May 2020 • Vol. 43, No. 5 crows.org

JED

Association of Old Crows

Journal of Electromagnetic Dominance

Next Generation SIGINT

- News: Germany to Buy Mix of EW Fighter Aircraft
- Interview: Gen Lance Landrum, Deputy Director, EMSO CFT
- Technology Survey: Comms and RCIED Jammers


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JED
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Technology advancements have steadily blurred the functional lines between SIGINT and EW for decades. In what ways does a radar ESM system differ from an ELINT system, for example. In this article, we look at how companies are approaching next-generations SIGINT systems. US AIR FORCE PHOTO

ON THE COVER: A WINGTIP SENSOR ARRAY ON A US ARMY RC-12X GUARDRAIL AIRCRAFT. PHOTO BY DUNCAN MONK

Hang Time: The Next Generation Jammer Mid-Band system completed part of its developmental testing in March. Above, two NGJ-MB Engineering Development Model (EDM) pods mounted beneath the wings of an EA-18G undergo tests in the US Navy's Air Combat Environmental Test and Evaluation Facility (ACETEF) anechoic chamber at Naval Air Station Patuxent River, MD. Over a three-month period, the pods, developed by the Raytheon Company in El Segundo, CA, completed more than 400 hours of basic functionality, Electromagnetic Environmental Effects (E3) data collection and performance testing. US NAVY PHOTO

Departments

ENGAGEMENT

Last month, the DOD and its supporters on Capitol Hill, in addition to several other government departments and agencies, pushed back hard against the Federal Communications Commission's (FCC's) decision to grant a spectrum licensing modification to Ligado Networks. The license approves the company's proposal to operate in a portion of L-Band spectrum adjacent to one of the frequencies used for the Global Positioning System (GPS). Opponents argue that this could interfere with military and civilian access to GPS signals.

Without going too far into the technical details of the case, Ligado's application sought terrestrial use of 1526-1536 MHz, 1627.5-1637.5 MHz and 1646.5-1656.5 MHz as part of the US government's strategy to build out its 5G telecommunications network. The GPS L1 signal, which is used for both military and civilian applications, is transmitted at 1575.42 MHz. The DOD and others are concerned that the low-power L1 signal will be overwhelmed by the signal from Ligado's terrestrial base stations. FCC Chairman Ajit Pai said that Ligado has addressed these concerns by reducing the power of its base stations from 32 dBW to 9.8 dBW (a reduction of 99.3%) and committing to a 23-MHz guard band. The DOD isn't buying it.

The DOD's concerns are understandable, and the FCC decision puts the DOD in a very bad situation. But, technical arguments aside, it's also worth noting that some of the responsibility lies with the DOD to be far more proactive in the way it engages with the telecommunications industry and the FCC. This is not the first time the DOD has lost a battle over spectrum access, but it could turn out to be the most significant in terms of operational impact. And, depending on what the fix is, it could turn out to be the costliest, as well. Doesn't this potential impact call for a more proactive strategy from the DOD's leadership?

It's not like DOD shouldn't have seen this coming and acted sooner. Back in 2011, during the previous round of the Ligado saga, the DOD was part of a large coalition of government and industry organizations that successfully blocked Ligado's predecessor, LightSquared, from licensing spectrum near the GPS L1 signal. Shortly afterward, LightSquared went bankrupt, and it emerged from Chapter 11 a few years later as Ligado (smarter and equally as determined). Ligado modified the original LightSquared application, as discussed above, to mitigate the concerns raised in 2011. This modified application was what the FCC approved last month.

The DOD, which doesn't generate licensing fees or taxes from the spectrum it occupies, can expect to lose more of these FCC decisions in the future. If access to the EMS is as important as the DOD says (and it is!), then the DOD needs to come up with a more proactive strategy for either retaining sole access, or sharing access, to the portions of the spectrum it occupies. Otherwise, the telecommunications industry is going to continue to chip away at the DOD's most valuable resource, and the DOD can only cast blame on itself. *– J. Knowles*

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Calendar *Conferences & Trade Shows*

MAY

Virtual EMS Summit 2020
May 19-20
Online
www.crows.org

JUNE

International Microwave Symposium
June 21-26
Los Angeles, CA
www.ims-ieee.org

5th Annual Directed Energy Summit Online
June 25-26
Online
www.idga.org

Defense officials have announced extended restrictions on domestic travel for service members, Department of Defense (DOD) employees and family members in response to the novel coronavirus, COVID-19. All travel will be halted through June 30, per the DOD's memorandum. For conferences taking place after June 30, please contact the conference organizer.

AUGUST

TechNet Augusta
August 17-21
Augusta, GA
www.afcea.org

Defense Services Asia
August 24-27
Kuala Lumpur, Malaysia
www.dsaexhibition.com

SEPTEMBER

AFA 2020 Air, Space and Cyberspace Conference
September 14-16
National Harbor, MD
www.afa.org

Modern Threats: Surface-to-Air Missile Conference
September 15-17
Redstone Arsenal, AL
www.crows.org

Africa Aerospace and Defense (AAD2020)
September 16-20
Centurion, Gauteng, South Africa
www.aadexpo.co.za

2020 DE Systems Symposium
September 28 – October 2
Washington, D.C.
www.deps.org

OCTOBER

AUSA Annual Meeting
October 12-14
Washington, DC
www.ausa.org

Electronic Warfare Gulf Cooperation Council (EWGCC) 2020
October 20-21
Abu Dhabi, UAE
www.electronic-warfare-gcc.com

6th Annual CEMA Conference
October 26-29
Aberdeen Proving Ground, MD
www.crows.org

NOVEMBER

EW Europe
November 16-18
Liverpool, UK
www.crows.org

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

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Calendar *Courses & Seminars*

MAY

AOC Virtual Series Webinar: The Basic Concepts of ELINT
May 7
1400-1500 EST
www.crows.org

AOC Virtual Series Webinar: Leveraging Publicly Available Information to Map and Track GNSS Interference
May 21
1400-1500 EST
www.crows.org

JUNE

AOC Live Professional Development Web Course: EW Modeling and Simulation
June 1-17
8 sessions, 1300-1600 EST
www.crows.org

Introduction to ISR Concepts, Systems and Test Evaluation
June 2-5
Atlanta, GA
www.pe.gatech.edu

AOC Virtual Series Webinar: Deep Learning and Waveform Classification
June 4
1400-1500 EST
www.crows.org

Fundamentals of Radar Signal Processing
June 8-11
Las Vegas, NV
www.pe.gatech.edu

AOC Virtual Series Webinar: The Fundamentals of Electro-Optical/ Infrared Sensor Engineering
June 18
1400-1500 EST
www.crows.org

Adaptive Arrays: Algorithms, Architectures and Applications
June 22-25
Las Vegas, NV
www.pe.gatech.edu

Basic RF Electronic Warfare Concepts
June 23-25
Las Vegas, NV
www.pe.gatech.edu

JULY

AOC Virtual Series Webinar: Denial & Deception: Getting back to SIGINT's Roots
July 9
1400-1500 EST
www.crows.org

AOC Live Professional Development Web Course: Missile Design, Development, and System Engineering
July 13-31
9 sessions, 1300-1600 EST
www.crows.org

Cyber Warfare/Electronic Warfare Convergence
July 21-23
Atlanta, GA
www.pe.gatech.edu

Infrared Countermeasures
July 21-24
Shalimar, FL
www.pe.gatech.edu

AOC Virtual Series Webinar: EW System Development: Critical Thinking in Design Tradeoffs
July 23
1400-1500 EST
www.crows.org

Defense officials have announced extended restrictions on domestic travel for service members, Department of Defense (DOD) employees and family members in response to the novel coronavirus, COVID-19. All travel will be halted through June 30, per the DOD's memorandum. For all in-person courses, please contact the course provider.

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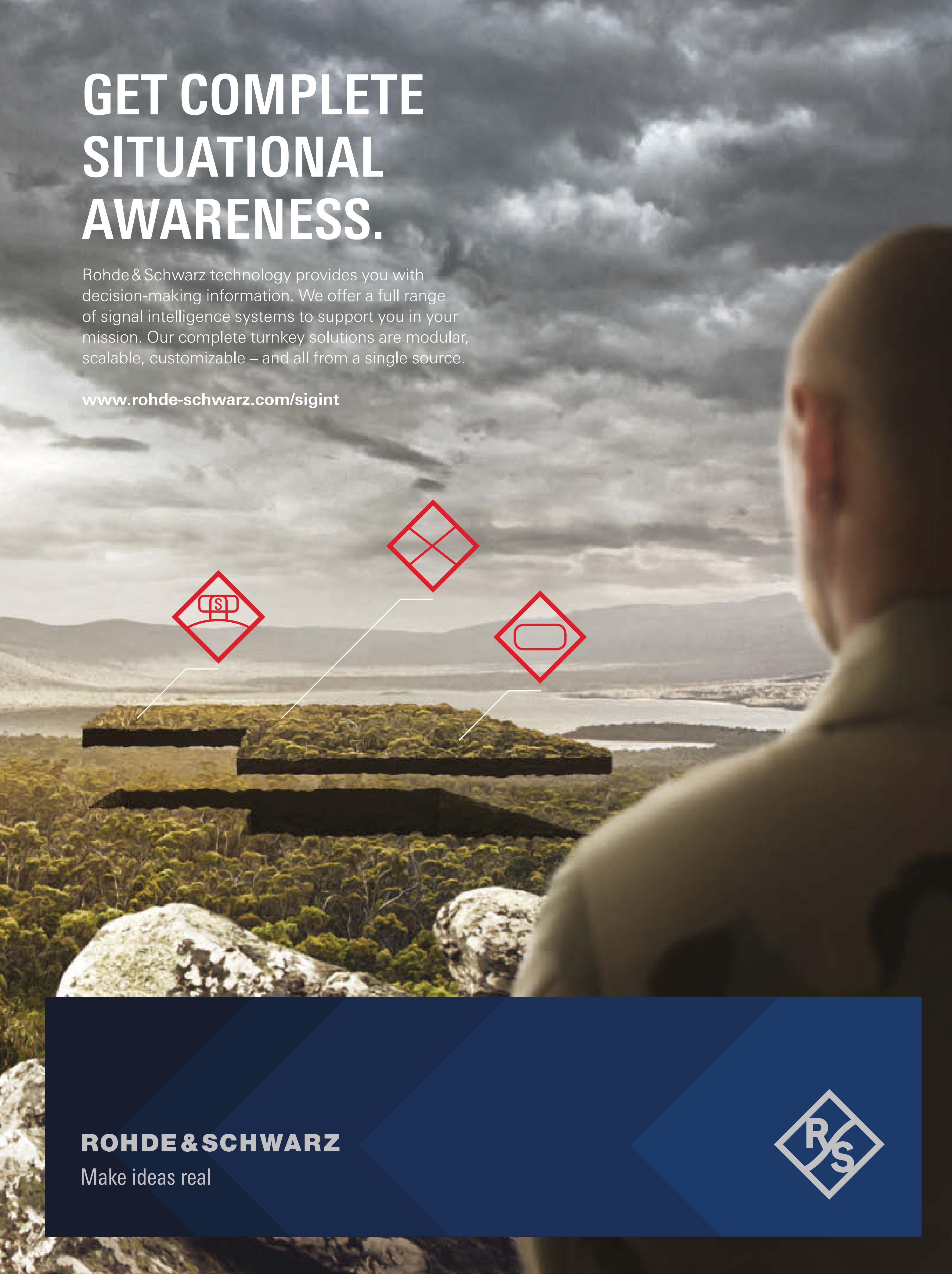

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NEW NAME FOR A NEW ERA

You may have noticed this month's *JED* looks a little bit different. We've updated the look of the magazine in several subtle ways, but the same basic structure is still there. For me, the biggest change is the magazine's new name – *Journal of Electromagnetic Dominance.*

The first issue of the *Journal of Electronic Defense* was published in 1977. Over the next 30 years, the Electronic Warfare (EW) and Signals Intelligence (SIGINT) disciplines steadily evolved, and they were primarily advancing along a technology-based vector. The larger, strategic approach to EW and SIGINT – how military and government leaders invested in, managed and employed EW and SIGINT – remained fairly consistent throughout this period. By the 2007-2010 timeframe, however, it was becoming clear that our traditional approach to EW and SIGINT – both inside and outside our community – would no longer work. Our primary focus on EW and SIGINT technology would not be enough for the greater challenges we would face in the future.

Our community needed to adapt and forge a new concept that would better connect the EW and Spectrum Management disciplines with each other, and it would also need to connect them with all of the other EMS-based communities (ELINT, COMINT, Directed Energy, Cyber, PNT, EO/IR sensing, radar, radio, etc.). We needed to think beyond technology and take an enterprise-level approach to EMS Operations that accounted for new doctrine and lexicon, creating stronger organizations, identifying senior leaders to lead our organizations, improving training, consistent technology investment, developing more personnel with the right skills, etc.

JED has been an important voice throughout this evolution, serving as a platform for our community's forward-leaning thinkers and advocating for change. In 2008, *JED* published its first contributed articles describing the EMS as a maneuver space. By 2010, *JED* began (and never ceased) calling for recognition of the Electromagnetic Domain. Since that time, *JED* has been writing about many of the big EMS challenges that are facing Western governments and helping the AOC advocate to military and government leaders for the new EMS-based strategy we need to adapt to this new reality.

Today, our community is pursuing a very different conversation than it was a decade ago. Instead of focusing mainly on a materiel-based EW paradigm, we are thinking in terms of an EM Domain and a wide-ranging, enterprise-based strategy for EMS Operations (EMSO). The AOC, while it is still firmly committed to serving the EW and SIGINT communities, is engaging with all of the military stake-holders that operate in the EM Domain. *JED* is at the forefront of this changing dynamic, and it is logical that its new name, the *Journal of Electromagnetic Dominance,* reflects this broader mission.

