August 2022 Vol. 45, No.8

ASSOCIATION OF OLD CROWS

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JED

Journal of Electromagnetic Dominance

USMC EMSO Evolves

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JED CONTENTS

Journal of Electromagnetic Dominance

August 2022 • Volume 45, Issue 8

USMC

A technician with the NATO Joint Electronic Warfare Core Staff (JEWCS) prepares a jamming pod under the wing of a Draken Europe DA-20 Falcon jet during last month's "Ramstein Guard 07" exercise managed by the Combined Air Operations Centre (CAOC) in Uedem, Germany. The training exercise saw the Belgian Air Force conducting air operations while facing ground- and air-based jamming from the JEWCS and against aircraft operated by EW training company Draken Europe. "We are conducting realistic scenarios simulating multinational mixed fighter-transport operations against a robust EW threat from both ground and air threats," said Captain Nick Droogers, Belgian EW and Mission Support Officer, in a NATO news release. "This coerces our aircrews and controllers to use on board warning devices and to develop and validate specific enhanced tactics, techniques and procedures (TTPs) to cope with the challenges posed by jamming activities. We're basically training pilots in discovering and avoiding these threats," he explained. "Under the overall aegis of the Supreme Headquarters Allied Powers Europe, the CAOCs at Uedem and Torrejón conduct the exercise about 12 times a year to provide tailored training in an electronic warfare environment to Allied forces all over Europe," said Lieutenant Colonel Fredrik Thomter, project officer at Allied Air Command responsible for scheduling the exercise series. "This is actually more of a continuous training program the Alliance offers to forces assigned to NATINAMDS especially to those involved in NATO Response Force operations," he added.

NATO

COVER PHOTO USMC

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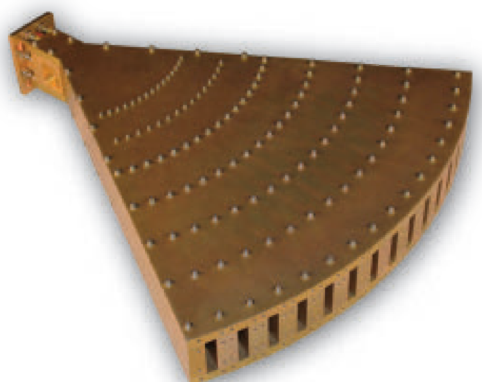

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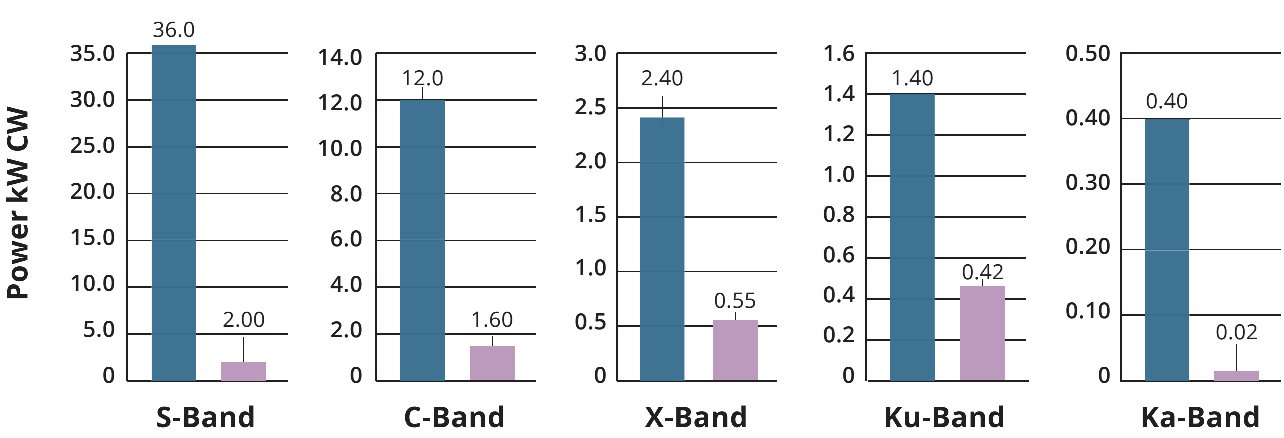
CW Power ■ E-Plane Combiner vs. ■ Radial Combiner



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TWO QUESTIONS

As the editor of *JED,* I mostly think in questions. Sometimes I'll ask myself, what is happening mission area "X" or organization "Y" that's new or important? Sometimes I'll ask, what is *not* happening in X or Y that should be happening? Writing about EW and EMSO for nearly 30 years has been a regular reminder that whatever we think we know about this discipline, our knowledge is in fact quite small. We are surrounded by incomplete data, partial information, hidden assumptions and (when we're being honest with ourselves) considerable uncertainty. It's humbling; so, we start every issue of *JED* by asking lots of questions – big and small.

The cover story in this issue of *JED,* written by John Haystead, began with questions about US Marine Corps EMSO. It's been more than 10 years since the Marine Corps published its Marine Air-Ground Task Force Electronic Warfare (MAGTF EW) Concept, and since then the Marines have been pursuing two big EMSO transformations. First, they are transitioning from an EW force comprised of low-density, high-demand platforms operated by a small cadre of EW experts to a force that distributes EMSO capabilities, knowledge and training widely across the Corps. Second, the Marines have made significant progress integrating their previously separate ground and air EW communities. So, the questions we started with were, "how has the MAGTF EW concept evolved over the past decade, and where is the Marine Corps taking it in the context of its larger focus on Information as a warfighting function?" John does a great job of exploring these questions in his article – looking backward and looking forward. Yet, reading his article brings me to another question: "what is happening to the Marine Corps' Airborne Electronic Attack (AEA) mission?" It retired its last Prowlers in 2019, and it has not named a follow-on AEA solution (manned or unmanned) to support its F/A-18s and F-35s, despite evaluating AEA concepts (including live-fire tests) over the past few years. With the Prowler squadrons now de-activated, the Marine Corps' AEA expertise seems to be atrophying, as EWOs are re-assigned or retire without being replaced.

My second question comes from our news article about the Senate Armed Services Committee's FY2023 National Defense Authorization Act (NDAA) bill. The SASC crafted several provisions about EMSO strategy and policy in its version of the NDAA. However, neither the SASC nor the HASC has commented on the DOD's EMS Spectrum Superiority Strategy (EMSSS) Implementation Plan (IP), which was released (in classified form) last summer. The EMSSS IP is fairly thin on two longstanding and well identified weaknesses in the DOD's EMS Enterprise: designating senior EMSO leadership and creating a coherent, centralized EMSO organization. The EMSSS IP assigned EMS policy and governance to the DOD CIO, and its operational thrusts mostly depend on strengthening the Joint EMSO organization within US Strategic Command. My question here is, "does Congress think the EMSSS IP got EMSO leadership and organization right or did it miss the mark?" Clearly, Congress didn't voice any major concerns with the EMSSS IP itself. That said, it may take a little while before Congress can determine if the DOD is on the right track. – *J. Knowles*

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Calendar *Conferences & Trade Shows*

AUGUST

TechNet Augusta
August 15-18
Augusta, GA
www.afcea.org

Defence & Security 2022
August 29 - September 1
Bangkok, Thailand
www.asiandefense.com

SEPTEMBER

4th Azerbaijan International Defence Exhibition
September 6-8
Baku, Azerbaijan
www.adex.az

29th International Defence Industry Exhibition MSPO
September 6-9
Kielce, Poland
www.targikielce.pl

MSPO
September 6-9
Kielce, Poland
www.spie.org

SPIE Laser Damage
September 18-21
Rochester, NY
www.targikielce.pl

AFA Air, Space and Cyber Conference
September 19-21
National Harbor, MD
www.afa.org

Africa Aerospace and Defense (AAD2020)
September 21-25
Air Force Base Waterkloof
Gauteng, South Africa
www.aadexpo.co.za

OCTOBER

AUSA Annual Meeting
October 10-12
Washington, DC
www.ausa.org

11th Annual Pacific IO & EW Symposium
October 18-21
Honolulu, HI
www.fbcinc.com/e/AOCPacific/

EURONAVAL
October 18-21
Paris, France
www.euronaval.fr

International Telemetry Conference 2022
October 24-27
Glendale, AZ
www.telemetry.org

59th Annual AOC International Symposium and Convention
October 25-27
Washington, DC
www.crows.org

SOFEX 2022
October 31 – November 3
Amman, Jordan
www.sofexjordan.com

NOVEMBER

MAST Med 2022
November 2-4
Athens, Greece
www.mastconfex.com

Indo Defence Expo and Forum
November 2-5
Jakarta, Indonesia
www.indodefence.com

Bahrain International Airshow 2022
November 9-11
Sakhir Air Base, Bahrain
www.bahraininternationalairshow.com

2022 Directed Energy Systems Symposium
November 14-18
La Jolla, CA
www.deps.org

11th International Defence Exhibition and Seminar
November 15-18
Karachi, Pakistan
https://ideaspakistan.gov.pk

EXPONAVAL 2022
November 29 – December 2
Valparaiso, Chile
www.exponaval.cl

JANUARY

Surface Navy Association 35th Annual National Symposium
January 10-12
Arlington, VA
www.navysna.org

FEBRUARY

Aero India 2023
February 3-5
Bengaluru, India
www.aeroindia.gov.in

AFCEA West 2023
February 14-16
San Diego, CA
www.westconference.org

IDEX
February 20-24
Abu Dhabi, UAE
www.idexuae.ae

MARCH

AFA Air Warfare Symposium
March 6-8
Orlando, FL
www.afa.org

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

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From the Crows' Nest

This regularly scheduled podcast, hosted by Ken Miller, AOC's Director of Advocacy and Outreach, features interviews, analysis, and discussions covering leading issues of the day related to electromagnetic spectrum operations (EMSO).

This includes current events and news from around the world, US Congress and the annual defense budget, and military news from the US and allied countries.

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SCAN ME

The History of Crows

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

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

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SCAN ME

Interested In Being a Guest?

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

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

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August 4
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AOC Virtual Series Webinar: EMBM Situational Awareness: Data Integration, Visualization and Analytics
August 11
2-3 p.m. EDT
www.crows.org

SEPTEMBER

AOC Virtual Series Webinar: Cognitive EW and Reinforcement Learning
September 8
2-3 p.m. EDT
www.crows.org

AOC Live Web Course: Cognitive Electronic Warfare: An Artificial Intelligence Approach
September 12-28
6 Sessions, 1-4 p.m. EDT
www.crows.org

RWR Fundamentals
September 13-14
Atlanta, GA
www.pe.gatech.edu

SIGINT Fundamentals
September 13-14
Atlanta, GA
www.pe.gatech.edu

Test and Evaluation of RF Systems
September 13-15
Lake Buena Vista, FL
www.pe.gatech.edu

Basic Electromagnetic Warfare Modeling
September 13-16
Online
www.pe.gatech.edu

AOC Virtual Series Webinar: Across the Spectrum Pond: How the US Military Can Procure Tested Solutions from Europe
September 22
2-3 p.m. EDT
www.crows.org

OCTOBER

AOC Virtual Series Webinar: The World of Small Unmanned Aerial Systems (sUAS) – 2022 Update
October 20
2-3 p.m. EDT
www.crows.org

NOVEMBER

AOC Virtual Series Webinar: Electromagnetic Maneuver: Towards a Theoretical Underpinning
November 10
2-3 p.m. EST
www.crows.org

RWR System Design and Analysis
November 15-17
Atlanta, GA
www.pe.gatech.edu

Infrared Countermeasures
November 15-18
Atlanta, GA
www.pe.gatech.edu

DECEMBER

Electromagnetic Warfare Data Analysis
December 6-7
Atlanta, GA
www.pe.gatech.edu

Test and Evaluation of RF Systems
December 6-8
Online
www.pe.gatech.edu

*AOC courses and webinars are noted in **red**. For more info or to register, visit crows.org.*

WHAT ABOUT CHINA?

