June 2021 Vol. 44, No. 6

ASSOCIATION OF OLD CROWS

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JED

Journal of Electromagnetic Dominance

Signal Recorders: Capturing the EMS

- Technology Survey: Airborne EW Suites
- News: Tremper Says DOD Must Prioritize EP
- EW 101: 5G Comms – Antenna Performance at mmW Frequencies

JED
Journal of Electromagnetic Dominance

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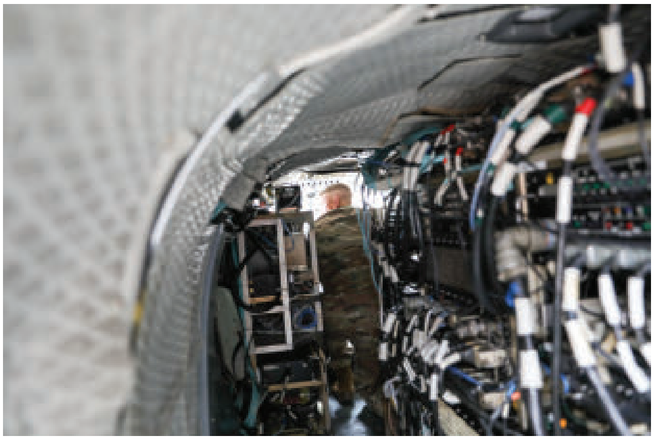
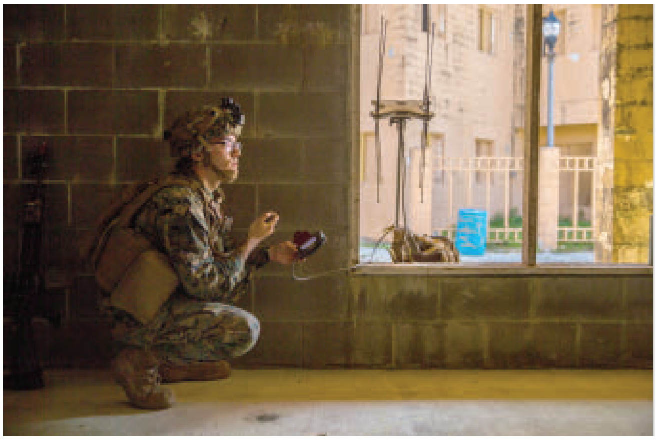


Signal recorders play an important role in capturing the large amounts of signal traffic collected by SIGINT platforms, such as the RC-12X (pictured above). 501ST MILITARY INTELLIGENCE BRIGADE

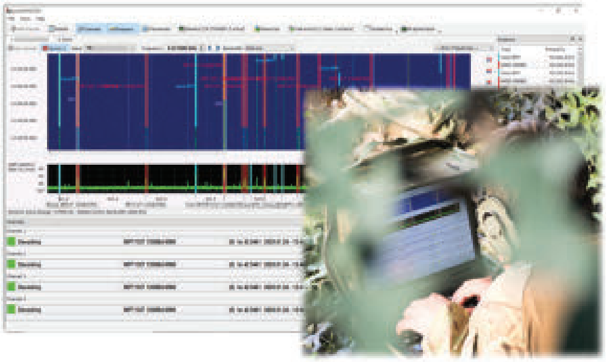


USMC LCpl Austen Brannen, a communication intelligence electronic warfare operator with Marine Air-Ground Task Force Company, 2nd Radio Battalion (2nd Radio Bn.), II Marine Expeditionary Force Information Group, II Marine Expeditionary Force, sets up a Wolfhound direction-finding "satellite" during a field exercise conducted at Camp Lejeune, NC, in April. 2nd Radio Bn. conducted FEX III, their culminating field exercise of their company training continuum, in order to maintain the Marine's tactical and technical skills. USMC PHOTO BY CPL HALEY MCMENAMIN

COVER PHOTO COURTESY OF US NAVY

Prosecution of V/UHF Trunked Speech Networks in Tactical ES Operations ...don't forget 'the Oldie'!

By Chris Slack
Field Ops Specialist PROCITEC GmbH



Operator of Light-ES system using integrated go2SIGNALS capabilities to prosecute local P/LMR networks

Global V/UHF Professional/Land Mobile Radio (P/LMR) network usage reached a milestone in 2017 when, for the first time, the number of trunked V/UHF digital-speech networks exceeded the number of trunked analogue-speech networks. Our global customers' Tactical Electronic Surveillance (ES) Teams are now confident in the techniques and procedures needed for efficient prosecution of V/UHF Digital Speech networks to deliver ES-derived I&W for SA.

For example, during recent field-ops with one of our equatorial customers, I happily noted that their ES-Teams are now using our wideband go2SIGNALS automatic signals exploitation capabilities integrated into their Light/Mobile ES Systems to successfully prosecute potentially adversarial V/UHF Digital Speech networks which are using DMR, dPMR, NXDN, APCO-25, Tetra, Tetrapol (and other) protocols, which is obviously good news.

However, I also quietly noticed the ES-Teams' lack of awareness of a specific legacy V/UHF Trunked Radio protocol which is still in use globally, which was a principal SOI during their ongoing ES operations, and which uses a digital Downlink to control and manage its analogue 'clear-speech' Uplinks.

The ES-Teams were incorrectly logging and reporting these analogue trunked clear-speech Uplink emissions as Line-Of-Sight Point-To-Point FM Push-To-Talk (PTT) Clear-Speech emissions, without reference to or knowledge of the specific protocol's real trunked-network architecture and its use of a cellular digital broadcast control channel Downlink to control and manage the clear-speech Uplinks.

I realised that their lack of awareness was because the ES-Teams were, understandably, much more familiar with the prosecution of standard V/UHF FM-PTT 'walkie-talkies' which enable the user themselves to select channels on their hand-held/mobile transceivers (via their transceiver's keypad or rotary 'channel' switch), and which the ES-Teams had prosecuted persistently during deployed operations over the past two decades.

When I'd explained my observations to the ES-Teams, I was asked for further detail and to deliver a related Training Package, so I've put this article together for wider publication to inform other ES-Teams also. The protocol in question is known as 'MPT-1327' – let's take a closer look:

HISTORY AND PRESENT-DAY

The MPT-1327 trunked radio protocol originated in the UK in the 1980s ('MPT' stood for 'Ministry of Posts and Telegraphy', which shows how old the protocol is!).

MPT-1327 is a standard for V/UHF trunked P/LMR systems for communication between a Trunking System Controller (TSC) via its cellular Base-Stations (BSNs) and the users' mobile 'Radio-Units' (RUs - usually handheld or vehicle-mounted transceivers). These Radio-Units use a 'Push-To-Talk' switch, which is why there was confusion within the ES-Teams when prosecuting these MPT-1327 networks 'on-air'. Also, when viewed at-range through optical-sights, the ES-Teams saw that the MPT-1327 Handheld Transceivers (HTs) looked very similar to cheap analogue 'walkie-talkies', which added to the Teams' confusion.

Worldwide users of MPT-1327 networks include taxis, dispatch services, hospitals, and (more importantly within our CEMA domain) security, military and paramilitary entities, especially (but not exclusively) those in Less-Developed Countries.

New MPT-1327 systems continue to be marketed by vendors to their public and private-sector customers due to their perception of cost-effectiveness and ease of network installation when compared to digital networks.

Of note, MPT-1327 networks enable connection of the user's Radio-Unit to regional Public Switched Telephone Networks (PSTNs) so that the user of the Radio-Unit can make and receive calls to and from landline, cellular and satellite telephones.

'MULTIMODE' PMR TRANSCEIVERS

Recent interest in the prosecution of MPT-1327 networks by Light/Mobile ES-Teams has increased dramatically due to some P/LMR manufacturers' integration of MPT-1327 protocol into their new digital-speech (e.g. DMR or APCO-25) transceiver models.

Termed 'Multimode', these P/LMR transceivers use MPT-1327 as a 'fallback' mode to enable long-range trunking via locally available MPT-1327 networks in the absence of DMR or APCO-25 trunked networks. Examples of these new 'Multimode' Handheld Transceivers include the Tait TP9300 series and the Hytera X1P model, both of which support DMR and MPT-1327 modes.

So, to the ES-Teams out there – don't forget 'the Oldie'!

This is an extract. The full article is available at www.procitec.com/mpt1327article.

The Author

Chris is a former CESM Mission Supervisor with the Royal Navy, deploying on surface/sub-surface platforms and to land/littoral operations in support of UK and NATO operational objectives. His final operational deployment was to Asia as a Radio Reconnaissance Team Leader with 30 Commando (IX) Group.More recently, Chris has contributed to the development and rollout of various Tactical-CEMA systems and capabilities in UK, USA, Australia and EU.

HOME vs. AWAY

It's budget season in Washington, DC – albeit an extended budget season. As this issue of *JED* went to press, the DOD was expected to deliver its FY2022 budget to Congress by May 22, which is about three months later than usual. Regardless of the amount the DOD asks for, Congress will debate the DOD's request, add money to some budget lines and remove money from others. As Congress debates the DOD budget, there will be arguments over the cost and viability of certain programs, and there will be arguments over the size of the DOD budget itself – some will say the budget request is too expensive and others will say the DOD is not asking for enough. This is all part of an annual process. And there will inevitably be those who trot out the argument (specially reserved for this time of year) that the US defense budget is larger than the next 10 countries combined.

Whether this figure is accurate or not, it is a meaningless statistic. The DOD budget is tied to the US defense strategy, which is tied to US grand strategy. No other country, including any of the next 10 highest defense spenders, has the same resources as the US military and shares the same commitment to global power projection. Some of these countries, such as Russia and China, are mainly focused on projecting power into their region. A few of the others (mainly European NATO members) may aim to deploy a small portion of their military for global and regional power projection operations, and the rest focus primarily on defending their borders.

I mention this because each of these countries has its own EMS strategy (formal or informal) that is tailored to meet its national military strategy. For the most part, their EMS strategies, are focused on playing a "home" game, with a very limited capability to play an "away" game (i.e., projecting power beyond their immediate neighborhood). For these "home" games, their EMS strategies do not need to be very sophisticated, as they can rely on internal and redundant (wired and wireless) lines of communications. Russia and China are example of countries that are primarily focused on regional power projection, and their EMS strategies are tailored for this. The UK, France and Germany must be capable of deploying a small number of forces globally (to Afghanistan or Northern Africa, for example).