As always, I hope you will enjoy this month's *JED.* It is essential reading for an essential community. – *Muddy Watters*

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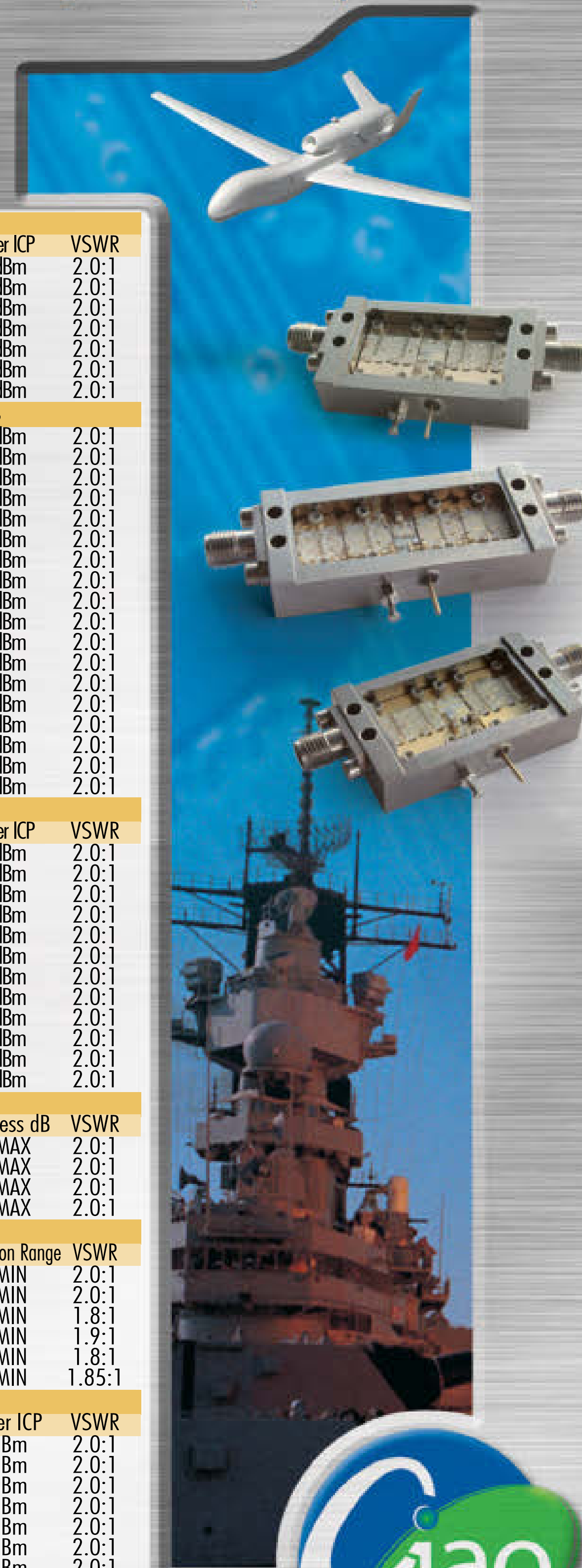

OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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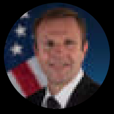


GERMANY ANNOUNCES MIXED BUY OF EUROFIGHTERS, GROWLERS, SUPER HORNETS

As part of a modernization plan to replace the remainder of the Luftwaffe's Panavia Tornado fleet, as well as its older Eurofighter Typhoons, the German Government has formally announced its plans to acquire Eurofighters, F/A-18E/F Super Hornets and EA-18G Growlers.

Under the plan, the Luftwaffe would receive 93 new Eurofighters, 30 Super Hornets and 15 Growlers to replace its Tornado aircraft, as well as its older Eurofighters. The new aircraft are needed to fill three essential combat roles performed by the retiring aircraft– a nuclear attack role delivering US-provided B61 nuclear weapons, an electronic attack role, and a conventional strike and reconnaissance role.

PHOTO: ALAN WILSON

Further out, Germany and France are cooperating on development of a stealthy Future Combat Air System (FCAS) that is slated for operational availability by 2040. Last year, the German Government decided against buying F-35s to meet the Luftwaffe's requirements. The split Eurofighter/Super Hornet/Growler buy was criticized by European industry, which had expected the government to replace all of the retiring aircraft with Eurofighters after the F-35 was eliminated from the competition.

Germany's decision to buy Growlers is significant, because NATO has set a goal for the Alliance's European members to take on 50% of NATO's suppression of enemy air defenses (SEAD) mission (both lethal SEAD and support jamming) by 2030. The planned retirement of Germany's Tornado aircraft provided the Luftwaffe with the opportunity to not only replace their lethal SEAD capability but also to add a support jamming capability in order to meet their national requirement, as well as part of the NATO SEAD requirement.

Germany is among the first European countries to take concrete steps to modernize its SEAD capabilities, and European EW companies have been working to offer solutions. (*JED* will cover European SEAD developments in greater detail its June issue.) In November 2019, Eurofighter consortium member Airbus proposed its Eurofighter Electronic Combat Role (ECR) concept, which featured an emitter location system, a pair of escort jamming pods, six loitering Selective Precision Effects At Range – Electronic Warfare (SPEAR-EW) munitions for stand-in jamming, as well as two short-range and four long-range air-to-air missiles. Hensoldt (Ulm, Germany) has been developing the escort jamming pod as part of its Kalætron family of EW systems, and Leonardo (Luton, UK) is developing the EA payload for the SPEAR-EW air vehicles.

The Luftwaffe has not disclosed if it will contract with Boeing to integrate some of these European capabilities onto its Growlers or use the Next Generation Jammer (NGJ) and MALD-N stand-in jammers that the US Navy is integrating onto the aircraft. The Luftwaffe's Tornado aircraft, as well as the Growler, already use the AGM-88E Advanced Anti-Radiation Guided Missile (AARGM). Although the 15 Growlers in the German acquisition represent a small number of aircraft, the EW equipment the Luftwaffe selects for them represents an important decision that will affect European EW companies. – *J. Knowles*

DARPA MOVES MIXED-MODE/ MIXED-SIGNAL CHIPS BEYOND CONVENTIONAL CMOS PROCESSES

Moving beyond today's conventional CMOS system-on-a-chip (SoC) capabilities, the Defense Advanced Research Projects Agency (DARPA) has selected nine research teams to develop advanced RF mixed-mode electronics critical to emerging defense applications in communications, radar and EW. The goal of the program, titled, "Technologies for Mixed mode Ultra Scaled Integrated Circuits (T-MUSIC)," is to integrate high-performance RF analog and advanced digital electronics onto a single wafer – through the integration of photonics and RF components – directly into advanced circuits and semiconductor manufacturing processes. According to DARPA T-MUSIC program manager, Dr. Y.K. Chen, the goal is to "develop next-generation terahertz (THz) mixed-mode devices that integrate digital processing and intelligence on the same chip through an advanced CMOS fabrication platform. These technologies will provide DOD systems with differentiating capabilities in advanced RF sensors, high-capacity

wireless and wireline communications, and beyond." In addition, the program will work to "establish a domestic ecosystem that can facilitate enduring DOD access to high-performance RF mixed-mode SoCs."

First announced in January 2019 as a part of the second phase of DARPA's Electronics Resurgence Initiative (ERI), the impetus of the program is the DOD's recognition that conventional CMOS platforms are unable to support operations at the higher frequencies, larger signal bandwidths, and higher resolutions needed for the next-generation mixed-mode interfaces of emerging defense applications.

The T-MUSIC research teams include both academic institutions and commercial companies. Five of the teams are assigned to developing and implementing advanced broadband RF mixed-mode circuit designs. These include: BAE Systems; Raytheon; University of California, Los Angeles; University of California, San Diego; and the University of Utah. The design teams will work closely with onshore foundry partners – GlobalFoundries (Santa Clara, CA) and TowerJazz (Migdal HaEmek, Israel). A third group of researchers will explore "foundational breakthroughs in ultra-broadband transistors, pushing well beyond current near-term advances in foundry technology." These teams from the University of California, Los Angeles (UCLA), and University of California, Berkeley, will explore new types of RF mixed-mode transistors capable of demonstrating transistor-switching speeds up to 1 THz in a scalable CMOS platform.

Dr. Chen, says that, beyond pure silicon, the program will also be exploring other semiconductor technology materials, such as silicon germanium, as well as incorporating ferroelectric materials to improve charge density, and at different device structures such as 3D CMOS, for better speed and performance. However, he added that ultimately, "The payload we plan to develop will be manufactured using a CMOS manufacturing platform, so everything we are exploring must be compatible with that platform, because this will be the main production capability in future."

The overall program funding is estimated to be approximately $70 million over four years. The first step is to develop the advanced foundry technology with existing CMOS capability on shore and to incorporate new material and device structure to provide some level of pre-production development for mixed-signal circuit devices.

As described by Dr. Chen, the program is pursuing three different technical areas. Technical Area 1 (TA-1) is pre-development – exploring how to export new materials, devices, and production technology into the foundry, as well as into research development areas, with the aim of improving transistor speeds from 300 GHz to 700 GHz. TA-2 will explore the creation of integrated circuits using the technology to build multiple "building blocks" to demonstrate superior mixed-signal devices for DOD-relevant applications. The building blocks will also establish the foundation of a mixed-mode IP library for the DOD user community. Finally, TA-3 will look into ways to get transistor speeds, from current CMOS-type fab levels, up to THz speeds.

In terms of schedule, the program is organized in three phases with the first two phases running 18 months each, and the final phase running 12 months. At the end of each phase, participants will be required to demonstrate their progress toward the final goals. – *J. Haystead*

US ARMY REQUESTS INDUSTRY INFO FOR FUTURE HELICOPTER MISSION SYSTEMS

The US Army's Program Manager for Future Attack Reconnaissance Aircraft (FARA) issued a Request for Information (RFI) last month soliciting industry input about potential FARA mission systems, including sensors, survivability, communications and navigation. These mission systems would be integrated onto FARA and possibly onto the Army's Future Long-Range Assault Aircraft (FLRAA) during their respective Engineering and Manufacturing Development (EMD) phases.

The RFI describes eight FARA mission system "domains" for which PM FARA is seeking information. In the Sensors Domain, it is looking for "Sensor systems and fused sensor systems capable of providing pilotage through a solid-state staring array covering 360 degrees in degraded visual environments (DVE), day/night air and ground targeting at close, mid, and extended ranges to maximize target acquisition capabilities and support all munition types, low-light and wire/obstacle detection, radar detection, radar interferometry, weather detection, terrain avoidance, and situational awareness." The system should minimize pilot workload and "all sensor data should be capable of internal transmission to pilot head-up displays and multiple cockpit displays and external transmission to other systems in the operational environment."

In the Survivability Domain, program officials are seeking information about, "...aircraft survivability systems capable of detecting RF, IR, and laser threats. Missile warning systems capable of threat launch detection. Hostile fire systems capable of ballistic fire detection. Countermeasure systems capable of protecting against RF and IR threats. Electronic Warfare (EW) to include RF jamming systems. The FARA PM is interested in a comprehensive ASE suite that minimizes weight, can be fused with aircraft navigation and pilotage systems, and fully integrated with and conformant to the aircraft open architecture." To learn more about the EW aspects of the FARA and FLRAA programs, see "FVL Program Aims for Overwhelming Advancement of Aircraft Survivability Capability" (p. 22 of the April 2020 *JED*).

For the Communications Domain, PM FARA is seeking, "A multi-band and single-band communications suite capable of providing line-of-sight and beyond-line-of-sight communications in HF, VHF (AM/FM), UHF (AM/SATCOM), Link 16, advanced networking waveforms, Blue Force Tracking, workload-reduced manned/unmanned (MUM) teaming through Level of Interoperability (LOI) 5, identification/transponders, and internal communications."

The RFI also describes the Navigation Domain needs and seeks responses about "Aircraft navigation sets capable of legacy and next generation civil navi-

US ARMY SEEKS SIGINT SOLUTIONS FOR ITS DEEP SENSING REQUIREMENT

The US Army has issued a Request for Information (RFI) for an airborne Multi-Domain Sensing System (MDSS) that can perform electronic intelligence (ELINT), communications intelligence (COMINT) and radar functions in support of large-scale ground operations. The RFI, issued by the Program Manager for Sensors and Aerial Intelligence (PM SAI), calls for non-developmental solutions that can meet the Army's MDSS High Accuracy Detection and Exploitation System (HADES) requirement.

As the Army continues to build its Multi-Domain Operations (MDO) concept, it wants to fill certain sensor capability gaps, including indicators and warnings, long-range precision fire targeting and situational understanding. The MDSS is the Army's main effort to address these gaps, and it focuses on six capability areas: 1) Platforms; 2) Sensors; 3) Integrated Intelligence, Fires, Electronic Warfare, Cyber and Mission Command; 4) Processing, Exploitations, and Dissemination (PED); 5) Data Transport; and 6) Cyber and Electromagnetic Spectrum (EMS) Resiliency. HADES is envisioned as part of the MDSS system-of-systems architecture and will "provide multiple sensing capabilities by developing and integrating sensor capabilities on different platforms that, as a system, will comprise a survivable sensing suite in MDO. These will allow stand-off operations to detect, locate, identify and track critical targets for the ground commander," according to the RFI. It adds that the current sensor priorities for HADES are ELINT, COMINT and radar.

PM SAI is using the RFI to identify non-developmental ELINT, COMINT and radar systems. It defines "non-developmental" as sensor systems that could be upgraded or enhanced to meet the HADES requirement within 12 months. The Army plans to hold a HADES sensor fly-off event in 2021.

In the near-term, the Army plans to conduct a two-phase evaluation of proposals. During Phase 1, PM SAI will review White Paper responses to the RFI. If needed, Phase 2 would involve discussions and/or hardware demonstrations with some companies.

The HADES RFI solicitation number is W56KGY-20-R-MDSS. White paper responses are due by May 7. The point of contact is Andrea Kuciej, +(443) 861-2287, e-mail andrea.d.kuciej.civ@mail.mil. – *J. Knowles*

gation modes in VHF Nav/ILS, TACAN, Doppler, EGI with M-code encryption, and assured precision navigation and timing (A-PNT), and Digital Terrain Elevation Data (DTED) assisted visual-based solutions for aerial navigation in GPS denied environments and under Instrument Meteorological Conditions (IMC). The FARA PM is also interested in solutions and software applications that support supervised autonomy / optionally-manned flight."

Other domains of interest described in the RFI include Infrastructure / Digital Backbone, Data Fusion, Pilot Interface and (hard kill) Effectors. Open standards are of particular importance in the program. The RFI describes the Digital Backbone Domain as "Components, technologies and standards that support and complement the Government's MOSA objective to enable rapid development, integration, and modification of mission systems and enhanced mission systems capabilities by qualified third-party integrators without air vehicle OEM involvement."

PM FARA is interested in solutions that present low aerodynamic drag; "centralize capabilities into a multi-functional component (weight/power reduction)"; and can be integrated into the FLRAA for commonality. RFI responses can focus on one or multiple mission systems domains.