As I discussed last month, we continue to watch the Ukraine-Russian war grind on, and hopefully we are actually learning lessons about what capabilities are need for the next fight. But will these apply to the Pacific Theater, specifically China? As China postures for strength and influence not just with Taiwan, but throughout the Pacific as a whole, do we have and are we designing, developing and producing the needed capabilities for the Pacific.

We see China heavily using the Information piece of EMSO. As a former War Theory Instructor, I thought it appropriate to include a "Dead Guy" quote from Sun Tzu: "To subdue the enemy without fighting is the acme of skill." China is heavily using the Diplomatic, Economic, Information and Military elements of power, in this order and for the distinct goal of avoiding direct conflict and war.

On the Diplomatic piece, they are aggressively negotiating new agreements and treaties, which will disrupt existing alliances within China's claim and desired control of the first and second island chains.

On the Economic side and closely linked to the Diplomatic, is China's "Road and Belt" efforts across the globe, including Africa, Europe, South America, North America and the Pacific. They are pursuing a "Free trade area" with the Pacific nations. They have proposed a "Common Development Vision" with the Solomon Islands, Kiribati, Samoa, Fiji, Tonga, Vanuatu, and Papua New Guinea, the Cook Islands, Niue and the Federated States of Micronesia.

They are using Information and EMSO to influence others and have focused their efforts not just on the military, but also the commercial and civilian.

On the Military piece they have suggested creating Pacific police officers, to team up on "traditional and non-traditional security," and jointly develop a marine plan for fisheries. This reminds me of how in 2021 China used their "fishing boats" in the Philippine Sea to flex their muscle on territorial/sovereignty claims, much like stating that the Taiwan Strait is not an international waterway. They are also using more "Show of Force" missions to ensure that the world and region are aware that they will continue to be an active participant in the region.

How would the world view a China brokered peace treaty between North and South Korea? What if China brokered a deal for Taiwan, similar to Hong Kong and sells it as being "for the good of the world"? While I find the later extremely unlikely, their use of Information has been effective and has led to other agreements.

The other point is, what is China learning about the EMSO and EW campaign between Russia and Ukraine? Are they updating equipment, developing new capabilities, updating training, adjusting maintenance practices?

So again, I ask if we are learning or just observing in this Information and EMSO campaign – and I sincerely hope we are learning important EMSO lessons.

I hope each of you continue to utilize the resources that AOC has regarding EMSO and continue to grow other Crows across the globe. – *Glenn "Powder" Carlson*

AOC Webinars

AOC WEBINARS

AOC webinars have been a tremendous asset providing AOC's audience with learning, advocacy, and the exchange of information. Register for an upcoming session to hear from subject-matter experts on all things EW!

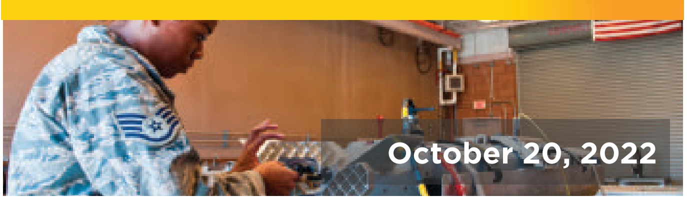
How to Conduct 30+ Capability Demonstrations on CMOSS Mounted Form Factor (CMFF) Prototype in 12 months • Presenter: Dr. Niraj Srivastava

EMBM Situational Awareness: Data Integration, Visualization, and Analytics • Presenter: Jose Perez

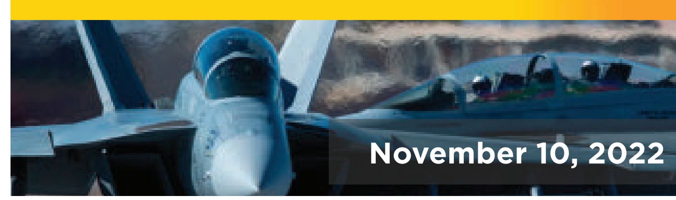
Cognitive Electronic Warfare and Reinforcement Learning • Presenter: Kyle Davidson

Across the Spectrum Pond: How the US Military can procure tested solutions from Europe • Presenter: Zachary George

The World of Small Unmanned Aircraft Systems (sUAS) — 2022 Update • Presenter: Dr. Patrick Ford

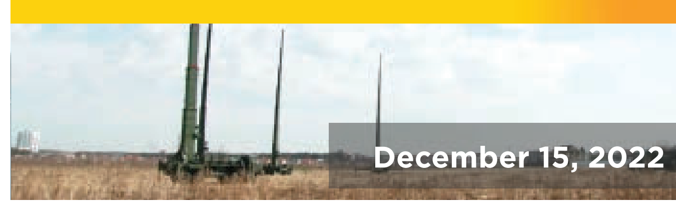


Electromagnetic Manoeuvre: Towards a Theoretical Underpinning • Presenter: Thomas Withington



Two-way Time-transfer Digital Design for Distributed Array Operations • Presenter: Jonathan D. Chisum

In the Flat Field: Did Russian Army Electronic Warfare underperform in Ukraine? • Presenter: Thomas Withington



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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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SASC PASSES FY2023 NDAA

The Senate Armed Services Committee (SASC) passed its version of the FY2023 National Defense Authorization Act (NDAA) shortly before this issue of *JED* went to press. The defense policy bill (Bill Number S. 4543) authorizes $847 billion for the Department of Defense (DOD) and for national security programs within the Department of Energy (DOE). This figure represents an increase of $45 billion over the DOD's request (submitted in April), including an additional $13.8 billion for procurement and an additional $7.5 billion for RDT&E.

The committee report accompanying the bill contained several provisions related to Electromagnetic Spectrum Operations (EMSO). Here are some of the highlights:

EW, SIGINT AND SELF-PROTECTION SYSTEMS

The Committee did not agree with the Navy's plan to retire its expeditionary EA-18G aircraft. The report states, "The committee is disappointed that the Navy would spring a decision to eliminate the expeditionary electronic warfare aircraft squadrons, with little or no coordination with the Air Force or the combatant commanders who rely extensively on these squadrons for electronic warfare support." The Committee recommended a provision that would require the Navy to retain the expeditionary Growlers; transfer the aircraft to the Navy Reserve Air Forces; directed the Secretary of the Air Force to designate one or more Air National Guard or Air Force Reserve units to join with the Navy Reserve to establish joint service expeditionary, land-based electronic attack squadrons to match the capability of current Growler expeditionary units; and directed the Air Force and Navy to submit a report describing how they will implement these changes. The report added, "Establishing joint-service units in the reserve components, modeled on the current operations of the expeditionary EA-18G squadrons, would modernize the reserve components, preserve similar capability to provide land-based electronic warfare capability to the combatant commanders, and save costs."

The SASC also took notice of the Air Force's plans to divest a portion of its MQ-9 Reaper fleet. "Supporters of continued MQ-9 employment have asserted that the MQ-9 possesses similar survivability as other fourth-generation aircraft, and there is no reason that they could not operate in threat environments similar to F-15s or F-16s," it stated in the report. In an effort to gain more clarity on the issue, the Committee directed OSD's Office of Cost Assessment and Program Evaluation (CAPE) to perform an analysis of the current missions of the MQ-9; identify potential additional missions for the MQ-9 through 2040 and the comparative cost of using the MQ-9 for "providing long-range (radar horizon) detection capability, identification, and location of radar and communication signals of interest." Following the CAPE assessment, the SASC wants a briefing on the potential for the MQ-9 to perform new missions "such as improved signals intelligence, communications intelligence, or disaggregated airborne moving target indicator capability." In addition, it wants and an assessment to improve the MQ-9's survivability and "to develop and integrate a self-protection capability into the MQ-9 to enable MQ-9 aircraft to operate in contested environments."

In another provision, the SASC also noted "…the substantial threat that anti-tank missiles and rockets pose to armored combat vehicles" and it sought to "accelerate fielding of highly effective, low detectable, low collateral-damage active protection systems (APS)." It added $10 million to the Army's $109 million request for PE 64852A Suite of Survivability Enhancement Systems – EMD "for the evaluation and integration of electro-optically triggered, low detectable, low collateral-damage APS on Stryker."

TECHNOLOGY PROGRAMS

The SASC recommended a provision that would require the Director of the Air Force Rapid Capabilities Office to "conduct competitively awarded demonstrations and tests of commercial electronics technology to determine whether technology exists to enable certain electromagnetic warfare capabilities. The provision would also require certain briefings and provide permissive funding authorities depending on the outcomes of the demonstrations and tests."

The SASC also focused on silicon carbide technologies, which are envisioned to provide weapons platforms with the power needed to support high-energy lasers. It stated, "The committee continues to support recommendations in the 2019 Naval Power and Energy Systems Technology Development Roadmap for development of advanced power electronics, including silicon carbide power modules, which can reduce the size and weight of power conversion modules and other electronic systems needed to power advanced sensors and weapon systems." The Committee recommended an $11.6 million increase to the Navy's $176.6 million R&D request for PE 63573N Advanced Surface Machinery Systems.

EMSO POLICY AND STRATEGY

The SASC had a lot to say about EMS policy and furthering the DOD's strategic interest in EMSO. One of its provisions called for development of a roadmap for spectrum planning over the 10- to 20-year timeframe in order to match up with the development timelines of Major Defense Acquisition Programs. It stated, "The committee notes that the roadmap is intended to develop an understanding of the warfighter spectrum requirements necessary to be successful in future multi-domain warfighting operations to allow for the Department to proceed with future discussions with the National Telecommunications and Information Administration (NTIA)." It directed the Secretary of Defense to "prepare a strategic next-generation warfighter EMS roadmap to provide recommendations to address the spectrum-related operational needs to support the mission of the Department" by July 1, 2023. The DOD should provide a "threat-informed roadmap for current and future EMS-based technologies for warfighter operations." The Roadmap should define "adequate EMS resources for the Department to support current and future warfighter EMS-based technologies"; identify "challenges to current and future military capabilities across the EMS"; "forecast capabilities to ascertain the expected EMS access requirements of all military users"; identify "potential gaps in processes and procedures within the Department"; note "opportunities to promote advanced forms of sharing between military users and on spectrum assigned to the Department"; assess "tools and other resources within the Department required to process large quantities of EMS data;" and recommend "actions the Department can take to improve communications and long-term planning with the NTIA on the military operational effect of EMS policy decisions."

In a separate provision, the SASC commended the DOD for its efforts to identify 100 megahertz of mid-band spectrum allocated to the Department and share it with commercial 5G telecoms providers under America's Mid-Band Initiative Team (AMBIT). However, the Committee said it was concerned "by the significant funds that were required to be reprogrammed within the Department's budget to support this effort." It wants DOD spectrum sharing or spectrum relocation to be funded by spectrum auction funds and not through DOD appropriated funds; and it has directed the DOD's Chief Information Officer to provide a report "that assesses the implications for the Department's access to the electromagnetic spectrum and resources in sections 113 and 118 of the National Telecommunications and Information Administration Organization Act."

