMAlite virtual conference on September 29, Army officials described the progress they are making in several CEMA areas, such as technology development, establishing acquisition programs, and integrating CEMA into operations, and training. Here is a brief summary:

- *Information Advantage:* LTGEN Stephen Fogarty, commander, US Army Cyber Command, provided an overview of where the Army's thinking on CEMA is headed. He explained how the CEMA concept has evolved over the past decade – from the Army's initial focus on cyber operations when Army Cyber command was first established to the later inclusion of electronic warfare (EW) and spectrum management. "Now we're at the point where we've opened the discussion to Information Operations (IO)," he said. "The task over the last 24 months has really been to figure out how to knit all three of those pieces together," he said. This is a process that has been led by the Army's Cyber Center of Excellence (Fort Gordon, GA) and the Army's Combined Arms Center (Fort Leavenworth, KS).

  "Now when we started this conversation two years ago, it was, 'Look we think Information Warfare is probably the right concept,'" he said. "And that has evolved over a period of time into something that I think will most likely be called Information Advantage."

  He went on to explain, "If you think about where we've been, which is trying to allow commanders to visualize their operations in the spectrum so they can see the adversary, they can see themselves, they can see everyone else that's in this very congested spectrum, and then actually span that to include the information environment. So now thy can see themselves real time – not just the physical effects and the physical space within the spectrum – but also in that information space, where ideas are being bounced around like crazy. So this idea that we would be able to see what's happening in a very holistic way to enable commanders with what we're currently calling decision dominance."

  General Fogarty explained further, "Decision Dominance is a desired state in which a commander can sense, understand, decide, and act faster and more effectively than an adversary. And that allows the commander to gain and maintain positions of relative advantage. And this is not only the cyber domain, it's not only in the RF spectrum, but it's in the larger or greater information environment."
- *Emerging Technologies:* Dr. Jeff Boskiner, Senior Research Scientist for EW at the Army's C5ISR Center, discussed the Army's Science and Technology (S&T) work for CEMA. He explained that the Army's S&T strategy is based on three factors: the threat environment; meeting the new way the Army wants to fight using Multi-Domain Operations; and the emerging technology that is coming out of basic research, DARPA, industry and academia. Dr. Boskiner discussed current EW S&T efforts focused on traditional areas, such as ground vehicle survivability and aircraft survivability equipment. He said that in the mid-term, new technologies, such as cognitive EW (ES and EA), RF resource optimization and simultaneous transmit and receive (STAR), are making solid progress.

  In the far term, Dr. Boskiner saw three technology areas that he thinks could revolutionize EW. One of these is photonic signal processing. The second is quantum sensors featuring low-noise sensitive receivers that use Rydberg atoms. And the third is cooperative and autonomous technologies that use Game Theory as a driver for EW and spectrum-dependent systems to self-organize. Of this last one, Dr. Boskiner explained, "As we evolve from individual systems to distributed systems, we really have to reconsider how we do EW C2. In fact, I think this is broader than EW. I think as we evolve to really distributed EW…we have to rethink how we do EMBM (Electromagnetic Battle Management). So, right now EMBM is a very linear process. We plan. We provide the plan. We execute the plan. Certainly, there are adjustments as conditions change, but it's very much a top-down approach. And one of the things that we've been looking at from an EW S&T perspective is changing the paradigm from this top-down C2 approach to what has been very successful in other areas, for example in networking – a much more autonomous approach. A combination of machine learning and game theory approaches to individual systems and collections of systems and talking to each other. We've done studies that show that this can be really as effective as very centralized C2. And again we know this is the case, in networking for example, where individual systems making decisions can be shown to be as effective as overall C2, and we think this is going to be true for spectrum systems, EW systems, different sensors and communications systems. So, I think this is not a near-term situation, but we really have to start preparing much more distributed and autonomous behavior by our RF systems because as the complexity evolves, the current approaches will not be viable."
- *Terrestrial Layer System – Echelon Above Brigade (TLS-EAB):* Three panelists discussed the Army's acquisition programs in the context of MDO. COL Jennifer McAfee, Army Capability Manager for Terrestrial & Identity, Intelligence Center of Excellence; COL Kevin Finch, Project Manager, Electronic Warfare & Cyber (EW&C); and COL Daniel Holland, Army Capability Manager Electronic Warfare, Cyber Center of Excellence introduced a new program, the Terrestrial Layer System – Echelon Above Brigade (TLS-EAB). Designed to support MDO, TLS-EAB will enable Division commanders to perform long-range sensing (COMINT, ELINT and FSINT), long-range EA, as well as defensive EA to protect command posts.

  The Army is already developing a Stryker-mounted version of TLS for Brigade Combat Teams operating closer to the fight. At the Division level, TLS-EAB will be able to sense targets at longer ranges and rapidly engage them with EA, RF-delivered cyber effects, de-

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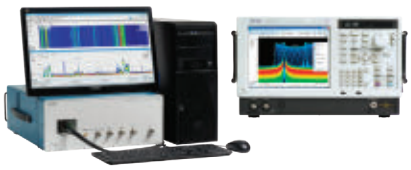

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livery of Military Information Support Operations (MISO) content or other technical operations like the ability to deceive adversary sensors or corrupt their decision cycle. The TLS-EAB is also an important sensor in the Army's rapid sensor-to-shooter concept needed for MDO. TLS-EAB will be interoperable with the Tactical Intelligence Targeting Access Node (TITAN), Multi-Domain Sensing System (MDS), TLS-BCTEWPMT, MFEW-Air Large, and the Integrated Tactical Network (ITN).

The Army plans to develop TLS-EAB in two variants. TLS-EAB Subsystem 1 will comprise a vehicle (possibly from the Medium Tactical Vehicle (MTV) family) towing a trailer-mounted shelter, as well as a support vehicle. This version will be manned by seven personnel – three SIGINT operators and a four-person EW team. In order to sense and deliver EA at longer ranges, TLS-EAB shelter will use either an adjustable antenna mast or a tethered UAS or tethered aerostat. Subsystem 1 can also be disassembled to enable the shelter to remain behind while the EA subsystem is transported several miles away to a hill or mountain to operate more effectively.

TLS-EAB Subsystem 2 will be operated by a four-person EW team and provide defensive EA to protect Division command posts from enemy UASs, as well as long-range precision guided missiles, rockets and artillery including rounds that use radar fuzing and homing. According to Colonel Holland, Subsystem 2 will likely be networked into a larger air defense network to provide cueing and data sharing via "cursor on target" message standards.

Colonel Finch outlined the TLS-EAB schedule, which includes an Industry Day in January 2021, followed by a draft RFP release in February and another Industry Day in June. The final RFP is slated for release in July, and an Other Transaction Authority (OTA) contract could be awarded in early 2022. The First Unit Equipped (FUE) is scheduled for late 2023. He also said the TLS-EAB will utilize Photon, a common integrated framework for implementing new capabilities rapidly, to ensure constant software updates that will enable TLS-EAB to pace threats that utilize fast-moving commercial technologies.

Colonel Holland also said the Army is exploring a requirement for TLS-Small for units at echelon Battalion and below. But he emphasized that this was in the early stages. – *J. Knowles*

DISA ISSUES EMBM RFI

The Defense Information Systems Agency (DISA) Defense Spectrum Organization (DSO) has released a Request for Information (RFI) for the Joint Electromagnetic Battle Management (EMBM) System. This will provide a new browser-based software toolset that will enable Joint Force Commanders, acting through their Joint EMS Operations Cells (JEMSOCs) to "…conduct the planning, monitoring, directing, and assessing of EMSO for the Joint Task Force," according to the RFI. The goal of the Joint EMBM program is to enable JEMSOCs to collect and fuse inputs from potentially thousands of EMS sensors in theater; visualize friendly, adversary and neutral activity in the Electromagnetic Operating Environment (EMOE) across their area of responsibility; interface with Service-level EMS planning and situational awareness tools, such as the Army's EWPMT; and support rapid EMSO decision making for the Joint Task Force Commander.

Currently, Joint Force Commanders have a very limited ability to view and understand the EMOE in real time. According to the RFI, "CCMD and JTF JEMSOCs and operations centers require near real time integration and display of foundational data, and processed electromagnetic spectrum (EMS) feeds of friendly, neutral, and adversary systems. This is necessary to provide an accurate characterization of the EMOE during time-constrained operations planning and command and control (C2) cycles in potentially degraded and low-bandwidth network environments. To enable timely situational understanding of the EMOE, an EMBM capability must have the capability to automatically extract, fuse, and analyze relevant data and information from multiple structured and unstructured EMS sources and across multiple security levels. An EMBM capability must have the ability to display the EMOE both geographically and temporally within a browser-based desktop computing environment showing EMS propagation effects and identifying impacts of Electromagnetic Interference (EMI). Additional toolsets are needed to predict the state of the EMOE at a future specific time and location, deconflict EMS assets, and evaluate the EMS risk and supportability of potential courses of action."

DSO is developing the Joint EMBM System to meet this need. The RFI states, "The Joint EMBM system addresses four capability priority areas identified by the EMBM Initial Capabilities Document (ICD) to improve Joint Electromagnetic Spectrum Operations (JEMSO) at Joint Force Commander (JFC)-levels (Combatant Command (CCMD) or Joint Task Force (JTF)): Situational Awareness, Decision Support, Command and Control (C2) and Training. The EMBM capability is envisioned as a suite of browser-based, computer capabilities available (at the NIPR, SIPR, and JWICS levels) to CCMD and JTF JEMSOCs, and later to joint all-domain command centers' Common Operational Pictures (COPs). EMBM will interoperate with Service-developed tools to enable CCMD and JTF JEMSOCs to coordinate, prioritize, integrate, synchronize, direct, and deconflict Service Component EMS Operations (EMSO) activities in their assigned joint operational areas across all domains and joint functions."

In terms of the EMBM program's acquisition strategy, the RFI states, "The Government is planning to develop these capabilities by implementing robust agile software development, and DevSecOps techniques using the Software Acquisition Pathway under the Adaptive Acquisition Framework. In addition, the Government intends to take advantage of existing, related capabilities, such as the Joint Spectrum Data Repository (JSDR), the Electronic Warfare Planning and Management Tool (EWPMT), and/or other fielded and future systems that could potentially fulfill portions of the Joint EMBM requirements."

DSO is planning to develop the Joint EMBM System incrementally. According to the RFI, these increment are:

1. Near Term Capability 1: EMOE Situational Awareness – Build an EMOE estimate by aggregating and fusing EMS information and fuse this infor-

mation with existing near real time data feeds into a visualization display

2. Near Term Capability 2: Automated Event Correlation Capabilities – Apply the toolsets needed to conduct situational analysis of the EMOE data repository in order to predict the impact of the EMOE on operations. The capability should allow users to understand the EMOE for the Joint Force and enable JEMSOCs to determine EMS dependencies, EMOE impacts, and requirements to shape military operations. EMBM will identify events of interest from the EMOE estimate and execute a machine aided correlation process to identify mission impacts and execute root cause analyses.
3. Mid Term Capability 1: Automated and User Customizable Mission Planning Tools – Enable users to analyze Courses of Action using the EMOE estimate and correlation views on a mission plan scenario in order to determine and mitigate risk.
4. Mid Term Capability 2: Component and Service EMBM Interoperability for C2 – Enable interoperability with component and service tools to exchange data and inform components of higher headquarters guidance, orders, and policy concerning EMS maneuver to gain a situational understanding of the EMOE.
5. Mid Term Capability 3: EMBM Training – Provide a dedicated training capability to ingest exercise data and feeds from various sources.
6. Long Term Capability 1: Common Operating Picture – Ensure EMBM is interoperable with existing CCMD, JTF, and Service Component operation centers' Common Operation Pictures and/or common tactical pictures. EMBM development will be coordinated with emerging Joint All Domain Command and Control (JADC2) development to achieve an agile and resilient C2 across all domains.

