JULY 2019
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ASSOCIATION OF OLD CROWS

JED

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In May, LTG Christopher Cavoli, US Army Europe commanding general, visited the US Army Paratroopers of the Combat Electronic Warfare Intelligence (CEWI) Platoon, Delta Company, 54th Brigade Engineer Battalion, 173rd Airborne Brigade, stationed in Vicenza, Italy. The 173rd Airborne Brigade is the US Army's Contingency Response Force in Europe, capable of projecting ready forces anywhere in the European, Africa or Central Command's areas of responsibility. US ARMY

News

Features

Departments

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READING BETWEEN THE LINES

Over the past few years, the Senate Armed Services Committee (SASC) and its counterpart in the House have exercised a firm guiding hand with the DOD when it comes to EW matters. Last year, for example, the Senate's version of the National Defense Authorization Act (NDAA) asked the DOD to name a "senior designated official" for EW and to establish an EW (now EMSO) cross functional team. This year, Congress seems to be continuing that trend.

Last month, the SASC passed its version of the FY2020 NDAA. (See the "Monitor" section of this month's *JED* for more information about the EW provisions in the bill.) Among the items was a "Limitation on availability of funds for communications systems lacking certain resiliency features" (Sec. 151). The SASC expressed concern that "…in the face of great power competition, the DOD has not assured servicemembers' ability to communicate and share data securely and consistently in a contested environment." The provision further states, "The committee defines these program resiliency requirements as features that: 1) Deny geo-location of a transmission that would allow enemy targeting of the force; 2) Securely communicate classified information in a jamming environment of like-echelon forces; and 3) Utilize a waveform that is made available in the DOD Waveform Information Repository." The limitation of funds, by the way, would "…prohibit funding of any current or future Department of Defense (DOD) communications programs of record that do not meet certain resiliency requirements."

In another section of the bill (Sec. 211), the SASC recommended "a provision that would require the Chief of Staff of the Air Force (CSAF) and Chief of Naval Operations (CNO) to develop a joint development and acquisition strategy to procure a resilient, low latency, and low probability of detection data link network capability that would enable effective operation in the contested environments highlighted in the National Defense Strategy." The language goes on to say that the Air Force and the Navy would only be able to spend 50% of their operations and maintenance budget until they submit their joint strategy to Congress.

It's not clear if the full Senate will pass the NDAA with these measures, or if they would survive in a conference session with the House. The language is ambitious, and the penalties are steep. Still, these are just two provisions in a bill that sends a clear message that Congress continues to be frustrated by the slow pace of EMS Enterprise development in the DOD.

The bigger question is, how can the DOD generate more momentum building and connecting its EMS Enterprise? The DOD is making some progress (mostly at the direction of Congress), but what is the vision? What does the DOD want its EMS Enterprise to look like in 5 years? What is the path to realize that vision? These are the answers Congress is really seeking. – *J. Knowles*

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AUGUST

TechNet Augusta
August 19-23
Augusta, GA
www.afcea.org

SEPTEMBER

MSPO 2019
September 3-6
Kielce, Poland
www.targikielce.pl

8th Annual AOC Pacific Conference
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Arthur.N.Tulak.ctr@pacom.mil

SPIE Security+Defence
September 9-12
Strasbourg, France
www.spie.org

3rd Electromagnetic Maneuver Warfare Systems Engineering and Acquisition Conference
September 10-12
Dahlgren, VA
www.crows.org

DSEI
September 10-13
London
www.dsei.co.uk

AFA 2019 Air, Space and Cyberspace Conference
September 16-18
National Harbor, MD
www.afa.org

Modern Day Marine
September 17-19
Quantico, VA
www.marinemilitaryexpos.com

Kittyhawk Week 2019
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Dayton, OH
www.kittyhawkaoc.org

OCTOBER

5th Annual Cyber Electromagnetic Activities (CEMA) Conference
October 8-10
Aberdeen Proving Ground, MD
www.crows.org

AUSA Annual Meeting
October 14-16
Washington, DC
www.ausa.org

Seoul ADEX 2019
October 15-18
Seoul, ROK
www.seouladex.com

56th Annual AOC International Symposium and Convention
October 28-30
Washington, DC
www.crows.org

NOVEMBER

Electronic Warfare South Africa (EWSA2019)
November 4-6
Pretoria, South Africa
www.aardvarkaoc.co.za

Dubai Airshow 2019
November 17-21
Dubai, UAE
www.dubaiairshow.aero

DSEI Japan
November 18-20
Tokyo, Japan
www.dsei-japan.com

Defence & Security 2019
November 18-21
Bangkok, Thailand
www.pandci.com

DECEMBER

Expodefensa 2019
December 2-4
Bogota, Colombia
www.expodefensa.com.co

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JULY

Airborne AESA Radar
July 9-11
Las Vegas, NV
www.pe.gatech.edu

Airborne Electronic Warfare Systems Integration
July 9-11
Atlanta, GA
www.pe.gatech.edu