The SASC also addressed "converged" cyber and EW operations. It recommended a provision that would require the Deputy Secretary of Defense, in coordination with the Vice Chairman of the Joint Chiefs of Staff to "develop a strategy for converged cyber and electronic warfare conducted by and through deployed military and intelligence assets operating in the radio frequency domain to provide strategic, operational, and tactical effects in support of combatant commanders. The committee strongly endorses the initiative to capitalize on radio frequency-enabled cyber effects opportunities and to create a framework to ensure that the Department of Defense's science and technology organizations have a pathway available to mature and transition new capabilities and are incentivized to continuously produce such capabilities. This provision is intended to ensure that there are also transition partners in the Department's operational forces and appropriate command and control relationships in place to successfully apply these capabilities."

In addition, the SASC report continued, "the Committee believes it is essential for the Department to determine its requirements and roles for what are referred to as "service-retained" cyber forces for both defensive and offensive support to combatant commands. The committee expects that these service-retained forces would become part of the personnel rotation through elements of the Cyberspace Operations Forces for career progression. These forces would also fulfill critical roles in protecting deployed and often disconnected weapons systems and platforms and supporting offensive cyber operations executed by military units and systems."

In other EMSO policy- and strategy-related provisions, the SASC lauded the Army for "the continued growth of the Army Research Laboratory's collaboration with academia in the development of technology to enable and validate new, distributed electromagnetic warfare and radio frequency (RF) sensors to provide leap-ahead performance improvement in coverage, targeting, engagement timelines, jamming power on target, new electromagnetic warfare ef-

MQ-9B SEAGUARDIAN UAS FLIGHT TESTS SIGINT CAPABILITY FOR RIMPAC 2022

General Atomics Aeronautical Systems Inc. (GA-ASI) has demonstrated the integration of a signals intelligence (SIGINT) capability on its MQ-9B SeaGuardian unmanned air system (UAS) ahead of the MQ-9B's participation in the RIMPAC 2022 maritime exercise.

SeaGuardian is an adaptation of the GA-ASI MQ-9B SkyGuardian UAS equipped for maritime surveillance, SIGINT, intelligence, surveillance and reconnaissance (ISR), and sonobuoy monitoring and control. Both electronic intelligence (ELINT) and communications intelligence (COMINT) mission payloads, together with Link 16 connectivity, were flight tested on MQ-9B N390MC near Palmdale and Edwards Air Force Base in California between 20 April-9 June.

Sierra Nevada Corporation (Sparks, NV) has supplied its AE-4500 ELINT payload for integration on SeaGuardian. Covering UHF through to K/Ka band, AE-4500 is a small form-factor system capable of detecting, identifying and localizing pulsed, continuous wave, frequency modulated continuous wave, and low probability of intercept emitters.

The COMINT payload module is a variant of the L3Harris Rio product family. Rio is a low-SWaP COMINT suite specifically designed for small manned and unmanned ISR platforms with the ability to intercept, locate, monitor and record communication signals using a common set of software applications.

RIMPAC 2022, a large-scale maritime exercise in Hawaii and Southern California, runs through to early August. In addition to the Sea Guardian, RIMPAC 2022 includes several other EW demonstrations, such as the USV *Sea Hunter*, which is equipped with an ESM system as part of a larger manned-unmanned teaming evaluation, and a "scaled" shipboard EA system that will be demonstrated on smaller vessels unable to host the SEWIP Block III EA system. – *R. Scott*

fects, and enhanced survivability of participating platforms."

The SASC also addressed EMSO training and recommended a provision that would "require integration of offensive and defensive electronic warfare capabilities into Tier 1 and Tier 2 joint training exercises, with certain requirements and a waiver option. The provision would also include a briefing requirement and definitions."

Other provisions in the Committee Report focused on counter-UAS, directed energy and microelectronics. *– J. Knowles*

IN BRIEF

The US Army's Program Manager for EW and Cyber (PM EW&C) (Aberdeen Proving Ground, MD), acting via the C5 Consortium, awarded a $58.8 million Other Transaction Authority (OTA) contract to **Lockheed Martin Rotary and Mission Systems** (Syracuse, NY) to support the manufacturing proof-of-concept phase of the Terrestrial Layer System - Brigade Combat Team (TLS-BCT) program. The TLS-BCT suite, which provides communications ES and EA among its capabilities, will initially be installed on Stryker vehicles. The Army envisions adapting the TLS-BCT for other platforms, such as the Armored Multipurpose Vehicle, an as-yet undesignated vehicle for Infantry Brigade Combat teams, and in a manpack configuration. Work under the support agreement runs through October 2023. The Army's Terrestrial Layer System – Echelon Above Brigade (TLS-EAB) program is expected to get under way this year.

The Department of Defense has indicated that the **Government of Australia** has formally requested the sale of up to 15 each AGM-88E2 Advanced Anti-Radiation Guided Missile (AARGM) guidance sections, control sections and rocket motors for the RAAF's EA-18G aircraft. The proposed Foreign Military Sale, valued at $94 million, also includes 15 HARM warheads and control sections.

The US Army's Product Director (PD) Aerostats has issued a Request for Information (RFI) for a fully integrated aerostat system "with primary radio detection and ranging (RADAR) and Electronic Intelligence (ELINT) payloads." The office is conducting the research as part of a potential FMS program for Poland. According to the RFI, Poland is seeking "a constellation of, at minimum, four (4) integrated aerostat systems with sustainment support to provide day/night persistent (24/7/365) detection, tracking, and monitoring (surveillance) capability for Poland against diverse air and ground threats. This includes low radar-cross-section (RCS) unmanned aerial systems (UAS) and low-flying inbound aircraft within its area of coverage. Options for additional future systems may be offered once the core constellation is successfully operating." The RFI also states, "Primary interest is air-to-air modes to include UAS Group I, II, and III threats, with ranges up to 350 kilometers (km) for Group II and III threats desired. Maritime mode and ground moving target indicator (GMTI) mode is a secondary interest. RADAR shall provide capability to report targets and tracks of maneuvering air breathing targets (ABT) between 100 feet (ft.) and 15,000 ft above ground level (AGL) traveling at speeds between 60 knots (kts) – 800 kts. (110 kph – 1482 kph). The system will be designed with an open architecture to readily support future expansion with additional aerostat and/or sensor systems." The ELINT payload requirements call for 0.5- to 18-GHz coverage of pulse, CW, frequency agile, frequency hopping, chirp, and jamming signals, LOB accuracy of 0.5 degrees RMS, 360-degree sensor coverage and emitter mapping when data is combined from two or more ELINT collectors. ELINT data from each individual aerostat system will be consolidated within a COP at a designated command center, in real- or near-real time. The RFI also indicates the customer wants to field the aerostat systems within 14 months of contract award. Responses to the RFI are due by August 11. The contracting point of contact is Jennifer Mattessino, e-mail jennifer.l.mattessino.civ@army.mil.

Elettronica Group (Rome, Italy) and partner LendLease (Sydney, Australia) have introduced a novel electronic solution to combat the SARS-CoV 2 (COVID-19) virus and its variants. The E4SHIELD is a small electromagnetic emitter that immediately neutralizes 90% of airborne viruses in the surrounding air, according to the company. More specifically, the radiated energy inactivates the virus by using microwaves to destroy the virus's external shell. According to the company, it is effective against viral particles in bioaerosols, including droplets up to 10 microns. The device is available in two configurations. The E4SHIELD Personal, which measures 8.5 x 8.5 x 2.2 cm (3.3 x 3.3 x 0.9 in.) and weighs 100 grams (3.5 oz.) can be worn on a lanyard or attached to a belt. The personal device provides 7W ERP, has a range of 3 meters and can operate on a rechargeable battery for up to 4 hrs. The E4SHIELD50 is designed for fixed applications, such as interior rooms and offices. It measures 15 x 15 x 2.5 cm (6 x 6 x 1 in.) and weighs 500 g (1.1 lb) and covers approximately $50m^2$. It provides 9W ERP and can be powered via internal battery for up to 4 hrs or off a wall outlet. The devices have been tested at Virostatics Laboratories (Tramariglio, Italy) and in proof-of-concept evaluations at the Scientific Department of the Military Polyclinic of Rome. Using microwaves to damage the COVID virus is not a new concept. In the first months of the COVID pandemic, for example, researchers at AFRL studied the effects of microwave energy (between 2.8 and 7.5 GHz) on SARS-CoV 2 virus carried in aerosols. However, the E4SHIELD is thought to be the first product introduced to neutralize airborne SARS-CoV 2 viruses with microwave energy. While not EW, strictly speaking, this is a novel approach to combatting COVID, and the company says the E4SHIELD holds potential for neutralizing other types of viruses and bacteria.

The Air Force Research Lab's Directed Energy Directorate (Kirtland AFB, NM) has awarded an $8 million cost-plus-fixed-fee contract to **Stellar Science LTD. Co.** (Albuquerque, NM) for the development of end-to-end directed energy (DE) modeling and simulation

(M&S) software, the application of end-to-end DE M&S software, and general development and support of the Galaxy Simulation Software Suite (GSSS). The work with the GSSS and underlying DE simulations will advance the state-of-the-art and scientific knowledge in DE technology, and increase knowledge of the physical processes affecting the high-fidelity simulation of directed energy devices which are applied in selected environments. The contract runs through June 2027.

Elbit Systems (Haifa, Israel) is providing the IR self-protection suite for the Gulfstream 650 VIP aircraft recently acquired by the Netherlands MOD. Elbit will supply its IR-based Passive Airborne Warning Systems (IR PAWS) missile warner and its J-MUSIC directed IR countermeasures (DIRCM) system, which will be integrated onto the belly of the aircraft. The J-MUSIC system has also been integrated onto German Air Force A400M transports and NATO A330 Multinational Multi-Role Tankers, as well as various Israeli aircraft. In 2017, the company won a contract to install the J-MUSIC system on a Gulfstream 650 for an undisclosed customer.

The UK Government has cleared the sale of **Ultra Electronics** to **Cobham plc**. The £2.57 billion sale, which was announced in July 2021, brings together two large defense electronics houses, both with extensive businesses in the UK and the US. Cobham AES is a major supplier of antennas, electronic components and microwave assemblies in the military EW, radar and communications markets. Among its businesses, Ultra Electronics provides airborne datalinks and threat simulators for EW testing.

UK Defence Procurement Minister Jeremy Quinn MP announced that the RAF will move forward with a £2.35-billion ($2.78 billion) program to upgrade its newest Typhoon multirole fighters with new radars that will also provide electronic attack functions. **Leonardo** will continue developing the European Common Radar System (ECRS) Mk II radar, and **BAE Systems** will integrate the system into 40 Tranche 3 Typhoons in the 2029-2030 timeframe. The RAF also hopes to retrofit the radar into a portion (up to 67) of its Tranche 2 aircraft at a later date. The Eurofighter program plans to fly the ECRS Mk II by the end of 2023.