The EMBM acquisition strategy also seeks to leverage existing capabilities to the greatest extent possible. According to the RFI the EMBM design must:

- Enable operators to capture and convey the boundaries of spectrum maneuver in a congested and contested EMOE, migrating away from traditional spectrum management and enabling users to dynamically adjust to an EMOE that constantly changes,
- Identify spectrum conflicts and assist in resolving spectrum conflicts,
- Anticipate future EMOE states so that actions can be taken to mitigate conflicts and to exploit opportunities to achieve an advantage,
- Support the operational planning cycle from an EMS perspective,
- Render EMS data from multiple EMS data sources,
- Support Coalition data sharing,
- Generate relevant products for consumption by operators and senior leadership to gain a situational understanding of the EMOE, and support decision making and command and control,
- Deploy EMBM in a cloud agnostic architecture,
- Integrate EMS modeling and simulation,
- To the extent practicable, take advantage of existing, related tools and sys-

tems (e.g., JSDR, EWPMT, Spectrum XXI, Fusion Analysis and Development Effort/Multi-Intelligence Spatial Temporal Tool Suite (FADE/MIST), etc.), and

- Provide a training capability that allows training scenarios to be injected into live EMBM systems while live operations are ongoing. This capability should keep the training data and user actions isolated from live data and operations.

The RFI calls for interested companies to submit white papers addressing resources such as available software tools and systems, as well as EMS modeling & simulation and C2 capabilities. Responses are due by October 30. The contracting point of contact is Gloria Norwood, e-mail gloria.r.norwood.civ@mail.mil. *– J. Knowles*

UK COMPLETES SWARMING DRONE EA DEMONSTRATION

Leonardo, working in partnership with the UK Royal Air Force's (RAF's) Rapid Capabilities Office (RCO), disclosed that it has successfully conducted a live trial of an electronic attack (EA) capability using autonomous "swarming drones."

During the demonstration, undertaken in late July, a number of small unmanned air vehicles (UAVs) equipped with EA payloads adapted from Leonardo's BriteCloud expendable active decoy (EAD) were used to saturate and confuse radar threats simulating those associated with adversary air defense systems. The BriteCloud EAD entered RAF service in 2018.

The RCO and Leonardo worked in conjunction with Callen Lenz and BlueBear Systems (both of which are UK-based small/medium enterprises) to go from concept to demonstration in just a few months. During the demonstration, a number of Callen Lenz UAVs were equipped with the modified BriteCloud payload, allowing each to individually deliver a highly-sophisticated "stand-in" EA effect. In addition, the decoy packages were programmed and navigated to work in collaboration so as to cause maximum confusion.

According to Leonardo, the trial proved the ability of BriteCloud-equipped UAVs to deliver EA effects sufficient to overwhelm threat radar systems. Information gained from the demonstration will now be used to inform potential future UK programs. *– R. Scott*

IN BRIEF

The Naval Surface Warfare Center – Dahlgren Division (NSWCDD), acting on behalf of Naval Sea Systems Command's PEO for Integrated Warfare Systems (PEO IWS), has announced plans to issue a Request for Prototype Projects (RPP) for concurrent Long Endurance Airborne Platform (LEAP) Future Naval Capability (FNC) and Program Executive Office Integrated Warfare Systems (PEO IWS) Long Endurance Electronic Decoy (LEED) acquisition programs. NSWCDD is expected to issue the RPP through the Naval Surface Technology & Innovation Consortium (NSTIC) this month. Only companies that belong to NSTIC will be able to bid on the LEAP and LEED programs. More information is available at NSTIC's Web site at www.nstic.org.

Army C5ISR Cen Pipeline for CEM

By John Haystead

Speaking during the AOC's Virtual EMS Summit earlier this year, GEN John Murray, Commander, US Army Futures Command, made it clear that the Army is placing an entirely new level of importance on being able to operate and fight in the anticipated EMS environment of the future, in particular in terms of Multi-Domain Operations (MDO). Among the Army's main tenets of Joint MDO is calibrated force posture, says Murray, "which means being in the right places, at the right time, with the right force, and with the right authorities." To that end, he adds that existing capability gaps can only be solved by technology, which is at the heart of the Army's modernization efforts. "We will never be done modernizing, but we have to take this opportunity to modernize now." And this is where the Army's new Cyber Electromagnetic Activities (CEMA) units come to the forefront.

In fact the Army's S&T Strategy/Roadmap for CEMA is all about making it an integral part of MDO. Army Cyber Command (ARCYBER) (Fort Gordon, GA) plans to field CEMA teams with every brigade combat team (BCT), division, corps and Army service component staff. CEMA is designed to provide tactical commanders with integrated cyberspace and information network operations together with support of electronic warfare (EW) and spectrum management operations.

Providing the technology and tools that will equip these CEMA units is the job of the Army's Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR) Center located at Aberdeen Proving Ground, MD – one of eight science and technology domains within the Army's Combat Capabilities Development Command (CCDC). CCDC was formerly the Army's Research, Development, and Engineering Command (RDECOM).

Drilling down further into the roles and responsibilities of the C5ISR Center, the Intelligence and Information Warfare Directorate (I2WD) is the group that researches, develops and evaluates the advanced technology and systems that will drive new intelligence, surveillance, reconnaissance, EW and cyber capabilities from initial concept to fielding – providing continuous engineering and management support to Program Executive Offices (PEOs). As part of this mission, it operates a range of unique laboratories and testing facilities to test and evaluate developmental systems in controlled but realistic environments.

According to Giorgio Bertoli, I2WD Director, "The Army realized several years ago the criticality of being able to conduct warfare across the traditional domains of air, land, sea and space – being able to work with all the Services in tandem during an engagement. Particularly, when you're talking about near-peer threats, MDO provides a huge advantage."

MDO, A2/AD AND SENSING

Bertoli identifies four particular focus areas where I2WD and the C5ISR Center are working to provide CEMA capabilities that can be brought to bear for MDO, in particular to address adversaries' Anti-Access/Area-Denial (A2/AD) strategies. He breaks down the challenges that must be addressed to counter an A2/AD strategy into phases with the first phase being a "competition phase," which occurs prior to an actual major conflict or, potentially, may help prevent such an escalation. Here, he says, "the name of the game is sensing. How do I sense the operational environment to the degree of accuracy I need to potentially support a follow-on conflict phase?"

For this sensing stage, the Directorate is pursuing several technology areas, which Bertoli describes as "trying to push the physics." These efforts include the use of novel materials to provide better dynamic range, and on improved beamforming technology to generate narrower beams over broader bandwidths.

Daniel Duvak, Chief of the C5ISR Center's RF Communications (RFC) Division, within the Space and Terrestrial Communications Directorate (S&TCD), relates this work on beamforming to his group's overall responsibilities for

"With 5G, you will have a lot of higher frequency bands which provide an opportunity to use a lot of antenna elements in a small package," Duvak says. "Think of something the size of a credit card with 50 or 100 antenna elements that allows you to get to a very highly-directional signal."

ter Feeds S&T A and MDO

spectrum management (see "ALL Things Spectrum – C5ISR Division of Spectrum Management Expertise and Technology" on p. 28). This includes the DOD's and Army's increasing challenges in obtaining adequate spectrum allocation. "One of things we're doing to get past this is moving toward directional beamforming. When our systems are sending their signals out omnidirectionally, they quite often interfere with each other and require the use of a lot of spectrum. With more directional systems, as long as you're not pointing in the same exact direction, we get all that frequency re-use."

Taking the concept a step further, Duvak notes that in terms of the tactical radios used by today's individual soldiers, "most of them have little omnidirectional antennas sticking up and radiating in all directions. As we go into contested environments against near-peer adversaries, that is not going to be optimal from a spectrum perspective." To address this, the RFC Division is working on a distributed beam forming program where essentially each dismounted soldier functions as a separate antenna element within one overall system. "Think of five or six soldiers coordinating amongst each other with the conglomeration of them performing as five or six antenna elements to create a directed beam of communication back to a vehicle or command post." Duvak says they're currently working with industry partners to make such a tactical solution available "in just the next few years."

Duvak further notes that the pursuit of increased directionality also relates to their initiatives in moving into new frequency bands, such as millimeter-wave frequencies, particularly their work in 5G technology, where they are looking at leveraging some of the antenna apertures that the commercial industry is developing for the 5G small cell. "With 5G, you will have a lot of higher frequency bands which provide an opportunity to use a lot of antenna elements in a small package," he says. "Think of something the size of a credit card with 50 or 100 antenna elements that allows you to get to a very highly-directional signal."

Bertoli says another promising approach to pushing the physics is the use of optical up-conversion. With optical up-conversion, instead of down-converting a signal into baseband and doing traditional signal processing, you instead upconvert to optical wavelengths and then perform analog processing using lenses. According to Bertoli, "This provides huge benefits because the wavelengths are much smaller and you can get better dynamic range and separation between different types of signals, allowing you to pull fainter signals out."

Ultimately, however, Bertoli acknowledges that there are limits to what can be accomplished in the physics arena. For example, he points to curvature-of-the-earth issues where greater distances mean more noise and co-channel interference. "Physics are physics, and the problems get very complicated," he explains. "So, yes, you can do some things, but you will eventually be limited by physics."

Although a limited increase in sensor range can be accomplished by deploying them at higher altitudes, such as on a UAS or an aerostat, ultimately the solution lies in getting the sensors closer to their targets of interest. To accomplish this, Bertoli points out that the Army is looking at an entirely new class of platforms to carry its sensors called penetrators. "The fundamental concept is that these are unmanned, attritable, or even disposable, assets that can be sent across a border, knowing that many will not come back, in support of potential follow-on maneuver operations." Among the new platform programs that the C5ISR is supporting with payloads and swarming technologies is the Air Launched Effects (ALE) family of small UAV systems, as well as high-altitude airships along the lines of Google's "Loon" project, which consists of a network of high-altitude balloons traveling as high as 75,000 feet to provide Internet service to remote areas.

Another approach being explored is the use of large numbers of very small, disposable unattended ground sensors

Says Bertoli of small, disposable unattended ground sensors, "Sometimes it's not the quality of the sensors, but the number. A lot of times you can do better with a large number of cheaper, smaller sensors than you can with a couple of really exquisite ones."

that can be distributed by UAVs, high-altitude balloons, or even artillery. Says Bertoli, "Sometimes it's not the quality of the sensors, but the number. A lot of times you can do better with a large number of cheaper, smaller sensors than you can with a couple of really exquisite ones."

PROCESS, EXPLOITATION AND DISSEMINATION (PED)

Following on the topic of sensors, Bertoli says the next step is to provide a process where all of the collected sensor data is refined and distributed via Processing, Exploitation, and Dissemination (PED) systems. "One of the big pushes in the Army right now is to recognize that we need to break the paradigm of 'system ownership,' where the entire data chain is controlled by one sensor or system and is tailored to focus on one specific data set." Bertoli points out that many individual sensors are actually capable of collecting and reporting a great deal of additional data beyond that of interest to its primary user. "Right now, much of this additional data is just going to waste," he says, "so we're looking at ways to direct other people to that sensor, as well to enhance their capabilities." Enhanced geolocation systems are currently doing this by networking multiple sensors together using the Joint Interface Control Document (JICD) 4.2 standard, and Bertoli says they are looking to expand this idea to other areas, such as SIGINT and EW.