Finally, there is the US, which has spent the decades since World War II tailoring the bulk of its forces (including Guard and Reserves) to achieve global power projection. In the 21st Century, this makes the US extremely dependent on using the EMS, as well as space and cyberspace, to execute its military plans. Without access to and control of the EMS, the US cannot fulfill its National Defense Strategy or its grand strategy. This is pretty obvious to many EMS professionals. As budget season approaches, however, it's worth remembering that US grand strategy is predicated on always playing an "away game," while most other nations are primarily focused on playing a home game. If the US Congress doesn't resource global power projection, which inherently depend on its EMS strategy, it can't expect to win away games. – *J. Knowles*

JED
Journal of Electromagnetic Dominance

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Calendar *Conferences & Courses*

JUNE

Land Forces 2021
Conference: June 1-3
Brisbane, Australia
www.landforces.com.au

AOC Virtual Series Webinar: Introduction to Direct Energy Weapons
June 3
1400-1500 EST
www.crows.org

International Microwave Symposium (IMS 2021)
Conference: June 7-10
Virtual Event: June 20-25
Atlanta, GA
www.ims-ieee.org

AOC Professional Development Live Web Course: C4ISR Requirements, Principles, and Systems
June 7-30
www.crows.org

Basic EO-IR Concepts
June 15-17
Las Vegas, NV
www.pe.gatech.edu

Adaptive Arrays: Algorithms, Architectures and Applications
June 15-18
Las Vegas, NV
www.pe.gatech.edu

AOC Virtual Series Webinar: Aircraft Combat Survivability and Radar Cross Section (RCS)
June 17
1400-1500 EST
www.crows.org

Basic Radar Concepts
June 22-24
Las Vegas, NV
www.pe.gatech.edu

Test and Evaluation of RF Systems
June 22-24
Las Vegas, NV
www.pe.gatech.edu

Fundamentals of Radar Signal Processing
June 22-25
Las Vegas, NV
www.pe.gatech.edu

AOC Virtual Series Webinar: What SOSA Means to the Warfighter
June 24
1400-1500 EST
www.crows.org

AFCEA West Conference and Exhibition
Virtual Conference: June 29-30
www.westconference.org

JULY

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

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

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

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

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

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

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

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

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

AUGUST

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

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

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

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

Modern Electronic and Digital Scanned Array Antennas
August 16-20
Las Vegas, NV
www.pe.gatech.edu

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

36th Space Symposium
Conference: August 22-26
Colorado Springs, CO
www.spacesymposium.org

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

Electronic Warfare Data Analysis – Online
August 24-27
www.pe.gatech.edu

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

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

SEPTEMBER

MSPO 2019
Conference: September 7-10
Kielce, Poland
www.targikielce.pl

Modern Threats: Surface-to-Air Missile Systems Conference 2021
Conference: September 14-16
Redstone Arsenal, AL
www.crows.org

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

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

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

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

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

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

crows.org/FromtheCrowsNest

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

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

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President's Message

WHAT FUTURE FUNDING MAY HOLD FOR EMSO

Out of curiosity, I decided the other day to take a look at a few websites (Market Watch, Yahoo Finance, Fortune Business Insights, and others) on the future global EW market. I found the predictions interesting and, I think, good news: expected growth of about 5%. I was not surprised to see that North America is expected to spend the most on EW through 2027, but I thought it was interesting that Asia is expected to see the most growth. Globally, nations appear to be putting more resources into the Spectrum, EW and Cyber.

One noteworthy estimate said that EW spending will be fairly evenly spread across the three pillars of EW (ES, EA and EP). Another interesting point is the expected dispersal of EW spending amongst domains of land, maritime, and air – but space is visibly absent.

There are a number of opportunities and challenges that the EMS industry faces to meet the needs and capabilities of the warfighter. Here are some of the characteristics that are cited, and most should be of no surprise. Cost is a major factor when developing and producing EW Systems; we need to work to make EW capabilities more affordable. Today and in the future, systems must be integrated, as they are needed to sense, decide, respond and protect in the modern EMS environment. Artificial Intelligence (AI)/Machine Learning (ML), and cognitive EW technologies that can adapt to the dynamic and ever-changing EMS environment are needed. Networked systems that have the ability to work together across domains and assets to put the appropriate effect in the right place at the right time. The need to operate in a congested and contested complex environment is still at the forefront, ensuring that we ensure the freedom of maneuver of friendly forces in the EMS while limiting an adversary's ability to do the same. As systems continue to miniaturize; size, weight and power will be a challenge, while ensuring that they bring the desired effects to the Electromagnetic Battlespace and Maneuver Space. Cyber systems will also see growth and the desire and need to interweave capabilities and effects with EW and the EMS. The inclusion of these capabilities on unmanned assets will also continue to grow both in numbers and capabilities.

EW, EMSO, Cyber and Information are needed and will continue to be major players in symmetrical and asymmetrical conflicts. I also expect to see an increase in Space assets, especially with more nations looking to operate in that domain.

I continue to see progress in returning to normal, as I continue to visit folks virtually and to visit others in person. I want to once again highlight our AOC Awards Program: please nominate your best and brightest, by June 30, 2021, so that they have a chance to be recognized by their peers, fellow Crows and the AOC. – *Glenn "Powder" Carlson*

DOD MUST PRIORITIZE EP TO ACHIEVE EMS SUPERIORITY

During the AOC 2021 Virtual EMS Summit in April, Mr. David Tremper, SES, EW Director, OUSD(A&S)/A/P&WPM, spoke to the Electromagnetic Warfare (EW) challenges currently facing the DOD at the force level. Tremper particularly noted the insufficient focus on Electromagnetic Protection (EP) within DOD EW, which contributes to and intensifies today's major Electromagnetic Spectrum Operations (EMSO) challenges.

Tremper said, "[EP] happens outside the purview of the DOD EW community, and very often the way we learn about EP features is when they fail operationally and they show up back in our office [in need of a solution]."

"Passive sensing and netted passive sensing is becoming more and more important every day because the more we emit, the more we become targets," Tremper said. "So we have this conundrum that we can either emit high-power signals to get exquisite battlespace awareness, or we can turn off those emissions and protect ourselves from passive targeting."

"There has been a recognition, as we have talked about connective tissue across spectrum systems, spectrum programs and the acquisition of spectrum capabilities, that EP has been falling through the cracks," he said. "The textbook defines EW as including EP, but the way that we [at DOD] manage EW, EP is not a part of EW. It's in the other spectrum-using systems."

The challenge is not, however, confined to acknowledging the importance of EP within the DOD, according to Tremper. It lies also in creating a firm understand throughout the department of *what* EP means.

Tremper said, "In the Department, I took for granted that people understood what the term 'electronic protection' meant, and what I have discovered is that… the perception is that electronic perception means platform protection. Platform protection is actually what we would call defensive electronic attack."

Electronic Attack (EA) and Electronic Support (ES) are currently the focus of DOD EW capability and systems development, according to Tremper. The onus of EP management, however, has been placed on non-EW RF system developers.

The DOD must, Tremper said, begin prioritizing and taking ownership of EP in order to ensure spectrum using systems (radar, communications, GPS, IFF, etc.) can function properly in a congested and contested EMS before they are fielded. Indeed, the entire concept of EMS superiority is dependent upon effective EP, according to Tremper.

"When we talk about EM Dominance and we talk about EM Superiority, Electronic Protection is critical. It's critical that all of our spectrum-using systems are capable and superior and can maintain resilience within a complex EMS environment."

Tremper noted that there are five "levels" to ensuring EMS system survivability. The first, awareness, was satisfied in 2018, according to Tremper, with the 2018 JCIDS Manual of Operations, which outlines the importance of EMS survivability. The second level, advocacy, was achieved through the publication of the latest EMS Superiority Strategy (EMSSS), which maintains a focus on EMS survivability.

The next three levels include verifying EMS systems are survivable via thorough, representative testing; enforcing survivability requirements via authority streamlined processes, actionable assessments and punishable non-action; and achieving survivability in systems and operations. Each of these remaining three levels cannot be achieved without DOD involvement in and understanding of EP, he said.

Artificial Intelligence (AI) and Machine Learning (ML) technology can assist in bolstering EP, according to Tremper, but that contention comes with its own set of complications. While AI and ML technology may allow for more effective EP capabilities in fielded platforms and systems, that technology depends heavily on acquiring real or realistic data from specific EM operating environments that is needed to train the AI-based systems. That EMS data is a commodity that's difficult to acquire in theater and slow to synthesize in training settings.

These data acquisition issues, however, are actively being addressed by industry through a variety of methods. One of the more promising techniques, according to Tremper, is the use of "operationally deployed digital twins as training environments for algorithms."

These digital, or "virtual," twins are AI-based systems deployed parallel to (and often physically collocated with) an operational radar or communications system, for example. The digital twin performs the same functions as the actual system, but in a virtual mode – without effecting any changes to their environment or connecting with other systems in on the weapons platfom. A virtual twin acts, Tremper said, as a "petri dish for new technology," by creating an environment where a learning algorithm can be "parked" to have access to all sensor data and operators' interactions with that data. This allows the virtual twin to learn while it's actively deployed rather than in a test or training setting.

The usefulness and viability of the virtual twin concept is that the "twin" system does not, at any time, have direct access to the weapons system. "It can build a firewall away from the combat system that allows it to avoid…the information assurance requirements that would be levied on it if it showed up in the combat system," Tremper said.

The process for getting approval to alter or add to a weapons system is lengthy and onerous, which makes virtual twins ideal, according to Tremper. A virtual twin is incapable of controlling a weapons system but can still see the information available to that system, effectively "firewalled" from combat capabilities. This allows an algorithm to be used and altered in the field as needed, rather than going through an approval process for each algorithmic change.

"When you think about that in terms of acquisition, it flips our acquisition process on its head," Tremper explained. "There's a possibility that the way we acquire AI and ML is not that we train it in a lab… with a bunch of computers, but that we deploy it – that we deploy untrained algorithms right at the beginning, and they learn 24/7, in the field, using real data, real operations, as a mechanism to achieve operator-level proficiency and beyond." – *H. Swedeen*

US ARMY AWARDS CIRCM FULL-RATE PRODUCTION CONTRACT TO NORTHROP GRUMMAN

On April 30, the US Army awarded Northrop Grumman Corporation (Rolling Meadows, IL) a $959.1 million, five-year, indefinite delivery/indefinite quantity (IDIQ) production contract for Common Infrared Countermeasures (CIRCM) systems. The contract provides justification and approval for the purchase of up to 596 CIRCM B-kit units over the contract period.

The CIRCM system uses advanced Quantum Cascade Laser (QCL) technology to protect US Army rotary-wing and medium fixed-wing aircraft against IR-guided missile threats. Speaking at a virtual media roundtable last month, LTC Preston Pysh, Product Manager for ASE Countermeasures within Program Manager Aircraft Survivability Equipment (PM-ASE), described the process: "CIRCM receives a handoff from the aircraft's missile warning system (MWS) which then provides the defeat capability (laser targeting) to the missile. Although the aircrew is notified of the systems' actions, they [the MWS and CIRCM systems] work together autonomously and do not require crew interaction."

Added COL Kevin Chaney – PM-ASE Program Manager, "From a strategic perspective, CIRCM fits in as part of our layered-protection approach. In combination with the MWS, it's a layered detect-and-defeat capability." Although active IR countermeasure systems, such as the Advanced Threat IR Countermeasures (ATIRCM) system, have been available on other, larger aircraft for some time, Chaney pointed out that "CIRCM is important because we didn't have that defeat capability on our smaller aircraft, which required a lighter-weight solution. Instead, these aircraft had to rely exclusively on flares. Now, in combination with the MWS, we have a layered detect-and-defeat capability with both CIRCM and flare combinations. The arrival of CIRCM will also now allow for the phasing out of the legacy ATIRCM systems to help offset costs."

In terms of the program's timeline, as described by Lieutenant Colonel Pysh, it's now moving on from the Low Rate Initial Production (LRIP) phase, which began in September of 2018 and lasted until April of this year. During the LRIP phase, the program successfully completed initial operational testing and evaluation in the Fall of 2019, and achieved a "first-unit-equipped" milestone in February of 2020. "The objectives, as we came out of the LRIP phase," said Pysh, "were really to learn about and evaluate the technical maturation level of both the system, through rigorous testing, as well as the maturation of

The CIRCM system (seen above mounted on top of the fuselage behind the main rotor) was tested on a UH-60 in July 2019 at the US Army's Redstone Test Center (Redstone Arsenal, AL). US ARMY

the production lines at Northrop Grumman and its subcontractors."

Northrop Grumman's Bob Gough, Vice President, Navigation, Targeting and Survivability, pointed to the fact that, "the Army set a very high standard in multiple parameters for getting to the full-rate-production decision. One was the very high-level of performance that had to be demonstrated in multiple free-flight missile tests against very challenging threats. Reliability was also a key determinant – being able to operate under the most extreme vibration, thermal, weather, etc,. conditions. And, proving flexibility was another high standard. Here, one of the key factors was our open architecture design that allows modular software upgrades to rapidly adapt to changes in threat profiles without major system redesign. Northrop Grumman appreciates the importance of setting such high standards, recognizing that lives are at stake here and our system must both work when needed, and it must be delivered on time."

Right now, CIRCM is planned for the Army's "big-three" rotary-wing platforms (Apache, Blackhawk and Chinook), as well as smaller fixed-wing aircraft. Although formal decisions have not yet been made regarding its possible inclusion on Future Vertical Lift (FVL) platforms, such as the Future Long-Range Assault Aircraft (FLRAA) or Future Attack Reconnaissance Aircraft (FARA), Colonel Chaney says he believes CIRCM is being considered along with other possible approaches to ASE. As to which specific fixed-wing airframes will receive the system, that has also not yet been finalized.