This summer, the FARA and FLRAA project offices are planning to hold a an Industry Day in Huntsville, AL. In the meantime, responses to the RFI are due by May 15. The contracting point of contact is Blanche Wilson-Noack, +(256) 876-4390, e-mail blanche.m.wilson-noack.civ@mail.mil. – *J. Knowles*

IN BRIEF

The Strategic & Spectrum Missions Advanced Resilient Trusted Systems (S2MARTS) consortium, acting on behalf of the Naval Surface Warfare Center-Crane (Crane, IN), is soliciting proposals for an "Electromagnetic Spectrum (EMS) Payload" that can "replicate with high fidelity a wide band and dynamic range of electromagnetic spectrum waveforms and signatures in both frequency and power," according to an S2MARTS opportunity announcement. NSWC-Crane wants to develop an EMS Payload prototype that will "will take a more proactive/offensive posture than simply reacting to a threat, providing a capability that will get ahead of the adversary." The LOKI group is seeking a solution that can be hosted on "autonomous, unmanned vehicles"; capable of supporting distributed, multi-static netted operations (e.g., swarms); capable of providing "persistent emissions at pre-programmed time intervals or events"; and presents a "reasonably small" low-SWaP footprint. Proposals are due by May 4. Bidders must be members of the S2MARTS consortium.

The **Defense Advanced Research Projects Agency (DARPA), Microsystems Technology Office (MTO)**, has issued a Request for Information (RFI) for "Techniques to Characterize the Susceptibility of Electronics to High Power Microwave Irradiation." MTO is seeking industry input for an upcoming program that will help the DOD to better understand how High-Power Microwave (HPM) weapons can create effects in victim electronics systems. The focus of the RFI is to "(1) obtain an appreciation for the current state-of-the-art in theory and computational methods capable of modeling these phenomena; (2) learn about new theoretical and modeling/simulation approaches that could lead to improved characterization and predictive capabilities; (3) understand new experimental approaches to measure coupling into enclosures and the

EM effects on electronics; and (4) identify specific metrics to assess the effectiveness of new theoretical, modeling and measurement approaches." The solicitation number is DARPA-SN-20-46. The Point of Contact is **Dr. David Abe, DARPA/MTO**, e-mail DARPA-SN-20-46@darpa.mil. Responses are due by May 11.

The US Army has announced plans to enter into a Prototype Other Transaction Agreement (OTA) with a new entity, the **Spectrum Forward Consortium**. The Consortium will provide collective expertise in a variety of EMS-related areas, including cognitive spectrum access and sharing, "RF free" space optics cooperative systems, electronic warfare, ISR and radar. Technology areas of interest include Massive Multiple Input, Multiple Output (MIMO) antenna arrays, 3D beam-forming, waveform diversity, multifunction RF, cognitive spectrum sharing, machine learning, cognitive sensing, 5G technologies and next-generation radio access networks.

South Korea's **Huneed Technologies**, working in partnership with **Hensoldt**, has delivered the first eight final assembled AN/AAR-60 MILDS ultraviolet missile warning systems to **Korea Aerospace Industries** for the Korean Utility Helicopter and Maritime Utility Helicopter programs. Huneed is responsible for the production of two printed circuit boards, configuration and calibration, final assembly and testing of the MILDS missile warner within the scope of offset obligations. The first MILDS delivery was completed on time at the start of April 2020. A Hensoldt team supported Huneed with the delivery (including working from home in Germany during the COVID-19 shutdown). Hensoldt's total offset commitment with Huneed aggregates to 258 sensors or approximately 64 MILDS systems.

DARPA's Small Business Programs Office (SBPO) announced plans to issue an SBIR/STTR Opportunity (SBO) on April 23 to better understand "... the feasibility of a wearable laser sensor that can rapidly detect laser irradiation day and night and rapidly alert the wearer of lasing. A desirable system would have low SWaP (size, weight, and power), act as a stand-alone sensor, and be used as a wearable sensor. The system must have very low weight and volume; detect and alert of lasing in real time; and detect laser illumination over the visible to shortwave infrared region of the electromagnetic spectrum (450-1600 nm target wave band). The system goal is for the wearable detection system to be 100 grams (g) or less and be powered by a rechargeable Conformal Wearable Battery, or CWB, that is less than 1.5 kg (to include wires and connectors) and can power the system for 72-hours of continuous operations. The wearable system must be comfortable to wear and be easily integrated into existing military use headgear." The solicitation number is HR001120S0019. The point of contact is **BAA Coordinator** HR001120S0019@darpa.mil. Responses are due by May 26.

Maj Gen Lance Landrum, Deputy Director, EMSO CFT

Maj Gen Lance Landrum, USAF, is Deputy Director for Requirements and Capability Development (J8), the Joint Staff, and Deputy Director of the Electromagnetic Spectrum Operations (EMSO) Cross Functional Team (CFT). The EMSO CFT, a SecDef-empowered cross functional team, was created last year at the urging of Congress to help the Department of Defense reverse negative EMSO trends and to help the US military regain and maintain EMSO superiority in an era of Great Power Competition. General Landrum is a command pilot with more than 2,800 flying hours, primarily in the F-16. Among his past assignments, he was commander of the 510th Fighter Squadron (Aviano AB, Italy), commander of the 332nd Expeditionary Operations Group (Joint Base Balad, Iraq), and Commander of the 388th Fighter Wing (Hill AFB, Utah). Prior to his current assignment in the Pentagon, he returned to Aviano as commander of the 31st Fighter Wing.

JED

Congress directed the DOD to establish an "Electronic Warfare CFT", but an "EMSO CFT" was the result. Can you describe that change?

General Landrum

I think to answer that, we need to look at the creation of the Electromagnetic Spectrum Operations Cross Functional Team (EMSO CFT) and the environment in which it was created. The EMSO CFT was created by Congress in response to a series of studies published over the last 15 years that essentially said that the US advantage in the electromagnetic spectrum is – or has been – eroding. Congress recognized that the situation was reaching a critical point where, if we failed to act, the US would find itself at a disadvantage in a future war, especially in an era of Great Power Competition. After Congress authorized the creation of Secretary of Defense-empowered cross-functional teams in the 2017 NDAA [National Defense Authorization Act], they specifically mandated that the Department of Defense create an "Electronic Warfare" cross-functional team in the 2019 NDAA, section 1053, to address this area of concern. When we looked at this as the CFT team in our first couple of months, as we were standing-up and developing our approach and focus areas, we came to the conclusion that we had to look at the electromagnetic spectrum not just as something that is managed or passed through as part of an attack, but as a physical maneuver space and as a battlespace. Like the air or the sea or the land, we believed that the electromagnetic spectrum is contested, and that commanders have to maneuver for dominance in the spectrum. We also believed that the electromagnetic spectrum is congested and constrained. There are more devices and users that rely on the spectrum now than ever before, and our reliance on the spectrum as a military is only increasing. At the same time, we are constrained by physics: we cannot create more spectrum, nor can we expect to have sole control over sections of the spectrum, or block off sections for our sole use.

Being in that mindset leads you to take a holistic view of the electromagnetic spectrum. In recognition of all this, we decided to instead stand up an "electromagnetic spectrum operations" CFT which takes into account both the electronic warfare aspects and the spectrum management aspects of the problem set. The two cannot be worked separately anymore. We cannot work electronic attack, electronic protection, electronic support absent the view of all of the spectrum management requirements that are also in place: the policies associated with the bandwidths and the frequency spectrums, the policies associated with things like the Federal Communications Commission, the International Telecommunications Union, telecommunications agreements both domestically and internationally, and things like that. All spectrum management aspects have wide ranging impacts on how we test, how we train, and how we operate around the world. So, you need to view it all together – both electronic warfare and spectrum management – and that's why we have the Electromagnetic Spectrum Operations Cross Functional Team.

JED

You brought up a lot of concepts of wholeness and being holistic. Do you see that evolution-in-thinking as an indication of broader change across the Department?

General Landrum

I think that we are seeing the impact of what I just mentioned, of electronic warfare and all of the spectrum management aspects coming together. I see some examples especially in the test and training community and those on staffs who shepherd test and training: the ability for us to test our systems, the ability for us to train operators in our systems, the ranges associated with those tests and training opportunities, the ability to radiate our techniques and our waveforms and our signals, both in live space and in synthetic environments. All of those come together in offices across the Services and the Department. We're seeing that across P&R [Office of the Secretary of Defense for Personnel and Readiness], DOT&E [Director, Operational Test and Evaluation], our partnership with the DOD CIO [Chief Information Officer], and other areas.

We're seeing all of this sort-of coalescing, and I think that the idea of electromagnetic spectrum operations and maneuvering within the spectrum is gaining a lot of traction across the department. I think we are also seeing this reflected in discussions around defining requirements for the Joint Force. I think in the future, we have to examine how we can write requirements for our systems and our capabilities that allow for dynamic maneuver in the spectrum, that allow for dynamic access to the spectrum, and that also allow us to simultaneously share portions of the spectrum with not just our allies, but with commercial industry as well. Commercial industry has rightful economic interest in the spectrum, and the economic benefits associated with the spectrum are part of our National interests. You've seen this a lot recently in discussions around 5G for instance. So, while we haven't written requirements yet, I see us in the future writing requirements that create a Joint Force demand signal for dynamic spectrum maneuverability.

JED

There are a number of new CFTs being formed and a lot of new initiatives that are in the news. How does this new thinking about the EMS align with other current or planned initiatives across the Department?

General Landrum

The requirement for EMS superiority is essential to future warfighting, and I think our dynamic maneuver mindset matches up with several initiatives in the Department. You've heard a lot about Joint All Domain Command and Control [JADC2] from the Secretary, as well as from our senior leaders. There's a big effort for JADC2, and the Department has created a cross functional team for that initiative. JADC2 and its associated concepts are going to be heavily reliant on the electromagnetic spectrum. Our ability to gain and maintain control of the electromagnetic spectrum, and our ability to maneuver in that battlespace is going to be critical for it. I think you see it in a number of other areas as well. I think you see it in space assets and space capabilities. I think you see it in things like DARPA's Mosaic Concept, where you flood the battlefield with systems and sensors, allowing you to mass firepower without massing forces, allowing you to reduce your vulnerability. I think you see it in various programs across the Services trying to bring different sensors and "shooters" together in a very fast network, or in a web of networks. That's going to be heavily reliant on the electromagnetic spectrum. These types of programs have the potential to make the Joint Force more lethal. They increase situational awareness of both warfighters and commanders through mission data integration and the sharing of data from a wide variety of sources that gives the big picture as far as targets and opportunities, and that allows decisions to be made. For us, and for the Department, fixing the EMS enterprise is aligned with all of these initiatives and is essential to their success.

JED

This all seems pretty sweeping and important. How does the CFT plan to 'lock-in' the potential benefits this new approach will have on military superiority?

General Landrum

We've had good momentum on harmonizing the two strategies associated with the spectrum. In the Department of Defense right now, we have two strategies: one is a 2013 Electromagnetic Spectrum Strategy that is from the DOD CIO, and we have a 2017 DOD Electronic Warfare Strategy. The existence of these two separate strategies is evidence of how we as a Department have kept spectrum management and electronic warfare separate instead of working them together. Now, we are weaving those two strategies together into a new and updated strategy. The goal is to create a singular strategy for the Department, an Electromagnetic Spectrum Superiority Strategy. That strategy will help codify some of these new ways of thinking. And then we're rolling right into creating an implementation plan. That will be the place where we put action to the ideas outlined in the Superiority Strategy. It will also be an opportunity to align the efforts with the Joint Warfighting Concept development, the Joint Concept for EMSO, and new Joint Doctrine. The implementation plan will be overseen by General Hyten in his capacity as the Senior Designated Official for the EMSO CFT, and that'll be good to have a senior-level champion associated with it.

JED

With all of this going on, what's on the horizon for the EMSO CFT?

General Landrum

Since we first stood up about a year ago, we will [have] hit our one-year anniversary on the first of April. We are going to have a new, full-time director of the Electromagnetic Spectrum Operations Cross Functional Team. That will be Brig Gen Darrin Leleux. He is taking my role which is technically called the "Deputy Director," working for the Vice Chairman as the SDO. He has a PhD in electrical engineering, and he has a good background in space systems and communications, and he's scheduled to begin in late May, pending DOD's decision on travel restrictions.

Beyond that, we are looking forward to making progress on some other things that we're working on. We have a year-long process to examine the EMS workforce that is ongoing. That effort is going to define the EMS professional workforce so that we can grow expertise and define ways to foster that workforce from accessions all the way through a lifetime of service associated with the electromagnetic spectrum. It will also help grow the leadership associated with the EMS enterprise that has the necessary knowledge and experience across spectrum operations, both in management and in electronic warfare. Creating this community is essential to creating culture change across the Joint Force and will enable commanders to fight effectively in the EMS.

There are a couple of other efforts that we want to go into. One is Mission Data Integration, and the CFT forming an integrator role for that work inside and outside the Department. There are a lot of efforts associated with how we reprogram our systems with the latest information on signals and waveforms, and that process really needs to be improved. It is not keeping pace with modern technologies, not keeping pace with Great-Power-Competition adversaries, and we think there is a lot of opportunity in Mission Data Integration as a concept that must be pursued.

Another effort is the modeling and simulation of the electromagnetic operating environment. I think we're challenged to model the electromagnetic operating environment. These models would be very useful across the board in things like mission-level and campaign-level analysis, prototyping, testing and training. Finally, the CFT will continue to engage with DOD CIO, the EW EXCOM [Electronic Warfare Executive Committee] and the EWCT [Electronic Warfare Capabilities Team] in the coming year to help shape priorities, requirements and efforts.

JED

In closing, what would you like JED readers to take away from our discussion?

General Landrum

The one thing that I think is important for everybody to know is that, ultimately, the CFT is not the solution for gaining and maintaining an advantage in the electromagnetic spectrum, right? The EMSO CFT was formed specifically by Congress – who asked the SecDef to stand this up – to address a list of things that are outlined in Section 1053 of the 2019 NDAA. As a result, the EMSO CFT is by its nature a temporary organization. While the CFT is certainly focused on delivering reports to Congress, we're also trying to look into other avenues by which we can make specific gains to solidify our advantage in the electromagnetic spectrum, but with an eye always toward transitioning the CFT into a permanent body. A goal of the EMSO CFT is to eventually transition its functions to an organization that is led by an individual with a rank that's commensurate with the importance of the electromagnetic spectrum in order to bring the right level of advocacy for it, that is organized with the staff to take roles and functions on from the EMSO CFT. And finally, we must always keep in mind that our separate Services have the Title 10 authorities to organize, train, and equip their forces. The CFT and its follow-on organization must be helpful to define Joint Force requirements and support an agile acquisition process so that the Services can deliver the capability we need to remain the world's best fighting force. It will ultimately be through the Services that we address our EMSO capability gaps.

Advertorial

PERFORMANCE THAT PREVAILS.

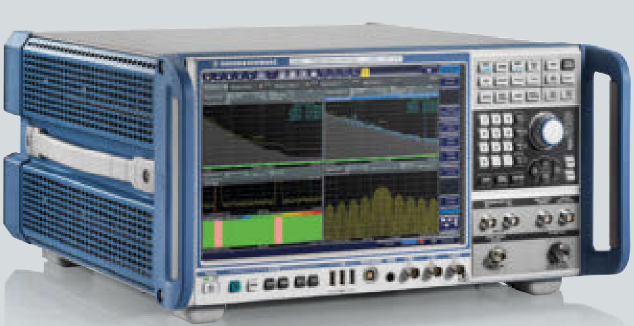
Advanced pulse stability measurements for radar system performance.