DATA FUSION AND CROSS-DOMAIN COMMUNICATION

The next step in the process of data collection for MDO aimed at the A2/AD challenge is to provide a mechanism to make sense out of the giant "data lake" that's been collected without putting all of the burden on intel analysts. Here, Bertoli observes that this is not just a challenge for the Army, but rather it involves all of the Joint Service and coalition forces, together with longstanding problems associated with cross-domain and classification boundaries in data standardization and formatting, as well as being able to correlate data across multiple sensor modalities – SIGINT, COMINT, EO/IR, etc. Another issue is the fact that the Services have historically built sensors to provide data to people. They now recognize that these sensors also have to provide data to machines, with machines not necessarily wanting to see data the same way people do. "It's not rocket science, but it's still critical work that someone has to do in order to provide for a common-core fundamental language, and we have efforts aimed at finding ways to do this," says Bertoli.

Another focus area relative to the data-fusion task is targeting, with one of core objectives of the Army's entire modernization strategy being able to engage the enemy further away on the battlefield. Bertoli says this means fundamentally changing how the Army executes targeting. "Historically, a commander has had a target prioritization list and they will try to find those items on the battlefield, then build targeting packages to engage them – kinetically or otherwise. The problem with this approach, however, is that it's very reactive. You have to wait for some sensor hit to come in to identify a target of interest and then a bunch of analysts have to go to work to determine which weapons systems can engage it, resulting in a lot of opportunistic targets being missed. Instead, we want to get to the point where we are continually identifying and locating targets, whether they are on a priority list or not. With this approach, as data comes in from various different sensors, we can start populating targeting packages automatically and putting in all the information needed to engage it. Then, it becomes only a yes or no question for a commander as to whether to engage it or not." More automation in the data fusion process will be required to accomplish this goal, and Bertoli says the C5ISR Center is working to provide this.

C5ISR/EW MODULAR OPEN SUITE OF STANDARDS (CMOSS)

Another major focus area for the C5ISR and I2WD is how to advance and implement the concept of Modular Open System Architecture (MOSA). Bertoli says they've actually been working in this space for over a decade, but it's now become absolutely critical to develop some boundaries within the development of a CEMA system that can allow for their rapid and efficient upgrade. "In the CEMA technical space, you're going to be obsolete sooner rather than later. You can't expect a system to last 30 years or even 10 years, and you'll also not want to upgrade the whole thing. Ideally, you'll want to upgrade strictly through software, but if that's not possible, then you'll want to be able to swap out or add pieces of hardware in a logical way, so you're not constantly developing a brand new system whenever you need a new or improved capability."

The C5ISR/EW Modular Open Suite of Standards (CMOSS) is a major effort aimed at providing an open system architecture that can make this possible. CMOSS will also allow the convergence of multiple mission functions, such as mission command, movement and maneuver, and fires into one system, ver-

"...we want to get to the point where we are continually identifying and locating targets, whether they are on a priority list or not. With this approach, as data comes in from various different sensors, we can start populating targeting packages automatically and putting in all the information needed to engage it. Then, it becomes only a yes or no question for a commander as to whether to engage it or not," explains Bertoli.

sus the current method of integrating a multitude of separate capability systems into vehicles.

As explained by Bertoli, CMOSS is actually a multi-layer or suite of standards primarily based on commercial standards developed in conjunction with industry. "It goes all the way from sharing screens, antennas, amplifiers, and data flows within a vehicle itself to the next level up of hardware – moving from boxes to card-level systems providing different capabilities that can be slid into a kind of common backplane. And, there's also a software layer. Ideally, we'd like to get to the point where we don't even need different hardware modules – just build in software modules taking advantage of the cards already there and eventually having different applications within different systems talking to each other, cooperating and leveraging each other to provide more complex capabilities. This will be a huge benefit to the Army and how we develop CEMA systems going forward."

The C5ISR Center expects to transfer its CMOSS technology work to the Program Executive Office, Command, Control Communications-Tactical (PEO C3T), which is executing the acquisition of the Army's network modernization strategy by rapidly inserting new technologies through a two-year incremental-capability-set fielding approach, which will begin in fiscal year (FY) 2021.

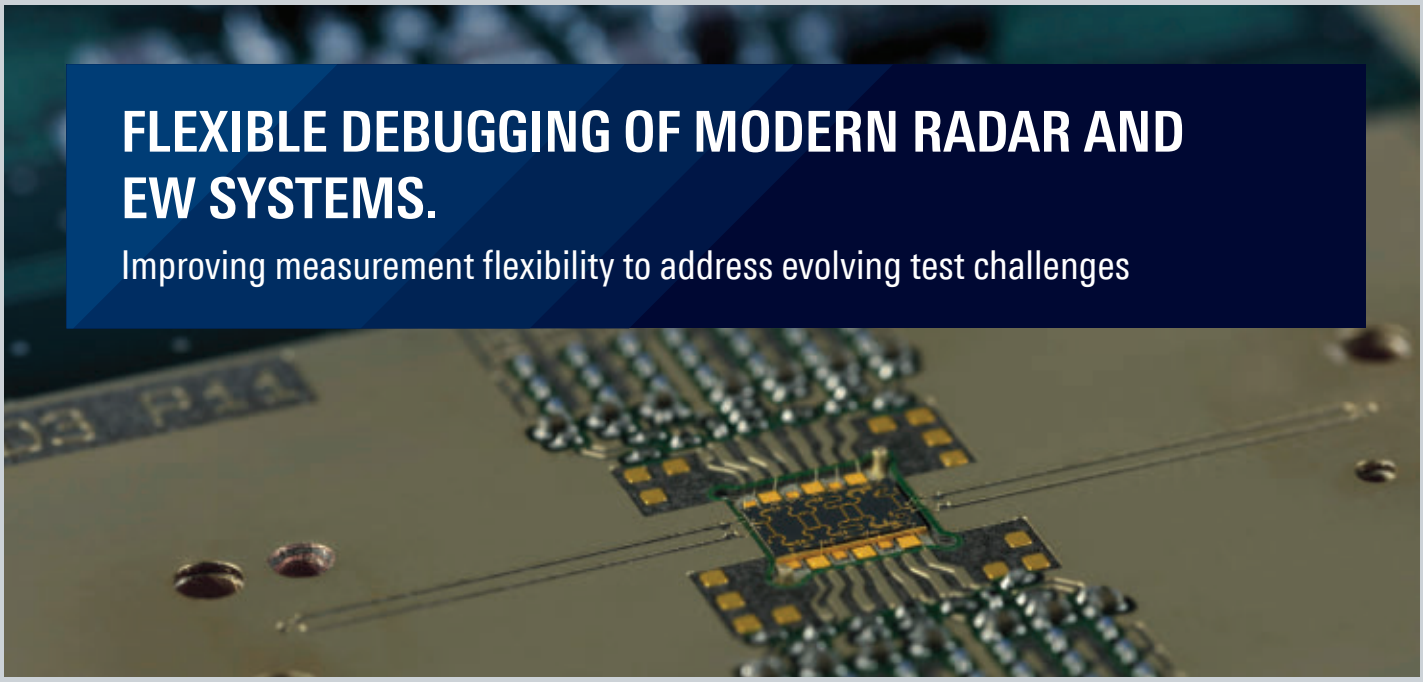
SOLDIER TOUCH POINTS

It's important to note that the C5ISR Center is not developing the technology and tools to support CEMA and MDO in a vacuum. In fact, General Murray has emphasized that another important concept that must be pushed throughout the enterprise is that of "soldier touch points, which is getting soldiers involved early in the development process so that we can deliver them a capability they want and provide important feedback loops that inform the next round of soldier test."

The primary way the C5ISR Center works to accomplish this soldier connection is by participating in various field-activity events and exercises, introducing and incorporating new technology and systems generally when they reach about a TRL-5 level.

Randy Wheeler, Associate Director for Field-based Experimentation at the C5ISR Center Ground Activity, points to the "Cyber Blitz" training exercise that the Center has been conducting together with the Cyber Center of Excellence since 2016. "The reason we do these field experiments is that they provide key soldier touch points," he explains, "allowing the hands-on soldiers to work with S&T prototypes in an all-domain space. And, it's really heavily focused on non-kinetic MDO to include cyber, space, information operations, EW, etc., ensuring soldiers are able to touch our S&T early and often and getting their feedback."

One of the unique aspects of Cyber Blitz is that beginning in 2019, the exercise has been aligned to an Army Service Component Command Tier 1 exercise. This was done specifically to provide a live non-kinetic training environment for the Army's new Multi Domain Task Force (MDTF). The MDTF was stood up as a pilot program under US Army Pacific Command and embedded into different



FLEXIBLE DEBUGGING OF MODERN RADAR AND EW SYSTEMS.

Improving measurement flexibility to address evolving test challenges

Modern radar and electronic warfare (EW) architectures are showing a multitude of technological advancements that raise the need for more flexible testing approaches. Originally a purely analog domain, radar and EW modules are getting more and more integrated and exhibit a variety of digital interfaces, especially with the extensive adoption of advanced digital signal processing (DSP) techniques for a fast and accurate signal analysis.

When characterizing and debugging their designs, developers of such systems often look for versatile instruments that can handle both their RF and digital test requirements and reduce the test effort and costs. In this context, the R&S®RTP high-performance oscilloscope represents a good fit by combining powerful RF signal analysis capabilities with a large set of features for signal integrity and digital interface test.

Precise characterization of multi-antenna designs

Sophisticated radar systems are increasingly relying on electronically steered phased array antennas. To characterize these types of systems, test equipment must exhibit multichannel capabilities and ensure that all channels are constantly phase-coherent. Rohde&Schwarz oscilloscopes are very well suited in this case since they provide multiple channels that are by design tightly aligned and do not need any additional calibration before performing multichannel phase-coherent measurements. The R&S®RTP oscilloscope can fully address this kind of measurement. In order to achieve the best possible phase accuracy, the R&S®RTP oscilloscope is also capable of measuring the channel-to-channel skew and compensating it across the entire signal path between the device under test (DUT) and the oscilloscope channel inputs by using the R&S®RTP-B7 high-accuracy differential pulse source option to generate the calibration signals.

Figure 1: The R&S®RTP oscilloscope

Leading-edge multichannel pulse analysis capabilities

Besides the characterization of multi-antenna designs, phase coherence has a crucial role when modulated pulsed signals have to be analyzed in relation to each other.

Webinar: Analyzing multichannel phase-coherent radar signals

This webinar explains the importance of phase-coherent measurements in a variety of real-world use cases and presents relevant Rohde&Schwarz solutions needed to perform them.

Watch our webinar at:
www.rohde-schwarz.com/aerospace-defense/multichannel-pulse-webinar

One of the most prominent examples is the digital radio frequency memory (DRFM) jamming technique, where the jammer is capable of receiving the original radar signal and creating a fake radar echo representing a false target that the transmitting radar cannot distinguish from other legitimate signals. For this purpose, the retransmitted false targets have to maintain coherence with the original signal. This can only be validated when both the original and retransmitted pulses are analyzed in relation to each other. The R&S®RTP oscilloscope allows a phase-coherent analysis of both signals in time and frequency domains. With an internal analysis bandwidth up to 16 GHz, it even offers the RF hopper analysis for frequency-agile radars over a relatively wide bandwidth, to verify if the DRFM is following that agility.