The Army is currently fielding the system at multiple locations using a "block-mod" approach. Chaney explains, "As we looked at it, we saw that we had the Limited Interim Missile Warning System (LIMWS) and the CIRCM system coming on line at about the same time, so we took on the challenge to see if we could combine those two system schedules along with other modifications from PEO Aviation, so that we'd only be taking the aircraft out of service one time while installing all of these modifications."

Chaney says there's no particular priority as to which of the big-three platforms will receive the system first. "At the time we did the first-unit-equipped, we were planning for roughly two years to outfit a brigade, but since then, the Army has made some strategic shifts in timelines, etc., so we're now trying to determine the optimal timeline for completion. In particular, we're looking at understanding what kind of impact the use of block-mod will have with the Army's Regionally Aligned Readiness and Modernization Model (ReARMM) going forward." The ReARMM effort is aimed at aligning units across the total Army in a predictable and sustainable life cycle through training, modernization, and mission windows. *–J. Haystead*

US AIR FORCE RELEASES EMS SUPERIORITY STRATEGY

In April, the Department of the Air Force (DAF) published its first EMS Superiority Strategy to guide the US Air Force (USAF) and the US Space Force (USSF) and align these organizations with the DOD EMS Superiority Strategy published in September 2020. The strategy addresses three main goals: 1) establishing organizations; 2) rapidly developing and delivering "agile EW/EMS capabilities; and 3) developing the EW/EMS superiority force for the future."

In the strategy's foreword, Acting Secretary of the Air Force John Roth, Chief of Staff of the Air Force Gen Charles Brown, Jr., and Director of Space Operations Gen John Raymond stated, "As described in Joint Operating Environment 2035 and the 2018 National Defense Strategy, we face serious and accelerating challenges from competitors and adversaries. We must accelerate change or lose. The purpose of this strategy is to articulate how we must do so in the context of the EMS." The foreword also explains that the USAF's Electromagnetic Spectrum Superiority Directorate (HAF/A5L) and the USSF's Chief Strategy and Resourcing Officer (CSRO) will act as the respective Offices of Primary Responsibility (OPR) for each organization and will oversee implementation of the EMS Superiority Strategy. This will include creating an Implementation Plan by September and reporting their progress quarterly.

The tone of the document is very focused on establishing an offensive framework for EMS operations. The introductory section of the Strategy describes some of the reasons why the US and the DOD are losing their competitive advantage in the EMS: "A lack of strategic focus on the EMS, constrained budgets, exponential increases in adversary capabilities, and increased military and civil use of the EMS have led to a contested, congested, and constrained operating environment." Further on, it states, "To overcome these challenges, the DAF will require an overmatching, offensive approach, while continuing to improve its defensive capabilities, to maneuver within the EMS. This approach will force our adversaries to invest heavily to defend their growing reliance on the EMS to achieve offensive capability parity with the United States. Our competitors' and adversaries' dependence on the EMS offers the Joint Force increasing opportunities to exploit new attack vectors throughout the competition continuum. Fielding superior EMS-based capabilities that deny, degrade, or disrupt adversarial situational awareness, their ability to command and control forces, and employ weapons effectively will ensure we maintain a decisive advantage in the EMS. The accurate characterization of the space and terrestrial environment can also provide useful situational awareness of potential degradations or disruptions to adversary capabilities."

The strategy lays out definitions for electromagnetic warfare (EW) and other terms, as well as discussing the role of the EMS in the strategic environment, which includes Great Power Competition; EMS in the competition continuum; and exploding global demand and increasing spectrum scarcity.

The document then dives further into the DAF's three strategic goals in the EMS. The first goal focuses on leadership and organizations. Objectives in this area include unifying DAF-wide EMS Enterprise activities; promoting US and international EMS policies that support DOD capabilities and operations; increasing EMSO leadership; and dedicating intelligence support to the EMS Enterprise.

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ITALIAN NAVY SELECTS ELETTRONICA TO PROVIDE EW SUITE FOR NEW U212 SUBMARINES

The Elettronica Group announced on May 10 that it had signed a contract with prime contractor Fincantieri Group to supply the Electronic Warfare Suite (EWS) for the Italian Navy's new U212 NFS (Near Future Submarine) program. The OCCAR (Organization Conjointe de Coopération en matière d'Armement) agency, acting on behalf of Italian Ministry of Defence, will deliver the U212 AIP (Air Independent Propulsion) submarines. Last February, OCCAR awarded Fincantieri a €1.35 billion contract for the development, construction, outfitting and delivery of the first batch of two new U212 NFS platforms, with options for two additional submarines.

The integrated EWS for the U212 NFS submarines represents the most technologically advanced and innovative answer for operations in the underwater and multi-domain scenarios, said Elettronica, which will develop and provide two suites for the first batch of submarines under the awarded contract plus options for two more systems for subsequent batches. The system design is significant, according to Elettronica, because it requires a very high level of functional integration and is able to perform self-protection, surveillance and intelligence tasks the communications bands to the radar bands.

The EWS features a set of three antennas positioned on top of the submarine's fin (i.e., sail). These comprise an integrated RESM/CESM antenna (integrated onto a non-hull-penetrating mast) that is the result of over two years of studies and simulations in collaboration with the Italian Navy. Another antenna, fitted to a non-hull-penetrating optronic mast, supports radar surveillance and detection functions, while an antenna for the threat warning function is mounted on the sub's periscope mast.

Inside the sub, the antennas feed RESM and CESM receivers, which send their information through an Electronic Warfare Management Unit (EWMU) that integrates the ESM information for further processing and fusion via the sub's combat management system (CMS).

According to Elettronica, this suite provides an integrated picture of the complex electromagnetic scenario in both littoral and blue-water environments to support self-protection, surveillance and intelligence activities at tactical and higher levels. Elettronica hasn't released further details, but such integrated EWS solutions can generally cover a frequency band from 30 MHz to 18 GHz, and can provide very accurate direction-of-arrival performance.

The EWS suite is characterized by a high level of digitization based on its software-defined architecture derived from the company's Zeus and Virgilius families of multi-domain EWS. The ESM receiver also utilize proprietary algorithms exploiting advanced machine learning capabilities.

Based on an evolved U212A AIP design by Fincantieri with an unprecedented level of national industry and technological content, the new U212 NFS boats will feature an enhanced propulsion system and a newly designed combat system centered on a Leonardo combat management system and a suite of advanced sensors and weapon systems, being fitted to launch deep strike cruise missiles and unmanned underwater vehicles. – *L. Peruzzi*

Signal Recorders Their Challenging

By Barry Manz

The ability to fully understand signal behavior in a specific portion of the spectrum over time is crucial for the design and validation of radar, EW, terrestrial and space-based communication, SIGINT and navigation systems. This once required an agglomeration of instruments and associated hardware, but thanks to advances in RF and digital technologies, today's signal recorders can do the same job in much smaller footprints with better performance.

Signals of interest, whether interference, stray emissions from known devices, or an adversary's intentional transmissions, are not easy to capture with traditional measurement tools. These "culprits of interest" are often unpredictable, as there is no way to know when they will occur, where they will appear or how long they will last. To fully understand the true nature of these signals, many seconds, minutes, or even days of recording time may be required to guarantee that all events are captured.

For example, a receiver operating in a congested RF environment occasionally and randomly shows a degraded signal-to-noise ratio. Since the events are random in time, a long-duration spectral recording is required to capture them. As the receiver's frequency may be populated with carriers outside the sampling bandwidth of the signal analyzer, a multi-channel, synchronized recording must be made.

For the Department of Defense, these capabilities are essential. Capturing analog signals from the air, sometimes over broad swaths of spectrum, converting them to digital form, and storing them securely is just the first benefit. After this, specific signals can be unearthed from this mountain of data, deconstructed to determine their characteristics, and compared with known threat signatures. Depending on the outcome of these analyses, the signals can be modified and jamming algorithms can be created. The ability to perform these functions with a high degree of accuracy is a formidable tool in the process of identifying and defeating enemy radars, communications systems, and jammers.

Signal recorders are also very useful for spectrum management because, unlike spectrum analyzers that have minimal internal storage, signal record-

Advance to Meet Missions

Although SIGINT platforms, such as the RC-135V/W Rivet Joint, can datalink a lot of the emitter data it collects, some signal recording capability is also required on the platform.

Steve Lynes, Wikimedia Commons

ers can be connected, typically by PCI Express, to large repositories of data that contain the results of long-term signal captures taken for hours or days. The system can tune to two adjacent or non-overlapping bands, record signal activity in both, and store them with 100% probability of capture. Two antennas feeding a dual-channel recorder will provide geo-location information as well.

Sorting out interference problems is another application in which dual-channel capture and measurement capability is highly desirable. Tracing an interfering emitter it to its source can be especially difficult when multiple transmitters are present at different power levels and without a predictable transmission schedule. The path to a solution is making a time-synchronized, multiband recording and recreating the field-recorded RF environment, shifting the playback of one channel relative to the other.

Advanced signal processing tools turn raw data into useful information and actionable results. For example, the ability to search through large sets of data and isolate specific signal behavior is essential to helping a system engineer or signal analyst determine whether the system performed as expected or if there were any timing anomalies or unexpected RF emissions detected. The process of characterizing these signals includes examining pulse widths, pulse-repetition intervals, modulation formats, frequency agility and many other signal parameters, as well as timing relationships, especially when dealing with threat-response interactions.

In addition, signal recorders attach metadata to the recording so that the precise time stamps can be associated with specific RF events. The recorder can also document items such as instrument settings and software or firmware version numbers that can help users understand discrepancies in data collected at different times. Many applications also require that the original or modified signals be played back – signals captured over many hours on a test range, for example – to determine how well radar warning receivers or other systems deal with them.

It is not unreasonable to wonder why the latest signal analyzers and real-time spectrum analyzers are not well suited for

During a mission, Norway's Marjata IV SIGINT ship records and stores a lot of the raw signals data it collects onboard the vessel.
AGOEKE, WIKIMEDIA COMMONS

these applications. These analyzers can create a high-fidelity window through which the spectrum is viewed. They can also digitize input signals into digital I & Q samples in real-time and, through mathematical transforms, they can present spectrum views that capture a detailed time slice across a fairly wide bandwidth.

That said, processing loads and available memory limit the time slice to a few seconds or less, and once the analyzer begins the "transform and display" pro-

Signal recorders are also very useful for spectrum management because, unlike spectrum analyzers that have minimal internal storage, signal recorders can be connected, typically by PCI Express, to large repositories of data that contain the results of long-term signal captures taken for hours or days.

cessing, it cannot capture another time slice until it has completed the task. This means that long-duration RF signal streams cannot be fully recorded, so elusive or intermittent events may be missed. They also are not designed to transfer what they capture to large arrays of storage devices. Consequently, the signal recorder is a purpose-built system that performs functions similar to those of signal and spectrum analyzers, but it is designed for applications that neither of these instruments is designed to serve.

TOO MUCH OF A GOOD THING?

The instantaneous bandwidth of most signal recorders ranges from hundreds of megahertz to at least 6 GHz, with some capturing signals over an even wider range of frequencies. Not surprisingly, bandwidth is one of their "headline specifications." In most applications, however, the ability to gulp massive amounts of spectrum is not as important as other metrics, and it can even be detrimental for several reasons.

Foremost is spurious-free dynamic range (SFDR). "Every recorder fights for as much SFDR as possible," says Sean Wallace, the owner of Spectra Lab (Dumfries, VA) that builds a family of recorders called Spectrum Defender that is based on technology developed by National Instruments. "In an EW environment with a high jam-to-signal ratio, SFDR is critical. And while ADCs, direct conversion, low-noise amplifiers, and preselector filters are important, in the end, they're all about achieving the highest possible dynamic range." Wallace's take is that preselectors, custom low-noise amplifiers, triple conversion superheterodyne architectures, high-SFDR ADCs, and low-phase-noise clocks are highly desirable.