Leonardo and **Mitsubishi Electric,** having completed joint concept work and feasability studies for the JAGUAR radar technology demonstrator earlier this year, announced that they have agreed to workshare on the next phase of the program and have signed contracts with their respective defense ministries. JAGUAR, represents a major building block of a future radar program that could be leveraged for Japanese and UK next-generation fighter aircraft. JAGUAR will support the development of the UK's ISANKE & ICS (Integrated Sensing and Non-Kinetic Effects & Integrated Communications System) on the TEMPEST fighter program.

Lockheed Martin announced that in February it delivered a compact high-energy laser to the Air Force Research Lab's Directed Energy Directorate (Kirtland AFB, NM), developed under the Laser Advancements for Next-Generation Compact Environments (LANCE) program. The laser is a key subsystem of AFRL's Self-protect High Energy Laser Demonstrator (SHiELD) program, which aims to integrate a high energy laser system into a pod for use on fighter aircraft. For the SHiELD program, **Northrop Grumman** is providing the beam control system and **Boeing** is responsible for the pod integration.

Indra (Madrid Spain) said it had received contracts from **Kongsberg Defence & Aerospace** (Kongsberg, Norway) to supply radar electronic support measures (RESM) and communications ESM (CESM) systems, as well as low-probability of detection navigation radars, for their new-build Type 212CD (Common Design) submarines. The company is understood to be providing the newest version of its Pegaso RESM/CESM system, as well as its ARIES-S low-power X-band radar for installation on two boats for the German Navy and four for the Royal Norwegian Navy. The six Type-212CD submarines, which are significantly larger than their Type 212A predecessors, were jointly ordered in July 2021, with the first in class expected to be laid down in 2023 and commissioned into the Royal Norwegian Navy in 2029. The Type-212CD's ORCCA combat system, which will manage the sensor systems, is being supplied by **kta naval systems** (a joint venture between Kongsberg and ThyssenKrupp).

The Defense Advanced Research Projects Agency (DARPA) (Arlington, VA) has awarded a $9.4 million cost-plus fixed-fee contract to **HRL Laboratories** (Malibu, CA) for the Electronics for G-band Arrays (ELGAR) program. Under this effort, the company will develop the integration technologies needed to create compact, high-performance RF electronics, including monolithic microwave/millimeter wave integrated circuits and transmit and receive array front-end test articles, to enable communication and sensing systems at G-band frequencies. The development program runs through January 2024.

SciTec Inc. (Princeton, NJ) was awarded a $25.6 million cost-plus-fixed-fee contract from the Army for support services for the Joint Mobile Infrared Countermeasure Test System (JMITS) and the Multi-Spectral Sea and Land Target System Missile Simulator (MSALTS). The two systems, which were developed by SciTec, are operated by the Center for Countermeasures, a Joint EW test organization at the US Army's White Sands Missile Range (WSMR) complex in New Mexico. The support contract runs through July 2027.

Lockheed Martin Missiles and Fire Control (Grand Prairie, TX) has received a $130.5 million contract option to manufacture Advanced Radar Threat System – Variant 2 (ARTS-V2) systems. The ARTS-V2 simulates long-range threat systems, such as the S-300 and S-400 radar families. Under the terms of the contract award, the company will deliver eight additional ARTS-V2 simulators. Final deliveries are expected in June 2024.

SYMPOSIUM

The EMSO Playbook: Maneuvering to Win in a New Era

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AGENDA UPDATES

WEDNESDAY KEYNOTE

Dr. William A. LaPlante
Under Secretary of Defense for Acquisition and Sustainment

CLOSING SPOTLIGHT SPEAKER

Mr. Chris O'Donnell
DASD, Platform and Weapon Portfolio Management OUSD, A&S

SYMPOSIUM BREAKOUT SESSIONS

JADC2

Session Moderator: Dr. Michael Zatman, Principal Director for Fully Networked Command, Control and Communications, Office of the Under Secretary of Defense for Research and Engineering

Space EMSO: C-C5ISRT

Session Moderator: Mr. Bryan Clark, Senior Fellow, Hudson Institute

Cognitive EW

Session Moderator: Colonel William "$" Young, Commander, 350th Spectrum Warfare Wing

Supply Chain

Session Moderator: Mr. Alan Shaffer, former Deputy Under Secretary of Defense Acquisition and Sustainment, current Board Member: Global Foundries Government Security Committee, Potomac Institutes Board of Regents, Strategic Advisory Board, Pacific Defense

Standards & MOSA

Session Moderator: Mr. Ben Peddicord, Branch Chief at CERDEC/I2WD

Unmanned/Uncrewed Systems

Session Moderator: Mr. Dan Patt, Senior Fellow, Center of Defense Concepts and Technology, Hudson Institute

5G/Next G

Session Moderator: Dr. Tom Rondeau, Program Manager, Strategic Technology Office, DARPA

Joint and Coalition EMSO Integration

Session Moderator: Mr. Tim Grayson, Special Assistant to the SecAF for Mission Centered Analysis and Operational Imperatives

**As of July 14, 2022 – Subject to Change*

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Staying the Course – Path to Advanced M

By John Haystead

MCDP 8 identified "information" as a warfighting function. USMC PHOTO

Ostensibly, the Marine Corps has a long history of appreciating the warfighting benefits provided by electronic warfare (EW) – particularly by airborne platforms, having flown the EA-6B Prowler in critical support of Joint Forces until its retirement in 2019. Ground-based capabilities, however, have always been extremely limited, and now with the Corps' decision to not replace its Prowlers with manned aircraft, such as the EA-18G Growler, the need to develop and implement an alternate approach and path for its AEA mission is even more critical and paramount in the near-term.

Despite many years of yeoman efforts by a dedicated cadre of Marine Corps EW advocates working to prepare for this exact eventuality, the process has been painfully slow to address the requirement with clear top-level direction and real funding. Today, however, this may be changing. With the emergence of "Marine Corps Force Design 2025 and 2030," and specifically the related Marine Air Ground Task Force (MAGTF) Information Environment Operations Concept of Employment (MAGTF IEOCOE), there appears to be a broader appreciation and determination to significantly advance Marine Corps EW capabilities through its contribution to the overall doctrine and stated goals of Information Operations.

The MAGTF IEOCOE was released in 2017, and according to LtCol Brian Ackerson, EW Branch Head at Marine Corps Deputy Commandant for Combat Development and Integration (CD&I), "It really shifted how we viewed the information environment and EW, allowing MAGTF-EW to begin taking a much more solid shape." Ackerson notes that the terminology was shifted to Operations in the Information Environment (OIE) but that, "this was the initial document that resulted in the creation of the Marine Expeditionary Force (MEF) Information Groups (MIGs) at each MEF HQ, who are ultimately responsible for all OIE activities."

Under the MIGs is the Information Command Center (ICC) which also includes an Electromagnetic Spectrum Operations Cell (EMSOC) with overall responsibility for EMS-EW operations and coordination. Says Ackerson, "We have 2600s (Radio Battalion Signals Intelligence (SI)/EW Marines) for each infantry company and SI EW Warrant Officers at the battalion HQs and Marine Littoral Regiment (MLR) HQs, as well. These Marines will be responsible for EW planning at their level and will coordinate with the MIG EMSOCs for authorities and operations. Ultimately, we see EW and primarily Electronic Support (ES) as something the Marine Corps can provide to the Naval and Joint Force during competition to sense in and through the EMS and, in conflict, advanced Electronic Attack (EA) will enable our actions as the stand-in-force."

In describing his own job and role at CD&I, Ackerson says, "My guys develop the requirements and work hand-in-hand with Marine Corps Systems Command (MCSC)(Quantico, VA) who ultimately develop and field the systems. We're responsible for developing requirements for all EW systems – both aviation and ground EW requirements."

Prior to Ackerson's posting to the job, LtCol Jeff Kawada was in the slot at CD&I (2015-2019). As such, he was one of the people integrally involved in the preparation of the IEO-

– Maintaining the arine Corps EMSO

COE document, along with Eric Schaner, Senior Information Strategy and Policy Analyst, Plans and Strategy, Deputy Commandant for Information (DCI.) Schaner is also the primary author of the just-signed Marine Corps Doctrinal Publication (MCDP) 8, Information. Developed in coordination with Doctrine Branch, Policy and Standards Division, Training and Education Command (TECOM), MCDP 8 is one of only eight such publications in the Marine Corps. It creates information as a warfighting function and translates the concept-of-operations to warfighting doctrine for the Marine Corps. It is comprised of four chapters describing: Nature of Information, Theory of Information, Effective Use of Information, and Institutionalizing Information. Said Schaner in a press release announcing the signing, "Any Service, or Service member, regardless of what their tactical implementation of information is can apply the core concepts outlined in MCDP 8, Information. Our intent is to increase overall understanding that information is a warfighting function that can be applied through combined arms and maneuver to support commander's objectives."

In the same press release, Lt. Gen. Matthew Glavy, Deputy Commandant for Information said, "MCDP 8, Information is written within the context of Force Design 2030: threat-informed, concept-based and accountable to a campaign of learning. To maximize the information warfighting function, we must make it a component of 21st Century Combined Arms – such that we generate, preserve, deny, and project information in full integration with fire and maneuver."

SYSTEMS AND CAPABILITIES

In describing the EW systems and capabilities of the Marine Corps since the retirement of the Prowlers, there is one system that has become pretty much synonymous with the Corps' current EW capabilities. On the aviation side, the AN/ALQ-231 Intrepid Tiger II (IT II) family of systems started out as a rapid deployment capability (RDC) developed and built by the Marine Corps Spectrum Integration Lab (Point Mugu, CA) back when Operation Iraqi Freedom (OIF) (2003-2011 timeframe) was going on. As described by Ackerson, "We didn't have enough Prowlers available to support Marines, so the initial IT-II (V)1 EW pod was developed for initial fielding on Marine Corps AV-8 Harrier aircraft and was also expected to go onto F-18 Hornets." The (V)1 flew on Harriers with Marine Expeditionary Units (MEUs) essentially since it was developed in 2011, but the additional deployment on F-18 and KC-130 aircraft didn't really advance as originally planned. Today, as with the Prowlers, Marine Corps Harriers are also being sundowned with the arrival of F-35 aircraft, with the Service likewise moving away from the IT II (V)1.

The ALQ-231(V)3 Intrepid Tiger II, seen above undergoing its first operational flight with MEU 22 aboard the USS Wasp in 2016, provides communications ES and EA. Newer versions will see it installed in an on-board configuration on MV-22 aircraft and as a roll-on/roll-off system on KC-130J aircraft. USMC PHOTO

There are no plans for IT II on the F-35, as it has its own inherent EW capabilities.

Says Ackerson, "As IT-II matured over time, it moved from an RDC to an official Program of Record (POR), with a new improved (V3) variant deployed on UH-1 'Huey' helicopters." The system is currently used by Marine Light Attack Helicopter (HMLA) Detachments that are now deploying with MEUs. Having achieved Initial Operational Capability (IOC), IT II (V)3 is expected to be full-up capable by the end of this year. According to Ackerson, "The (V)3 variant has more capability in terms of Direction Finding (DF) and Electronic Support (ES) than the (V)1 did, together with the inherent communication jamming Electronic Attack (EA) capability that was baked into the initial (V)1."