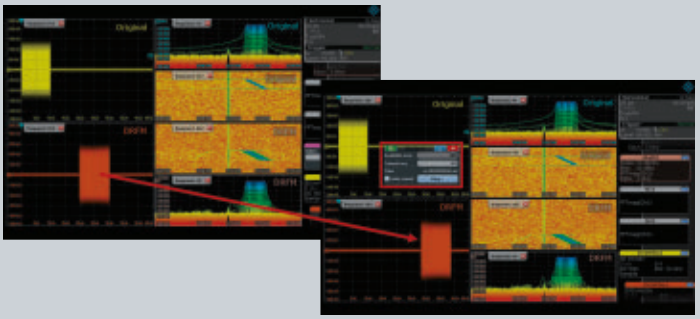


Figure 2: Analysis of retransmitted echo in relation to the original pulse with the R&S®RTP oscilloscope onboard-tools. Changes over time can be tracked in both time and frequency domain

The detection accuracy of the pulses is greatly improved by the advanced trigger system of the R&S®RTP oscilloscope. All Rohde&Schwarz oscilloscopes have the particularity, that their trigger system is fully digital so that it operates directly on the samples of the A/D converter. The measurement signal is not split up into two paths as for conventional analog triggers. Therefore, the impairments of an analog trigger system are eliminated by design. This results in a lower trigger jitter and a flexible trigger sensitivity that can be optimized depending on the actual needs.

For a more in-depth analysis of the pulses, The R&S®RTP oscilloscope can be combined with the R&S®VSE vector signal explorer software, a powerful analysis tool for a variety of signals. The R&S®VSE software has the unique capability of providing the R&S®RTP oscilloscope trigger system full support without any limitations regarding the trigger types or parameters. This allows for a flexible optimization of the trigger settings to get a stable and reliable trigger condition of the signal of interest, and leads to a better measurement performance, especially when irrelevant signal portions, such as off-times, have a significantly larger duration than the pulses/pulse sequences.

Considering the DRFM example, the R&S®VSE-K6A multichannel pulse analysis option delivers a comparison of pulse parameters and statistics over multiple channels. This allows a comprehensive analysis of the DRFM retransmitted pulse changes over time with respect to the original signal.

A single solution for all digital design test needs

Current digital testing needs (including signal integrity, high-speed digital interface and memory tests) are gaining more importance for the prototyping and validation of radar and EW designs. This is increased by the intensive use of DSP blocks for real-time signal processing and the current trend that is going towards the deployment of wideband converters as close as possible to the antennas and relying on advanced digital technologies for beamforming and beam steering. Oscilloscopes represent the tool of choice for such measurements. For example, the R&S®RTP offers a wide range of signal integrity functions (such as eye diagram and jitter analysis). Additionally, it provides a variety of digital interface and memory test solutions for multiple standards (e.g. PCIe and DDR) and for aerospace and defense specific buses (e.g. MIL-STD-1553, ARINC 429 and SpaceWire).

Combined with its RF multichannel analysis capabilities, it becomes clear that the R&S®RTP oscilloscope represents a general-purpose solution that is best suited for debugging complex systems by providing research and development and validation engineers with an all-in-one solution to help characterize their prototypes from the RF frontend up to the bitstream.

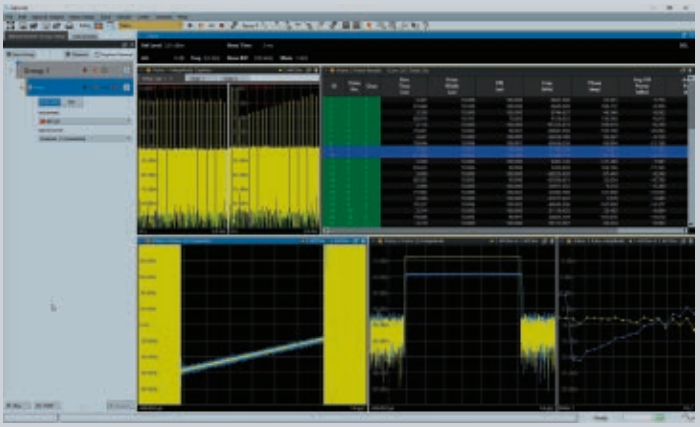


Figure 3: In-depth analysis of the retransmitted pulse echo (channel 3) in relation to the original pulse (channel 1) with the R&S®VSE-K6A multichannel pulse analysis option

Rohde&Schwarz offers:

- Analysis bandwidth up to 16 GHz
- Advanced fully digital trigger system supporting the full instrument bandwidth
- Dedicated multichannel pulse analysis tool
- Wide range of digital design measurement functions
- Unrivaled update rate of 750000 waveforms/s
- Versatile solution than can handle both RF and digital test requirements

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exercises in the Pacific. As described by Wheeler, however, "when it came to non-kinetics, they were white carding a lot of things, and the Army wanted to get away from that." (White carding involves telling exercise participants that a certain action has occurred. This was typical of cyber effects, given that it was difficult to realistically simulate them, which diminished the training value in exercises because participants didn't experience the full breadth of these actions.) Instead, the Army wanted these MDTF units as they were being built to really get hands-on with some of this equipment, which up until then was not readily available except for the S&T world.

Beginning in FY2021 Cyber Blitz will be growing in size and scope and also be receiving a new name – "MDO Live," which, according to Wheeler, "better represents what we're providing as an experimentation environment with extensive soldier touch points."

> "The reason we do these field experiments is that they provide key soldier touch points," Wheeler explains, "allowing the hands-on soldiers to work with S&T prototypes in an all-domain space. And, it's really heavily focused on non-kinetic MDO to include cyber, space, information operations, EW, etc., ensuring soldiers are able to touch our S&T early and often and getting their feedback."

Wheeler describes the event a "three-way, win-win" for the Army Modernization Enterprise, "providing a unique venue environment that helps us: integrate and operationalize our technology development and S&T, providing key soldier touch points and integrating things in the spirit of MDO – to be able to sense,

All Things Spectrum – C5ISR Division of Spectrum Management Expertise and Technology

The C5ISR Center's RF Communications (RFC) Division, within the Space and Terrestrial Communications Directorate (S&TCD) works on all things spectrum management. This includes spectrum policy, where they work closely with the Army Spectrum Management Office as well as the Network Cross Functional Team (CFT) on updating spectrum policy – such as getting spectrum approvals to do experimentation with the C5ISR Center's S&T prototypes, and how to gain efficiencies in how to get spectrum allocated, not only for experimentation, but also working with program management offices for fielding systems from a spectrum-policy perspective.

In addition, the Division is developing tactical spectrum management solutions working with the Product Manager Electronic Warfare Integration (PdM EWI) which works within the Program Manager, Electronic Warfare and Cyber (PM EW&C), under the Program Executive Officer for Intelligence, Electronic Warfare and Sensors (PEO IEW&S). This includes the EW Planning and Management Tool (EWPMT), which allows soldiers to comprehensively see what the EMS around them looks like, both own and enemy forces, as well as to simulate an environment to help create tactical plans on how to use the spectrum. Daniel Duvak, RFC Division Chief, says they are currently working to increase the accuracy and speed of the Tool's calculations as it senses different things in the EMS, and present that information back to the soldier. "We're also working to automate a good amount of the process of how we collect that spectrum data so that it is more transparent to the soldier and easier for them to use."

According to Rinnetta McGhee, RFC Division Electronics Engineer, in addition to the software tools that the Division has transitioned to the EWPMT, they have also provided software for PM EW & Cyber's Real Time Spectrum Situational Awareness (RTSSA) tool which canvasses an electromagnetic environment and correlates whatever transmissions it finds with the National Telecommunications & Information Administration (NTIA) Spectrum XXI database, which is an authoritative database of all Army frequency use. "If you're not included in this database, you're considered a rogue piece of equipment. So the system will know who has authorization and should be transmitting at a certain time and location. If there's no match, you know it isn't an Army device with authority to transmit and you can take appropriate action," says McGhee.

Together with its technology-development work in areas such as advanced beamforming, spectrum sharing, and 5G spectrum capabilities, another particular program of interest is aimed at the Next-Generation Combat Vehicles family to provide a communication network allowing manned and unmanned vehicles to talk to each other with enough resiliency and sufficient video data streaming capability. According to Duvak, this is a top priority of the Network CFT, and the Division is currently working to harden two commercially-available radio products from both a cyber and anti-jam perspective, "as well as lowering their detectability, while not reducing their bandwidth. We're also incorporating some beam-forming capabilities to be more spectrally efficient." Duvak expects to have the radios available in the first quarter of 2021. – *J. Haystead*

target and deliver effects in all domains, specifically non-kinetic domains; supporting unit training for the MDTF and their Intelligence, Information, Cyber, Electronic Warfare and Space (I2CEWS) unit, which is really the non-kinetic heartbeat of the MDTF. MDO Live will also provide the Army Modernization Enterprise an opportunity to conduct DOTMLPF experimentation and get after what it takes from an equipping and manning perspective to actually execute MDO." Overall, Wheeler sees their exercises as bringing the realities of what can be brought to the table in all domains in terms of challenges, and what can be done to maneuver and deal with them in the real world. "They're seeing what the realm of the possible is, which is a very positive thing for the Army."

Cyber Blitz and the follow-on MDO Live exercises are not just of tremendous benefit to CEMA and MDO training, but also provide significant benefits to industry in the development and evaluation of new EMSO technology and systems. Wheeler says they've already identified four industry opportunity areas for MDO Live 2021 – Sensor Communications Architectures for long-range capabilities in delivering non-kinetic efforts; Sensor Fusion and Translation capabilities for the handling of Joint MDO feeds; Cross Domain Solutions for sensors operating at different levels of complexity; and Multi Domain Common Operational Picture, visualizing across all domains from undersea to space and cyber, what we look like and what the enemy looks like, and what our effects might look like to a commander. "This is how we get industry involved. As we pull together these experimentation plans, we often see gaps, or 'opportunities,' that we can direct industry to and give them a chance to share their wares with a unit that is actually performing MDO."

Targeted for the July timeframe, MDO Live 2021 will again be supporting US Army Pacific and one of their Tier 1 level exercises under the Defender Pacific umbrella of exercises. Unlike Cyber Blitz, however, which has been conducted primarily from Joint Base McGuire-Dix-Lakehurst (MD), MDO Live is being planned for in theater deployment. Says Wheeler, "It will be a bit of a challenge to bring a lot of our S&T forward, but it's also very exciting for everyone at the same time."

ALIGNMENT IS KEY

As pointed out by Bertoli, the C5ISR must not only align its S&T work with the soldier, but also must fundamentally align with the Army's overall Cross Functional Team (CFT) roadmap, as well as a Product Manager (PM) and a Program of Record (POR). "It's really a four-legged stool. You have the CFT, the PM, the Army Capability Manager (ACM) who write the capability requirements, and us. Especially in the CEMA space, the new concepts really do change the way the Army is used to functioning. All four groups must come together and cooperate to ensure that, as we invest in technology, the PEO will have a 'catcher's mitt' if you will when we get to a TRL-6 transition stage, and that the ACMs will have the requirements in place for the acquisition (POR) to actually implement the effort, and make the envisioned capabilities a reality."

Consciousness and Resilienc Electromagnetic Environmen Operations: The Crucial Role

By Capt. Pasquale IORILLO, ITA Army

While wars between nations have significantly diminished within the 20th and 21st centuries, a new era of global power dynamics and tensions is increasing the possibility of interstate confrontations in the future. Worldwide competition among state actors in different fields is a condition that may affect the global order and involve NATO and national military instruments. In this fluid and unsettled context, all military organizations in the world rely on the vital relevance of command and communications and the ability to share real- and near-real-time information, that have their fundamental pillar in the use of the electromagnetic spectrum (EMS). As a consequence, all military organizations are very concerned about the control of the EMS. In this regard, Electronic Warfare (EW) represents "military action involving the use of electromagnetic and direct energy to control the electromagnetic spectrum or to attack the enemy."