"For any receiver, achieving the highest level of performance is a trade-off", says Rodger Hosking, cofounder and vice president of Pentek (Saddle River, NJ), which has been making signal recorders in various form factors for many years. "For example, if you are ingesting over a very wide bandwidth, the ADC can be overwhelmed by the amount of information coming into it, which make accurate processing impossible. When this happens, the ADC can be overloaded and it will start to clip, making it impossible to digitize the whole range of frequencies," Hosking explains. "For example, if the ADC has a full-scale input range of +/- 1 VDC and the signal is greater than this, overloading will result in intermodulation distortion. When the signal of interest is at the microvolt level, well below 1 VDC, the ability to detect a very weak desired signal becomes impossible."

One solution is to use an RF tuner in the front end or a tunable bandpass filter to focus on specific frequencies that can reduce this bandwidth. "But you cannot see everything if a signal comes up at a frequency you're not tuned to, so you'll miss it," adds Hosking. "That is, for a SIGINT application, for example, in which the frequency of a signal of interest may be unknown and the desired signal is between the passbands of the filters, it will not be possible to capture it."

There are other ways to mitigate this problem by reducing bandwidth. "If you have a test being conducted at a range with trucks driving around the range for 8 hours, the useful information typically occurs in a few narrow windows," says Wallace. "If you know when they are expected, you can record only at these times, and export just these results.

"But one of the great benefits of recording on a test range is by direct observation – ground truth. But when you filter and decimate data, you begin to stray from the fidelity of the original signal, so it's best to perform this later during analysis so you can maintain signal fidelity as long as possible throughout the entire process."

The takeaway from this is that while the capture of data over wide bandwidths is desirable for some applications, in others it makes it more difficult. "People often think more bandwidth is better," says Wallace, "but a 2-GHz RF recording is generally not a useful thing unless you are well into the microwave region, where there is less congestion. It also uses up precious dynamic range that some other interesting signal could be using. SFDR is not just about the best ADCs with the best SFDR. It is really making sure that the signals using your dynamic range are the ones you are interested in."

MANAGING THE MASS OF DATA

After capturing the signal data, the next challenge is how to store and analyze so much data. A high-level view of signal

Evaluating Signal Recorders

There are several main considerations that must be considered when evaluating signal recorders. The first is their ability to simultaneously capture signals over a wide bandwidth and to provide a high SFDR. For most applications, only the bandwidth required to ensure all signals of interest are captured, and as noted earlier, high SFDR is essential. Record time relies on system memory, so more is better, depending on whether there will be many short recordings of just a few seconds or one long, continuous stream.

For many users, a single channel record/playback solution is sufficient to characterize an emitter or emitters of interest, but sometimes it is necessary to monitor more than one band at a time, such as satellite uplinks and downlinks. Synchronous measurements across two channels allow the user to correlate the timing of emissions, and for missions that collect data over large geographic distances, many channels may be required to associate the timing of events with GPS.

Metadata marks individual samples when events of interest appear in the IQ data stream, which for long recording is absolutely necessary. For example, it is useful to know when a weapons system has changed modes or has exceeded a power threshold. If these event lines are available, they make excellent data markers. In addition, when viewing I/Q data sets, it is helpful to know when the data was taken, the specific instrumentation used, and the instrument configurations, all of which can be included as metadata.

Prospective users of signal recorders also need to consider what types of data analysis tools are available. Some manufacturers offer their own proprietary solutions that may be within the recorder itself or externally, residing in a PC, while others are also available.

Finally, there are really no "bad" solutions, only those that best suit the needs of the missions their operators, so the most expensive, multi-featured recorders are not always the best choice. – *B. Manz*

Although the cost of solid-state drives (SSDs) continues to decrease while their performance increases, recording over massive bandwidths requires banks of these devices. For example, streaming an I/Q signal with a bandwidth of 100 MHz at 16-bit resolution for 10 minutes will produce 300 Gbytes of data.

flow inside an RF streaming solution from a signal recorder consists of data streams directed to separate drives in a redundant array of independent disks (RAID). A key component is the FPGA that controls the system and configures it for recording or playback.

It manages the routing of I/Q samples and provides the deterministic association of metadata with I/Q data. Although the cost of solid-state drives (SSDs) continues to decrease while their performance increases, recording over massive bandwidths requires banks of these devices. For example, streaming an I/Q signal with a bandwidth of 100 MHz at 16-bit resolution for 10 minutes will produce 300 Gbytes of data. At a 250 MHz bandwidth (or 300 Msamples/sec), every second consumes 1.2 Gbytes of storage.

For defense systems, a primary benefit of SSDs is their immunity to shock and vibration that in older recording systems required protection to isolate these effects from rotating drives to maintain head-to-platter alignment for reliable, sustained operation. This factor made systems bulky and expensive to maintain, so SSDs naturally presented an immediately attractive alternative.

"We're taking advantage of SSDs that can record at very high rates, using multiple one- and two-terabyte SSDs in multiples of four or eight that we combine to appear as a single logical drive," says Hosking. "We're also using NVMe [Non-Volatile Memory Express standard) instead of the SATA [Serial Advanced Technology Attachment] because it can use a PCE Express interface that can contain the equivalent of a RAID controller, which means you can effectively eliminate the controller, speeding the data to the drive."

While SSDs are superior to their mechanical counterparts, as they have no moving parts, each SSD memory cell in the devices has a finite number of write cycles before it can no longer reliably retain data. To mitigate this problem, SSDs include microcontrollers that keep track of how many times each cell is written to and allocate new write operations to cells with low write counts. Other algorithms

Signal Recorder Manufacturers

Acquitek	www.acquitek.com
Ampex	www.ampex.com
Avalon Electronics	www.avalonelectronics.com
Bird RF	www.birdrf.com
Comms Audit UK	www.commsaudit.com
Conduant	www.conduant.com
CRFS	www.crfs.com
Curtiss-Wright Defense Solutions	www.curtisswrightds.com
Delphi Engineering Group	www.delphieng.com
El-OR Systems	elor-systems.com
Giga-tronics	www.go-asg.gigatronics.com
Herrick Technology Labs	www.herricktechlabs.com/
IZT GmbH	www.izt-labs.de
Kratos Defense & Security Solutions	www.kratosdefense.com
Leonardo DRS	www.leonardodrs.com
Mercury Systems	www.mrcy.com
Novator Solutions	www.novatorsolutions.com
Pentek	www.pentek.com
Rohde & Schwarz	www.rohde-schwarz.com
SIGINT Systems LLC	www.sigintsystemsllc.com
Signatec (Vitrek)	www.signatec.com
SpectraLabs LLC	www.spectrumdefender.com
Symmetric Technologies PVT. LTD.	www.symmtech.com

the recording," Wallace continues. "GPS is not phase-coherent. Its two carrier frequencies are synchronized at baseband, but not at RF. This is a different scenario than other signal recording applications, such as phased arrays, in which you have multiple synchronized, phase-coherent channels."

"If the phase relationship between the two ADC clocks is not known, you cannot guarantee both channels will trigger on the same clock edge. The only way to achieve this is if the clocks have an aligned phase relationship. That is, you have to lock and phase-align the sample clocks to ensure the recording starts on the same clock edge on all channels."

A FINITE SPECTRUM BECOMING FULL

The operating environment in which hundreds of signals (or more) appear within even a small swath of the spectrum is now the norm between 100 MHz and 3 GHz. Inside this region, the spectrum is so densely populated that once the spectrum is captured, finding a signal of interest is almost impossible without extensive filtering.

This reality is now appearing at frequencies up to at least 7 GHz, as the FCC has auctioned off whatever spectrum slices are available, and if not actioned, the FCC is allowing multiple services to operate on a shared basis. The wireless carriers themselves use techniques such as carrier aggregation to stitch together channels that are composed of different frequencies to create wider ones that can provide the bandwidth required by data-intensive applications, such as video streaming. They are also beginning to deploy dynamic spectrum sharing (DSS) that allows 5G and 4G to coexist in the same spectrum, with LTE acting as a coverage layer for 5G.

The result of even a short-term "recording session" from signal capture at these frequencies will be tens of thousands of signals, from navigation to AM, FM, shortwave, and TV broadcasts, to amateur radio, industrial, scientific, and medical (ISM) systems, also including Wi-Fi, Bluetooth, and other short-range wireless solutions used for IoT, cordless phones, aviation, government and military systems, all commercial wireless networks, GPS, and some radar and satellite communications systems. In a typical situation, the content will mainly consist of legitimate signals operating within their allocated spectrum. However, it is also possible that signals will be found that do not conform to their required specifications for spectral purity, are of unknown origin, or do not belong at a particular frequency.

In some cases, interfering signals may simply be spurious content or harmonics emitted from a malfunctioning but otherwise legitimate system at a lower frequency. But in other cases, they may have been intentionally hidden either close to or beneath a legitimate signal, and if they use spread-spectrum techniques, signal analysis becomes extremely difficult.

The most challenging signals are those that appear either randomly or intermittently, so the ability to view them and their characteristics over time is essential. That is an easy task in an operating environment that appears on a spectrum display as a solid line, with spikes at frequencies where very high-power transmitters are operating.

MILLIMETER WAVELENGTHS FINALLY GET ATTENTION

When autonomous vehicles arrive, they will rely extensively on communications between vehicles, connected infrastructure such as cameras and radar, and possibly even people. In short, it will not be long before virtually every frequency below 8 GHz will be used for something. To continue the development of commercial and defense communications, systems will obviously require more bandwidth, and the best available spectrum is in the millimeter-wave region.

Not long ago, the millimeter-wave region was primarily populated by satellites for communications and remote sensing, so there were few other emitters to obscure a signal of interest. This is no longer the case, because the higher regions of the spectrum are the only ones with enough available bandwidth to enable the exceptionally high data rates required by applications such as video streaming. So, while for more than half a century, millimeter wavelengths were considered of little use for terrestrial applications because of their inability to cover distances greater than a few hundred feet, they are now becoming "alive" with signals.

These signals are generated by emitters, such as small-cell base stations that allow the network to achieve extremely high data rates in hard-to-reach places (such as indoors) and can be deployed in stadiums and other areas where large numbers of people congregate. In addition, AT&T and Verizon are using the 24- and 28-GHz bands, respectively, to provide fixed wireless access (FWA) broadband service to homes and businesses to provide an alternative to coaxial cable and fiber-to-the-home. When the sixth generation of "cellular" appears in a decade, wireless devices will not only operate at millimeter-wave frequencies but even into the terahertz region. On both the military and the commercial sides of the market, these trends are going to create significant demand for signal capture and storage.

TECHNOLOGY SURVEY

A SAMPLING OF AIRBORNE ELECTRONIC WARFARE SUITES

By John Knowles and Hope Swedeen

Airborne self-protection EW suites were introduced into fighter aircraft, such as the F-15A and F-16A, in the 1970s. Along with the radar, communications and other systems in the aircraft, the EW suite had become automated enough by that time to enable a single person to pilot the aircraft and operate all of its systems. (Admittedly, a single pilot had quite a workload to manage in an engagement– monitoring a number of displays and tracking the status of various weapons.) In the decades that followed, airborne EW suites continued to evolve – tying together more sensors and countermeasures and presenting more fused information to the pilot.

There is no hard and fast definition for what an EW suite is, exactly. But EW suites imply the integration of one or more types of sensors, such as a radar warning receiver (RWR) or electronic support measures (ESM) system, a missile warning system (MWS) or a laser warning system (LWS), with one or more countermeasures systems via a suite controller or some sort of EW management system. The objective, as explained above, is to automate the process of threat detection/identification and to determine and initiate an optimal countermeasures response. An EW suite can be as sophisticated as the one on the F-35, which is really part of a full sensor suite that fuses inputs from the aircraft's radar, Electro-Optical Targeting System, EO/IR Distributed Aperture System, and ESM system to present a single situational awareness picture to the pilot. The aircraft also supports weapons selection and automates the countermeasures response. At the other end of the spectrum, on a utility helicopter for example, the EW suite can be as simple as an RWR and MWS feeding inputs to a suite controller/manager, which automatically cues a chaff and flare dispenser.