Ensuring higher performance for modern radar systems

With the arrival of sophisticated radar and communication systems, phase noise has become the most important factor that is addressed during the design and validation phase of these systems. This is because phase stability is the key parameter defining target acquisition in radars, spectral integrity in communication systems and precision beam steering capabilities in active electronic scanned array antennas (AESA).
This is exceptionally true for the latest generation of multifunctional radar system designs that were developed in response to the increasing complexity of missions, physical requirements of congested and contested electronic environments and rapid advances in electronic warfare (EW) capabilities.

The measurement challenges of modern radar designs

The latest radar architectures come with a number of key design challenges, such as frequency, waveform and mode agility. Phase and amplitude stability of transmitted radar pulses are crucial to assessing the radar's sensitivity and are vital to detect e.g. small and slow moving targets like drones and UAVs. Power amplifiers (PA) in particular can degrade phase stability, making engineers look for new tools for precise measurements.
These high-sensitivity measurements of the phase and amplitude stability of pulses previously required complicated test setups with multiple instruments. A new option for the R&S®FSWP phase noise analyzer by Rohde & Schwarz makes these measurements easy and straightforward. The R&S®FSWP-K6P option takes full advantage of the unmatched ultra-low phase noise design of the R&S®FSWP. This one-instrument solution offers high sensitivity measurements to design engineers.
Based on the ability to generate demanding pulse sequences like the original radar systems, the R&S®FSWP can feed the power amplifier - or other device under test - and analyze the response signal from the amplifier at the same time.



The R&S®FSWP phase noise analyzer and VCO tester

Unmatched sensitivity for best phase noise measurements

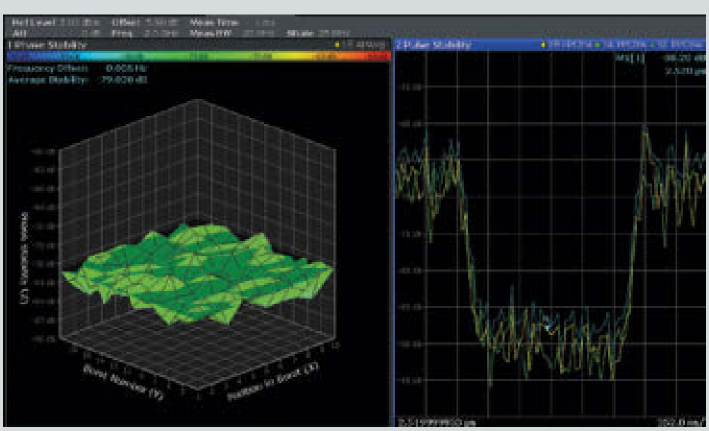
The R&S®FSWP has a built-in ultra-low phase noise oscillator and internal components optimized for phase noise testing. This provides a wide dynamic range for phase stability measurements. Since the local oscillator in the R&S®FSWP and the pulsed signal applied to the DUT are correlated, the phase noise can be even more suppressed by up to 50 dB, testing only the phase instability caused by the device. This residual measurement has a sensitivity of less than –80 dB. For even more flexibility, the R&S®FSWP also allows users to an external source as a local oscillator for the measurement.

Application Note: Measurement setup for phase noise test at frequencies above 50 GHz
The R&S®FSWP is the most modern phase noise tester on the market with unrivalled sensitivity. It combines high-end internal local sources with the latest technology for AD converters in combination with cross-correlation.
Discover the full potential of the R&S®FSWP for your radar measurement applications with this practical application note by Rohde & Schwarz.
Download here: **www.rohde-schwarz.com/applications/phase-noise-test-above-50ghz**

Complex burst and pulse sequences for real-life performance measurements

Advanced radar applications employ bursts or complex pulse sequences. Consequently, the same burst signals are required to accurately test radar components under realistic modes of operation. The R&S®FSWP can generate pulse sequences and bursts based on the original pulse descriptor word (PDW) information from the radar system. Operational effects like the heating of components during the "on" portion of the burst and their effect on the system's phase and amplitude stability can hence be analyzed with great precision and in a well-defined and reproducible environment.

The burst signal consists of 10 pulses, followed by a pause.



Phase deviation from the average of each pulse, for all recorded bursts (left). Pulse-to-pulse phase stability (yellow), amplitude stability (green) and the sum of the two (blue) averaged over all pulses (right).

Full measurement flexibility to support every test requirement

The R&S®FSWP-K6P option also allows users to choose whether to make measurements using the broadband spectrum analyzer or the highly sensitive phase noise tester. With the latter, users can either measure the pulsed signal directly or employ the residual test mode using internally generated pulses to stimulate the device being tested.
Phase and amplitude stability can be displayed for each individual pulse, with the deviation from the average at each sampling point in a pulse calculated and displayed. The R&S®FSWP can average the values over an entire burst or calculate the difference between pulses, delivering pulse-to-pulse phase and amplitude stability. Both of these averaging techniques produce smoother, more instructive traces.

Rohde & Schwarz offers:

- High sensitivity for phase noise measurements thanks to cross correlation and extremely low noise internal reference sources
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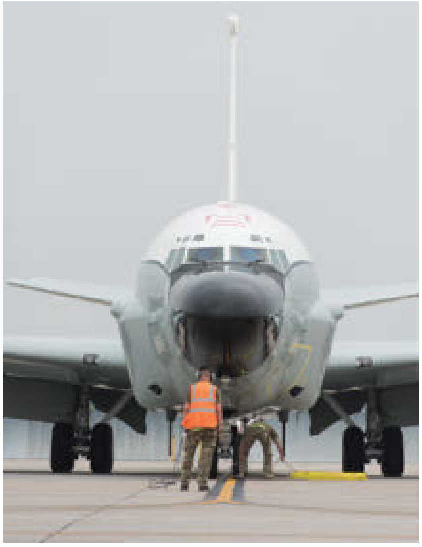
Modernizing SIGINT–
to Serve Multiple Mis

By John Haystead

According to the US DOD Dictionary of Military & Associated Terms, Signals Intelligence (SIGINT) is defined as "a category of intelligence comprising, either individually or in combination, all communications intelligence (COMINT), electronic intelligence (ELINT), and foreign instrumentation signals intelligence (FISINT), however transmitted; or more simply as intelligence derived from communications, electronic, and foreign instrumentation signals."

Sounds clear and comprehensive enough until questions are raised as to what exactly is meant by "intelligence" in this context, and what is done with that intelligence after it is detected and/or collected. Are you doing ELINT or COMINT or both? And, this necessarily also leads to a discussion of the evolving relationship between SIGINT and electronic support measures (ESM). In truth, the two have always been closely related, but technology limitations effectively provided distinctions restricting systems to focus on the primary purpose/mission being pursued. Today, that is no longer the case, with systems described under both categories more than capable of effectively serving multiple missions and masters.

In terms of the actual sensors and systems, the reality is that the different nomenclatures, acronyms, definitions and distinctions mean less and less in today's real-world electromagnetic spectrum monitoring task. All of it really comes down simply to spectrum surveillance and intelligence gathering. (Why not SSIG for fun, or just back to plain old SIGINT?) What does remain distinct and different, however, is what happens with the spectrum intelligence after it is collected, and how it is made to serve the missions and needs of the various people receiving it. This is truly where SIGINT modernization is taking place today.



US AIR FORCE PHOTO

IS TACTICAL SIGINT A REAL THING?

One good example of the disconnect between the current mix of definitions and distinctions in the SIGINT world can be seen in attempting to address the differences between strategic and tactical SIGINT. In fact, this first discussion point turns out to be whether something called "tactical SIGINT" even really exists. Once again, it appears that the real distinction is actually a matter of the end-user and how the same information is being used by different people in different ways rather than the systems and technology being used to collect it.

Robert Seymour, Cyber & Electromagnetic Activities (CEMA) Campaign Lead at Roke Manor Research Ltd. (Romsey, England), makes this exact point wondering whether "tactical SIGINT isn't really just warnings and indications driven by a threat library that delivers timely intelligence (threat data and warning) to the tactical commander. Another point is that modern-day ESM sensors are delivering multiple capabilities beyond traditional ESM DF [direction finding] and monitoring. They're also delivering true SIGINT with more frequency band coverage within a single sensor, as well as delivering a certain amount of electronic protection (EP) capability if they have a threat library or something in terms of warnings and indicators."

In terms of meeting overall mission requirements, Seymour says, "It's evident that the biggest area that needs to be concentrated on is not the sensor arrays, not the ability to integrate them into vehicles, or training, etc., it's the enterprise architecture that's going to deliver that data to the different customers in the right format, because a DF monitoring analyst needs very different data from someone who is doing warnings and indicators in the tactical SIGINT space (if you want to use that term), vs. a strategic SIGINT analyst that needs to be taking data in from a vast array of different sensors from air, land, and sea and painting a much more strategic picture."

Dave Logan, Vice President and General Manager of C4ISR at BAE Systems (Nashua, NH), makes a similar point, noting that "We do talk about doing SIGINT 'kind of at the tactical level' when we're doing work with some of our podded solutions." This work includes flight testing in partnership with Lockheed Martin of the U-2's high-altitude stand-off SIGINT, and with the USAF on solutions for the MQ-9 Reaper UAS for international markets. But, he also points out that, "With regard to what SIGINT as a term actually means these days, as these systems become more COTS-based solutions, and the compute engines behind the RF front ends of these systems become more powerful and generic, my sense is that the lines between SIGINT, COMINT, ELINT, etc., are tending to blur and that ultimately, at the end of the day, what customers want is spectrum dominance. They want to be able to have situational awareness across a variety of those missions and they want it in as compact, efficient and upgradeable a package as possible."

Technology Adapts sions and Masters

US ARMY PHOTO

DESIGNING FOR MODERNIZED SIGINT

Having recognized the changing operational requirements and demands of signal collection and analysis, together with the new level of capabilities now available through advancing technology, the next question is, what are system designers and builders doing today to take advantage of these advancements to make their systems more suitable and attractive to the broad SIGINT user community?

One area being examined is the desire for wider bandwidth systems. Here, for example, as part of its CEMA family of EW equipment, Roke is developing a next generation of very wide bandwidth sensors with user-configurable instantaneous bandwidth. According to Bob Seymour, the effort is driven by Roke's software-defined architecture incorporating elements of machine learning and potential artificial intelligence. "The software algorithms are the very core of a new wideband sensor that will drive, iterate and react to the adversary's operation, as well as being able to network sensors so that you can do much of your analysis away from the actual operational area." Adds Roke's EW Business Development Manager, Eric Herron, "It's also about having an adaptable sensor for different roles, with one head that can, for example, go up against narrowband transmissions, follow very wideband hoppers, or a radar transmission, and deliver high quality threat data for SIGINT analysis."

Mark Walker, Market Area Director for Radar and Electronic Warfare at Cobham Advanced Electronic Solutions (CAES) (Arlington, VA), describes his company's perspective as that of a "Tier 2-4 technology provider to SIGINT and EW system integrators, and reflects the dynamics from these levels of technology integration." As such, he says they are also "seeing factors such as wider Instantaneous Bandwidth (IBW) and wide bandwidth millimeter-wave frequency inclusion playing an increasingly important role in SIGINT."

Not surprisingly, another area of interest is providing for increased range of operation. But, as pointed out by, Mark Warman, Roke Account Manager, "You can't just expect the equipment to do it for you. You can improve your detection/collection technology to make it more sensitive, or you can create algorithms that will make the data that you get far more accurate, but this does not necessarily translate to increased range. You still have physics and the actual geographic environment involved to contend with." Instead, Warman says you also need to recognize that there's a "crossover point" in terms of how much you can improve the technology with the actual skill level of the operator. "Operator skill is actually one of the biggest factors when you talk about increasing range. It's really about the operator being able to understand the surrounding environment. You can have a very sensitive antenna and an emitter that is putting out several watts, but if the operator is in the wrong position or doesn't fully understand the environment around them, then you aren't necessarily going to increase your range."

In that regard, Roke's Seymour, references feedback he recently received from a commanding officer who emphasized his need to be able to "look into his adversary in depth." To accomplish this, Seymour says that elevation is absolutely critical. "A lot of systems now absolutely have to be elevated with such things as lightweight tactical masts. So, while we're looking at sensitivity and operator skill in terms of enhancing range, you

"It's evident that the biggest area that needs to be concentrated on is not the sensor arrays, not the ability to integrate them into vehicles, or training, etc., it's the enterprise architecture that's going to deliver that data to the different customers in the right format."

– Robert Seymour, Roke Manor Research

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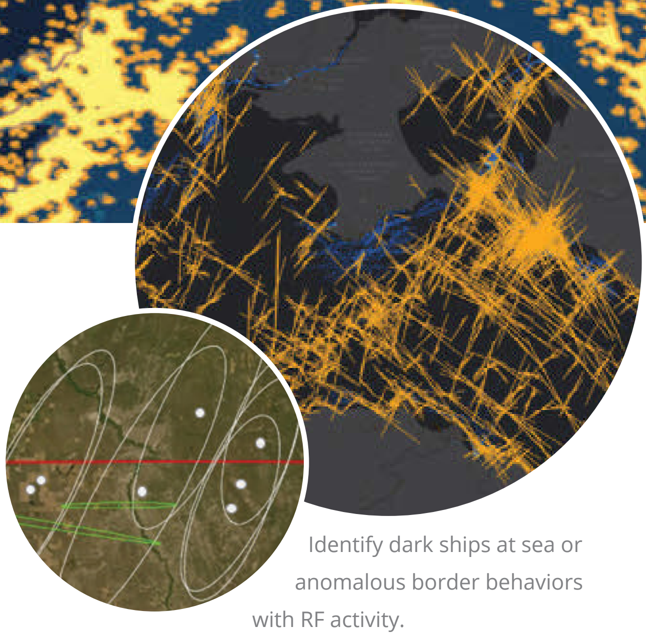

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S-BAND	S-band Marine Navigational RADAR
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will also see more focus on elevation with masts being a critical factor in next-generation sensors in order to better see an adversary in depth."

Currently, Roke's SIGINT products are exclusively ground-based, but Seymour says they do also have some preliminary sensor designs aimed at UAS deployment, particularly in terms of low size weight, power and cost (SWAP-C). "This third dimension will become increasingly important in terms of sensors and looking in depth," says Seymour.