AOC Virtual Series Webinar: Understanding Tracking Radars
July 11
1400-1500 ET
www.crows.org

Signals Intelligence Fundamentals
July 23-24
Las Vegas, NV
www.pe.gatech.edu

Basic Electronic Warfare Modeling
July 23-26
Las Vegas, NV
www.pe.gatech.edu

AOC Live Professional Development Web Course: Introduction to Radar Systems
July 29 - August 9
6 sessions, 1300-1600 EDT
www.crows.org

Cyber Warfare / Electronic Warfare Convergence
July 30 - August 1
Atlanta, GA
www.pe.gatech.edu

AUGUST

AOC Virtual Series Webinar: An Introduction to Radio Direction Finding Methodologies
August 8
1400-1500 ET
www.crows.org

Space-Based Radar
August 12-16
Atlanta, GA
www.pe.gatech.edu

Test and Evaluation of RF Systems
August 13-15
Las Vegas, NV
www.pe.gatech.edu

AOC Live Professional Development Web Course: Airborne Expendables / UAS Capabilities and Potential
August 19-28
4 sessions, 1300-1600 EDT
www.crows.org

AOC Virtual Series Webinar: Evolving to the Next Generation of Multifunctional Electronic Warfare – Part 2
August 22
1400-1500 ET
www.crows.org

SEPTEMBER

AOC Live Professional Development Web Course: Space EW
September 4-20
8 sessions, 1300-1600 EDT
www.crows.org

AOC Virtual Series Webinar: Introduction to Machine Learning for EW
September 5
1400-1500 ET
www.crows.org

Radar Fundamentals
September 9-11
Canberra, Australia
www.unsw.adfa.edu.au

Fundamentals of Radar Signal Processing
September 9-12
Winter Garden, FL
www.pe.gatech.edu

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EMSO EVOLVES

I commend the DOD's Joint Requirements Oversight Council for tasking the Electronic Warfare Executive Committee (EW EXCOM) to look at options for DOD organizational changes for Electromagnetic Spectrum Operations (EMSO). Last year, the EW EXCOM commissioned the Institute for Defense Analysis (IDA) to conduct a wargame to evaluate and recommend organizational changes for EMSO. Based on the wargame results, IDA made a number of recommendations that were presented to the EW EXCOM. After careful review this year, the EW EXCOM co-chairs accepted some of IDA's recommendations but modified or rejected others.

This is good news on multiple fronts. The DOD's organization for EMSO is a high priority. There was agreement that the Electromagnetic Spectrum is a medium of maneuver for the Joint Force – our modern way of war crumbles if we cannot shoot, move and communicate. The EW EXCOM also concluded that the military departments are making progress in organizing for EMSO.

Based on the results of the wargame, IDA recommended assigning the EMSO mission to USCYBERCOM. However, the EW EXCOM agreed that the EMSO mission belongs to USSTRATCOM, and that the commander of USSTRATCOM should propose the optimum organizational structure to execute its EMSO responsibilities and authorities. The DOD will consider expanding USSTRATCOM authorities to accomplish the additional responsibilities. The EW EXCOM considered that the EMS is one, but not the only, possible delivery mechanism for cyberspace effects, and that USCYBERCOM should continue to focus on improvements to Joint Force cyberspace operations. I think Cyber's interest in EW is narrow and Cyber Comand could lead the DOD into following an unbalanced EW strategy that our adversaries would easily recognize and quickly exploit at very little cost.

Another outcome from the wargame was the recommendation that the DOD Chief Information Officer (CIO) responsibilities be broadened for all EMSO activities. As a result, the EW EXCOM tasked the Department to consider what specific responsibilities and functions are required for EMSO, and what changes to the current DOD CIO organization are needed to better accomplish these.

The wargame findings also recommended standing-up a new defense agency or field activity responsible for EMS capability analysis and integration. As an action item, the EW EXCOM determined the Department will review existing responsibilities for EW field activities and agencies to determine if a new activity is warranted.

How is this going to happen?: The OSD's EMSO Cross Functional Team (CFT) is the lead organization for addressing near-term EMSO issues. The Vice Chairman of the Joint Chiefs of Staff (who is also the co-chair of the EW EXCOM) leads the EMSO CFT as the Senior Designated Official (SDO).