Another variant, IT II (V)4, flew for the first time on an MV-22B Osprey aircraft in the summer of 2021. This was also the first time the capability was incorporated internally rather than as a pod. As described by Ackerson, "The (V)4 variant is a roll-on/roll-off kit variant of the system. It's the newest variant, with Developmental Testing (DT) last year flying in an MV-22 Osprey and it's going through Operational Testing (OT) over this summer-to-fall timeframe. We expect to deploy a decent number of those with the VMM Squadrons." According to Ackerson, "the (V)4 has somewhat similar capability to the V3, with additional ES/DF capability."

Going forward, the Marines are also developing a (V)5 variant of the IT II intended for KC-130 tanker aircraft. Although the IT II (V)1 pod was also intended to be flown on the KC-130, the (V)5 version will be an actual aircraft modification program. Ackerman also reports that the Service is also currently researching various technologies, with a focus on an ES capability that could potentially go onto the proposed Marine Air-Ground Task Force (MAGTF) Unmanned Aerial System (UAS) Expeditionary for Medium-Altitude, Long-Endurance – or MUX/MALE platform. This is currently the MQ-9 Reaper. At one time, the Marines had looked at trying to put an EW pod on the RQ-21 Blackjack UAS, but it didn't go forward, and they are, in any case, now divesting the RQ-21.

Summing things up, Ackerson says, "So we've gone from the IT II's (V)1 original Comms-EA type mission to the (V)3, (V)4, and (V5) variants, and onward onto UAS in the future. Overall, we intend to keep the same EA type capabilities it currently has, but shifting focus more towards an EW support/sensing type role."

The latest version of the Communication Emitter Sensing and Attack System II (CESAS II), shown above in an exercise at Camp Lejeune, NC, with 1st Battalion, 2d Marine Regiment (1/2), 2d Marine Division (MARDIV), achieved Initial Operational Capability last year. USMC PHOTO

GROUND-BASED OPERATIONS AND SYSTEMS

As observed by Ackerson, there's also progress on the ground side of Marine Corps EW. "All of the things that have gone on in the force design are really looking at having high-density/on-demand type capabilities down to the infantry squad level, and we're looking at a mix of capabilities with things that will be operated by 2600s, our SIGINT/EW professionals (think of a Radio Battalion (RadBn) Marine), as well as a plethora of systems that are 'incidental-operator' focused. These would be a combination of back-pack or wearable systems carried by Marines, but not operated by them. It's kind of similar to IT-II in that we're not looking for systems to be operated by an aircraft pilot or crew chief. The expectation is that the mission planning, etc., will be done through a dedicated 2600 operator, either operating the pods or the system remotely from the ground, or from onboard the aircraft. Particularly when you're talking about a UH-1, MV-22 or KC-130, they can easily be in the back of the aircraft running the mission."

According to Ackerson, with the current force design, the Marines are looking at having SIGINT/EW teams in each infantry Company. "So, you'll have a team of 2600s – about a half-dozen in each Company – and they'll be your EW experts at the Company level. They would also be the people responsible for providing the mission planning, command and control and mission loading for the systems carried by the Marine incidental-operators at the Squad level."

The Company-level teams would also have the Service's Communication Emitter Sensing and Attack System II (CESAS II), which is currently being fielded. This is the Corps' sole high power, ground-mobile EA asset providing the MAGTF the capability to detect, deny and disrupt threat communications. The CESAS II upgrade makes the new system lighter and doubles its frequency range. Ackerson says, "The latest variant of the system was IOCd last year, and we're planning on having each of those teams operating those as well as additional SIGINT gear. The focus on the EW side is sensing in the EMS to control it."

Moving forward, MCSC is developing the new MAGTF EW Family of Ground Systems (MAGFOS). As described by Ackerson, "This is the family of systems we're looking at for incidental operators, and will include a team-portable version (but one that operates largely like a fixed-site operation), which will have counter-UAS, counter-RCIED, counter-comms, and counter-C5ISR Center capability baked into it."

There will also be a vehicle-mounted variant which is intended to be carried on a wide range of wheeled vehicles, including the Marine Corps' Amphibious

Combat Vehicle (ACV) and its Advanced Reconnaissance Vehicle (ARV). In addition, two dismounted MAGFOS variants are planned – a backpack system as well as a wearable system, such as a helmet-mounted capability or something worn on a flak vest. Ackerson says, "The focus for the infantry is having a sensing capability in the EMS where you can detect and target the enemy. Tying into the aviation side, the focus is on the ES piece, where the objective is domain awareness."

Emphasizing that the MAGFOS family is intended to be used against peer adversaries, Ackerson says the overall focus of the effort is that the different variants operate together to deliver a fully-robust capability. All of the systems are networked through the Electromagnetic Battle Management System (EMBS) spectrum services framework. "With one system, you won't have the full capability, but with multiple systems, you can have synergistic effects and networked EA/ES capabilities, all working together to give you an advanced capability. Starting with the wearable gear, we're looking at systems down to the Squad level that provide basic DF and threat localization, then with the backpack variant, you'll have some basic level of defensive EA, and then as you move into the mounted or team-portable capability, you'll have more of the robust capabilities."

MAGFOS is also are embracing the Army's C4ISR/EW Modular Open Suite of Standards (CMOSS) architecture. "It's a key part of the program," says Ackerson, "and we're looking at having a CMOSS chassis populated with carded solutions. It doesn't necessarily have to be just an EW system. As we look at software defined radios (SDRs), and advanced receivers, etc., your radio system can also be used to sense in the EMS and contribute to battlefield awareness. And, without the need for multiple boxes, you can put a host of system capabilities in a single vehicle – saving space while not being vendor locked."

Marine Corps Systems Command began developing MAGFOS in 2020, and it is currently going through mid-tier acquisition for the team portable element. The other capabilities are in development, with the goal being to have these systems delivered in the next five years. According to Ackerson, "As the new force design units – such as the Marine Littoral Regiments (MLRs) and new infantry battalions – come on line, these will be the some of the first to receive the systems. In the interim, we've divested our old CREW-type systems and are using multi-function EW (MFEW), which is currently the Modi II backpack and vehicle mounted (Modi Vehicle Power Adapter II – MVPA II) variants. The Modis are currently fielded, with the vehicle-mounted capability intended more for the MEU type mission, or more of a counter-insurgency role, being delivered over the past two years."

IT'S A PROCESS

The realization of an all-new, comprehensive EW capability for the Marine Corps is best described as an ongoing process that has already been decades in the making, and has not been without obstacles and challenges all along the way. Not the least of these challenges has been the institutional resistance to the adoption of such unfamiliar technology by the intended users, whose mission focus and training has long been on other priorities. With the exception of the Prowler community, the big-picture benefits and critical importance of EMSO was not fully appreciated or expounded across the Marine Corps. And, even that base of advocacy and expertise began to quickly disappear with the EA-6Bs' retirement.

One early example of these growing pains can be seen with the initial deployment of the first Intrepid Tiger pods to the Corps' Harrier squadrons. Not surprisingly, Harrier pilots already saw themselves having a clear combat-mission profile delivering kinetic weapons, and they weren't really excited about this new role of providing communication-jamming support. Add to this, the fact that this strange pod, with invisible effects – as far as they were concerned – was disrupting their own friendly aircraft communications, and it wasn't seen as much of a match made in heaven. Overcoming this initial reticence was one of the main challenges for those tasked with building and fielding an effective airborne EW capability to replace that of the Prowlers.

Ackerson says that today, however, with better education and training, this early resistance has pretty much disappeared among all of the platform communities now flying with IT II. "As far as interference issues with own communications," he says "it's not seen as anything significant. You just have to develop the tactics, techniques and procedures (TTPs) to work around it. It's all things that can be dealt with through good mission planning."

On the ground side, the Marines found other issues to address. For example, it was the Corps' Radio Battalions (RadBns) that were now being tasked with a new, heretofore antithetical, EW mission. Having expertise in (and tightly intertwined with) the intelligence community signal-collection mission, RadBn units were trained to listen to, not disrupt, enemy communications. And the equipment they used, and were extremely familiar with, did not include EA systems.

Ackerson says the RadBns are now fully onboard with the EW mission. "As the capabilities have matured and been

The Marine Corps wants to extend EW operations down to its smaller units. Late last year, 3d Battalion, 3d Marines; 3d Radio Battalion, III Marine Expeditionary Force Information Group, and 2nd Infantry Brigade Combat Team, 25th Infantry Division, conducted a joint EW training event at Schofield Barracks, HI, to learn how EW can enhance the lethality of small units.

USMC PHOTO

fielded, the 2600 community has kind of come in and said, 'yeah, this EW thing is actually important,' and they're are definitely supportive of all of this as they realize they will be an integral part in how we want to operate and what we're looking at the Marine Corp to bring to bear for the Joint and Naval Force. It's this sensing capability, which isn't just SIGINT, but rather the EA piece as well in conjunction with SIGINT."

Ackerson notes that, in the initial stages, it will be the RadBns' responsibility to train the professional SIGINT/EW Marines, "but the real goal is that these SIGINT/EW teams belong to – and are fully integrated into – the infantry battalions and that they operate seamlessly and in full support of the Battalion."

Perhaps the most important lesson learned and the biggest obstacle needing to be overcome, in terms of truly and widely accomplishing the acceptance, adoption, and appreciation of the critical importance of EMSO in the Marine Corps, may have been self-inflicted. As Kawada observed, "The thing I think that is often overlooked is that the technology is kind of the easy part. Industry is going to build it, but it's the experience and expertise of the people needed to implement it and the DOTMLPF [doctrine, organization, training, materiel, leadership, personnel and facilities] that is the difficult part. This is what the Marine Corps may not have not gotten quite right with the retirement of the Prowlers. Maintaining the Marine Corps' EW expertise has been not been as deliberate as it could have been, and that is the piece that is going to require time."

NEXT PERSON UP

As already noted, the process of bringing advanced EW capabilities to the Marine Corps has gone through, and continues to go through, many stages of maturation. One thing that has not changed, however, is a continued focus on the need for a consistent overall strategy, and this has been steadily advocated for and advanced by a core group of Marine Corps EW leaders, such as those serving in the role of CD&I's EW Branch Head and other similarly-tasked, action-officer-level colleagues. As described by Kawada, "The goal has always been to stay the course and remain consistent with the strategy – handing the torch to the next person and pushing ahead. Over the years, everyone has done their part to adhere to and advance this strategy. Rather than focusing on a particular technology, it is the architecture that is key to this strategy, with all the shiny objects that get plugged into that architecture coming and going. More recently, those of us tasked with the job have been involved with the development of capabilities, but the overall strategy was set by those that came before us."

Among this group who "came before," are LtCol Jason Schuette, USMC (Ret.) and Maj Matt Poole, USMC (Ret.) – both well-known names to the AOC and EMSO community at large. Prior to Kawada and Ackerson, Schuette had also served in the role of EW Branch Head, CD&I and later on doctrine and requirements development for Marine Corps EMSO. Among his postings, Poole served as the Spectrum Warfare Division Head, Marine Aviation Weapons and Tactics Squadron 1 (MAWTS-1), as well as two tours working Joint requirements at the Joint EW Center (JEWC). Those interested in reviewing some of the foundational plans that now form the basis for today's Marine Corp EMSO strategy and what is now known as the Electromagnetic Spectrum Operations Cell (EMSOC) are referred to their article, "Cyber Electronic Warfare – Closing the Operational Seams," published in the August 2015 edition of *Marine Corps Gazette.* One prescient quote from that article is, "In order to properly coordinate, deconflict, and synchronize execution, the Marine Corps requires a focusing entity for holistic planning, integrating, and coordinating 'spectrum warfare' capabilities…"

Clearly the MAGTF IEOCOE reflects and carries forth this view, and as Ackerson observes, "All the Services and across the DOD have really woken up in the last few years to the importance of Information Operations and spectrum operations and superiority. It's not just a bunch of disparate things, which is good."