EW has expanded beyond electronic attack, protection, and support to include sophisticated actions within the electromagnetic environment (EME) that impact all other military operations. Consequently, the EME becomes the critical warfighting environment where EW is actively fought. NATO and its member states continue to face emerging challenges in the EMS, leading to the need for a rapid adaptation in response to the increased complexity and unpredictability of the global security environment.

The Alliance should consider strengthening its overall posture on deterrence and defense not only in land, sea, air, cyber and space domains, but also within the EME. In light of the growing influence of EW, the Alliance should develop highly enhanced responsiveness and readiness, as well as bolstering modernization and resilience through new EME policies, coordinating measures and systems/tools. The need for an urgent change is critical to respond to the sensors and weapons employed and deployed by countries such as China, North Korea and Russia, while preventing a possible escalation.

The employment of military power during the last two decades has been mainly focused on counterinsurgency and counter-terrorism operations. Such operations are effective when forces are highly dispersed in the area of operations. In this context, military forces are dependent on satellite and other communications across Ultra High Frequency (UHF) and Very High Frequency (VHF) frequencies. Unfortunately, these kinds of communications means are particularly vulnerable to acquisition and jamming by hostile EW activities. On the other side, the use of High Frequency (HF) signals, which provides significant protection against enemy denial, has faded among western troops.

These aspects lead to the false expectation that the EME will remain, for military forces, an uncontested environment and guiding EW units to focus their responsibilities mainly on defeating IEDs and on performing intelligence acquisition. Recent study has examined how long-range sensors and weapons networks can be countered without direct hostilities, and the use of EW continues to be noted as having, in this regard, great potential.

Russia, North Korea and China are developing and deploying/employing innovative military capabilities with the installation of advanced electronic weapons and sensor networks within their borders, and in the territories they influence. For these reasons, it is anachronistic to talk about absolute dominance in the EME today.

This article explores how the EME represents a contested, congested, and constrained environment crucial for NATO and its member states even more exposed to rivalry and competition. Although technological developments and related investments are essential, without the promotion of a specific awareness and culture on this matter, combined with clear and implemented working and coordinating measures, NATO will hardly achieve the expected resilience and freedom of action within the EME.

As such, this paper describes the current situation of the EME exploitation, taking some examples from recent conflicts, an insight on the links between the evolution of area denial and horizon technologies, the centrality of satellite signals, and lastly, a perspective on future warfare in Multi-Domain Operations (MDO).

THE CURRENT SITUATION OF EME EXPLOITATION AND THE UKRAINIAN CASE

EME denial operations, or even attacks, have become more advanced, increasingly frequent, highly organized and more dangerous. They inflict severe consequences to governments and economies through damaging critical infrastructures, some of them with military purposes. Notably, the growing Russian EW skills may have reached the threshold that can promptly threaten national, as well as Euro-Atlantic, security, stability and military capabilities.

The possible advantage in Russia's EW techniques and tactics could represent, above all, a significant threat for NATO and national military C2, ISR and targeting capabilities resulting in a decreased strategic advantage during a future engagement. In this regard, Russian military forces have learned much from their activities in Ukraine, as well as in Syria, deploying and testing sophisticated equipment that indicates the extent of

e in the Exploitation of the t for Future Multi-Domain of Electronic Warfare

Russia's modern EW capabilities. Moreover, in the Ukrainian Donbas region, Russian military forces have deployed various weapons, such as Leer-3 RB-341V, L269 Krasukha-2, R-330ZH "ZHITEL", Tirada-2 and RB-109A Bylina, with high capability in jamming, intercepting communications signals and spoofing GPS receivers, in addition to tapping into cellular networks and hacking cell phones.[i]

The EW deployment in the Ukraine scenario has allowed the degradation of command and control (C2) networks, disrupting radar communication systems, intercepting signals and targeting command posts. This scenario demonstrates how hacking and artificial intelligence threats can compromise decision-making processes and support military operations, giving the adversary operational advantage. Yet, the offensive use of EW is not the only one of interest for this article.

ANTI-ACCESS AREA DENIAL (A2/AD) EVOLUTION

As a set of "warfighting strategies focused on preventing an opponent from operating military forces near, into, or within a contested region,"[ii] denying access to the battlespace has regained centrality in military operations. Moreover, differently from the past, the extensive use of EW increases the complexity of A2/AD within the operational environment. The former anti-access capabilities, such as minefields, air defense systems and missiles, are now enhanced by electromagnetic (EM) sensors and systems, capable of operating in EME and increasing the ability to prevent the enemy from gaining access in the contested region. This approach represents a significant risk in the conduct of combat operations across all domains. For NATO, enemy A2/AD capability represents a severe risk to bases, troops, and assets close to the contact layer by denying force deployment capabilities and influencing all domains of operations while impeding communications as well as C2 capabilities.

In this regard, A2/AD capabilities, together with Command-and-Control-Denied and Degraded Environments (C2D2Es) by peer and near-peer adversaries, may vitally affect Alliance military advantage. The general assumption is that the enemy will try to erode the Alliance advantage by denying its ability to conduct ISR operations; reducing intelligence effectiveness; hampering C2 systems; diminishing the ability to create a common operating picture (COP) and the capability to perform proper targeting; and lastly reducing the level of domestic and international support to military operations.

GLOBAL NAVIGATION SATELLITE SYSTEMS AND SPACE OPERATIONS

In this fluid, contested and congested scenario, Global Navigation Satellite Systems (GNSS) are a critical area within the EME that is inherently vulnerable to deliberate jamming and spoofing through EW. The Global Positioning System (GPS) is the most widely used resource for providing continuous positioning, navigation and timing (PNT). In addition to GPS, other GNSS constellations are the European Union's Galileo, Russia's GLONASS, and China's Beidou. GNSS is critical to modern military operations because of their utilization of positioning and timing data for military activities such as navigation, tracking and mapping. For combat purposes, GNSS enables accurate coordinating measures and targeting as well as advanced logistical support. Therefore GNSS's criticality spans all warfare domains. The protection of GNSS integrity and capabilities for NATO and its member states represents an emerging concern. Jamming and spoofing GNNS signals can be used to send wrong information and deceive the decision-making process. Related to these aspects, according to analysts, the scale and scope of Russian EW capabilities will represent an essential threat due to highly sophisticated countermeasures techniques and tactics that have significantly evolved. To succeed in operations in future conflicts and ensure tactical and operational superiority, the Alliance and its members should consider inherent GNSS vulnerabilities and develop appropriate policies, resilient options and even alternative PNT means.

DISCERNING ABOUT FUTURE WARFARE

Political and military leaders should develop and implement the new EME strategy quickly, including investments, procedures, tools, training, policy and doctrine, with the intent to succeed in the future warfighting environment. EW planners and practitioners should advocate for adequate funding, appropriate doctrine, deep synergy with all warfighting functions, and lastly, help to set a clear end-state which includes the most favorable EME operational outcomes. With sound doctrine, informed leadership and the right organizational structure in every echelon of the defense system, the military HQs will be able to develop the right technology and capabilities in the EME.

In reinventing the EW competence and capability, NATO and its members should review their procedures to create permanent cross-functional teams at all echelons of command. Each team should be able to identify clearly the equivalent upper and lower level focusing on the continued development and implementation of EME synergies.

We could imagine this organization between the different levels of command

as a covalent chemical bond. (See Figure 1.) This means that, as in the case of the covalent bond, the exchange between the different members involved would be bidirectional, straightforward and firm by offering direction and guidance from the top and feedback from the bottom in a virtuous cycle. This hierarchical structure, just as in a chemical molecule, makes it clear that all levels of command are equally indispensable in maintaining the proper functioning of the system, imagining it as a network capable of guaranteed resilience.

This feedback loop will ensure that joint forces will benefit from a coherent approach instead of combining incongruent capabilities during joint force deployment. This system should also follow the above-mentioned dynamic and responsive approach so that EW will become part of the EME strategy. Adopting a dynamic and responsive approach may also mean the achievement of superiority in the EME that, in future warfare, as previously mentioned, will be strictly correlated with the advantage and dominance in the other warfighting functions.

Appropriate and standardized training and education will provide NATO and its members with the opportunity to identify and have the proper leaders in place overseeing EW and EME management, from joint down to combat and service commands, identifying and implementing the right leadership structure to avoid a precarious and centralized authority. Even though highly networked and centralized command and control is a crucial part of the military organization and cannot be eliminated, this approach must be employed in novel ways with distributed command and control mechanisms that reduce rigidity. In this regard, military forces may successfully face the triple challenge of advanced Electromagnetic Operations, Cyber Warfighting Operations, and Information Operations that may escalate in future conflicts. (See Figure 2.)

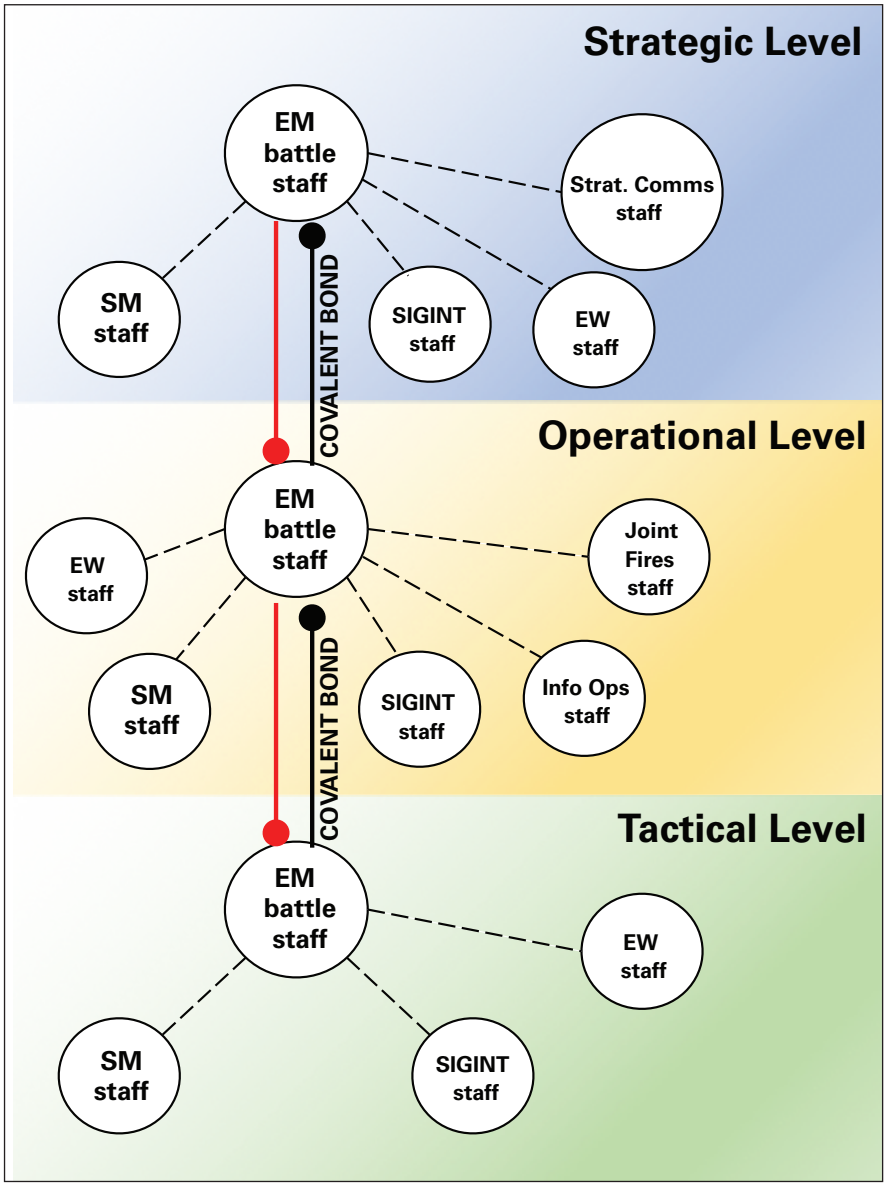

Fig 1: *EM battle staff covalent bond.*

Navigating in these new types of warfare requires that military doctrines clearly define how the Information Operations, Cyber Operations, and the Electromagnetic Operations will be synergistically integrated into future strategies. These critical shifts, primarily focused on cultural aspects, will allow the Alliance to react decisively in the future, utilize conventional tactics and face hostile hybrid strategies in Grey Zone Operations, to avoid being constrained and incapable of taking decisive action due to adversaries' A2/AD strategies.