Airborne EW suites can be configured internally or in pods. Sometimes the suite is a hybrid, with an RWR and MWS installed internally on the aircraft, but with a suite controller and a countermeasures system, such as an RF jammer, chaff/flare dispenser or a directed IR countermeasures (DIRCM) system, installed in a pod or a weapons pylon. This makes sense for fighter and helicopter users that expect to deploy a relatively small number of aircraft to support international operations. Many European nations, for example, have used this type of strategy to equip their aircraft during operations in Afghanistan over the past two decades.

Aside from building a threat picture for the air crew, an EW suite also be used to monitor useful information, such as how many flares remain in a countermeasures dispenser or it can help run a built-in test of the entire suite to ensure that all EW systems are functioning properly.

THE SURVEY

This month's survey includes 33 airborne integrated EW suites from 16 companies that are mainly located in Israel, Europe and the US. As you might expect, most of the EW suites are made by the major EW primes in these countries. Several of the EW suite manufacturers who did not respond to this survey are from India, Japan and South Korea, and they are mostly focused on their domestic markets.

In the survey table, the first column indicates the name or model number of the EW suite. The second column shows the general types of threats the EW suite addresses. The third column describes the EW suite's warning systems, and the next column describes which frequencies or IR bands are covered by those warning systems.

The fifth column indicates the EW suite controller or suite management system. Some suite controllers are discrete systems and others are integrated into one of the warning systems, such as an RWR. The next two columns describe the suite's countermeasures system(s) and the frequencies they cover.

The following column indicates if the suite is configured for internal installation on the aircraft or if it is housed in a pod or weapons pylon. RWRs are typically internal installations because the antenna positions on the aircraft are critical for threat coverage and for determining a threat signal's angle of arrival. Missile warning sensors and DIRCM systems are positioned mainly to provide the best spherical coverage around the aircraft, which means they can be more easily installed in a pod or a weapons pylon.

The next column indicates the types of aircraft the EW suite is designed for. The following two columns describe the suite's weight and power requirements. These figures can be very configuration dependent, as many suites can utilize a variety of warning sensors and countermeasures systems.

NEXT MONTH

In the July issue of *JED,* we will publish a technology survey on communications intelligence (COMINT) receivers. To request a survey questionnaire, please e-mail JEDEditor@naylor.com.

AIRBORNE INTEGRATED EW SUITES

EW SUITE NAME/MODEL	SUITE TYPE	WARNING SENSORS/ SYSTEMS	WARNING SENSOR OPERATIONAL FREQUENCY COVERAGE	SUITE CONTROLLER	COUNTERMEASURES SYSTEMS
ASELSAN; Ankara, Turkey; 90 (312) 592 10 00; aselsan.com.tr					
HEWS	RF, UV, EO/IR	RWR, LWR, AN/AAR-60 (MILDS)	RWR: C-J; LWR: Band I, II, III, IV; MWS: Solar Blind UV	Suite Central Processing Unit	RF jammer; OZISIK CMDS
BAE Systems, Inc.; Nashua, NH, USA; +1 603-885-4321; www.baesystems.com					
AN/ASQ-239 Electronic Warfare / Countermeasure System	*	RWR/ESM	*	*	RFCM and IRCM
AN/ALQ-250 Eagle Passive Active Warning Survivability System (EPAWSS)	*	RWR/ESM	*	*	*
ALQ-239 Digital Electronic Warfare System (DEWS)	*	*	*	*	*
BIRD Aerosystems Ltd; Herzliya, Israel; +972-9-9725700; www.birdaero.com					
AMPS-MLR	RF, EO/IR	MWS, LWS, RWR	MWS UV; RWR 0.5-40 GHz; LWS - Band I, II, III, IV	MCDU - Control and Display Unit	CFDS with Smart Dispensers
AMPS-MD	EO/IR	MWS	MWS: UV	MCDU	SPREOS DIRCM; CFDS
AMPS-MV (MACS Verification)	EO/IR	MWS; MACS semi active pulse Doppler radar	MWS: UV	MCDU	CFDS with Smart Dispensers
Elbit Systems EW and SIGINT - Elisra; Holon, Israel; +972-77-293-5229; www.elbitsystems.com/elisra					
All In One	RF, EO/IR (incl. laser)	SPS-65V5 (RWR, LWS) PAWS (MWS)	RWR: 0.5-18 GHz; 24-40 GHz; LWS: bands I, II, III, optional IV; MWS: IR	Embedded, part of SPS-65V5	CMDS, Light SPEAR™ (radar jammer), Mini-MUSIC (DIRCM)
ALL-in-SMALL™	RF, EO/IR (incl. laser)	SPS-65-PAWS-V5.5 (RWR, LWS and MWS)	RWR: 0.5-18 GHz; 24-40 GHz; LWS: bands I, II, III, optional IV; MWS: IR	Embedded, Part of SPS-65-PAWS-V5.5	CMDS, Light SPEAR™ (radar jammer), Mini-MUSIC (DIRCM)
Elettronica S.p.A; Italy; +39064154717 www.elettronicagroup.com / www.elt-roma.com					
Integrated EW Suite	RF, EO/IR	VIRGILIUS familyESM, MWS (UV/IR)	RWR ELT162 fully digital: 0.5-40 GHz; MWS: Band I, II and IV	ELT-950, Advanced EW Management System	VIRGILIUS (RF jammer); ELT-577 (QUIRIS) (IR jammer); ELT-590 (SPARK, DRFM based expendable active decoy)
EDGE	RF	EDGE family	RWR: 0.7-40 GHz	ELT-950, Advanced EW Management System	VIRGILIUS (RF jammer)

COUNTERMESURES FREQ. COVERAGE	CONFIGURATION	PLATFORM	WEIGHT (LB OR KG)	PWR (W)	FEATURES
RF Jammer: H-J bands	Internal	Rotary Wing, Transport, Business Jet	155 kg	3030 W	Helicopter EW Suite (HEWS); MWS: detection in "solar blind" UV band; RWR: high-sensitivity, multi-channel digital receivers; RF Jammer: solid-state AESA amplifier architecture, integrated receiver/TG with digital RF memory (DRFM)
*	Internal	F-35 Lightning II	*	*	360° situational awareness; radar warning, targeting support and self-protection.
*	Internal	F-15 Eagle and F-15 Eagle II	*	*	360° situational awareness; all-aspect, broadband radar warning and geolocation; multi-spectral, RF and IR countermeasures; simultaneous jamming.
*	Internal	International F-15	*	*	Fully integrated radar warning, 360° situational awareness, advanced electronic countermeasures, targeting support, geolocation, self-protection.
*	Internal or pod	Rotary wing; narrow and wide body aircraft, UAV	Config. dep., min. 32 kg	Config. dep	Internal or integrated in BIRD's AREOSHIELD all in one POD. RWR: Elettronica ELT-160, Hensoldt Kalætron RWR;MWS: Hensoldt AAR-60 MILDS; LWS: ATLAS-2QB.
SPREOS DIRCM operates in Band 1 & 4	Internal or pod	Rotary wing; narrow and wide body aircraft, UAV	Config. dep., min. 32 kg; SPREOS DIRCM 15 kg	Config. dep	SPREOS DIRCM uniquely confirms the incoming threat and eliminates the system false alarms while extracting valuable threat information such as: velocity, range, RCS and Doppler map which enablesit to fine tune the jamming of the threat.
*	Internal or pod	Rotary wing; narrow and wide body aircraft, UAV	configuration dependent; system minimum of 32 kg; MACS confirmation sensor 7 kg	Config. dep	Missile Approach Confirmation Sensor (MACS) confirms incoming threats with zero false alarms while additionlly extracting valuable threat information; supports multi turret configuration that can fit very small aircraft.
*	Internal or pod	Rotary wing; narrow and wide body aircraft	Config. dep.	Config. Dep	RWR: advanced wide band and narrow band digital receivers; MWS: IR-based MWS, IR Centreic™; and DRFM-based jammer all in a single LRU. Advanced Suite features: ESM, Multi-Spectral Threat Geo-Location, Net-Centric EW Applications.
*	Internal or pod	Rotary wing; narrow and wide body aircraft	Config. dep.	Config. dep	See above.
2-18 GHz; Band I, II and IV; C, X, and Ka bands decoy.	Internal	Fighter, Transport, Rotary Wing	Config dep.	Config. dep	Completely integrated suite, the EW Manager ELT-950 uses AI technology and functionally integrates sensors and countermeasures, including smart cooperation among active and passive effectors and on-board/off-board countermeasures.
1-6 GHz, 4.5-18 GHz, 26.5-40 GHz	Pod	Fighter, Transport	<700 kg, config. dep.	Self powered, self cooled	EDGE is based on state of the art technology (DRFM, digital receiver, solid-state RX/TX modules) and phased-array antennas, featuring electronic beam steering.

AIRBORNE INTEGRATED EW SUITES

EW SUITE NAME/MODEL	SUITE TYPE	WARNING SENSORS/ SYSTEMS	WARNING SENSOR OPERATIONAL FREQUENCY COVERAGE	SUITE CONTROLLER	COUNTERMEASURES SYSTEMS
EuroDASS Consortium (Leonardo, Elettronica, Indra, Hensoldt); Luton, United Kingdom; +44 01582 886000; uk.leonardocompany.com					
Praetorian	RF, EO/IR	ESM, LWR, MAW	*	Defensive Aids Computer (DAC)	RF jammer, towed decoy, CMDS, active expendable decoy
Hensoldt Sensors GmbH; Taufkirchen, Germany; +49.89.51518-0; www.hensoldt.net					
Hensoldt AMPS-MLR	RF, EO/IR	AAR-60 MILDS MWS w/ HFI, ALTAS-2QB LWS; Kalætron RWR; ELT 160 IFM RWR	MWS: UV; LWR: 0.5-1.65 µm; Kalætron RWR: 0.5-40 GHz; ELT160: 2-40 GHz	AMPS Control and Display Unit (ACDU)	ACDS
Hensoldt AMPS-MD	EO/IR (incl. laser)	AN/AAR-60 MILDS MWS w/ HFI	UV	ACDU	MIYSIS DIRCM, ACDS
Hensoldt AMPS-MV	EO/IR	AN/AAR-60 MILDS MWS w/ HFI	UV	ACDU	ACDS
Indra Sistemas, S.A.; Madrid, Spain; +34 91 627 10 00; www.indracompany.com					
MIPS-IR	EO/IR	MWS-IR/LWS: INDRA InWarner (IR Hostile Fire Indication) MWS-UV: HENSOLDT MILDS family; SAAB MAWS family	*	Indra InShield	InShield DIRCM; Opt. CMDS
SIMBA-FD	RF, EO/IR	ALR-400FD RWR; InWarner IR MWS, LWS and HFI; MWS-UV/LWS: MILDS/ALTAS	*	ALR-400FD EW Manager	InShield; CMDS
AACS-FD	Multispectral (RF and EO/IR)	ALR-400FD RWR; InWarner IR MWS, LWS	*	ALR-400FD EW Manager	CMDS; ALQ-500 Airborne Self Protection Jammer
L3Harris Technologies, Inc.; Melbourne, FL, USA; +1 321-727-9100; www.L3Harris.com					
AN/ALQ-211 A(V)4 Advanced Airborne Integrated Defensive EW Suite (Advanced AIDEWS)	RF	AN/ALQ-211 A(V)4 RWR	C - J Band	AN/ALQ-211 A(V)4 RWR; also interfaces with ALQ-213	AN/ALQ-211 A(V)4 Jammer
Viper Shield™ AN/ALQ-254(V)1 All-Digital EW Suite	RF	AN/ALQ-254(V)1 digital RWR	*	AN/ALQ-254(V)1; interfaces with APG-83 AESA radar	AN/ALQ-254(V)1 Jammer
Leonardo; Luton, United Kingdom; +44 01582 886000; uk.leonardocompany.com					
Modular Advanced Platform Protection System (MAPPS)	RF, IR and Laser warning	RWR/ESM, LWS, IR-MWS	RWR: C/D, E-J and K bands; LWR: 0.5-1.8µm	MAPPS Controller	Miysis DIRCM, BriteCloud Expendable Active Decoy, Vicon CMDS
My-konsult System AB; Gelbgjutarevägen, Sweden; www.mykonsult.com					
ASTOR III(V)	RF	RWR	RWR: 0.5-18 GHz, optional Ka band	Yes	RF jammer