Cobham's Walker notes that SWAP-C concerns for all application environments can benefit from advancing technology. One particular design element related to this is toward greater integration between the analog and digital portions of systems. "Increasingly, systems are being engineered with a digital front end user development environment with a partitioned application programming environment. Demand is also growing for high dynamic range components with lower power consumption. In addition, system-on-a-chip solutions allow for the integration of analog and digital capabilities on a single chip. SWAP-C has been a driving force in the industry for some time and that has not changed. Customers are still demanding smaller footprints with integration and advanced packaging."

> "With regard to what SIGINT as a term actually means these days, as these systems become more COTS-based solutions, and the compute engines behind the RF front ends of these systems become more powerful and generic, my sense is that the lines between SIGINT, COMINT, ELINT, etc., are tending to blur and that ultimately, at the end of the day, what customers want is spectrum dominance."
>
> – Dave Logan, BAE Systems

MISSION/TASK ORIENTED REPORTING STRUCTURE, SYSTEMS AND DATABASES

Perhaps more important than any other factor in fully meeting today's signal collection, analysis, and distribution requirements, is the recognition that intelligence information is useless if it is not provided to the person(s) who need it in a timely fashion. In other words, location is everything, and one example of this can be seen in the growing need for shared databases and threat libraries.

According to Roke's Herron, "The way ahead in terms of indicators and warnings in this whole modernizing SIGINT piece is going to be based on databases, but it doesn't have to be national databases. If you're going into an area where a standard transmission protocol is being used and that protocol is recognized as a threat, then that should be included in a common database. This gives the people on the ground immediate indications and warnings on their highest threats."

Seymour agrees on the premise, but notes that not everyone agrees on how and where such databases should reside. "Some are of the view that a lot of this has to go back to a centralized location because of national security classifications for strategic SIGINT." For his part, Seymour says, "That's fine and must continue, but we still need to also bring some of those threat libraries forward into the tactical space to create the warnings and indicators for the tactical commander that, for example, a certain type of system is in the area, or by virtue of that system being there, a certain type of unit is deployed there."

Beyond databases, Roke's Warman points out that, while SIGINT sensor technology is converging, there still exists a very real need to efficiently direct the intelligence collected to the right people for different purposes. "Technology now allows things to be brought together in terms of form factors with multiple applications in single bits of equipment, but what is important to remember is that they are indeed different disciplines, and it's still the operator at the other end that's going to have to be individually trained in the skill sets. You can perhaps overlay artificial intelligence software, which can sort through features in a database to identify a potential threat, but then to take those any further and actually analyze them further, it will still come down to an individual skillset within each of the disciplines."

Eric Herron doesn't disagree with the point, but also points out that the level of skill required for different disciplines or tasks can vary. "At the indicator and warning level, you don't really need to be that kind of expert. This is about your immediate reporting. With the technology we have now, and a properly built database, you can actually perform the indication and warning task as a forward recce. You really don't need to be EW trained in any way. You are reporting into your situational awareness hub to inform the actions your commander needs to take right at that time."

Seymour expands on this example of the primary needs of a forward recce force. "If you're a recce force commander, what you really want to know is where my enemy is, what is my immediate threat, and how can my EW or EM sensor tell me that? Equally, however, that sensor should be delivering data that's offloaded via the network to signals analysts – so you will have both tactical and strategic analysts looking at different aspects of the intelligence that the data provides in terms of the overall bigger picture." Seymour says we also need to recognize that analysis needs to be distributed across the battlespace. "What you don't want to create is EW fusion centers where one round from an adversary's fires takes out your entire EW analysis capability. Either we need to get analysis out of the direct or indirect fires zones and get it further away, or we need to disperse it and get it into smaller packages."

BAE's Logan points out that the US Army continues to work toward accomplishing improved SIGINT data distribution goals, pointing to its investments in their Distributed Common Ground System (DCGS), and "depending on what echelon you're operating at, they serve different elements of the force structure. SIGINT has an important role to play up and down that chain of command where different people need access to the same data for different reasons. A tactical unit near the "pointy end" wants it for situational awareness, and as you move up the echelons, they are looking at things like schemes of maneuver and how to gain an advantage over an adversary on a broader scale."

SOFTWARE DRIVES BOTH DIVERGENCE AND CONVERGENCE

There's no doubt that, with increased digitization and exponentially more powerful processors, software has become the most critical component on the path to modernizing SIGINT. As observed by BAE's Logan, "The spectrum continues to get more and more cluttered, and the signals that we're going after with our adversaries are more elusive and adaptive, sometimes at the pulse-to-pulse level. This has driven us and our architectures, investments and products to focus on a couple of things. First of all, software-defined algorithms are fundamental. You need to have those in order to be able to adopt and implement things like cognitive SIGINT, where we can learn over time to process signals we haven't seen before. And then, given the cluttered or crowded nature of the spectrum, there is more and more interest in our ability to geolocate efficiently."

According to Logan, BAE has pivoted over the years into a series of modifications to provide open architectures that now are embodied in all their fielded systems. "Through this, we've been able to build up most of the processing on things like general-purpose, graphics processing units (GPGPUs). This allows us to do most of the work in software, and it allows us to do rapid updates to push out new capabilities to systems in the field much faster."

Looking out further, says Logan, "As you head down that path of software configurability, another interesting dynamic that you see is that SIGINT systems and radios actually look more similar than different. Going forward, you can now start thinking about things where you make an investment in more generic hardware that can serve multiple functions. This is something that we continue to see more interest in."

Similarly, Roke's Seymour, says "We will soon start seeing some very, very capable, multi-channel, wideband antennas or sensors that can go all the way from HF to 4G and 5G bands and also look at radar. What tunes that sensor in to what you want to look at, and how you drive the capability across different signal type environments is through dif-

JED 2020 Writing Contest

The *Journal of Electromagnetic Dominance* (*JED*) is pleased to announce a new writing contest open to all active duty military personnel from the armed forces of any nation.

The subject area of the writing contest is operations and/or operational support (training, testing, spectrum management, etc.) in the Electromagnetic Environment (EME).

TOPICS INCLUDE (BY DOMAIN):

- Multi-Domain Operations in the EME
- Maritime Operations in the EME
- Air Operations in the EME
- Land Operations in the EME
- Space Operations in the EME
- Cyberspace Operations in the EME

SUBMISSION GUIDELINES:

- Articles must be 3,200 words or less and sent in Microsoft Word format.
- All articles must be unclassified, original and unpublished material.
- Academic theses edited to meet the word count requirement (3,200 words) and written less than one year prior to the submission due date are welcome.
- Supporting photos must be high-resolution (1 MB or larger), print-quality JPEG or TIFF files. Figures must be sent in Microsoft PowerPoint format.
- Authors, please identify your title, military unit and commanding officer.
- Authors who wish to submit separate articles for more than one topic are welcome.

Submissions are due Tuesday, June 30.

Please send all questions and submission materials to JEDEditor@naylor.com.

By submitting your article, you are granting the editors of *JED* permission to publish your article in The *Journal of Electromagnetic Dominance* at such a time as we are able. If we do not intend to publish your submission in *JED* within one year of submission, you will be notified within 30 days of the submission due date.

ferent software builds. You can have a very generic build that does one type of surveillance (DF looking for both comms and radars), or you can have the system perform multiple roles at the same time. The market is potentially diverging because, at the other end, you have people that are developing very, very narrow sensors for specific frequency areas, or one that works better in a contested/congested environment or an urban environment over very short range. At the same time, with the blurring of COMINT, ELINT and ESM, and sensors that can deliver all of it, the question becomes how you package the data up and how you get it to different people to analyze it for different purposes."

In terms of whether COMINT and ELINT system design requirements are converging, Logan says, "When you look at those missions and the signals you're going after, you have to keep in mind that there are some physics associated with the different parts of the spectrum that they operate in, and that means there's always advantage to having apertures that are tailored to that respective portion of the spectrum. But, when you get past that and into the digital processing side, there are a lot of common challenges. Referencing the agility of our adversaries, by getting into the digital area sooner, and being able to use the more powerful COTS-oriented processors, you can run the same kind of advanced algorithms to operate on those signals with a common set of hardware. So parts are converging at different rates, and the further you are from the front-end, the more convergence you see."

OPEN ARCHITECTURES AND NETWORKING

An additional element key to accomplishing the objectives of modernizing SIGINT is the adoption of open architectures and the implementation of adequate networking. This is, in fact, happening at multiple levels of system design. Cobham's Walker says they're "increasingly seeing open architecture designs with backplanes like SOSA/MOSA (3U, 6U) applied to integrated functions to include electrical and mechanical fit." Examples include: wide bandwidth converters, the integration of converter and digitizers, high-dynamic-range and high-speed digital signal interfaces, and simplified interfaces with common data ports (Eth, PCIE, etc.).

Roke's Herron says these open architectures at the front end provide the ability to integrate and share multiple, single-sensor data collectors. In addition, he points to the need to have large "data pipes" for rapid information transmission right at the forward edge, rather than just down to headquarters locations. "The data needs to be shared at the forward edge and be part of an open exchange of information that is useable by everybody in the field. If you've got forward sensors which are detecting signals associated with weapon systems, that possible threat information is not only useful to those in the immediate operational area, but is possibly also of interest to off-shore and/or overhead assets. In order to collect all of the available information and make it useful in real time, open architectures at the

front-end together with big data pipes is absolutely essential."

Looking at the back-end, BAE's Logan, observes that the shift to more and more digital processing and the use of more powerful GPUs has allowed them to move to a common set of architectures across their family of products. "We're getting away from tailored solutions addressing a particular class of signal with a dedicated board in a chassis, to using very similar, if not equivalent, back-end processing for the SIGINT missions."

In that regard, Roke's Warman adds that traditionally, a lot of the collection systems have been "stovepiped," which "although they can work very well in isolation, means a lot of the information is frequently lost or ends up being moved around fairly 'handraulically' – increasing the time to build up and fuse an EW situational picture." Instead, what needs to happen going forward, says Warman, is that "the multi-feed collection systems and sensors across multiple domains (land, maritime, air) be able to efficiently cross-deck their various SIGINT feeds to build a clearer and better situational awareness picture for command elements."

MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE

The incorporation of automation through artificial intelligence (AI) and/or machine learning (ML) is another major feature of modernized SIGINT capabilities. As observed by Roke's Seymour, "We recognize that there are fewer and fewer of what I would call 'deep specialists,' whether they are in SIGINT, ESM or other specializations." As such, Seymour says it's even more essential to get useable data to these specialists sooner. "Machine learning and artificial intelligence are absolutely critical to this. The sooner you can fuse the data together, the sooner you can get your analysts onto the information they need and turn it into intelligence in a timely manner." To address this, Seymour says they're spending a lot of time looking at AI and ML software to help make processes more intuitive, providing for increased analytical time and reduced training burden. "We think that's where the future lies. The sensors are the sensors, so we're concentrating on iterating our software, at software-defined networks and radios, and on improving how our sensor arrays fit into an overall network picture to deliver against a number of different customers' needs."

> "SWAP-C has been a driving force in the industry for some time and that has not changed. Customers are still demanding smaller footprints with integration and advanced packaging."
> – Mark Walker, Cobham Advanced Electronic Systems

BAE's Logan, says they're also concentrating heavily on AI and ML, noting that advances in processing have "allowed us to leverage things like cognitive processing, which basically just looks for patterns in the signals that allow us to make inferences and decisions on signals that we may not have seen before. These are the kinds of things that are really allowing us to regain advantage over our adversaries. In the past, as they went to agile solutions, and we had a non-agile architecture to pace them, we were instantly behind. By translating as much functionality into software, and in some cases software that has the ability to adapt and learn over time, you can update the performance of your system at mission timescales, as opposed to acquisition timescales."

USER INTERFACES AND CRITICAL FEEDBACK

Regardless of the actual inherent capabilities or performance designed into a signals collection and/or analysis device or system, if it does not perform efficiently to the mission or requirements of the end-user, it will be judged a failure and perhaps even more of a nuisance than an asset.

This, says Roke's Seymour, "is why our user interfaces are absolutely paramount. We want to deliver an intuitive interface for the 'smart-phone generation.'" Seymour says they are currently running a number of tasks for the UK Army that allow them to participate in live field exercises to rigorously test their user interfaces for user acceptance. "It also allows us to develop new features and benefits for the operators. With so much of our sensor technology being software driven and software defined, software is the key. We can iterate software very quickly to improve a sensor or interface, but if industry doesn't have access to the operators to get the feedback, then we can't deliver 'agile-sprint' software."

BAE's Logan, agrees. "It's often true that engineers will typically design a user interface to one end of the spectrum with every bell and whistle that you could ever imagine, but we work hard to ensure they are much more approachable in the sense that they also strongly target helping the end-user get rapidly to the analysis or functionality that they need. You have a spectrum of users with different needs and skills and those user interfaces have to be scalable."

Speaking from his personal experience "constantly interacting face-to-face with end users," Andy X (last name withheld for security reasons), of Roke Field Operations and Training, emphasizes the invaluable usefulness of talking to the end users for their feedback. "It's probably the most critical feedback or criticism you can get, and as our products evolve, it's apparent that a lot of user feedback is being integrated into them in terms of both our hardware and software. Our design teams are all taking this into consideration and giving it the due diligence that it deserves, and not going off on tangents and designing things that will not be of much benefit to the warfighter. The feedback that I get from the warfighters and provide up through my chain of command is absolutely vital."

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Dave Adamy

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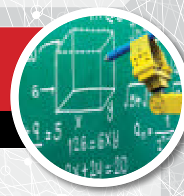

Kyle Davidson

Mondays, Wednesdays, & Fridays

13:00 – 16:00 EDT | September 14 – 30, 2020

This course introduces students to the fundamentals of machine learning and its application to modern Electronic Warfare (EW) and cyber solutions.

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09:00 – 17:00 EST | Dec 11 – 12, 2020

Hands-on Introduction to Radar and EW

Dr. Warren Du Plessis

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Dave Adamy

Friday & Saturday

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TECHNOLOGY SURVEY

A SAMPLING OF COMMUNICATIONS JAMMERS AND RCIED JAMMERS

By John Knowles

This month's technology survey covers communications jammers and remotely-controlled improved explosive device (RCIED) jammers. Communications jammers are the oldest type of electronic warfare systems. The first military use of communications jamming was in 1902 and 1903, during Royal Navy and US Navy fleet exercises, respectively. In 1904, during the Russo-Japanese War, a Russian radio operator used his set to jam Japanese Navy communications during an attack on Port Arthur.

As radios began to see wider use in World War I and World War II, military forces also pursued the development of dedicated communications jammers to disrupt enemy communications. In response to the growing use of jammers, radios began to feature electronic protection measures, particularly frequency hopping and other spread-spectrum technologies. Across decades of technological competition between radio anti-jamming innovations and jammer development, however, jammers have been able to remain effective.