CHALLENGE FOR RESILIENCE AND CONSCIOUSNESS IN FUTURE MULTI-DOMAIN OPERATIONS

The current scenario represents for NATO and its members the opportunity for change within the strategic, operational and tactical background of the EME. In future conflicts, the adversary will deeply and intensely target C2 systems and architectures. Therefore, the safety of forward operating bases and fighting units may be highly compromised. An adversary's deployment and employment of sophisticated hostile EW capabilities will primarily focus on attacking communications systems, as well as PNT systems, in an attempt to disrupt or compromise their operation. All of this may mean a strategic threat to the Alliance's ability to achieve information superiority and the degradation of its communications capability.

In a future peer-to-peer conflict, military forces on each side must not assume that the EME will remain undisrupted. In reality, the strategic surprise will also

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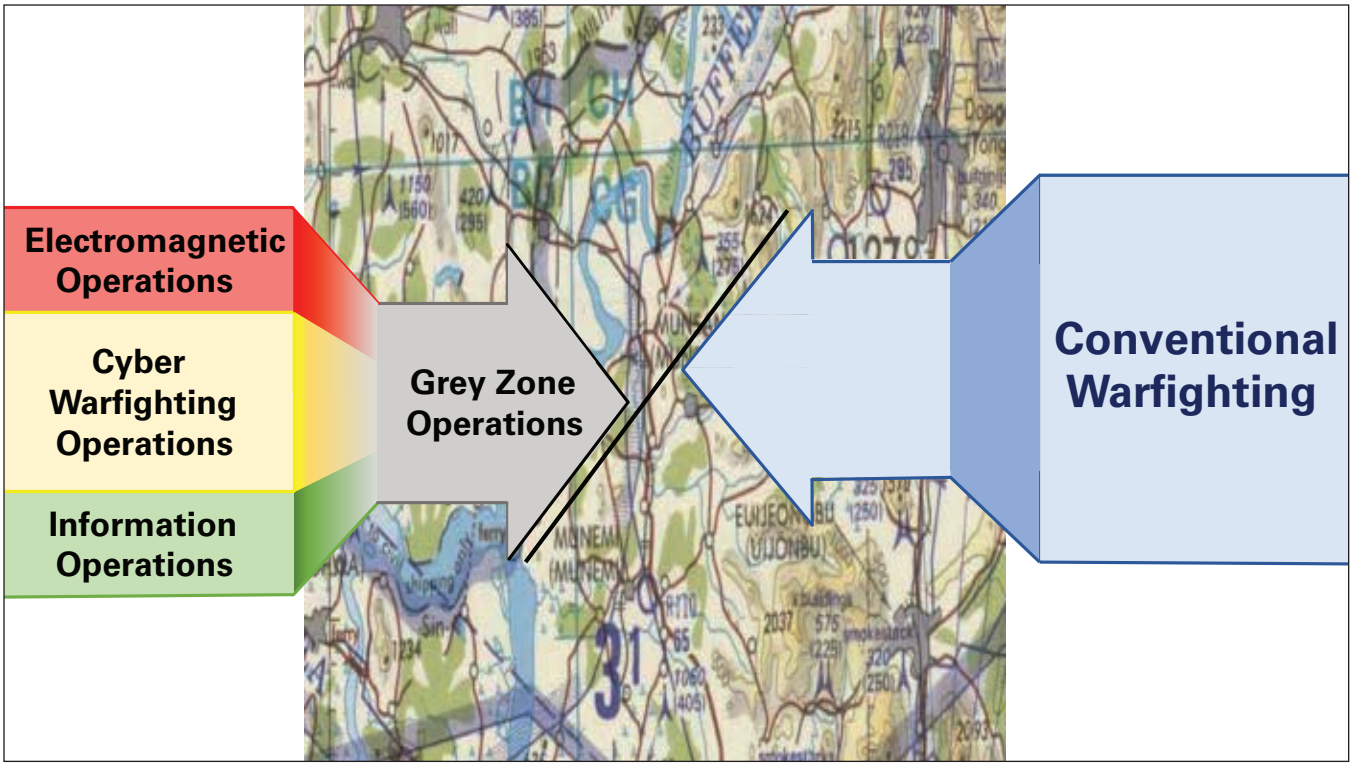

Fig 2: *Military forces' triple challenge.*

be attained by employing a sophisticated EW shaping campaign to significantly reduce an adversary's ability to communicate. The paradox is here, and it is dangerous: activities in an intangible environment will result in a concrete and lethal threat. As a consequence, the focus for NATO and its members should immediately move from the perception of the EME, which is dominated by friendly actors, providing readily available bandwidth, and undisrupted communications over multiple channels. It is imperative for NATO and its member states to develop advanced levels of consciousness and resilience in the exploitation of the EME for future Multi-Domain Operations. In this regard, the cultural and professional training of military personnel – leaders included – combined with a constant and dynamic overhaul of the specific doctrine, moves in parallel with the technological evolution of the systems employed.

The challenge for NATO soon is not only the achievement of EME superiority but also maintaining the level of adaptability and efficiency of EW capabilities even in a highly contested environment. But there is more: NATO and its members should promote the EW culture among its troops so as to be mentally and technically prepared to exploit the EME opportunities for future multi-domain campaigns.

Lastly, the Alliance should also focus on, and wargame in advance, how different adversaries may exploit friendly EME vulnerabilities with a particular fo-

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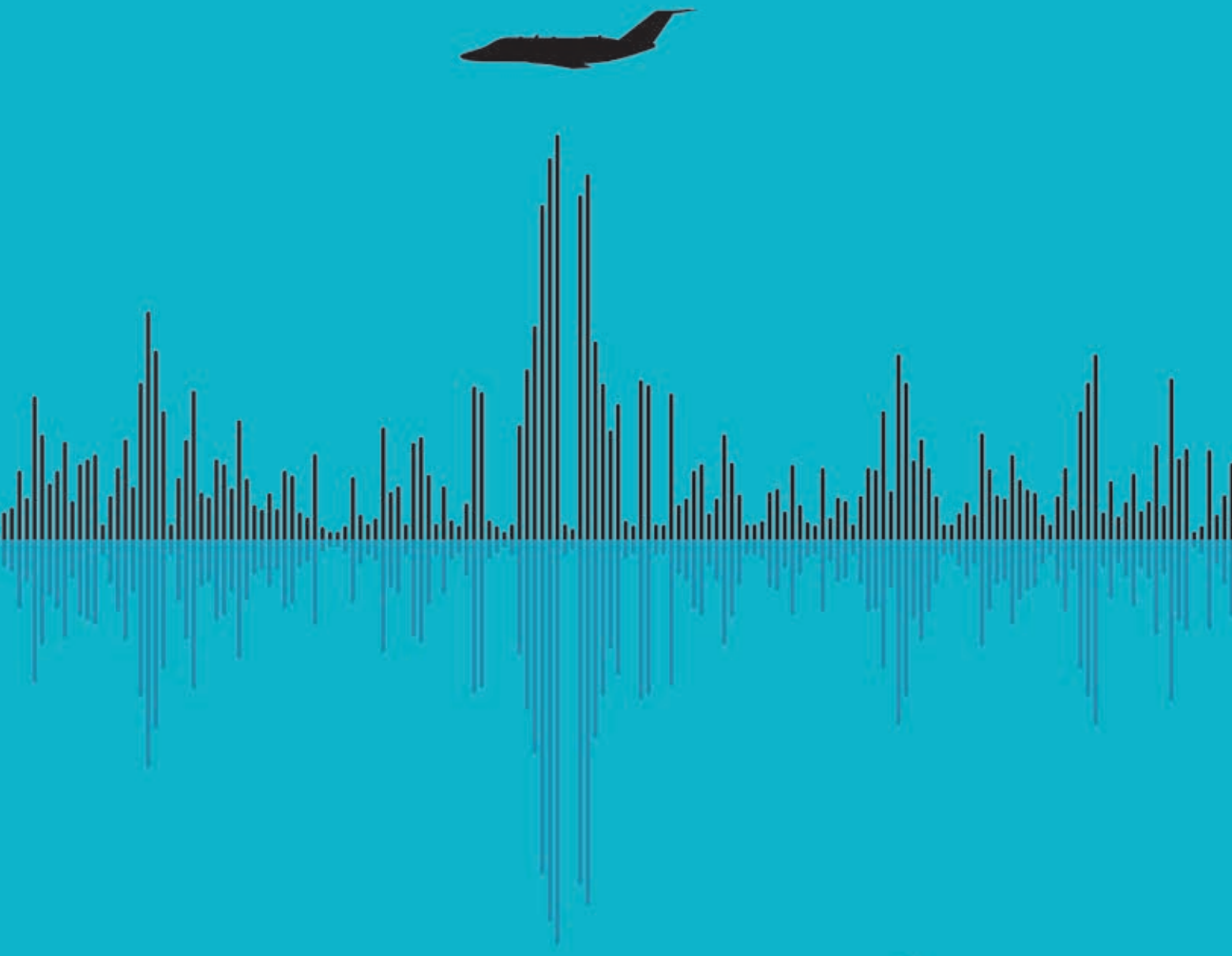

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cus on degradation of communications. NATO and its members should be able to survive initial strategic limitations imposed by hostile acts which directly affect communications between ground forces, airpower, naval assets, ISR collection systems and targeting systems. In sum, MDO will rely on communication channels within the EME. The key to success is to prepare the military organization and its leadership to exploit all the strengths and opportunities that this environment presents.

A COMPLEX EME

Future wars, conflicts, or deterrence postures may be mainly decided through the control of EME. Achieving mission success will depend on how well military forces will be able and capable to operate in a very contested, congested, and constrained operating environment.

In this chaotic context, marked by an increasing reliance on the EME, further complicated by the civilian use of it, Armed Forces and non-conventional entities will struggle to control it for strategic, operational and tactical purposes related to the ever-present command-and-control (C2) functions, building up and sharing situational awareness, communications, navigation and timing.

NATO and national military entities must seek to increase culture, training and exploitation of the EME to lead MDO to positive results by pushing EW to the forefront of their planning and resourcing.

Within this framework, alongside the necessary and imperative investment and improvement in new technologies and adaptive solutions, this author wants to underline the need for change in the following areas:

1) developing new EW concepts, procedures and related aspects of planning at all national and multinational levels;
2) providing to staff and leaders with a clear understanding of threat and risk to operate in an aggressive and hostile electromagnetic environment during training activities; and
3) implementing a fragmented, modular, and flexible specialized EW support element to all the major combat units.

Considering the pivotal maneuver space the EME represents, NATO and the member nations must recognize EW's impact at the strategic, operational, and tactical levels and its ability to prevent an adversary's use of military power in this contested, congested, and constrained environment.

Disclaimer: The views expressed are those of the author and do not reflect the official policy or position of the Italian Army and Italian Defence Forces.