COUNTERMESURES FREQ. COVERAGE	CONFIGURATION	PLATFORM	WEIGHT (LB OR KG)	PWR (W)	FEATURES
*	Internal	Eurofighter Typhoon	*	*	Fully integrated DAS on Eurofighter Typhoon.
*	Internal or Pod	Rotary wing; narrow and wide body aircraft, UAV	Config dep.	Config. dep	MILDS (Missile Launch Detection System) Block 2 HFI (Hostile Fire Indication) AN/AAR-60 MWS; ALTAS-2QB (Advanced Laser Threat Alerting System - 2 Quadrants with Beamrider Detector LWS; Kalætron RWR; Digital IFM RWR: ELT160
Band 2 and 4	Internal or Pod	Rotary wing; narrow and wide body aircraft, UAV	Config dep.	Config. dep	Federated, fully modular system optional iterface to Avionics, Solar blind MWS; Hostile Fire Indication for tracer ammunition; flexible system configuration with 1, 2 DIRCM turrets and optional 0-16 chaff- & flare dispensers.
*	Internal or Pod	Rotary wing; narrow and wide body aircraft, UAV	Config dep.	Config. dep	Opt. confirmation sensor MACS: pulse Doppler radar; Hostile Fire Indication for tracer ammunition; very low false alarm rate close to 0 in 100 flight hours.
*	Internal or Pod	Rotary wing; narrow and wide body aircraft, UAV	Config. dep, min. 40 kg	Config. dep	MIPS - Infrared Missile Protection Suite; MWS-IR/LWS: INDRA InWarner (IR Hostile Fire Indication); MWS-UV: HENSOLDT MILDS family; SAAB MAWS family
*	Internal	Rotary wing; narrow and wide body aircraft, UAV	Config. dep, min. 30 kg	Config. dep	Full-digital integrated multi-band threat protection suite; full digitization of RF & IR spectrum close to sensors, fiber optic inter-LRUs cabling; AI through machine-learning algorithms, intelligent countermeasures management.
*	Internal	Fighter, Large Aircraft	Config. dep, min. 40 kg	Config. dep	AACS - Advanced Air Combat Suite ; full-digital; incorporates RF jamming on top of other EW functions.
E - J Band	Internal or Pod	Fighter, Transport	186 lb	4.3 kW	Stand-alone RWR/technique generator option in small form factor; AESA interoperability interface; digital technology DRFM architecture; 3U COTS format for long-term sustainability
*	Internal	F-16 Block 70/72 aircraft	*	*	*
*	Internal	Rotary Wing, Fixed Wing Transport, Fixed Wing C4ISR	Config. dep	Config. dep	Options include: Leonardo SEER RWR, Leonardo SAGE ESM, Thales Elix-IR MWS , RALM LWR, AAR-60 MWS; modular system concept to allow easy integration of existing platform sensors and effectors, or inclusion of future systems as required.
*	Pod	Fighter, UAV	*	*	Basic to advanced simultaneous ECM, ESM and Threat Emitter Simulation of multiple radars in different bands. Digital Set-On Receiver-, Digital Generator -, Digital RF Memory (DRFM)- and PRI Predictor /Trackers with data bank.

AIRBORNE INTEGRATED EW SUITES

EW SUITE NAME/MODEL	SUITE TYPE	WARNING SENSORS/ SYSTEMS	WARNING SENSOR OPERATIONAL FREQUENCY COVERAGE	SUITE CONTROLLER	COUNTERMEASURES SYSTEMS
RAFAEL Ltd.; Haifa, Israel; +972-73-335-4444; www.rafael.co.il					
Lite-Shield	RF	Top Scan RWR/ESM	RWR: 0.5-40 GHz	*	Lite-Shield jammer; X-GUARD FOTD
Sky-Shield - Support Jamming	RF	Top Scan RWR/ESM	RWR: 0.5-40 GHz	*	Sky-Shield Jammer
Saab AB; Järfälla, Sweden; +46 8 580 840 00; www.saab.com					
Arexis Fighter EW	RF	RWR/ESM	VHF to Ka-band	Interface to systems computer and/or DASS-controller; platform dependent	RF jammer
IDAS-100 series	EO/IR (incl. laser)	MAW-400 w/ HFI; LWS-310: Laser Warning	MAW: Sun blind UV; LWS: 0.5 to 1.8 µm; Elix-IR: Single colour Mid-Wave (MW) IR	Saab Defensive Aids Controller (DAC)	CMDS and DIRCM (opt.)
IDAS-300/400/700 series	RF, EO/IR (incl. laser)	RWR-310, RWR-400 or RWR-700; MAW-400 w/ HFI; LWS-310: Laser Warning	RWR: 0.5 to 40 GHz; MAW: Sun blind UV; LWS: 0.5 to 1.8 µm ; Elix-IR: Single colour MW IR	Saab Defensive Aids Controller (DAC)	CMDS and DIRCM (opt.)
Terma A/S; Lystrup, Denmark; +45 87 43 60 00; www.Terma.com					
MASE	RF, EO/IR	ALR-69DK(V)2, AAR-54(V) (NGC)	*	ALQ-213(V) EWMU	ACMDS
C-130	RF, EO/IR	ALR-69(V) Class IV/DK(V)2, AAR-54(V) (NGC), AAR-60(V)2 MILDS-F (Hensoldt)	*	ALQ-213(V) EWMU	ALQ-162(V)6 (NGC), ALQ-131 (NGC), ACMDS
F-16	RF, EO/IR	ALR-69(V) Class IV/DK(V)2, ALQ-131 (NGC), ALQ-162(V)6 (NGC), AAR-60(V)2 MILDS-F (Hensoldt)	*	ALQ-213(V) EWMU	ALQ-162(V)6 (NGC), ALQ-131 (NGC), ACMDS
Terma North America Inc.; Atlanta, GA, USA; +1 703-412 9410; www.terma.com					
EWMS, Navy ISR	RF, EO/IR	AAR-54 (NGC), NextGen MWS (NGC), APR-39B(V)2	RWR: 0.5-18 GHz	ALQ-213(V)	ALE-47, AAQ-24 DIRCM
IEWS, ISR	RF, EO/IR	AAR-60-V2, ALR-400, AVR-2B	RWR: 0.5-18 GHz	ALQ-213(V)	ALE-47
Thales DMS France; Elancourt Cedex, France; +33 (0) 1 34 81 95 96; www.thalesgroup.com					
SPECTRA	RF, EO/IR	RWR, MWS, LWS	*	Yes	RF jammer, CMDS

COUNTERMESURES FREQ. COVERAGE	CONFIGURATION	PLATFORM	WEIGHT (LB OR KG)	PWR (W)	FEATURES
RF jammer: 2-18 GHz	Pod	Fighter, Transport, Rotary Wing	Config. dep	Config. dep	Self-protection suite; 360°, AESA solid state transmitter, Digital receivers and DRFM based techniques generator, integrated with Kanfit CMDS.
RF jammer: 1-18 GHz	Pod	Fighter, Transport	Config. dep	Config. dep	Escort Jammer & Electronic Attack - spatial coverage - 360°, high ERP with AESA solid state transmitter, Digital receivers and DRFM based techniques generator.
VHF-Ku band	Internal or Pod	Fighter	Internal: 70-150 kg; podded: 300-600 kg	Config. Dep	360° spherical coverage EW system with GaN AESA technology; high precision direction finding and geolocation: Ka-band jamming as option; AESA technology available from L to Ku band; currently flyong on Grpen E/F and podded demonstrator flying from 2017.
*	Internal or Pod	Rotary-Wing, Transport, Fighter	< 28 kg; config. Dep	< 150 W config. Dep	Optional: Elix-IR Threat Warning System (TWS) comprising of MAW, HFI, Situational Awareness through IR imagery; chaff and flare options: BOP-L (Saab) or 3rd Party CMDS, including Vicon XF (Thales UK) and ACMDS (Terma); DIRCM options: Miysis (Leonardo), InShield (Indra), South Korea DIRCM.
*	Internal or Pod	Rotary-Wing, Transport, Fighter	< 48 kg; config. Dep	< 340 W config. Dep	RWR-310 provides coverage from 0.5 to 40 GHz; offline ELINT capability of detected and recorded radar pulses; RWR-400 digital receiver provides a 4-GHz instantaneous bandwidth; RWR-700 digital receiverprovides a 16-GHz instantaneous bandwidth.
*	Internal or Pod	Rotary Wing	*	*	Advanced and modular/open system architecture supporting adaptability for aircraft and best-of-breed subsystem configurations and cohenrence to standards (e.g. FACE, NDAS).
*	Internal or Pod	Transport	*	*	Advanced and modular/open system architecture supporting adaptability for aircraft and best-of-breed subsystem configurations and cohenrence to standards (e.g. FACE, NDAS).
*	Pylon, pod, internal	Fighter	*	*	Advanced and modular/open system architecture supporting adaptability for aircraft and best-of-breed subsystem configurations and cohenrence to standards (e.g. FACE, NDAS).
*	Internal	Fixed wing Navy ISR	*	*	Suite level capabilities like mission data recording, embedded training and Aadvanced threat response; open system architecture - FACE standard compliant; smart dispensing.
*	Internal	Fixed wing, ISR	*	*	Suite level capabilities like mission data recording, embedded training and Aadvanced threat response; open system architecture - FACE standard compliant; smart dispensing.
*	Internal	Rafale	*	*	SPECTRA:Self-Protection Equipment to Counter Threats for Rafale Aircraft. Developed with MBDA, which provides the MWS.

SURVEY KEY – AIRBORNE INTEGRATED EW SUITES

EW SUITE NAME/MODEL
Product name or model number

SUITE TYPE
Types of threats the EW suite detects and defeats (RF, EO/IR)

WARNING SENSORS/SYSTEMS
Types or models of threat warning sensors or systems
- ESM = electronic support measures
- LWS = laser warning system/ sensor
- MWS = missile warning system/ sensor
- RWR = radar warning receiver

WARNING SENSOR OPERATIONAL FREQUENCY COVERAGE
Indicates the operating frequency range of the warning sensor or system

SUITE CONTROLLER
Indicates the name of the suite's controller

COUNTERMEASURES SYSTEM
Indicates the type of countermeasures system(s) provided by the EW suite
- CFDS = countermeasure flares dispensing system
- CMDS = countermeasures dispenser system (chaff/flare)
- DIRCM = directed infrared countermeasures system
- DRFM = digital RF memory
- RFCM = radio frequency countermeasures

COUNTERMEASURES FREQUENCY COVERAGE
Indicates the operating frequency range of the suite's RF and IR jammers

CONFIGURATION
Indicates if the EW suite is configured for internal installation on the aircraft or carried externally in a pod or pylon.

PLATFORM
Indicates why types of airborne platforms the EW suite is designed to protect
- UAS = unmanned aerial system

WEIGHT
Weight in lb or kg

POWER
Indicates the power consumed by the EW suite in Watts.

FEATURES
Additional features

OTHER ABBREVIATIONS USED
- config. dep. = configuration dependent
- COTS = commercial off-the-shelf
- ECM = electronic countermeasure
- opt = optional
- UV = ultraviolet

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

JULY 2021 PRODUCT SURVEY: COMINT RECEIVERS
This survey will cover communications intelligence (COMINT) receivers. Please e-mail JEDEditor@naylor.com to request a survey questionnaire.