Throughout the Cold War, communications jamming systems were employed primarily against tactical communications systems to hinder enemy command and control functions. These targets could range from simple push-to-talk radios to data links in an air defense network. Many of these jammers were large, heavy and were often operated from dedicated ground-vehicles and aircraft. By the 1990s, communications jamming was beginning to focus on networking multiple jammers and employing "smart" jamming techniques that were less reliant on brute force. New, low-SWaP technologies also led to the development of smaller, remotely operated and autonomous communications jammers, such as those developed under DARPA's "WolfPack" program in the early 2000s.

In 2005, the wars in Iraq and Afghanistan led to development of a new class of communications jammer that was used for self-protection against RCIEDs, as opposed to offensive communications jamming against enemy command and control networks. These were smaller, more automated, and they were bought in the thousands, and in some cases the tens of thousands. This was a significant shift from the traditional communications jamming market.

More recently, beginning around 2015, the advent of inexpensive commercial drones drove demand for a new type of communications EW system, the counter-UAS jammer. These systems share a lot in common with RCIED jammers in terms of their frequency coverage and SWaP footprint. However, the antennas are typically directional and many counter-UAS jammers are integrated with other sensors and sometimes with other countermeasures systems, as part of a multispectral counter-UAS solution. While some of the communications jamming systems in this survey can perform counter-UAS missions, dedicated counter-UAS systems are covered in a separate JED Technology Survey. (See the May 2019 *JED,* p. 43, for our most recent Counter-UAS Survey.)

THE SURVEY

In this month's survey, the first column in the table lists the manufacturer and model number of the jamming system. The next column describes the systems frequency coverage. The following column describes the jammer's output in Watts of effective radiated power (ERP).

The next column lists the system's power supply. Because communications jammers typically operate in CW mode, they use a lot of power. Larger communications jammers that are installed on a ground vehicle or an aircraft can usually rely on the host platform's engine(s) to provide power. If the jamming system is portable, however, battery life becomes important, especially if it is an RCIED jammer protecting soldiers' lives.

The next column describes the receivers associated with the jammer. A good jammer depends on a good receiver. Some RCIED jammers are "active" systems, meaning that they are transmitting continuously regardless of the communications environment. Most jamming systems, including many RCIED jammers, are reactive. This means they use a receiver to identify the target signal and cue the jamming subsystem. This jamming response may use a digital RF memory (DRFM) to mimic or modify the target communications signal.

The next column describes the types of weapons platforms that will carry the jamming system. The next column addresses the system's jamming techniques and waveforms. Most systems are field programmable, which is an important consideration in expeditionary operation. The remaining survey columns cover size, weight and describe additional features.

NEXT MONTH

Our June product survey will look at power amplifiers for electronic warfare applications. Please request a survey questionnaire by e-mailing jededitor@naylor.com.

COMMUNICATIONS JAMMERS & RCIED JAMMERS

MODEL	FREQUENCY RANGE	ERP	POWER SUPPLY	RECEIVER	PLATFORM
ALBRECHT Telecommunications GmbH; Huenenberg, Switzerland; +41 41 7804701; www.albrecht-telcom.ch					
SAJ-2000MD (COMJAM family)	0.1 MHz - 26 GHz, in bands	100W - 2kW, dep. on bands	24/28VDC, 230/400VAC	Superhet, digital signal processing	Air, grd-mob, grd-fix, ship
Allen-Vanguard; Ottawa, ON, Canada; +1 613-739-9646; www.allenvanguard.com					
3140/3230/3330	21 MHz - 6 GHz	50W (3140); 30W (3230); 40W (3330)	12-24 VDC vehicle power supply	None, active	Grd-fix, grd-mob
EQUINOX	20 MHz - 6 GHz	35-100W per module	24-28 VDC vehicle power supply	Superhet; digital channelized	Grd-fix, grd-mob
SCORPION 2	20 MHz - 6 GHz	Up to 20W per channel	2590 Li-ion batteries or external 24-28 power supply	Superhet; digital channelized	Manpack, grd-fix
ASELSAN; Ankara, Turkey; +90-312-592-10-00; www.aselsan.com.tr					
GERGEDAN Multirole Jammer	20 MHz - 6 GHz	650W	20-32VDC external power supply; 24/28VDC vehicle/ additional alternator power supply; external 24VDC Li-ion, lead-acid battery	In support of external hand-held receiver (MİRKET); superhet, 20 MHz - 6 GHz, instantaneous BW of 80 MHz	Grd-mob, grd-fix, ship
OPKAR	V/UHF	*	Battery / AC mains	Wideband receiver to detect target signal presence	Manpack, grd-fix, air
V/UHF Jamming System	V/UHF	*	Operation with 220 / 380 ±%10 VAC, 50±3 Hz, 3 phase generator; operation with 220/380 ±%10 VAC, 50±3 Hz, 3 phase AC mains	Wideband/narrowband signal receivers (search, detection, demodulation)	Grd-mob
Avantix; Aix-en-Provence, France; +33-04-42060-70-00; www.avantix.net					
Black Shadow	20 MHz - 2.5 GHz	100W	*	Yes	Grd-mob
CellAntenna Corp.; Coral Springs, FL, USA; +1 954-780-5538; www.cjam.com					
CJAM Protector	20 MHz - 3 GHz	25-700W	Battery, 12-28VDC, 110-220VAC	Yes	Grd-mob
Chemring Sensors and Technologies; Romsey, Hampshire, UK; +44-1794-833211; www.chemring.co.uk					
Resolve Comms EA	25 MHz - 2.7 GHz	20W	12/24VDC, LIPS, 2590	Yes	Manpack dismounted man-portable, clip-in and integrated grd-mob
Elbit Systems EW and SIGINT - Elisra; Bene Beraq, Israel; +972-3-6175707; www.elbitsystems.com					
Ground Application	20 MHz - 3 GHz	200W -1kW	28 VDC	Digital	Grd-fix
MRJ Family	20 MHz - 6 GHz	10-275W	Battery / 28 V	Digital channelized	Manpack, trolley, grd-mob
SKYJAM	30-500 MHz	50W	28 VDC	Digital	UAV

TECHNIQUES	SIZE (HxWxL in/mm/cm)	WEIGHT	FEATURES
Spot, noise, broad-band, sweep, FSK/PSK, programmable multi-carrier generation	MIL 19-in. system, config. dep.	> 30kg, config. dep.	Software-defined active/reactive COMJAM ; true multi-thread capability with spoofing; fast frequency-hopping; comfortable software-defined programming; man/semi-/full-automatic operationL; look-through and other special operation modes; stored jamming profiles; multi-band antenna selector and remote antenna control; Interoperability with EW systems; local or remote operation for unmanned stations; interface for future extensions.
*	21.5 x 16.9 x 10 in. each system	33-40 lb	Combination vehicle mount ECM system consisting of any 2 sub-units.
*	12 x 12 x 22 in.	86 lb	Software-defined scalable system operating in active, reactive, or hybrid (combination) modes.
*	16 x 14 x 6 in.	14.5 lb	Software-defined scalable system operating in active, reactive, or hybrid (combination) modes.
Software-defined jammer; programmable 250 preset jamming modes; dynamic notch filters for friendly comms; jamming techniques: spot, sweep, barrage, multi-frequency TDM; reactive with external hand-held receiver	600 x 600 x 600 mm	55 kg (RF jammer unit)	Combat proven; software-defined jammer; DDS-based, FPGA controlled jamming; application areas: counter-RCIED, tactical electronic attack and counter-UAV; MIL-STD 810 compliant; ICNIRP health standard compliant; omni-directional/directional antenna options.
Spot jamming (Single/Multiple targets); Barrage jamming; Reactive jamming; Deception; Spectrum monitoring; Scheduled Operations; Mesh network operation (config dep.)	Config. dep.	20 kg	Signal detection, jamming and deception of the target communication system in UHF and VHF frequency band. It has 2.5 hour non-stop jamming capability with built in standard battery.
Continuous, look-through, target triggered; jamming modes: spot, sequential, multiple, barrage, reactive; deception capability/deceiving talents: analog deception recources (microphone, recorded voice, recorded IF), digital deception recources (solid bit sequence, recorded IF)	The system is integrated ergonomically to a 4x4 vehicle with its shelter	Config. dep.	System is developed to provide electronic attack against target V/UHF communication systems. With this system, target communication systems are blocked or deceived, providing advantage to allied forces on the tactical field.
*	36 x 46 x 58 cm	*	Option up to 18 GHz; Black Shadow is basic vehicle version; COMJAM Shadow fitted with direction finding features; White Shadow is lightweight version.
*	500 x 430 x 352 mm	55 kg	RCIED jammer; sweep mode, spot mode; open communications window, 11 system modules operate seperately.
Narrowband modulated and IQ, record/playback wideband modulated and IQ	*	9 kg	Prepared for advanced smart EA; integration with Resolve sensor baseline; remote operation; 5 hrs full power output w/ single battery pack; high power external PA in clip-in and integrated configurations; up to 8 concurrent jam signals.
SDJ	2/3 rackmounts 19 x 30 in.	250 kg	Configurable as active, reactive, hybrid.
SDJ	Config. dep.	20-65 Kg	Configurable as active, reactive, hybrid.
SDJ (software defined jammer)	Controller: 18 x 25 x 35 cm; OPU: 15 x 15 x 30 cm	< 18 kg	COMINT - monitoring; classification and COMJAM; configurable; option to 3 GHz; high efficiency with onboard power.

COMMUNICATIONS JAMMERS & RCIED JAMMERS

MODEL	FREQUENCY RANGE	ERP	POWER SUPPLY	RECEIVER	PLATFORM
ELT-ELETTRONICA GROUP; Roma, Italy; +39 06 4154 745; www.elt-roma.com					
ELT/334 product family	20 MHz - 6 GHz	20W - 1kW	Battery; external power 28 VDC	Wideband superhet	Manpack, vehicular, grd-fix (C-Drone)
ELT/335 product family	20 MHz - 6 GHz	100W - 4kW	External power 28 VDC; external power 115VAC/400 Hz	Wideband superhet	Vehicular, grd-fix, air, ship
ELTA Systems; Ashdod, Israel; +972-8-857-2333; www.iai.co.il					
ELK-7020	30 MHz - 3 GHz	*	Power supply	No	Grd-mob, air, ship
Enterprise Control Systems Ltd.; Wappenham, Northamptonshire, UK; +44 (0) 1327 860050; www.enterprisecontrol.co.uk					
Falcon Plus	VHF, UHF, GSM and 3G bands	140W	24 - 30 VDC Power consumption 700 W nominal (all channels operational). Power can be drawn from an additional 24 VDC alternator and separate batteries or, an (optional) mains supply	*	Grd-mob
Kestrel Alpha	20-520 MHz	10W	LIPS5 or LIPS9 Li-ion Battery	*	Manpack, grd-mob
GEW Technologies (Hensoldt South Africa), Silverton, South Africa, +27 421-6200, www.gew.co.za					
GEW® GMJ9 Software-defined multirole jammer	20 MHz - 6GHz	up to 280W	24 VDC	Wideband superhet up to 80MHz	Manpack, grd-mob, grd-fix
GEW® GRJ8500 Communications Jammer System	20 MHz - 6GHz	Depending on PA configuration	24V DC or 220/240V AC	Wideband superhet up to 120MHz	Grd-mob, grd-fix, ship
Hensoldt; Ulm, Germany; +011-49 7 31 3 92 36 81; www.hensoldt.net					
SOJA RCIED and Communications Jammer Family	20 MHz - 6 GHz	Up to 20W TOP (dep. on variant)	24 VDC, 100W max	External	Grd-mob, grd-fix
Tactical Multirole ES/EA System Solutions	1.5-30 MHz (HF); 20 MHz - 6 GHz	2kW TOP (dep. on variant)	240/400 VAC power generation included	Superhet	Grd-mob, grd-fix, shipboard
VPJ-R RCIED/ Multirole Jammer Family	20 MHz - 6 GHz	Up to 400W TOP (ERP dep. on antenna system)	24/28 VDC; 500-1500W (config. dep.)	Superhet	Grd-mob, grd-fix
H.P. Marketing & Consulting Wuest GmbH; Reinfeld, Germany; 00494533-7011-0; www.hp-jammer.de					
HP3260H/ HP3260M (Convoi-Jammer)	20 MHz - 6 GHz	*	18-36V	*	Grd-mob, grd-fix, air
IACIT Soluções Tecnologicas S/S; Sao Paulo, Brazil; +55 12 3797-7777; www.iacit.com.br					
SCE 0100R - RCIEDBlocker SCE 0100C - COMBlocker	25 MHz - 6 GHZ, divided in bands	Output power of 10W / 50W / 100W per channel; Antenna gain > 0 dBi for all channels, except for low VHF	110V/220V VAC (Bi-Volt), or any VDC using an adequate inverter	No built-in Receiver for the anti-RCIED version; jamming is performed "without asking any questions"	Grd-mob, grd-fix

TECHNIQUES	SIZE (HxWxL in/mm/cm)	WEIGHT	FEATURES
Active, reactive, adaptive, hybrid	Config. dep.	Config. dep.	Communications Jammer
Blind/active, responsive, frequency follower, spot/ barrage	Config. dep.	Config. dep.	C-RCIED
*	90 x 50 x 205 mm	1 kg	Miniature high ERP jammer; may be installed on UAV for stand in operations, w/o interfering with allied forces; may be fully remotely controlled
*	180 x 450 x 450 mm	30 kg	Suitable for force convoy and VIP protection applications; utilizes sophisticated Direct Digital Synthesis (DDS) technology; two independent 10 W (nom) GSM inhibitor channels to cover low and high GSM bands and, a 20 W (nom) 3G inhibitor channel; available with a unique vehicle antenna system designed to cover the VHF, UHF, GSM and 3G bands.
*	225 x 215 x 77 mm	3 kg (excluding battery and antennas)	LIPS5 battery offers 4 hrs of operation; 2 antenna ports: antenna #1 20-100 MHz, antenna #2 100-500 MHz
Jamming algorithms for Ccomms jamming, RCIED threats and counter drones	600 x 500 x 680 mm	Typical 65 kg - depending on configuration	Vehicular multirole jammer (RCIED, comms Jam (incl. Hhopping radios) and counter-drone.
True follow hopper jamming (per hop), waveform generator for deceptive jamming of new-generation threats	*	*	SWAP and output power depend on amplifiers used; HF extension available.
Spot, noise, sweep, reactive with external receiver	100 x 220 x 320 mm	<10 kg	Based on Hensoldt's "SWaP Optimized Jammer Architecture" (SOJA) for compact and clandestine systems; suitable for vehicle and infrastructure installations (e.g. Counter RCIED, EOD, building communications jamming).
Spot, noise, sweep, pulse/ASK, FM/FSK, combined active and reactive, deception	19-in./ 80 HU (dep. on variant)	4000 kg (e.g.)	Integrated ES and EA workflows, reactive jamming capabilities in combination with high fidelity ITAR-free receiver exciter unit, remote control capability, enhanced ES and DF, self protection capability.
Spot, noise, sweep, pulse/ASK, FM/FSK, combined active and reactive	613 x 475 x 585 mm	75 kg	Provides multirole jamming capabilities, including comms hopper jamming and EOD support; supports SMARTScout Extension for reconnaisance and COMINT purposes.
DDS-sweep	43 x 17 x 12.2 cm	10kg (Channel)	RCIED jammer; programmable via NATO-GUI for programming; notebook; upgradble; remote-control, RF-indicator.
Sweep, barrage, spot, mixed	Config. dep.	Config. dep.	RCIEDBlocker - Software-defined scalable system, with up to 18 attack channels and various configurations available; COMBlocker - reduced configuration with up to 6 channels, against cellular communication. Easy integration with a variety of sensors and receivers; Command, Control and Inteligency (C2I) system that can integrated IACIT's and also third-party equipment