How this translates in terms of real-world budgeting and funding in future, of course, remains to be seen. As always, "The proof will be in the pudding." For his part, Kawada says that, "The good news is that the Corps has built the MIGs and have stood up a 3-star Deputy Commandant for Information (Maj. Gen. Matthew Glavy), so, we've gained in the leadership area, as well as within the OIE organizational structure, as EMSO falls within this 'bucket of Information'."

In addition to the individuals cited or referenced in this article, the author would like to thank Lt. Col. Scott Cooper, USMC (Ret.) for his valuable insight and assistance with this article. With twenty years of service in the Marine Corps, including as an EA-6B Squadron Commander, Cooper is one of the early advocates and planners for Marine Corps EMSO.

TECHNOLOGY SURVEY

A SAMPLING OF DIGITIZER/MULTIFUNCTION BOARDS FOR EW AND SIGINT APPLICATIONS

By Barry Manz

The world of embedded systems is changing fast. Product families once dedicated to specific functions, such as analog-to-digital conversion, signal processing, or general-purpose processing, have been replaced with boards that do them all and a lot more, increasingly using only one or two system-on-a chip (SoC) units.

Some of this change can be attributed to DOD's focus on lowering SWaP-C, but the real drivers are extraordinary achievements in semiconductor technology and fabrication. Of course, single-function boards dedicated to single-board computers, ADCs, DSP, and DACs still exist and probably will for a long time, as designers need the ability to mix and match devices to meet specific requirements. However, multifunctionality is here to stay.

This month's survey on digitizer boards and RFSoC boards amply demonstrates this trend, with more boards than ever combining multiple functions in a small factor. The emergence of the Xilinx Zynq UltraScale family of FPGA-based devices made a great leap forward in this regard by integrating virtually all required functions to build a software-defined radio in a single device.

Now in its third generation, the Zynq family includes a product called the ZU49DR UltraScale+ RFSoC DFE (digital front end) that has an instantaneous bandwidth of 7.125 GHz, Soft-Decision Forward Error Correction (SD-FEC), 16 14-bit ADCs, 16 14-bit DACs, 930 logic cells, 4,272 logic slices, 16 GTY transceivers, eight lanes of Gen 4 PCI-e, quad-core and dual-core and quad-core Arm Cortex processors, and massive amounts of I/O.

All this comes at a steep price. However, just one high-performance ADC with specifications similar to those in the ZU-49DR can cost more than $3,000, and integration of all these functions in a single device dramatically improves SWaP. So the argument for using discrete devices is impressive.

Speaking of converters, ADC and DAC components often make or break a software-defined radio (SDR), now used almost universally in both commercial and defense systems. Unfortunately, as speed increases, resolution decreases, so while higher conversion rates allow more bandwidth to be digitized, higher-resolution converters provide greater dynamic range.

Designers follow advances in DAC performance with rapt attention while the DAC often gets less attention because, as noted, the former is what determines how well the rest of the system can perform. In addition, if the signals remain in the digital form (i.e., not converted back to analog form for rebroadcast) as they are in signal recorders and analysis platforms, the DAC has far less importance. However, EW systems that perform electromagnetic attack (EA) demand exceptional DAC performance because the retransmitted signal must have the precise characteristics required to counter threats.

As a result, the best DACs available today typically have performance characteristics equal in critical metrics to their counterparts at the front end. No matter how precisely the ADC maintains input signal fidelity during the "capture and convert" process, it's the DAC that must maintain that fidelity. Creating a DAC with the best combination of resolution, data-rate conversion, spurious-free dynamic range, settling time, distortion, and signal-to-noise ratio (and others) is difficult to achieve but essential.

For example, unlike ADCs, DACs have a unique characteristic that leads to undesirable image signals appearing within each Nyquist zone of the output. That is, in addition to the desired spectrum, there will also be noise and distortion products that must be dealt with by filtering. DAC designers also face other challenges, such as offset and gain errors and nonlinearities causing distortion, along with the other metrics its shares with ADCs. Analog bandwidth interleaving is now common in high-end DACs (and ADCs) because it overcomes bandwidth limitations by interleaving the output signals of multiple DACs in the frequency domain.

In summary, as the embedded industry is continuously striving to reduce SWaP-C through higher levels of integration, it's easy to overlook the contribution of each process, and analog-to-digital and digital-to-analog conversion performance is obscured. But a deep dive into the details of these processes within the whole reveals spectacular performance that increases every year.

THE SURVEY

Our survey includes 31 examples from 12 companies. The first column indicates the model number of the board or module. The next six columns describe the board's analog-to-digital performance, including the number of A/D channels, bit resolution, sampling rate and input bandwidth. The next three columns describe board's the D/A performance (if the board has D/A capability), such as the number of D/A channels and the number of bits. The next column describes the form factor of the board or module. Additional information about performance and options is included in the final column.

DIGITIZER AND MULTIFUNCTION RF BOARDS

PRODUCT NAME or MODEL NUMBER	ADC MODEL	A/D CHANNELS	A/D BITS	ENOB	SAMPLE SPEED	INPUT BANDWIDTH
Abaco Systems, Inc.; Huntsville, AL, USA; +1 866-652-2226; www.abaco.com						
VP431F	Zynq Ultrascale+ RFSoC Gen3 ZU47DR	8	14	*	5 Gsps	*
VP430	Zynq Ultrascale+ RFSOC ZU27DR	8	12	*	4 Gsps	*
FMC172	ADC12DL3200	2	10	*	6.4 Gsps	>6 GHz
Alpha-Data Inc.; Golden, CO, USA; +1 303-954-8768; www.alpha-data.com						
ADA-VPX3-9R1	Zynq Ultrascale+ RFSOC ZU27DR	8	12	*	4-5 Gsps	*
Annapolis Micro Systems; Annapolis, MD, USA; +1 410-841-2514; www.annapmicro.com						
WWDME1	Jariet Technologies Electra-MA	2	10	*	40-64 Gsps	*
WWGM63	Zynq UltraScale+ RFSoC: ZU27DR, ZU28DR, or ZU47DR	4	14	*	4-5 Gsps	*
WB3XR2	Two Gen 3 Zynq UltraScale+ XCZU43DR RFSoCs	8	14	*	0.5-5+ Gsps	*
ApisSys SAS; Archamps, France; +33 450360758; www.apissys.com						
AV138	Zynq UltraScale+ RFSoC: ZU25DR, ZU27DR or ZU47DR	4	14	7.7 @5.9GHz, -1dBFS	5 Gsps	6 GHz
AV140	AD9082 MxFE	4	12	8.3 @2.7GHz, -1dBFS	6 Gsps	8 GHz, usable 12 GHz
AV143	ADC12DL3200	2	12	8.5 @2.1GHz, -1dBFS	3.2 Gsps / 6.4 Gsps single channel	8 GHz
BittWare; Concord, NH, USA; +1 603-226-0404; www.bittware.com						
RFX-8440	Zynq ZU43 RFSoC	4	14	11	5 Gsps	4 GHz
Curtiss-Wright Defense Solutions; Ashburn, VA, USA; +1 703-779-7800; www.curtisswrightds.com						
VPX3-534	ADC12DJ3200	2 or 4	12	8.7 @ 513 MHz (3 Gsps)	6 or 3 Gsps	8 GHz
XMC-518	ISLA214P50	4	14	11.6 @ 105 MHz	500 Msps	400 MHz
VPX3-E320	AD9361 RFIC	4	12	*	61.44 Msps	70 MHz to 6 GHz
Delphi Engineering Group; Irvine, CA, USA; +1 949-537-7701; www.delphieng.com						
ADF-QMX44	AD9081	4	12	9	4 Gsps	5 GHz
ADF-Q3114	AD9208	4	14	9.4	3.1 Gsps	3 GHz
ADF-3030	AD9208	2	14	9.5	3.1 Gsps	3 GHz

DAC MODEL	D/A CHANNELS	D/A BITS	FORMAT	FEATURES
Zynq Ultrascale+ RFSOC ZU27DR	8	14	3U VPX	Applications include EW, SIGINT, radar and multifunction comms; 8-channel DAC provides 10 Gsps w/ DUC.
Zynq Ultrascale+ RFSOC ZU27DR	8	14	3U VPX	RFSOC feaures 8 integrated ADCs at 4Gsps, 8 DACs at 6.4 Gsps, a user-programmable FPGA fabric, and multi-core Zynq ARM® processing subsystem.
EV12DS460A	1	10	FMC+	Suited for applications where low latency high bandwidth sampling are the driving requirements such as DRFMs; one 10-bit D/A channel at 6 Gsps.
Zynq Ultrascale+ RFSOC ZU27DR	8	14	3U VPX	14-bit 6.5/10 Gsps DAC; on-board microcontroller accessible via USB. Also available in XMC format as ADM-XRC-9R1.
Jariet Technologies Electra-MA	2	10	FMC+	Targeted at demanding applications requiring direct sampling frequency coverage anywhere from 0.1 to 36 GHz, and/or wide instantaneous bandwidths.
Xilinx Zynq UltraScale+ RFSoC: ZU27DR, ZU28DR, or ZU47DR	4	14	FMC+	Operates as a standalone "brick" that is 1/3 smaller and lighter than 3U VPX, or pair with 3U or 6U Baseboard for additional processing.
Two Gen 3 Zynq UltraScale+ XCZU43DR RFSoCs	8	14	3U OpenVPX	Supports third party/customer-designed Analog Interface Cards for direct RF digitization, or filtering/amplification, or analog tuning for digitization of higher frequency signals.
Xilinx Zynq UltraScale+ RFSoC: ZU25DR, ZU27DR or ZU47DR	4	14	3U OpenVPX, Air and Conduction cooled	Standalone 4-channel transceiver with processing capabilities and NVMe storage on board.
Analog Devices AD9082 MxFE	4	16	3U OpenVPX - SOSA aligned, Air and Conduction cooled	X-band capable 4-channel transceiver with quad 12-bit 6 Gsps ADC, quad 16-bit 12 Gsps DAC and Virtex UltraScale+ FPGA VU9P/VU13P
TI DAC12DL3200	2	12	3U OpenVPX, Air and Conduction cooled	Ultra low latency Wideband 2-channel DRFM with Virtex UltraScale+ FPGA VU9P/VU13P
Zynq ZU43 RFSoC	4	14	PCIe/standalone	DAC 10.0 Gsps; ultra-low-jitter PLL; 30 dB of variable, front-end gain; Xilinx Zynq RFSoC FPGA and dual ARM; 200 Gbps digital I/O.
EV12DS460A	2	12	3U VPX, -55°C to +71°C (conduction cooled)	Stand-alone or peripheral solution with a user-programmable Kintex UltraScale KU115 FPGA and ZU4 MPSoC. Ultra-low-latency DAC.
*	*	*	XMC, either 0°C to 50°C or -40°C to 71°C (air cooled)	User-programmable Kintex-7 325T FPGA. 16 bit, 250 Msps version available, as are FMC versions.
AD9361 RFIC	2	12	3U VPX, -40°C to +71°C (conduction cooled)	SOSA-aligned Software Defined Radio based on NITM USRP E320. Supports industry-standard user-programmable SDR development. 2x2 MIMO, 56 MHz IBW.
AD9081	4	16	FMC	Quad 16 bit 12 Gsps DAC; features an 8-lance 24.75 Gbps JED204C transceiver port.
*	*	*	FMC+	2.5 Gsps to 3.1 Gsps sampling rate (Other sample rate options available)
AD9172	2	16	FMC	Dual Channel 3.0 Gsps 16-bit DAC, 12 Gsps in Interpolation Mode.