The strategy's second goal is materiel development. This includes rapid development of EW/EMS capabilities that also utilize open architectures. The strategy states, "The DAF must leverage technology and methods to proactively (vs reactively) respond to an adversarial threat. DAF must guide development of the EMS GRA [Government Reference Architectures] and harvest best of breed technologies from the Air Force Research Laboratory, the Defense Advanced Research Projects Agency, other DoD labs, and industry, to transform the DAF EMS capabilities. Additionally, The DAF must expand and leverage the use of technological capability and innovation investments from the private sector to address EMSO challenges."

The second objective under the materiel goal is to develop robust Electromagnetic Battle Management (EMBM) capabilities. The strategy states, "To support JADO, Joint All Domain Command and Control (JADC2) capabilities are being developed across the DoD. The DAF's primary contribution to JADC2 is Advanced Battle Management System (ABMS). The DAF will support the 2020 DoD EMS Strategy by funding and implementing ABMS as the DAF contribution to the multi-service technology and infrastructure needed to realize JADC2.

"ABMS is a network-focused approach that connects sensors, decision nodes, and weapons in all domains and moves data to enable rapid artificial intelligence-enabled decision-making and support EMBM. EMS Superiority and EMBM are prerequisites to ABMS, therefore, the deliberate development of robust EMBM capabilities is essential. EMBM technologies must operate in the JADC2/ABMS/Sensing Grid architecture with open systems for rapid implementation, adoption, and upgradeability." The third objective is to modernize the DAF's EMS operational test and training infrastructure.

The DAF's third and final strategic goal is to develop its EW/EMS Superiority Force. This includes three objectives: developing EMS Enterprise-wide expertise; ensuring "access and interoperability" with allies and partners; and accelerating EMS information integration into intelligence, operations and planning.

In the strategy's final summary, the document is very clear about the purpose and the path the DAF must pursue. "The Department of the Air Force must move in a new direction regarding EMSO. We must overcome the atrophy of our EMS skills and knowledge brought on by years of a false sense of US EMS dominance. We must invest in developing experienced EMSO leaders. Leaders that will be fundamental to achieving the EMS superiority objectives described in this strategy. A strategy that is focused on creating new joint and allied capabilities to provide a dynamic maneuver space for our forces, and complexity for our adversaries." – *J. Knowles*

Correction: Due to an editorial error, the News section of the May 2021 *JED* incorrectly named the principals of the RJV Institute. The two principals are co-founder and BOD Chair Melinda Tourangeau and Steve Tourangeau, co-founder and Dean.

IN BRIEF

The DOD's Defense Security Cooperation Agency has proposed the sale of as many as 12 **General Atomics MQ-9B Sky Guardian** unmanned aerial systems to the Australian Government. The MQ-9Bs would be procured by the Royal Australian Air Force (RAAF) under its Air 7003 program. The MQ-9Bs would be fitted with a variety of sensors and weapons. The package includes 15 RIO COMINT systems from L3Harris and Leonardo Sage 750 ESM systems, as well as Raytheon Multi-Spectral Targeting Systems-D (MTS-D), Lynx AN/APY-8 Synthetic Aperture Radars (SAR) with Ground Moving Target Indicator (GTMI), SATCOM and ARC-210 radios. The RAAF selected the MQ-9B as its preferred solution in 2018, and the formal request for the Foreign Military Sale is just the latest step in the procurement process. The total value of the sale is estimated at $1.7 billion. The Australian government is expected to vote on the sale in mid-2022.

US NAVY

The **US Navy** completed an advanced captive-carry flight evaluation of the AGM-88G Advanced Anti-Radiation Guided Missile-Extended Range (AARGM-ER) on April 22 on an F-18F Super Hornet. "During the test, the F/A-18 Super Hornet conducted a series of aerial maneuvers in order to evaluate compatibility of the AARGM-ER with the F/A-18 Super Hornet," Naval Air Systems Command said in a press release. "The test points completed during this flight test event substantiated F/A-18 carriage compatibility." The captive-carry test marked the first time the AARGM-ER weapon demonstrated it could communicate with the F/A-18 E/F aircraft during flight. As its name suggests, the AARGM-ER is a longer-range variant of the AGM-88E AARGM. Developed by **Northrop Grumman,** the new missile is slated for use on F/A-18E/F and EA-18G aircraft, and potentially suitable for use on the F-35.

The **Indian Government** has formally requested the sale of six P-8I Poseidon maritime patrol aircraft from the US via FMS channels. The proposed deal includes MX-20HD EI/IR sensors, AN/AAQ-2(V) l Acoustic System, ARES-1000 "commercial variant" ESM systems, AN/APR-39D radar warning receivers, AN/AAR-54 missile warning systems and AN/ALE-47 countermeasures dispensing systems. The package's maximum value is estimated at $2.4 billion, although the actual contract is expected to be lower. India bought 14 P-8I aircraft from Boeing beginning in 2009, and the Indian Navy took delivery of its first aircraft in 2013. The INavy's 312A Naval Air Squadron based at Arakkonam in Tamil Nadu operates the aircraft.

System Technology and Research (Woburn, MA) received a $5 million contract from Naval Sea Systems Command (Washington, DC) to provide engineering services for cognitive electronic warfare, signal detection and classification, and Machine Learning in support of AN/BLQ-10 ESM systems on US Navy submarines.

The Naval Research Lab (Washington, DC) has announced plans to award a sole-source contract to **L3Harris NEXGEN Division** (Dulles, VA) to for Surface Electronic Warfare Embarkable Prototype System (EPS) development. NRL will conduct the four-phase EPS program over a five-year period. During the first two phases of the effort, the company will support EPS conceptual design, as well as developing and testing RF and electrocial components. During the third phase, the company will fabricate and deliver eight EPS Engineering Development Models (EDMs) for installation aboard various ship types. The fourth phase calls for an additional seven EPS systems and ship installations on forward deployed naval forces. Before its acquisition by L3Harris, NEXGEN Communications also provided spares and repairs for the AN/SSX-1 Specific Emitter Identification System, which was part of the US Navy's Surface Electronic Warfare Improvement Program Block 1B1 effort.

Due to "refocused priorities," **Air Combat Command** announced on April 22 that is putting its Advanced Radar Threat System-Variant 4 (ARTS-V4) acquisition program on indefinite suspension. The notice added that "the Government is currently in the process of submitting requirements documents through the Aviation & Missile Technology Consortium (AMTC) OTA. Industry feedback obtained from this announcement will help inform the ARTS-V4 Acquisition Strategy Panel, which will be formalized later this summer." In other program news, Capt Lucas Hash became the new Program Manager for ARTS-V4 as of May 1.

Hensoldt (Ulm, Germany) has received a €90 million contract from the EuroDASS consortium to provide core components for the Eurofighter's PRAETORIAN self-protection system. The contract supports the German Air Force's Quadringa fighter replacement program, specifically 38 new build Eurofighters, which will replace legacy Tranche 1 Eurofighters. Deliveries are planned from 2023 through 2027.

5G Communications (Part 3)

Antenna Performance at mmW

By Dave Adamy

There are several important antenna considerations in 5G. This is particularly true in the millimeter wave (mmW) frequency range. Important features of 5G are the performance advantages that will come from expansion into millimeter wave that we discussed last month. Since 5G stations will primarily have phased array antennas, particularly in the mmW frequency range, here are some applicable formulas and tables detailing the antenna specifications.

GAIN OF A PHASED ARRAY ANTENNA

The gain of a phased array antenna is given by the formula

$$G = (4 \pi A n) / \lambda^2$$

Where:

The main beam boresight gain of a phased array antenna is *G* in dBi,
the area of the array is *A* in square meters,
the efficiency of the antenna is *n,* and
the wavelength is λ in meters.

Table 1 gives the area and gain for an array as a function of frequency and the number of elements with half-wavelength spacing. You will note that the gain vs. the number of elements is the same for each of the frequencies considered. However, the area of the array is significantly larger for the lower frequencies.

Table 1: *Gain of a phased array antenna vs. frequency and number of elements*

Frequency	Elements	Area	Gain
3.5 GHz	64	.116 m^2	19.0 dBi
	100	.181 m^2	20.9 dBi
	144	.260 m^2	22.5 dBi
	196	.354 m^2	23.9 dBi
	256	.462 m^2	25.0 dBi
28 GHz	64	1.83 cm^2	19.0 dBi
	100	2.86 cm^2	20.9 dBi
	144	4.12 cm^2	22.5 dBi
	196	5.61 cm^2	23.9 dBi
	256	7.33 cm^2	25.0 dBi
60 Ghz	64	0.40 cm^2	19.0 dBi
	100	0.63 cm^2	20.9 dBi
	144	0.90 cm^2	22.5 dBi
	196	1.2 cm^2	23.9 dBi
	256	1.6 cm^2	25.0 dBi

BEAM WIDTH OF A PHASED ARRAY ANTENNA

For this discussion, we assume that the array is square and that there is no beam sharpening.

The 3 -B beam width of a square phased array antenna (that is, with the same number of rows and columns) is given by the formula:

$$BW = (.866\, \lambda)/(Nd \cos \Theta)$$

Where:

The 3 dB beam width is *BW* in radians,
the wavelength of the signal is λ in meters,
the number of elements on a side of the array is *N*,
the separation of the elements is *d* in meters, and
the offset angle of the beam from the boresight of the array is Θ in degrees.

Table 2 shows the beamwidth as a function of the number of elements on a side of a square array and the beam offset angle from the bore sight of the array (i.e., the perpendicular to the plane of the array). The element spacing is one half of the signal wavelength. The beam width has been converted into degrees

Table 2: *Beam width vs. elements per side and offset angle*

Cells on side	No offset	15° offset	30° offset	45° offset	60° offset
8	12.4°	12.8°	14.3°	17.3°	24.8°
10	9.9°	10.5°	11.4°	14.0°	19.8°
12	8.3°	8.6°	9.5°	11.7°	16.5°
14	7.1°	7.3°	8.2°	10.0°	14.2°
16	6.2°	6.2°	7.2°	8.8°	12.4°

GAIN REDUCTION CAUSED BY ANTENNA MISALIGNMENT

If the transmitting antenna is not pointed directly at the receiving antenna or the receiving antenna is not pointed directly at the transmitting, antenna the antenna gain contributing to the communication link is reduced by the formula:

$$\Delta G = 12(\Theta/\alpha)^2$$

Where:

The reduction of the gain from bore sight is ΔG in dB,
the offset angle is Θ in degrees, and

the beam width of the antenna is α in degrees.

This formula deals with the impact of the accuracy of antenna steering, which will be significantly challenging in mmW 5G applications involving maneuvering assets.

The geometry of link misalignment is shown in **Figure 1.**

ANTENNA SIDE LOBES

Particularly in mobile applications, it may not be practical to have the main beams of transmitting and receiving antennas aligned. **Figure 2** illustrates the situation in which a transmitter may be transmitting into a side lobe of a receiver's antenna. **Figure 3** shows the power of the first four side lobes relative to the main beam bore sight signal.

The signal strength received by the receiving station (i.e., the output of its antenna) is given by the formula:

$$P_R = P_T + G_T - L + G_R$$

Where:

The received power is P_R,

the transmitter output power is P_T,

the transmitting antenna gain (toward the receiver) is G_T,

the propagation loss between the antennas is L, and

the receiving antenna gain (toward the transmitter) is G_R.

In this case, let the signal frequency be 28 GHz and the link range be 25 km. Thus the link loss (from Table 1 in last month's EW 101 column) is 149.3 dB. Both the transmitting and receiving antennas have 256 elements. If the transmit antenna is aimed directly at the receiver, the applicable transmit antenna gain (from Table 1, above) is 25 dBi. If the receiving antenna is aimed so that its first sidelobe is toward the transmitter, its effective gain is 13.5 dB less than its main beam bore sight gain (from Figure 3, above). Thus the effective receiving antenna gain is 11.5 dBi. If the transmitter power is 1 Watt (30 dBm), the received power is:

$$P_R = 30 \text{ dBm} + 25 \text{ dB} - 149.3 \text{ dB} + 11.5 \text{ dB}$$
$$= -82.8 \text{ dBm}$$

WHAT'S NEXT

Next month, we will continue our 5G series with a discussion of modulation. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.