COMMUNICATIONS JAMMERS & RCIED JAMMERS

MODEL	FREQUENCY RANGE	ERP	POWER SUPPLY	RECEIVER	PLATFORM
HF Jamming System	1-30 MHz	Config. dep.; up to 2kW per amplifier	220/240 VAC, 48 VDC	Direct digital	Grd-mob, ship
VHF/UHF Jamming System	20 MHz - 3 GHz	Config. dep.; up to 1kW per amplifier	220/240 VAC, 48 VDC	Wideband digital	Air, grd-mob, ship
L3Harris; Melbourne, FL, USA; +1 603-459-2200; www.L3Harris.com					
CVRJ (V)2 System - AN/ VLQ-13(V2)	Band A, B, C	*	R/T-1968/VLQ-13(V)2: 850W; R/T-1969/VLQ-13(V)2: 350W	Symmetric transceivers	Grd-mob, grd-fix
EGON	Band A, B, C, D	*	Up to 2kW	Symmetric transceivers	Grd-mob, grd-fix
L3Harris - TRL Technology; Tewkesbury, Gloucestershire, UK; +44-1684-852829; www.L3Harris.com					
BROADSHIELD HCS	Low-band: 20-520 MHz; High-band: 420 MHz - 6 GHz	*	24 VDC vehicle battery or equiv	*	Vehicle systems w/ covert solution options
BROADSHIELD LCS	Low-band: 20-520 MHz; High-band: 420 MHz - 6 GHz	*	External LIPS battery, BB-2590, or equiv military primary or secondary battery pack (eg B-390, BB-590, BB-5590, BA-5390)	*	Manpack (for SF, infantry and EOD)
BROADSHIELD MCS	Low-band: 20-520 MHz; High-band: 420 MHz - 6 GHz	*	External LIPS battery, BB-2590, or equiv military primary or secondary battery pack (eg B-390, BB-590, BB-5590, BA-5390)	*	Manpack (dual use for SF, infantry and EOD)
Leonardo; Basildon, Essex, UK; +44 1268 823400; www.leonardo.com					
CoDeSS	20 MHz - 6 GHz	Typical 1KW	24V	Internal	Grd-mob, grd-fix
Guardian HFE	2.4-6 GHz	*	22-30VDC	*	Grd-mob, grd-fix
Guardian Manpack (6GHz Responsive)	20 MHz - 2.6 GHz	*	*	*	Manpack
Lockheed Martin Rotary & Mission Systems; Syracuse, NY, USA; +1 315-456-4596; www.lmco.com					
Symphony Block 20A	Bands A, B	*	*	*	Grd-mob
Symphony Block 40	Bands A, B, C	*	*	*	Grd-mob
PKI Electronic Intelligence GmbH; Hamburg, Germany; +49 (0) 4154 98 96 32; www.pki-electronic.com					
Portable RCIED Jammer System	20-500 MHz	*	Battery, vehicle power	*	Man-portable; grd-mob, grd-fix

TECHNIQUES	SIZE (HxWxL in/mm/cm)	WEIGHT	FEATURES
*	Config. dep.	Config. dep.	Jamming modes: preset, multi-frequency, transmit-receive, broadband, adaptive broadband, attack, deception; look through capability; omni high-efficiency tranmit antenna.
*	Config. dep.	Config. dep.	Jamming modes: preset, multi-frequency, transmit-receive, broadband, adaptive broadband, attack, deception; look through capability; omni high-efficiency tranmit antenna.
Active, reactive	R/T-1968/VLQ-13(V)2: 13.18 x 13.40 x 19.37 in; R/T-1969/VLQ-13(V)2: 16.5 x 10 x 11.52 in.	R/T-1968/VLQ-13(V)2: 67 lb; R/T-1969/VLQ-13(V)2: 37 lb	Operationally deployed; modular active/reactive system; 25,500-plus units delivered. (V)3 available with upgraded amplifier, RF section and techniques.
Active, reactive	Master Modue (5 x 10 x 12 in.) and up to 5 Band Modules (4 x 10 x 12 in.)	95 lb (4 band modules)	Scalable, modular active/reactive systems. MIL-STD-810-F/G, completed 1000-hr Munson Road Testing. Operationally Deployed.
*	31 (H) x 40 (W) x 38.6 cm	25 kg	Very compact, integrated design w/ low SWaP; combat proven in high threat environments and exterme temps.
*	205 (H) x 169 (W) x 71 (D) mm (excluding battery and antennas)	< 2 kg (excluding battery and antennas); 2.5 kg w/ battery	The lightest manpack system available; high compact form factor; compatible w/ multiple user roles; combat proven in very high threat environments; SWaP capability for SOF, infantry, VVIP protection and EOD carry forward operations.
*	28 (H) x 30 (W) x 9 (D) cm	< 9 kg (including batteries and antennas)	Lightweight man-pack system for dual role use force protection and electronic attack options; combat proven in high threat environments and extreme climactic conditions.
Programmable	19-in. Rack	Installation dependent	High powered comms jammer, configurable to address a wide range of EA applications; local and remote user operation, look through and frequency agile jamming capability. Multiple simultanious target jamming.
FM, PCM, FSK, PSK	150 x 382 x 510 mm	13 kg	Remotely controlable; can be integrated as an additional slice to Augment GUARDIAN-H3 giving 20MHz to 6GHz active jamming; 4-channel DDS; power conditioning unit for 12V DC vehicle supply available.
Programmable	*	*	EOD, FP, VIP and fixed infrastructure roles; active, responsive or hybrid techniques
*	18 (H) x 20 (W) x 24 (D) in.	*	Four-channel output.
*	14.7 (H) x 17.6 (W) x 19.3 (D) in.	*	Open architecture, expansion slot to address new and emerging threats; Band C capability.
*	49 x 35 x 12 cm	9.7 kg	Jamming range 40m; 2-hr battery operation; 2 cases cover 20-500 MHz frequency range.

COMMUNICATIONS JAMMERS & RCIED JAMMERS

MODEL	FREQUENCY RANGE	ERP	POWER SUPPLY	RECEIVER	PLATFORM
PLATH AG; Bern, Switzerland; +41 31 311 64 46; www.plath-ag.ch					
AJS-2700P	30 MHz - 2.7 GHz	Up to 100W output power (ERP depending on antenna)	18 to 36 VDC; supplied battery unit (Li-ion 21.6 VDC/54 Ah)	Yes (digital channelized)	Manpack
AJS-30R	1.5-30 MHz	Up to 2kW output power (ERP depending on antenna)	220 VAC ± 10%, 50/60 Hz	Yes (digital channelized)	Grd-mob, grd-fix
AJS-6000R	30 MHz - 6 GHz	Up to 2kW output power (ERP depending on antenna)	100–240 VAC, 50/60 Hz	Yes (digital channelized)	Grd-mob
Rohde & Schwarz Asia Pte. Ltd.; Singapore; +65 63070000; www.rohde-schwarz.com/sg					
R&S Communication Jamming System HF	1.5-30 MHz	Up to 1kW output power	400/230 VAC or 28 VDC	Combined wideband detector and exiter	Grd-mob, grd-fix, ship
R&S Communication Jamming System VHF/UHF/(SHF)	27 MHz - 3.6 GHz	27-100 MHz: up to 1kW; 0.1-1 GHz: up to 2kW; 1-3 GHz: up to 200 W; 3-6 GHz: up to 90W	400/230 VAC or 28 VDC	Combined wideband detector and exiter	Grd-mob, grd-fix, ship, air
Samel-90 PLC; Samokov 2000, Bulgaria; +35972268201; www.samel90.com					
Artillery Radiojammer	1.5-120 MHz divided in 8 subbands	1W per band	Li-Ion battery	*	Artillery round
SMJ-100	20 MHz - 3 GHz	20-100W	Li-Ion battery and 220VAC	Opt.	Manpack, grd-fix
SVJ-2000	2 MHz - 6GHz	2-3kW	High power DC generator	Opt.	Grd-mob; grd-fix
SESP Group; Paris, France; +33 (1) 73 04 91 17; www.sesp.com					
JAMKIT	66 MHz - 2.5 GHz	10-100W	12 VDC or 24 VDC	*	Grd-mob
Sierra Nevada Corporation (SNC); Sparks, NV, USA; +1 775-331-0222; www.sncorp.com					
AN/PLQ-9 JCREW 3.1 (Thor III)	*	*	2 x BB-2590/U Li batteries	*	Manpack, grd-mob
AN/PLQ-11 (Baldr)	*	*	1 x BB-2590/U Li battery	*	Manpack
SRC, Inc.; North Syracuse, NY, USA; +1 800-724-0451; www.srcinc.com					
CREW Duke AN/VLQ-12	*	*	*	*	Grd-mob
Thales; Gennevilliers, France; +33-1-41-30-30-00; www.thalesgroup.com					
Eclipse	20 MHz - 6 GHz	Up to 220W	24-36 VDC	Embedded ultra wideband receiver	Grd-fix, grd-mob
Storm-H	20-470 MHz, 2G, 3G	1W	Battery	No	Individual
TRC 274 SDJ	20 MHz - 3 GHz	Up to 1kW in low band	230 or 380 VAC	Embedded wideband receiver	Grd-mob, ship, air

TECHNIQUES	SIZE (HxWxL in/mm/cm)	WEIGHT	FEATURES
Noise, waveform; manual and responsive jamming; follower jamming	260 (H) x 200 (W) x 340 (D) mm (core unit only)	< 12 kg (core unit only); 8 kg (battery unit)	Man-portable communication jamming system with tablet PC for system control; set of omnidirectional Rx/Tx antennas for 30–500 MHz; omnidirectional Rx and directional Tx antennas for 500–2700 MHz, and back carrier; instantaneous receiver bandwidth of 50 MHz.
Noise, waveform; manual and responsive jamming; follower jamming	10 RU total (H) x 19" (W) x 600 (D) mm	85 kg approx. (excluding accessories and antennas)	Rack-mount communication jamming system; instantaneous receiver bandwidth of 8 MHz.
Noise, waveform; manual and responsive jamming; follower jamming	29 RU total (H) x 19" (W) x 600 (D) mm	160 kg approx. (excluding accessories and antennas)	Rack-mount communication jamming system; instantaneous receiver bandwidth of 200 MHz.
Continuous, deception, wideband, barrage, sweep, fast sequential, look through, FH follower	19 in. x 12-35 HU	120-300 kg	Jams conventional and frequency-agile comms signals; can be used to selectively jam advanced comms systems in HF range; gain tbd by configurable antenna selection; available in variety of customized configurations.
Continuous, deception, wideband, barrage, sweep, fast sequential, look through, FH follower	19 in. x 12-35 HU	120-300 kg	Jams conventional and frequency-agile comms signals; can be used to selectively jam advanced comms systems in VHF/UHF/(SHF option) range; gaindetermined by configurable antenna selection; available in variety of customized configurations; 6 GHz option.
Barrage jamming	Config. dep.	Config. dep.	Tactical jammer for enemy HF and VHF communicatioon interuption.
Barrage RCIED jammer	Config. dep.	< 17 kg	Lightweight RCIED manpack jammer.
Barrage RCIED jammer for convoy protection	Config. dep.	Config. dep.	Convoy jammer for VVIP, VIP, police and army troops, secutity agencies.
*	55 x 25 x 46 cm	40 kg	RCIED jammer providing 66-2500 MHz coverage over 9 frequency bands via 6 antennas.
*	17.5 x 9.3 x 7.3 in. per module	10.4 kg per module	Interoperability, programmable.
*	7 x 8.4 x 3 in.	3.8 kg	Interoperability, programmable.
*	2 cubic ft.	20 lb (with 2 units)	Programmable; high temperature operation; built-in test; MIL-STD-810F compliant; proven high reliability/operational availability.
Active, reactive, hybrid jamming	44 x 42 x 24 cm	< 45 kg	Software defined vehicle-mounted hybrid FP-ECM; compact, scalable and modular HW & SW architecture; compatible with friendly CNR; Multi-modes (ED, EA) solution covering also counter-UAV applications.
Active jamming waveforms	21.3 (H) x 3.8 (D) x 7.5 (W) cm	1 kg	Storm-H is an ultra-compact, lightweight programmable ECM system that provides protection for individuals. Solutions for compatibility with friendly equipment available.
Selective, chirp barrage, repeater, follower jamming	19-in. rack, height config. dep.	Config. dep.	Electronic attack software defined COMJAM; embedded wideband ESM. EIRP depending on antenna configuration and power amplifier.

SURVEY KEY – RCIED JAMMERS AND COMMUNICATIONS JAMMERS

MODEL
Product name or model number

FREQ RANGE
Operating frequency range (in MHz and/or GHz)

ERP
Effective radiated power (ERP) in Watts

POWER SUPPLY
System power required in volts or Watts
- Li-ion = Lithium ion battery
- LIPS5 = Lithium Ion Power System 5

RECEIVER
Indicates if the jammer is cued by a receiver or is an "active" jammer broadcasting continuously
Superhet = superheterodyne

PLATFORM
Indicates the weapons platforms that can carry the system
- air = aircraft
- grd-mob = ground mobile vehicle
- grd-fix = fixed ground installation

TECHNIQUES
Indicates the types of jamming techniques provided

SIZE
H x W x L/D in inches, millimeters or centimeters

WEIGHT
Weight in pounds (lb) or kilograms (kg)

FEATURES
Additional features

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

GENERAL ABBREVIATIONS
- config = configuration
- max = maximum
- opt = optional
- R/T = receiver transmitter

UPCOMING TECHNOLOGY SURVEYS
- **JUNE 2020: POWER AMPLIFIERS FOR EW APPLICATIONS**
- **JULY 2020: AIRBORNE RADAR JAMMERS**
- **SEPTEMBER 2020: RF TUNERS FOR SIGINT APPLICATIONS**

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Space EW (Part 19)

Link Vulnerability *cont.*

By Dave Adamy

This month, we will continue our review of the link losses between Earth stations and satellites and also the losses in links to or from target transmitters or receivers.