DIGITIZER AND MULTIFUNCTION RF BOARDS

PRODUCT NAME or MODEL NUMBER	ADC MODEL	A/D CHANNELS	A/D BITS	ENOB	SAMPLE SPEED	INPUT BANDWIDTH
GaGe by Vitrek, LLC; Poway, CA, USA; +1 800-567-4243; www.gage-applied.com						
EON Express	*	1 or 2	12	8.7	6 Gsps or 3 Gsps	1.75 GHz
RazorMax Express	*	2 or 4	16	11	1 Gsps or 500 Msps	700 MHz
Razor Express	*	2 or 4	16	11.7	200 Msps	125 MHz
Interface Concept; Quimper, France; +33 298 573 030; www.interfaceconcept.com						
IC-ADC-FMCPa	*	4	14	9.6 (Fin dep.)	2.6 / 3 Gsps	10 MHz - 4 GHz
IC-ADDA-FMCa	ADC12d1600	1	12	*	3.2 Gsps	2.2 GHz
IC-ADC-FMCd	Dual AD9652	4	16	10.8 to 12.0 (Fin dep.)	80 to 310 Msps	400 MHz
Mercury Systems; Andover, MA, USA; +1 978-256-1300; www.mrcy.com						
5553	Zynq UltraScale+ RFSoC Gen 3 Processor	8	14	*	4 Gsps	5 GHz
DCM3220	ADC12DL3200	2	12	8.5 bits @ 1.5 GHz	6.4 Gsps	2 GHz
52141	ADC12DJ3200	1	12	*	6.4 Gsps	7.9 GHz
Sundance DSP; Reno, NV, USA; +1 775-827-3103; www.sundancedsp.com						
FMCP-ADC3p0	AD9208 (pin compatible with AD9689)	4	14	9.6	3 Gsps	5 GHz
FMC-DAQ2p5	ADC12J2700	1	12	8.8	2.7 Gsps	1.8 GHz
VadaTech, Inc.; Henderson, NV, USA; +1 702-896-3337; www.vadatech.com						
AMC589C	AD9208	4	14	*	3 Gsps	6 GHz
VME599	ADC12DJ3200	2 or 4	12	*	6.4 or 3.2 Gsps	*
VPX596	ADC12DJ3200 or ADC12DJ2700	2	12	*	6.4 Gsps	*

KEY: DIGITIZER AND MULTIFUNCTION RF BOARDS

MODEL
Product name or model number=

ADC MODEL
Specific analog-to-digital converter model number

A/D CHANNELS
Number of analog-to-digital channels

A/D BITS
Number of analog-to-digital bits

ENOB
Effective number of bits

SAMPLE SPEED
Sample speed in MHz or GHz
Msps = mega samples per second
Gsps = giga samples per second

INPUT BANDWIDTH
The input bandwidth in kHz, MHz or GHz

DAC MODEL	D/A CHANNELS	D/A BITS	FORMAT	FEATURES
*	*	*	PCIe	6 GBps continuous data streaming rate; eXpert FPGA or CUDA processing options; 8 GB onboard RAM
*	*	*	PCIe	6 GBps continuous data streaming rate; eXpert FPGA or CUDA processing options; 8 GB onboard RAM
*	*	*	PCIe	2 GBps continuous data streaming rate; eXpert FPGA or CUDA processing options; 16 GB onboard RAM
*	*	*	FMC - VITA57.1/57.4	SMP-Lock / 50Ω AC coupled, 2* Clock inputs, Clock source : ext. or FPGA.
AD9129	1	16	FMC - VITA57.1	ADC: 2 channel option @ 1.6 Gsps per channel; 5.7 Gsps DAC; SSMC connectors.
AD9142A	8	16	FMC - VITA57.1	SSMC coax jacks / 50Ω AC coupled, Clock & Trig inputs, Clock source : onboard, ext. or FPGA.
Zynq UltraScale+ RFSoC Gen 3 Processor	8	14	3U VPX	Zynq UltraScale+ RFSoC Gen 3 Processor, SOSA aligned, Dual 100 GigE UDP interface, 4, 1.5 GHz ARM Cortex-A53, 2, 600 MHz ARM Cortex-R5: 600 MHz, DDC and DUC, Navigator® board support package and FPGA design kit support
*	2	12	3U VPX	Conduction Cooled Configurable, low-latency, coherent 3U OpenVPX module for SWAP constratined environments - 2Rx + 2Tx, V67 Rear I/O. One Xilinx Virtex® Ultrascale+™ VU9P and one Ultrascale+ ZU11EG.
DAC38RF82	2	14	3U VPX	Kintex UltraScale FPGA, Navigator® board support package and FPGA design kit support.
*	*	*	FMC+	AC coupled differential (or single ended as a build option) input module, without input balun. Trigger and external clock input connectors are available on the module.
AD9136	2	16	FMC	High Pin Count (HPC) FMC module with a single 12-bit ADC @ 2.7 Gsps and dual 16 bit DAC @ 2.8 Gsps; 4 differential low-speed lane and 10 single ended IO. LM95233 for ADC temperature monitoring.
AD9162 or AD9164	4	16	AMC	Onboard, re-configurable UltraScale+TM XCVU13P FPGA that directly interfaces with ADC/DAC and a single bank of DDR4 memory channels (64-bit wide for a total of 8 GB).
*	*	*	VME	Onboard, re-configurable UltraScale+TM XCKU115 FPGA that directly interfaces with ADC and three banks of DDR4 memory channels.
AD9162 or AD9164	2	16	VPX	Onboard Kintex UltraScaleTM XCKU115 FPGA that directly interface with ADC/DAC and two banks of 64-bit wide DDR4 memory channels with a total of 16 GB memory.

DAC MODEL
Specific digital-to-analog converter model number
D/A Channels
Number of digital-to-analog channels

A/D BITS
Number of digital-to-analog bits

FORMAT
If circuit card, 6U, 3U, PMC, XMC or component package type

AMC = Advanced Mezzanine Card
FMC = FPGA Mezzanine Card
PCIe = Peripheral Component Interconnect Express
VME = Versa Module Europa
XMC = Switched Mezzanine Card

FEATURES
Other functionality or options.

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

Electromagnetic Protection (Part 4)

Pulse Compression by Barker Code

By Dave Adamy

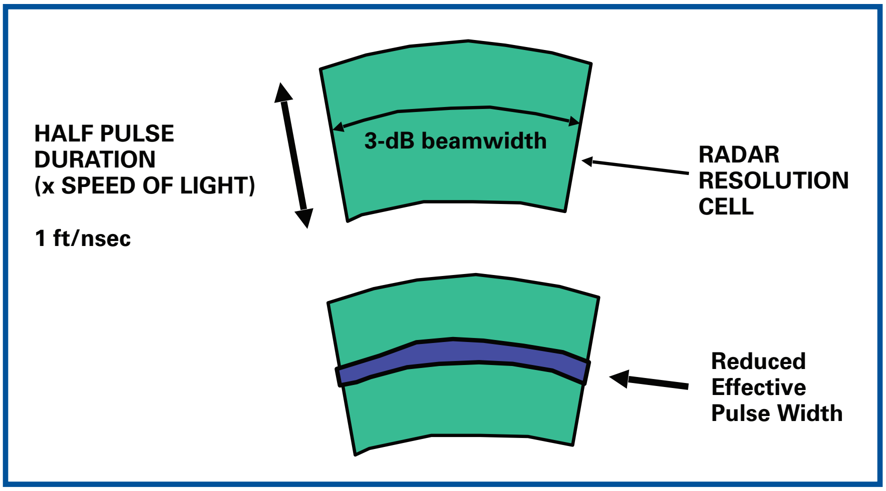

Fig. 1: *Pulse compression using the Barker code technique reduces the pulse duration after processing to the duration of one bit of the code.*

BARKER CODE

Last month, we discussed the pulse compression technique, linear frequency modulation on pulse (LFMOP). A second pulse compression technique is the application of a binary phase shift keyed (BPSK) modulation over the duration of the pulse. The ideal code is the Barker code. However, this code cannot have more than 13 bits.

The Barker code has ideal correlation characteristics. Longer codes can be used and will provide the same befit with proper thresholding. Even though another code can be used, this technique is still called "Barker code."

Figure 1 shows the radar resolution cell for a normal pulse (i.e., one-half of the pulse duration x speed of light in depth and the 3-dB beamwidth in width). The dark blue portion of the lower sketch shows the resolution cell if the Barker code technique is applied. The Barker code pulse has a resolution cell with depth equal to the duration of one bit of the code multiplied by the speed of light.

The pulse with the BPSK code is transmitted and brings the full energy of the pulse to the target. But when it is returned from a target, it is passed to a tapped delay line assembly as shown in Figure 2. The delay line has one tap for each bit in the code. In this case, the code is a true seven-bit Barker code, so there are seven taps. In Figure 3, the pulse is exactly aligned with the delay line. The bits that are 180° shifted are denoted as "-", while the unshifted bits are denoted as "+". The taps in the delay line are shown in Figure 4. Note that when the code exactly fills the delay line, the phase-shifted bits are shifted another 180°. This brings the summed output to full

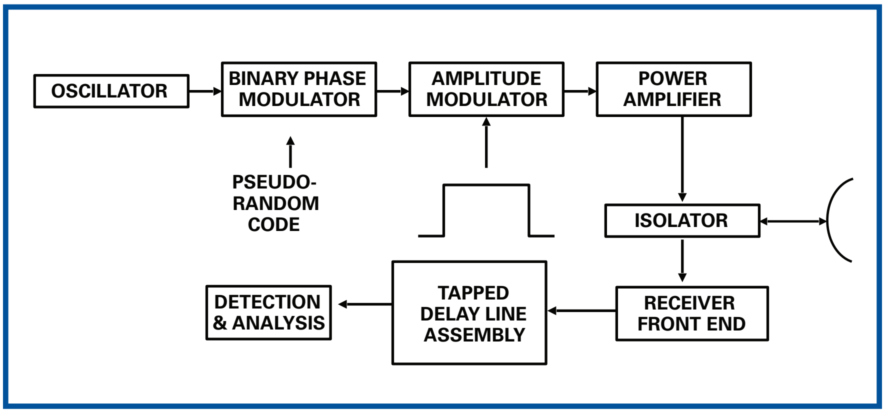

Fig. 2: *When a "Barker coded" pulse return is received by the radar, it is passed through a tapped delay line assembly.*