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i. Organization for Security and Co-operation in Europe (OSCE). Special Monitoring Mission to Ukraine (SMM). Daily Report 10 August 2018, 3 February 2019, 3 and 4 April 2019.

ii. Tangredi. "Anti-Access Warfare. Countering A2/AD Strategies." Annapolis, Naval Institute Press, 2013, p.1.

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All In

A Temporary Solution to a Lack of Organic EW Equipment

By LTC Edward Ortiz, MAJ Luke Plante, MAJ Richard Purcell and CW3 James Turner

It is well-known within the electronic warfare (EW) community that the United States Army not only lacks organic EW equipment, but that it will continue to lack this equipment for several years to come. The year is 2020, and no EW personnel in the Army have had organic EW equipment as part of their modified table of organic equipment (MTOE) or table of distribution and allowance (TDA). Many will finish their careers without ever seeing a single EW program of record. We know that we need equipment to perform electronic attack (EA), electronic warfare support (ES), and electronic protect (EP), but we can only resort to creative means to temporarily secure some equipment. Equipment is not scheduled for fielding until 2028 at the earliest, so we need to make the most of what we have to train ourselves. One piece of equipment that is plentiful and that can help bridge the gap between what we do have and what we will have in several years is the Duke V3.

With the emergence of Multi-Domain Operations (MDO) and a focus on large-scale ground combat, we need to integrate EW into all operations so commanders and staffs at all levels know how to use EW capabilities. We need to train at home station as we will train in combat training centers (CTCs), and more importantly, as we will fight future wars. Enemies have advanced EW capabilities, so we will be behind until we field and train with programs of record.

Installations may receive some EW training aids for use by opposing forces (OPFOR) by the year 2023, but this still leaves us with a gap of three years for home-station training. In the meantime, we need to train on countering enemy use of the electromagnetic spectrum (EMS) and ensuring our dominance within this major component of MDO. Radios, radars, control of unmanned aerial systems (UASs), as well as position, navigation, and timing (PNT), all operate in the EMS. In fact, many have called for Joint doctrine to designate the EMS as its own domain.

The Duke V3 is a very prolific system. Thousands exist across the United States in warehouses, in Kuwait as prepositioned stocks, and in use in several theaters. The Army primarily treats this system as counter-radio controlled improvised explosive device (RCIED) EW (CREW) equipment, and because of this the Army cannot release these from warehouses for use within the United States.

A way to make the most out of what we have is to treat Duke V3s as software-defined radios (SDRs) instead of simply as CREW systems. Army EW personnel can reprogram Duke V3s to not simply jam threat RCIEDs, but to transmit for other purposes as well. Several Duke V3 installed into tactical vehicles can equip OPFOR EW personnel at home station training exercises to deny friendly forces specific uses of the EMS. This trains the OPFOR Army EW personnel, the friendly EW and intelligence personnel,

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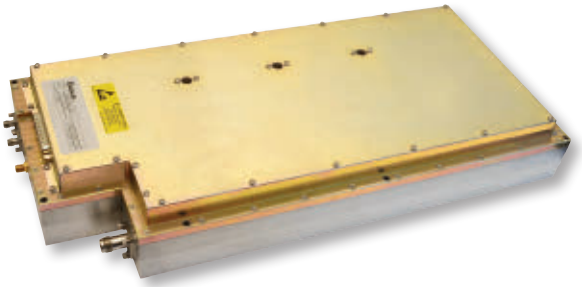

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and the friendly commanders and staffs. These OPFOR Duke V3s would provide friendly EW and intelligence personnel with targets to find thereby providing additional tactical training. This training sets our units up for success for their CTC rotations, and it sets them up for success for any mobilizations and deployments they may conduct.

Additional Duke V3s can equip friendly forces for use both at home station training and at CTCs. Duke V3s installed in friendly tactical vehicles can perform EA against several enemy targets. They can certainly disrupt OPFOR ability to use significant portions of the EMS to demonstrate the importance of EW to friendly units. Duke V3s can defeat critical enemy systems at CTCs to help level the capabilities between friendly forces and OPFOR.

The main disadvantages to using Duke V3s in this manner are their operational state and the lack of maintenance they will have. Duke V3s have been in service for over 10 years, so only the least-used and most recently-produced systems are best for this role. These systems would see significant use over the next several years. As there is no maintenance contract for these systems, inoperable systems would require replacements. These are, however, already paid for, they are more than capable of fulfilling additional roles for the Army, and destroying them would be a waste of an abundant resource that we can easily repurpose at a time when we critically need SDRs for training.

Repurposing Duke V3s is the best solution to the Army's lack of EW training equipment. It makes the most of what we already have, and it gets us the most out of our taxpayer dollars. We need EW equipment for training purposes, so we should use these SDRs that we already paid for instead of simply shredding them. The Army has long-term solutions for EW, but we cannot let our formations spend several more years without using EW equipment – especially when we have plenty of it.

About the Authors: LTC Edward Ortiz, MAJ Luke Plante, MAJ Richard Purcell and CW3 James Turner are assigned to the 10th Mountain Division (Light Infantry) at Fort Drum, NY.

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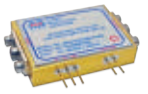

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SDLVA-0R71R3-75-MEC https://www.pmi-rf.com/product-details/sdlva-0r71r3-75-mec	0.75- 1.3	-70	40	15 / 15	40	-70 to +5	3.75" x 1.5" x 0.5" SMA (F)
SDLVA-1G20G-55-12-SFF https://www.pmi-rf.com/product-details/sdlva-1g20g-55-12-sff SDLVA-1G20G-58-12-SFF https://www.pmi-rf.com/product-details/sdlva-1g20g-58-12-sff	1 - 20	-58 -60	50 14	5 / 20	28	-55 to +5 -54 to +5	PE2 Housing 1.08" x 0.71" x 0,29" Removable SMA (F)
SDLVA-2G6G-70-CD-1 https://www.pmi-rf.com/product-details/sdlva-2g6g-70-cd-1	2 - 6	-70	40	15 / 25	50	-65 to +5	3.75" x 1.5" x 0.5" SMA (F)
SDLVA-212-65-16MV-12DBM https://www.pmi-rf.com/product-details/sdlva-212-65-16mv-12dbm	2 - 12.5	-64	16.7 ± 1.3	10 / 12	30	-55 to +10	4.24" x 0.994" x 0.38" SMA (F)
SDLVA-218-65-16MV-12DBM https://www.pmi-rf.com/product-details/sdlva-218-65-16mv-12dbm SDLVA-218-75-16MV-12DBM https://www.pmi-rf.com/product-details/sdlva-218-75-16mv-12dbm	2 - 18	-64	16 ± 2	10 / 15	30 25	-55 to +10 -60 to +15	4.24" x 0.994" x 0.38" SMA (F)
SDLVA-6G18G-CD-2-OPT218 https://www.pmi-rf.com/product-details/sdlva-6g18g-cd-2-opt218	2 - 18	-70	25 ± 10% 50 Ohms	10 / 30	60	-70 to +5	3.2" x 1.8" x 0.4" SMA (F)
SDLVA-6G18G-CD-2 https://www.pmi-rf.com/product-details/sdlva-6g18g-cd-2	6 - 18	-70	25 ± 10% 50 Ohms 48 ± 10% No Load	10 / 30	60	-70 to +5	3.2" x 1.8" x 0.4" SMA (F)
PLVA-6G18G-40-1 https://www.pmi-rf.com/product-details/plva-6g18g-40-1	6 - 18	-42	50 ± 4%	20 / 45	150	-40 to 0	2.2" x 1.5" x 0.4" SMA (F)
SDLVA-18G40G-65-CD-292FF https://www.pmi-rf.com/product-details/sdlva-18g40g-65-cd-292ff	18 - 40	-65	25	11 / 30	60	-63 to +2	2.37" x 1.8" x 0.42" 2.92mm (F)

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SDLVA-218-65-16MV-12DBM
SDLVA-218-75-16MV-12DBM

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Space EW – Part 24

Intercept of Uplinks

Intercepting uplinks to satellites involves receiving signals from the ground station that are sent to the satellite. Unless the intercepting station is *extremely* close to the ground station, this can only be accomplished by looking down from a (perhaps unmanned) aircraft flying over the satellite's ground station, as shown in **Figure 1**. Note that the aircraft must be above the local horizon from the ground station.

In order to determine the quality of the intercept, it will be necessary to know the distance from the aircraft to the ground station and the sidelobe isolation of the satellite link's receiving antenna. The ground station antenna is, of course, aimed at the satellite, so the intercepting aircraft will be in a sidelobe with reduced antenna gain. By making the assumption that the aircraft is not in the main beam of the satellite uplink antenna, we can use its specified average sidelobe gain reduction rather than using precise antenna-pattern data. In setting up this problem, we need to place the aircraft at a specified location. The latitude and longitude of the ground station, and the latitude, longitude and altitude (relative to the ground station) of the aircraft need to be input.

We start with **Figure 2**. The sub-vehicle point of the aircraft, the ground station and the North Pole form a spherical triangle.

- *Side c* = 90° – the latitude of the aircraft sub-vehicle point
- *Side b* = 90° – the latitude of the ground station location

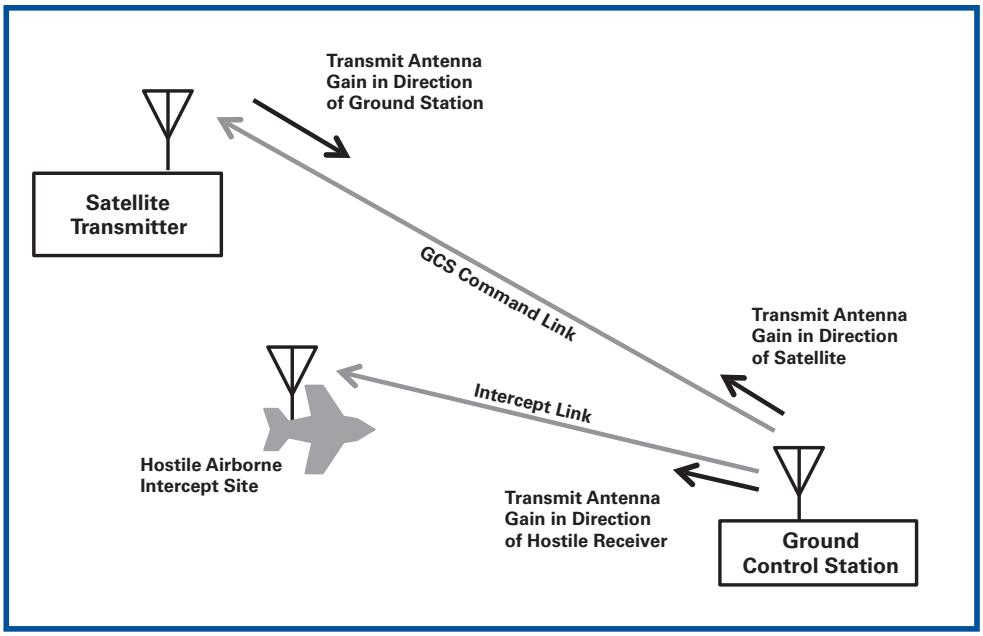

Fig 1: *An airborne hostile receiver could intercept a satellite or payload uplink.*