ATMOSPHERIC LOSS

The atmospheric loss between a satellite and its ground station is a function of the link frequency and the elevation of the satellite above the ground station's horizon, since the link passes through the whole atmosphere. **Figure 1** shows this function. To use this graph, move vertically at the link frequency to the curve for the satellite elevation and then horizontally to the attenuation scale. You will note that at elevations above about 30° the atmospheric attenuation is very low because the signal path passes through little of the atmosphere. This figure also applies to intercept and jamming path losses between targets on the Earth and the satellite.

Since we will be talking about vulnerability of the satellite link, consider the losses between hostile transmitters (jammers or spoofers) and the appropriate link receiver. For an uplink, the path is from the transmitter to the satellite. For down link hostile transmitters, the link is from the transmitter to the satellite Earth station. Note also that when the satellite is jamming a target link, the atmospheric loss is between the hostile transmitter and receiver. Within the atmosphere, the atmospheric loss is as shown in **Figure 2**. For this figure, move horizontally to the link frequency, then vertically to the appropriate curve (dry air or normal humidity) to read the attenuation per kilometer.

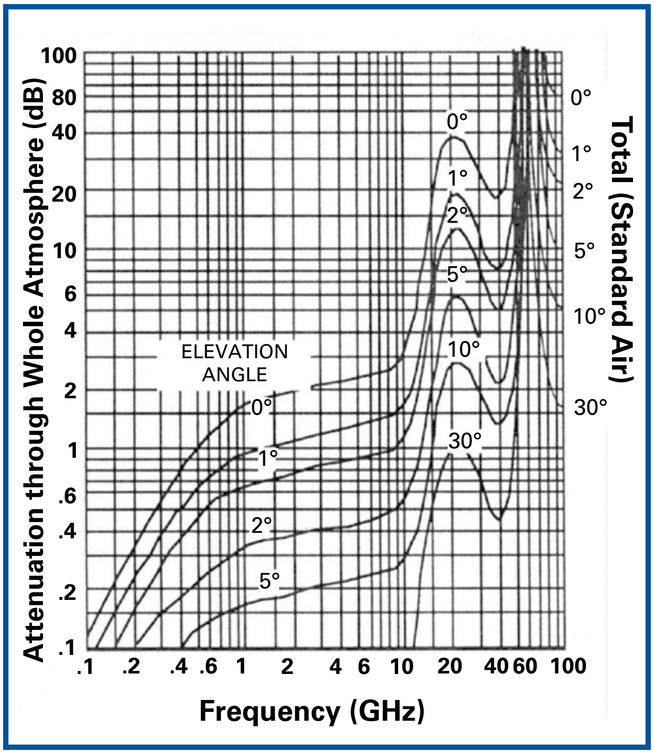

Fig. 1: Atmospheric loss in a satellite to ground link is a function of frequency and satellite elevation angle.

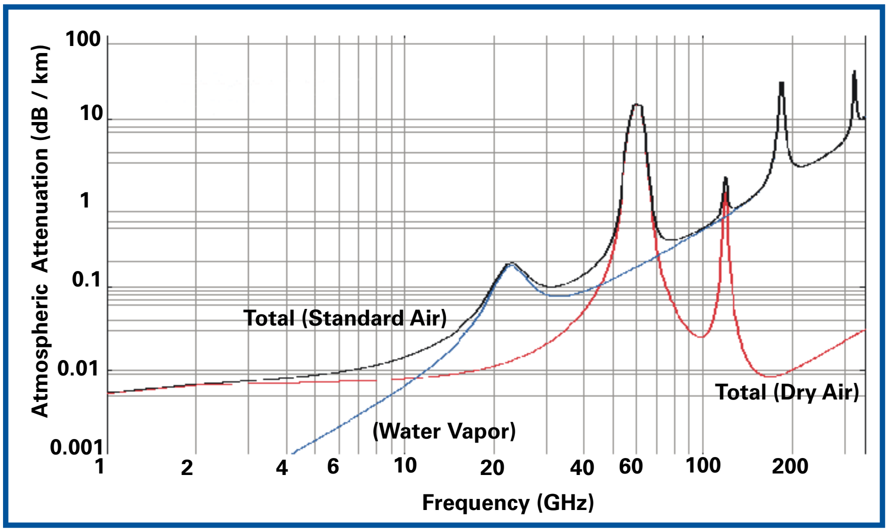

Fig. 2: Atmospheric attenuation is a function of frequency and humidity. This shows the attenuation per kilometer of link distance.

ANTENNA MISALIGNMENT LOSS

The alignment of the ground station and satellite antennas impacts the up and down link losses. If an antenna is misaligned by more than half of its main beam width (null to null), it is normally assumed to have the average sidelobe gain. However, unless its boresight is perfectly aligned toward the antenna at the other end of the link, there is an alignment loss that can be calculated as a function of the antenna's 3-dB beam width and the misalignment angle. This calculation applies to transmitted and received signals that are within the antenna's main beam (i.e., not side lobes). **Figure 3** shows the antenna main beam and the angle between the antenna and

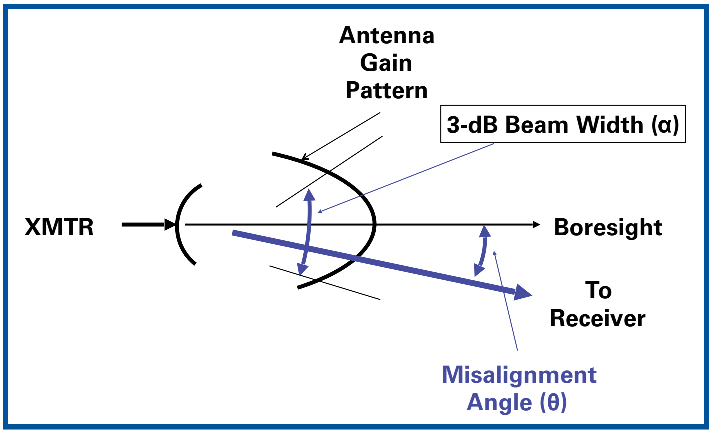

Fig. 3: *For small misalignment errors, the antenna gain is reduced by a function of the angular error and the antenna 3-dB beamwidth.*

the receiver or transmitter at the other end of the link. This can refer to either a transmitting or receiving antenna.

The loss from antenna misalignment is determined from the formula:

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

Where:

- ΔG is reduction from boresight gain in dB,
- α is 3 dB beam-width (degrees), and
- θ is offset angle (degrees).

The total link loss from antenna misalignment is the sum of the transmitting and receiving antenna misalignment losses.

In jamming problems, we compare the jamming power in the target receiver to the desired signal power in the target receiver. The antenna losses in links between target transmitters or receivers and the satellite can be determined as just discussed if the target has a directional antenna. However, the problem often assumes that the target (transmitting or receiving) antenna is aimed far from the satellite (such as an air defense radar tracking an aircraft). Thus, the side-lobe gain of the target radar antenna is assumed as shown in **Figure 4** or of the target receiver as shown in **Figure 5**.

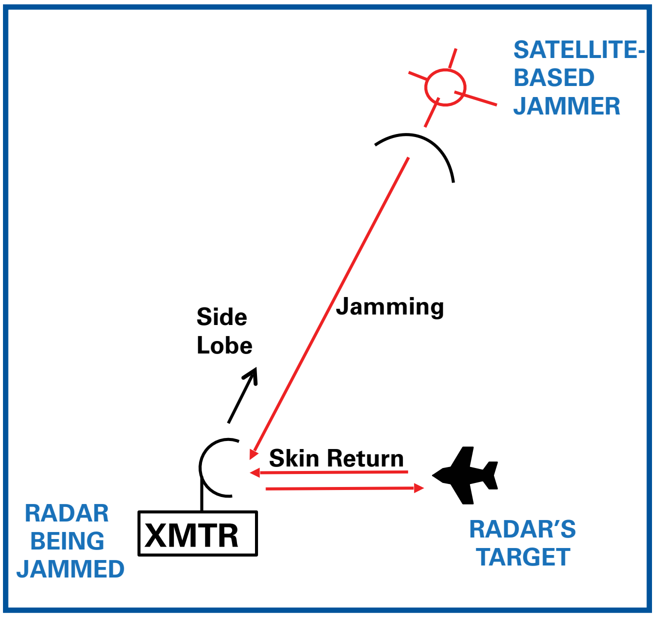

Fig. 4: *For radar jamming problems, the side lobes of the radar antenna are assumed to be toward the satellite.*

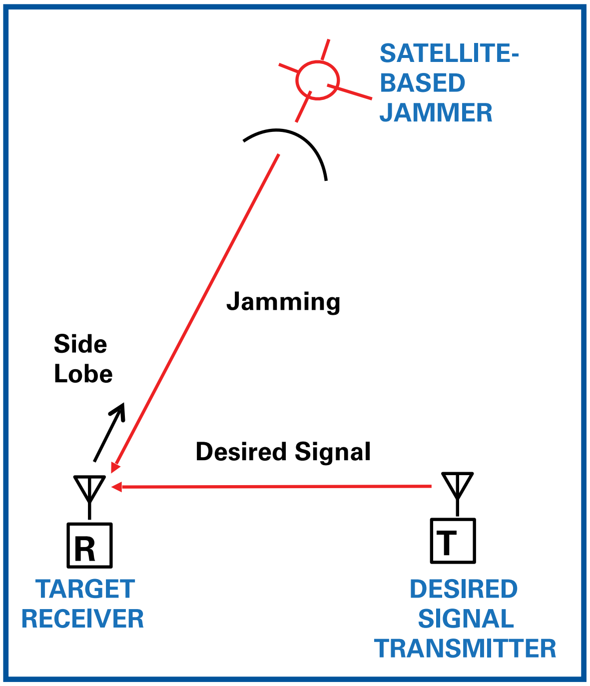

Fig 5: *For communication-jamming problems, the side lobes of the target receiver antenna are assumed to be toward the satellite.*

If the target has a "non-directional" whip or dipole antenna as shown in **Figure 6**, it is normally assumed that the satellite will see the average gain of the target antenna. In reality, there is a null in the gain pattern of a whip or dipole antenna if viewed from the end of its element. This must be considered if the problem is set up to place the satellite in or near the null of the target antenna.

WHAT'S NEXT

Next month we will continue the Space EW series with the space-related link loss discussion. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.

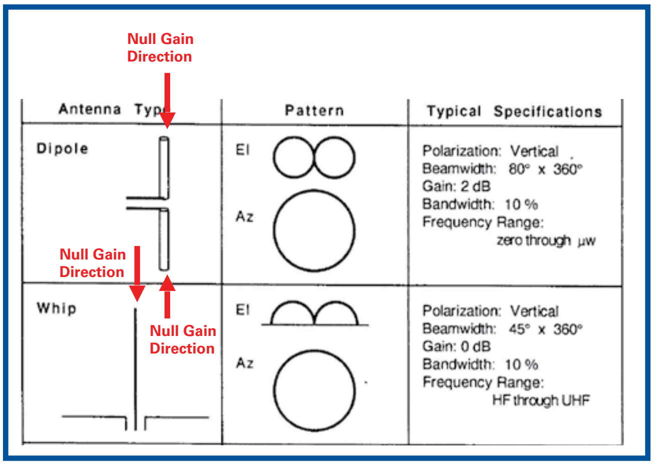

Fig. 6: *Non-directional target antennas are typically considered to have constant gain vs. aspect angle in intercept and jamming problems, but they can have nulls in their coverage.*

REMEMBERING AN ARMY VETERAN: RETIRED COLONEL SAMUEL FUOCO

By AOC India Chapter

Retired Colonel Samuel Fuoco of Eatontown, NJ, passed away April 3 due to complications fighting the COVID-19 virus. Sam was a decorated veteran who spent more than 37 committed years in the Army and the Army Reserve, rising to the rank of full Colonel.

COL Fuoco began his military career as an Airborne Infantry Platoon Leader in the 82nd Airborne Division at Fort Bragg, NC. He served a year-long combat tour as part of Operation Iraqi Freedom, during which he was awarded a Bronze Star, along with numerous other medals and recognitions throughout his military career, ultimately retiring in 2011. After a distinguished career in the United States Army, COL Fuoco never stopped serving the Army through his volunteer efforts supporting our active duty military, veterans and their families. COL Fuoco, United States Army, retired, was the president of the Association of the United States Army (AUSA) Monmouth Chapter. Under COL Fuoco's leadership, the Monmouth Chapter has been selected as the best chapter among hundreds across the country for the last three years, a first in the over 35-year history of the organization. COL Fuoco was also an extremely active member of the AOC Garden State Chapter, giving unyielding support to all of its soldier and veteran events, especially the annual Membership Appreciation and ROTC Scholarship Awards Dinner, as well as the annual Gingerbread Ball to benefit Fisher House.

COL Fuoco's selfless service is an inspiration to all and a beacon of light, especially during this pandemic which took his life.

DIXIE CROW CHAPTER VOLUNTEERS AT CAREER DAY

Ken Cirilli, AFSOC Det 1 492 SOW and Lifetime AOC Member, volunteered to talk to fifth grade students about the importance of software programming in CMDS (Countermeasure Defensive Systems) at Pooler Elementary's Career Day on Feb 27. Videos of various weapon systems dispensing were shared via YouTube during each discussion. The students had excellent questions and were very interested in how and when countermeasures were used.

GRANITE STATE ROOST HOSTS NASHUA COUNTRY CLUB CURLING EVENT

In February, the Granite State Roost held a curling event at Nashua Country Club. Almost 20 attendees came out to enjoy the ice. The event began with instruction on the uses of each type of "shoe:" one is used to slide on the ice while the other prevents slipping. Those used for sliding made the ice slipperier than when on ice skates! Attendees learned techniques for "throwing" the stone, sweeping and scoring. Despite the cold, we all warmed up soon enough! After the training, teams were created, and games were played – competition was fierce!

Granite State Roost's next outings include a Fisher Cats baseball game in Manchester in June, a dinner cruise on Lake Winnipesaukee in July, and to finish off the year, the annual holiday party in December. Tech talks will be sprinkled among these events, if allowed, due to current circumstances.

The Granite State Roost maintains a strong commitment to advancing knowledge of Electronic Warfare and Electromagnetic Spectrum Operations (EMSO) by inspiring local industry to contribute their skills and products to serve the EW Community. The Granite State Roost continues to provide opportunities for interaction among its membership by holding social events throughout the year. For additional information about Granite State Roost, contact the chapter president, Mr. Duane Beaulieu, at duane.a.beaulieu@baesystems.com.

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