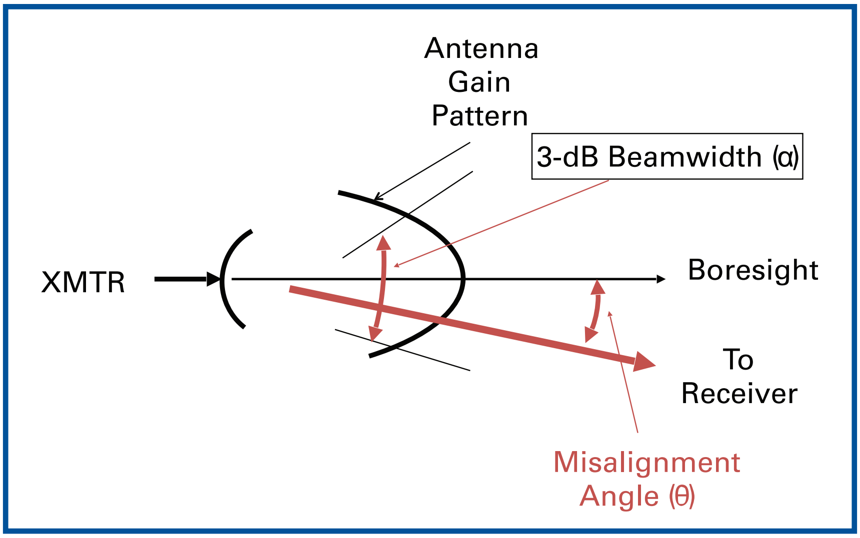


Fig. 1: This figure shows how the reduction in gain, when an antenna is transmitting to a receiving antenna that is away from its boresight, is a function of the misalignment angle and the antenna beam width.

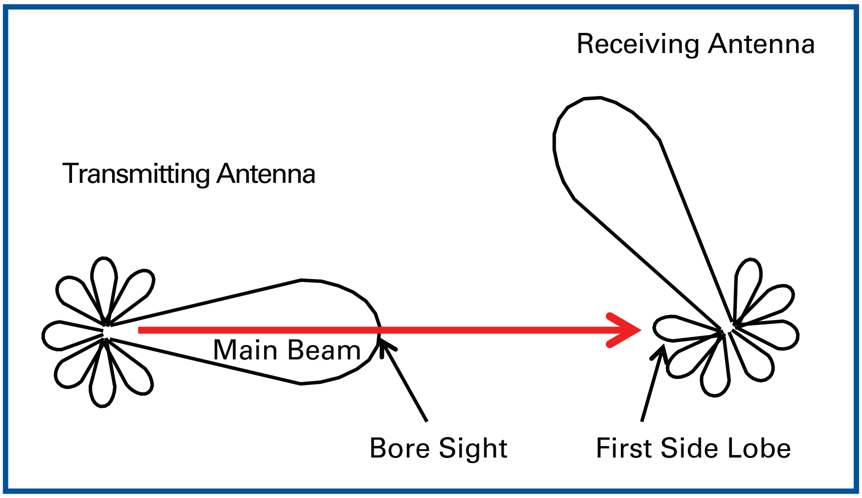


Fig. 2: The receiving antenna is directed away from the transmitter, so the transmitted signal is received in a side lobe (in this example, it is the first sidelobe).

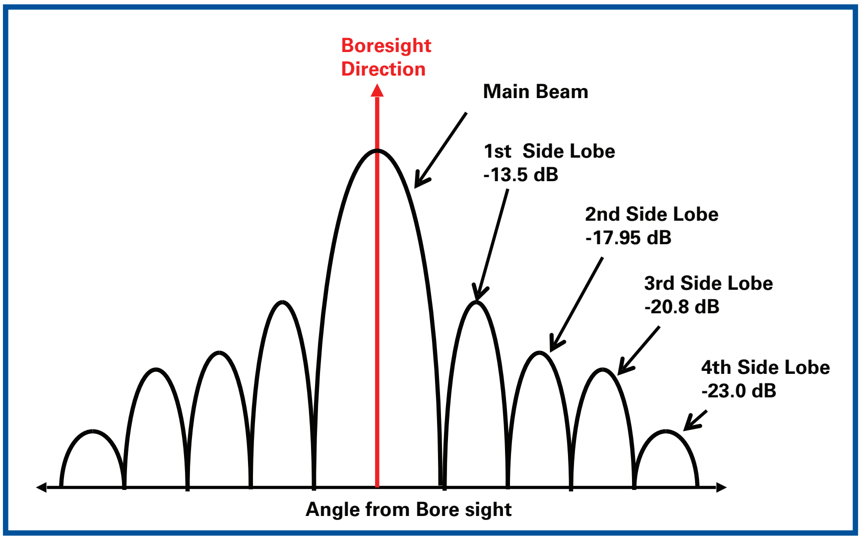


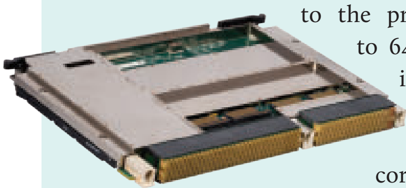
Fig. 3: The side lobes of an antenna pattern are reduced relative to the boresight gain, and they are narrower. Note that the nulls between lobes are much narrower than the widths of the lobes.

COMPACT KA-BAND MPMS

The PTX8808 and PTX8811 are a pair of microwave power modules (MPMs) from TMD Technologies that operate in Ka-Band with power outputs of 60 to 160 W (CW/pulsed, 100% duty cycle). Both units are designed for EW applications and employ a Ka band helix, mini–Travelling Wave Tube (TWT) and a matched, high density switched mode power supply to form a single drop-in microwave amplifier unit measuring 450 x 224 x 59.5 mm. The PTX 8808 covers 26.5-40 GHz with output levels of 60-115W, and the PTX8811 covers 30-40 GHz at115-160W. Both units are conduction cooled. *TMD Technologies; Hayes, Middlesex, UK; +44 (0)20 8573 5555; www.tmd.co.uk*

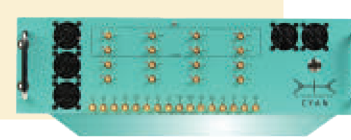
6U VPX SINGLE BOARD COMPUTER

The VPX6-1961 from Curtiss-Wright Defense Solutions is a rugged, high-performance 6U OpenVPXTM single board computer (SBC) that combines Intel's 11th Gen Intel Core (formerly "Tiger Lake-H") processor with the power and flexibility of the VPX platform's high speed fabric interconnects. With a high-speed, dual-channel DDR4 memory subsystem connected directly to the processor supporting up to 64 GB SDRAM, the SBC is able to maximize the performance of the multiple processing cores, the GPU cores and the AVX512 floating-point processing units of the processor. The unit provides up to 1 TB of high-speed NVMe SSD memory, includes dual XMC mezzanine sites to support a wide variety of expansion mezzanine daughter card, and supports 16 lanes of PCI Express® (PCIe), with flexible port configurations (1x16, 2x8, 4x4) for expansion plane connectivity. *Curtiss-Wright Defense Solutions; Ashburn, VA, USA; www.curtisswrightds.com*



64-CHANNEL SDR

Per Vices Corporation has introduced Cyan EC (extended channel), an upgraded version of its Cyan software defined radio (SDR) platform designed for use in radar systems, GNSS/GPS, MRI receivers and exciters, spectrum monitoring, as well as test and measurement applications. The new channel extension enables up to 64 DSP channels across 16 physical SMA ports, which allows users to break up the one large bandwidth physical chain into multiple digital channels and permits the radio platform to do the multiplexing. By providing additional digital chains, which are coherently superimposed into a single physical channel, the computational complexity required to address wide bandwidths is further reduced, which helps to achieve better SFDR, sensitivity, and SNR in a high-throughput SDR solution. *Per Vices; Toronto, ONT, Canada; www.pervices.com*



8-CHANNEL PHASE COHERENT RF SIGNAL RECORDER

Pentek's Talon Model RTR 2628 is an eight-channel recorder optimized for applications including signals intelligence, direction finding, spectrum monitoring, phased array radar and beamforming. The 4U 19-inch rackmount unit features eight phase coherent RF tuners (one per channel) that are tunable up to 6 GHz and able to capture up to 80 MHz of instantaneous bandwidth. Each input channel includes a 250-MHz 16-bit analog-to-digital converter and an FPGA-based digital downconverter with programmable decimations from 2 to 65536 for instantaneous bandwidths from 80 MHz down to 3 kHz. RF signals up to 6 GHz in frequency can be tuned, sampled, digitally-downconverted and streamed to disk in real-time at sustained aggregate recording rates up to 3.2 GB/sec. The recorder includes as many as 32 hot-swappable SSDs to provide flexible storage capacities up to 122 TB. *Pentek Inc.; Upper Saddle River, NJ, USA; 201-818-5900; www.pentek.com*

PORTABLE JAMMER TRAINING SYSTEM

The JTS0100 Jammer Training System from Mercury Systems is designed to train radar and communications operators in harsh tactical environments. The system transmits across four independent channels from 2-18 GHz, with up to 4 beams per channel. It is configured around three subsystems: a human-machine interface (HMI) subsystem for greater operator control and adaptability, an advanced spectrum processing unit for signal tracking and modification, plus antennas for signal reception and amplification. It also incorporates advanced digital RF memory (DRFM) technology and a library of US government-validated, reconfigurable jamming and deception threats for accurate and scalable training. *Mercury Systems; Andover, MA, USA; +1 (978) 967-1401; www.mrcy.com*

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Dr. Clayton Stewart

Mondays & Wednesdays
1:00 – 4:00 PM ET | June 7 – 30, 2021
This 24 hour web based course delivers a thorough overview promoting an understanding and building a successful Command, Control, Communications, Computers, Intelligence, Surveillance, Reconnaissance (C4ISR) architecture.

Aircraft Radar Cross Section Engineering

Renan Richter

Mondays, Wednesdays & Fridays
1:00 – 4:00 PM ET | July 12 – 30, 2021
This course introduces students to Radar Cross Section (RCS) engineering and its basics fundamentals inside the modern EW context. Stealth technology will be addressed by presenting current challenges and future perspectives.

Direct Energy Weapons

Kyle Davidson

Mondays & Wednesdays
1:00 – 4:00 PM ET | August 2 – 18, 2021
This course introduces students to the fundamentals of Direct Energy Weapons (DEW) across the electromagnetic spectrum. The goal is to provide an understanding of the operation of laser and high-power microwave DEWs in military applications, including their design trade-offs, and target effects.

Introduction to Satellite Communications (Satcom)

Dr. Patrick Ford

Mondays, Wednesdays & Fridays
1:00 – 5:00 PM ET | December 6 – 10, 2021
This course will cover the core material required for participants to understand and discuss basic Satcom theory and operations.

= Web Course, no travel required!

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AOC has launched two new podcasts to bring our community together: "The History of Crows," launched in May, which illuminates the evolution of Electromagnetic Spectrum Operations (EMSO); and "From the Crows' Nest," launched in April, which features interviews and analysis of the leading issues of the day. Stakeholders and professionals across government, industry and academia, not to mention the self-described technologist, can learn our history and engage in the issues impacting our community today. Advertisements and episode sponsorships are available. Please visit crows.org/podcast for more information, or find the podcasts on Apple, Spotify or wherever great podcasts are found!

LAST MONTH FOR AOC AWARDS NOMINATIONS

A central tenant of AOC's mission is recognizing individuals, groups, and military units for their outstanding performance in furthering the aims of the AOC and the Electromagnetic Warfare enterprise. AOC has a number of awards that are available each year, with two categories – Competitive and Non-Competitive. Nominations are due by June 30, 2021. Please visit crows.org/awards for more information.

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