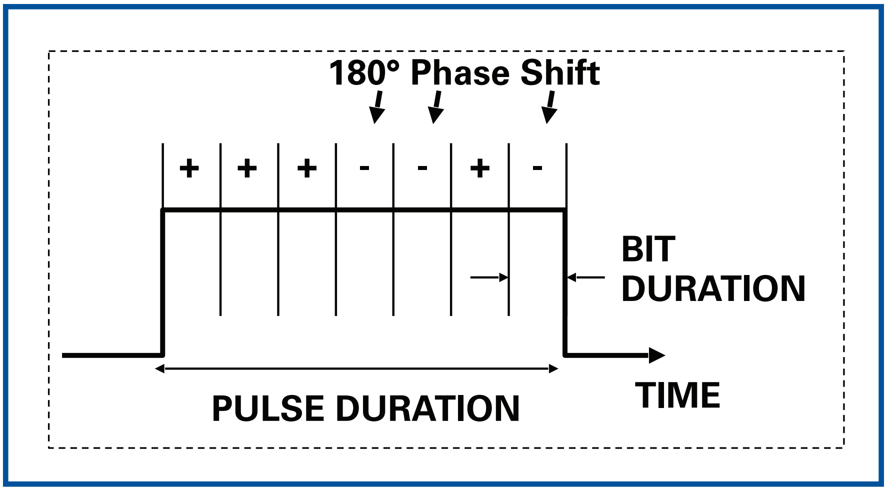

Fig. 3: *The digital signal on the pulse is a binary phase shift keyed (BPSK) code that fills the whole pulse duration. This figure shows a seven-bit Barker code. Much longer codes can be used. A "+" symbol means the bit is not phase shifted, and a "–" symbol means that the bit is shifted 180°.*

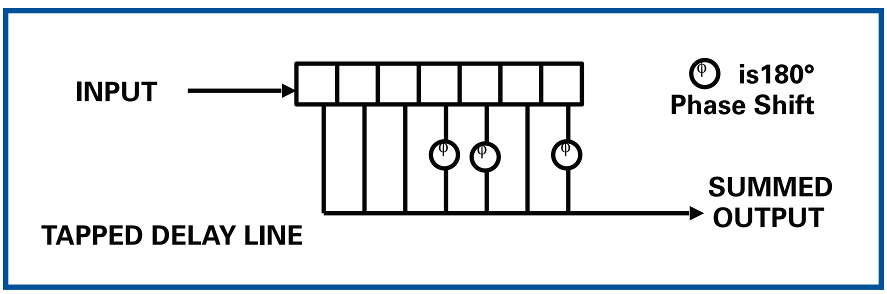

Fig. 4: *When the pulse exactly fills the delay line, the taps for the phase shifted bits are shifted another 180°, causing the summed output to have the full amplitude – in this case, seven. If the pulse does not exactly fill the delay line, the summed output value is either 0 or -1.*

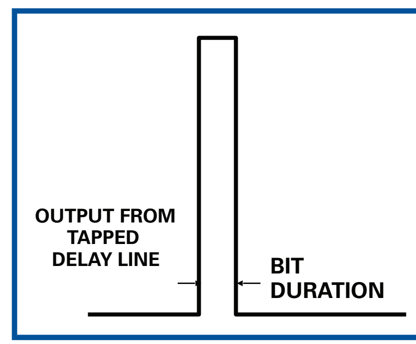

Fig. 5: *The output of the delay line assembly is a pulse that is only as wide as the duration of one bit of the code.*

value (in this case 7), but only during the time that the pulse exactly fills the shift register.

Consider the characteristics of a true Barker code. If the unshifted bits are assigned a value of 1, and the shifted bits are assigned a value of -1, the register tap values will add to the number of bits. However, if the code is not exactly aligned with the register, they will add to -1 or 0. For longer codes (which are not Barker codes) there will be other times when the bits will add to larger numbers (but can be designed to be well short of the value of the number of bits in the code). This can be subjected to a threshold to allow only the maximum value output to be considered. Thus, the output of the shift register will be only a pulse with the duration of one bit of the code, as shown in Figure 5.

JAMMING A BARKER-CODED PULSE RADAR

If a jamming pulse does not have the Barker code digital modulation, it will not be compressed by the tapped delay line. Thus, it will be weaker by the number of bits in the code (after processing) in the summed output of the delay line taps. **Figure 6** shows the Barker-coded pulse in black along with the non-Barker coded jamming pulse in blue. The jamming-to-signal ratio (J/S) is reduced by the ratio of the number of bits. Since open-source literature mentions that there can be up to 1000 bits in the compression code, the post-processing J/S can be reduced by up to 30 dB, unless the jammer has the same code BFSK modulation.

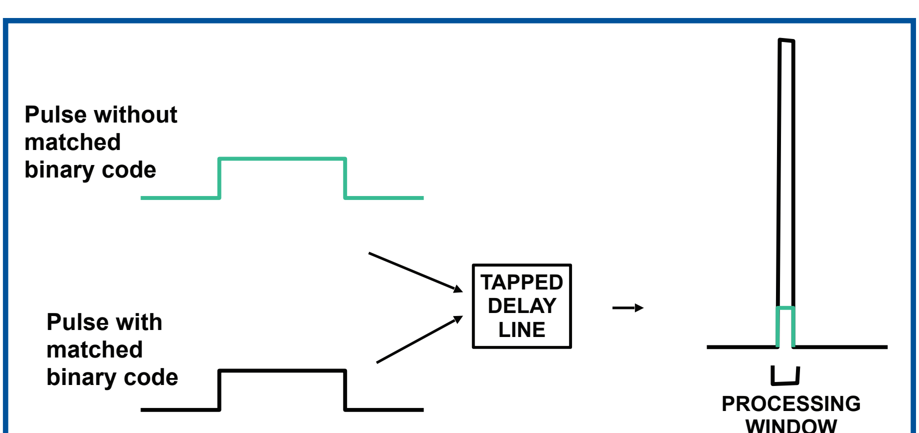

Fig. 6: *If a jamming pulse does not carry the binary code, its power leaving the delay line is reduced by the factor of the number of bits in the code – which can be as many as 1000. This reduces the power of the jammer by 30 dB.*

The technique for avoiding this loss of J/S involves the use of a digital radio frequency memory (DRFM) in the jammer. The DRFM analyzes the first pulse it sees and causes all following pulses to have the same Barker code. This means that the incorporation of a DRFM in a jammer can avoid up to 30 dB of J/S loss. This will be discussed in detail in a later column.

WHAT'S NEXT

Next month, we will continue our radar electromagnetic protection discussion by considering monopulse radars. Dave Adamy can be reached at dave@lynxpub.

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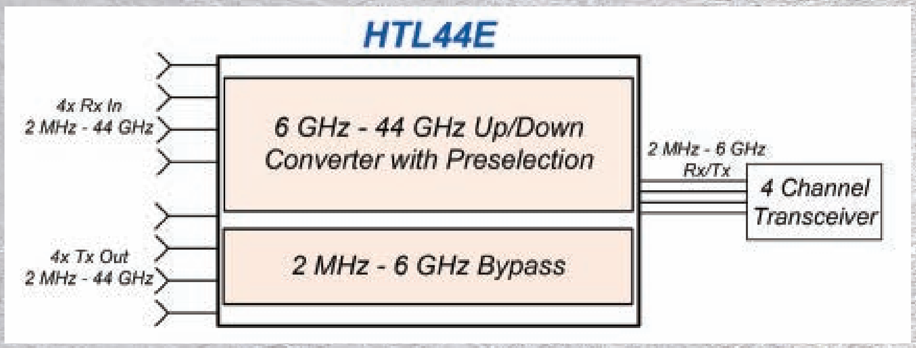

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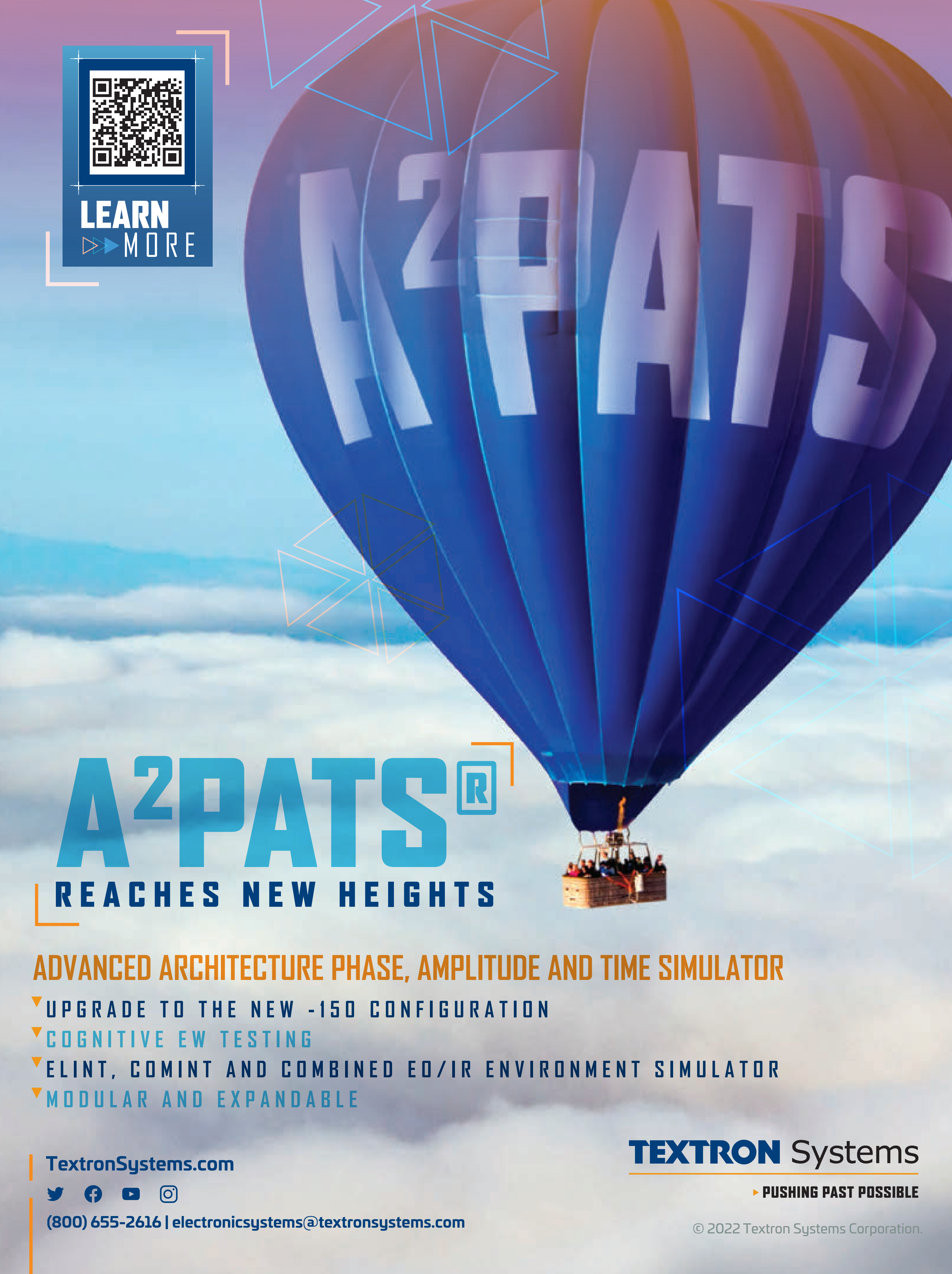

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