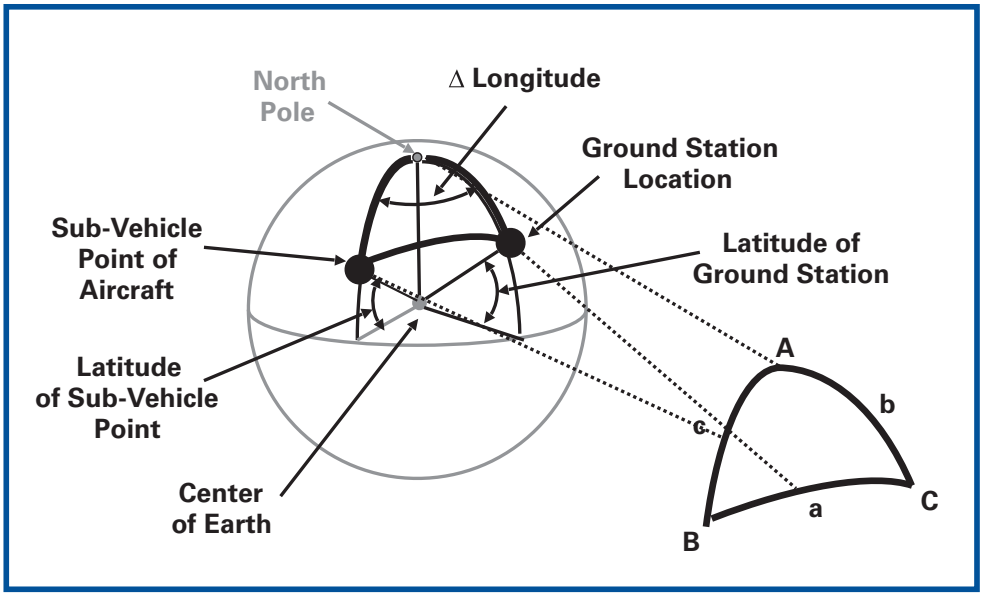

Fig 2: *A spherical triangle is formed between the North Pole, the sub-vehicle point of the aircraft and the ground station.*

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- *Angle A* = the difference in longitude between the aircraft and the ground station

Using the spherical law of cosines for sides, we can calculate the geocentric angle from the aircraft to the ground station as:

Side a = arccos[(cos b)(cos c) + (sin b)(sin c)(cos A)]

Now consider **Figure 3**, which is a plane triangle formed by the aircraft, the ground station and the center of the Earth.

- *Side d* = the radius of the Earth increased by the altitude of the ground station
- *Side e* = the radius of the Earth increased by the altitude of the aircraft
- *Angle F* = the same as *side a* from **Figure 2**
- *Side f* = the range from the aircraft to the ground station

The range is found using the planar law of cosines for sides:

***Side f* = sqrt[$d^2 + e^2 - 2de \cos F$]**

Let's plug in some numbers:

- The ground station is at sea level at 45° North latitude and 100° East longitude
- The aircraft is at 46° North latitude, 101° East longitude and 3 kilometers altitude
- The uplink transmit frequency is 5 GHz
- The uplink transmitter power is 100W (+ 50 dBm)
- The uplink ground antenna is a 3-meter parabolic dish with circular polarization
- The average sidelobe from the satellite's ground antenna is 20 dB below the boresight gain
- The intercept payload antenna on the aircraft is a cavity backed spiral with matched circular polarization and 3 dB gain

The geocentric angle from the aircraft to the ground station is:

Arccos[(cos 45°)(cos 44°) + (sin 45°) (sin 44°)cos(1°)]
= arccos[(.7071)(.7193) + (.7071)(.6947)(.9998)]
= arccos[(.5086) + (.4911)]
= arccos[.9998] = 1.403°

From the planar law of cosines for sides, the range is:

sqrt[(6371^2)(6374^2) – 2(6371)(6374)(.9997)]
= sqrt[(40589641) + (40627876) – (81193143)]
= sqrt[24374] = 156 km

This is the intercept link propagation range.

Since the satellite down link frequency is 5 GHz and the receiving antenna is a parabolic dish 3 meters in diameter, its gain can be calculated by formulas given in the September 2020 EW 101 column. The boresight gain of the antenna is:

Gain = -42.2 + 20 log (diameter in meters) + 20 log (frequency in MHz)
= -42.2 + 20 log(3) + 20 log(5000) = -42.2 + 9.5 + 74 = 41.3 dB

The aircraft will be in a sidelobe that is 20 dB weaker than the boresight gain, so the effective antenna gain to the intercept receiver is 21.3 dBi. Thus, with 50 dBm transmitter power, the ERP of the uplink toward the aircraft is 50 dBm + 21.3 dBi = 71.3 dBm

The received power at the intercept receiver is:

$P_R = ERP_T - 32.4 - 20 \log d - 20 \log F + G_R$

Where: P_R the received power
ERP_T is the effective radiated power of the uplink transmitter,
d is the distance between the ground station and the intercept aircraft,
F is the uplink transmitting frequency, and
G_R is the gain of the intercept receiver's antenna.

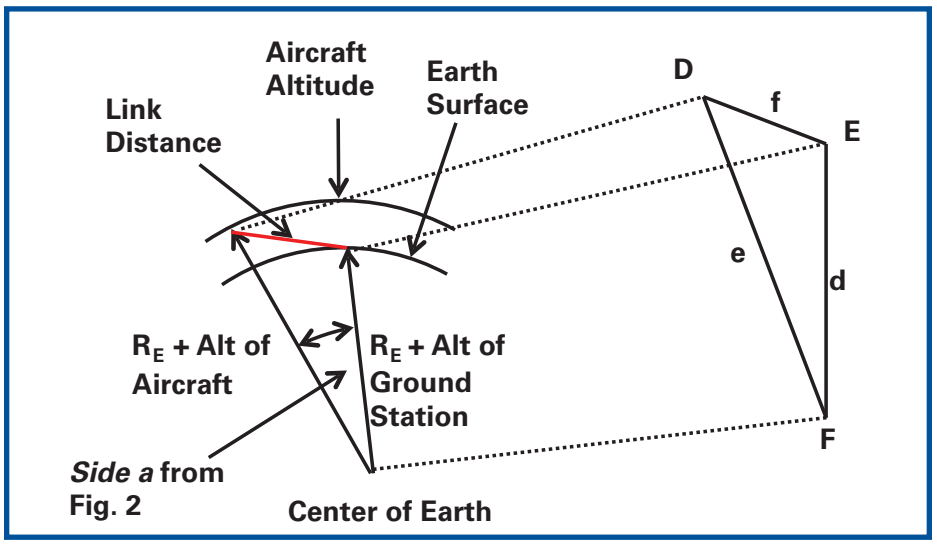

Fig 3: *The distance from aircraft to ground station can be calculated from this plane triangle.*

Plugging in our numbers, the intercept receiver in the aircraft will receive:

P_R = 71.3 – 32.4 – 20 log(156) – 20 log(5000) + 3
= 71.3 – 32.4 – 43.8 – 74 + 3
= -75.9 dBm

This is a nice strong signal. Since the intercepting aircraft is above the horizon from the ground station, a successful intercept has taken place.

WHAT'S NEXT

Next month, we will look at jamming satellite downlinks. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.

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REMEMBERING A FALLEN CROW: BOBBY MCDONALD

1 Aug 1936 – 2 May 2020

AOC Dixie Crow Chapter

Bobby Gerald McDonald was born in Doerun, Georgia on August 1, 1936. He began his career in electronic warfare at the age of 18, when he served as a Naval Aircrew aboard P2V "Neptune" anti-submarine and patrol aircraft. As an in-flight avionics technician, he operated and repaired early generation electronic warfare avionics systems. Later, Bobby was also part of the Navy's Blue Angels flight demonstration team when they flew F9F Panthers.

After his naval service, Bobby attended the Georgia Institute of Technology and received his Bachelor of Science in Electrical Engineering. After graduation, he worked engineering roles in several fields. He helped design early memory systems at IBM, worked on avionics design at Lockheed Martin and worked for NASA on telemetry systems installed on the Saturn V rocket.

Bobby moved to Warner Robins in 1969 and began working as an engineer at Robins Air Force Base shortly after. His career took him from major technical roles in the design of the AN/ALQ-131 ECM pod to the deputy division chief of his organization. One highlight of Bobby's career was his instrumental involvement in the establishment of the Electronic Warfare Avionics Integration Support Facility (EWAISF) at Robins in the mid-1970s. He briefed the need for an EW reprogramming facility to all management levels, up to the Pentagon. The end result was that Robins was selected as the location for the new EWAISF facility and is now the Air Force avionics and EW depot. The EWAISF Bobby lobbied for is even more important today, as work done here continues to help the warfighter through changing EW operational environments.

On a humorous note, Bobby traveled for work under the name BG McDonald. On at least one occasion, he mistakenly received brigadier general accommodations. It was not his mistake, so he did not change his travel name.

Bobby retired from government service in 1995. Bobby's calm demeanor and fair leadership style influenced many throughout his life. His work still impacts Air Force systems and processes today. He was a dedicated sailor, engineer, civil servant, husband and father. Bobby passed away May 2, 2020.

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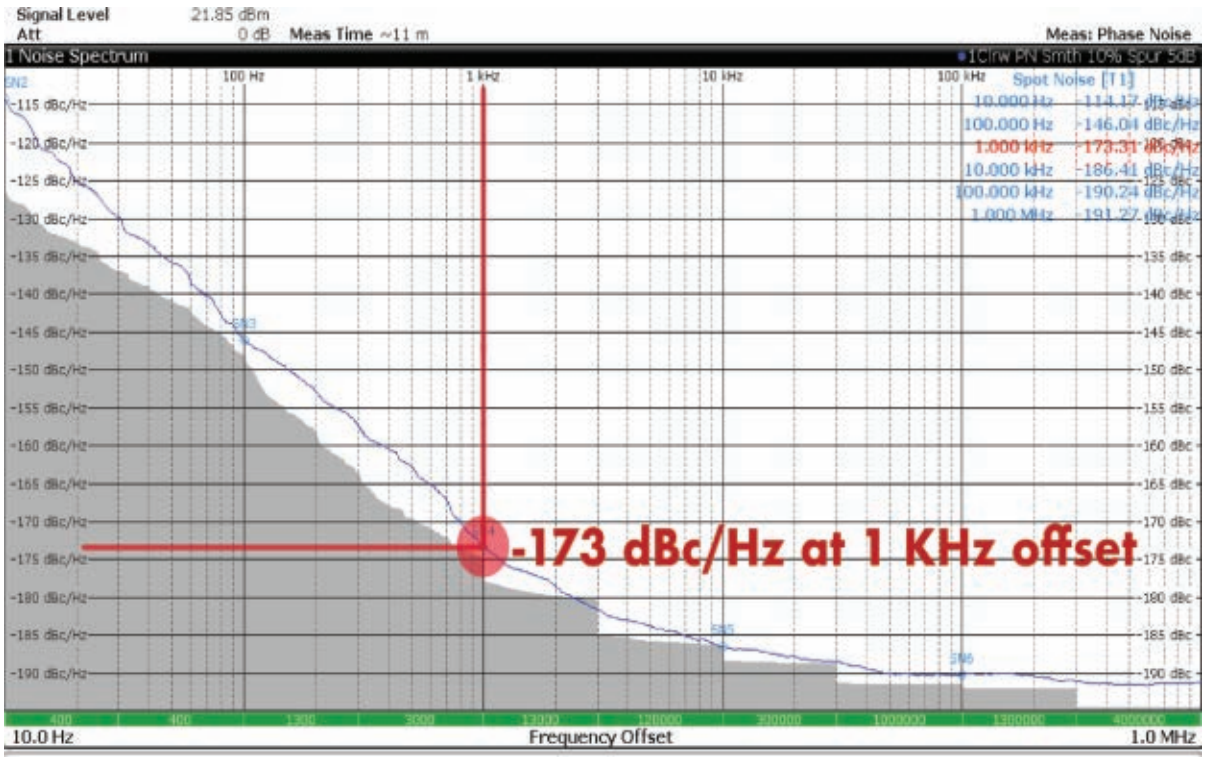

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