Closing thoughts: 1) EMSO a priority = good. 2) Recognizing the EMS as a medium for maneuver = good. 3) Departments are making progress in organizing for EMSO – maybe a little bit. 4) EMSO not under Cyber Command = very good. 5) USSTRATCOM gets the EMSO mission = jury is out. (We'll see if authorities, funding and manpower are allocated – if not, nothing has changed.) All the rest is TBD. Overall, we're making progress, but we're not there yet. – *Muddy Watters*

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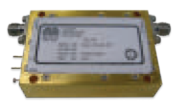

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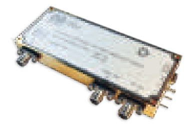
DLVA-70M-80-12V



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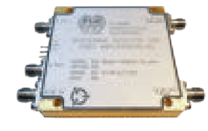

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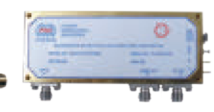

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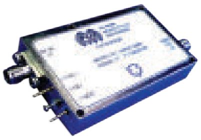
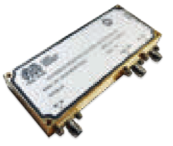
DLVA-70M-80-12V https://www.pmi-rf.com/product-details/dlva-70m-80-12v	50 - 90	-80 dBm	25	-80 to 0	3.51" x 1.5" x 0.47" SMA (F)
SDLVA-315M362M-65-CD-1 https://www.pmi-rf.com/product-details/sdlva-315m362m-65-cd-1	315 - 362	-80 dBm	50	-65 to 0	3.75" x 1.5" x 0.5" SMA (F)
SDLVA-100M3G-70-MAH https://www.pmi-rf.com/product-details/sdlva-100m3g-70-mah	100 - 3000	-70 dBm	10	-60 to +5	2.3" x 2.2" x 0.36" SMA (F)
SDLVA-0120-70-0225 https://www.pmi-rf.com/product-details/sdlva-0120-70-0225	200 - 2500	-65 dBm	25	-65 to +5	3.75" x 1.5" x 0.5" SMA (F)
GMDA-D1007 https://www.pmi-rf.com/product-details/gmda-d1007	500 - 2000	-65 dBm	25	-60 to +7	3.5" x 3.2" x 0.5" SMA (F)
HADA-D2001 https://www.pmi-rf.com/product-details/hada-d2001	500 - 2000	-44 dBm	50	-40 to 0	2.5" x 1.5" x 0.44" SMA (F)
SDLVA-0R5G4G-70dB-100R https://www.pmi-rf.com/product-details/sdlva-0r5g4g-70db-100r	500 - 4000	-73 dBm	25	-70 to 0	3.2" x 1.8" x 0.4" SMA (F)
SDLVA-0R71R3-75-CD-1 https://www.pmi-rf.com/product-details/sdlva-0r71r3-75-cd-1	700 - 1300	-70 dBm	40	-70 to +5	3.75" x 1.5" x 0.5" SMA (F)

GMDA-D1007



HADA-D2001

SDLVA-0R5G4G-70dB-100R



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news

ELECTRONIC RESURGENCE INITIATIVE PUSHES 4TH-WAVE OF INNOVATION

This month in Detroit, MI, the Defense Advanced Research Agency (DARPA) will hold a second summit highlighting the accomplishments and future plans of its Electronic Resurgence Initiative (ERI). A five-year, upwards of $1.5 billion investment, the ERI was first announced in June 2017, "to forge forward-looking collaborations among the commercial electronics community, defense industrial base, university researchers, and DOD to move from an era of generalization to one of circuit specialization."

Multiple initial "Page 3" ERI program awards were made during the first ERI Summit held last July in San Francisco, CA. Page 3 refers to ideas expressed on the third page of Gordon Moore's seminal 1965 paper introducing "Moore's Law," and emphasizes enhancing silicon circuits with unconventional materials, building novel architectures for programmability and configurability, and dramatically lowering the barriers to circuit design.

Recently, DARPA has been announcing program awards for the second phase of the ERI. Phase II will focus on some of the key issues raised at the 2018 event, including "the need to support domestic manufacturing options and enable them to develop differentiated capabilities for diverse needs of the defense and commercial sectors; a demand to invest in chip security; and a desire to create new connections between ERI programs as well as to demonstrate the resulting technologies in defense applications." Phase II areas of exploration include the integration of photonics and radio frequency (RF) components directly into advanced circuits and semiconductor manufacturing processes.

Phase II also includes the ERI Defense Applications (ERI-DA) effort, which is aimed at developing "revolutionary national defense capabilities that capitalize on technologies developed in existing ERI thrusts – namely, the need to support domestic secure integrated circuits manufacturing; invest in chip security; and demonstrate new ERI technologies for defense applications." DARPA says it particularly wants to promote teaming arrangements between organizations that can move electronics innovations rapidly into military hardware.

The 2019 ERI Summit will run from July 15-17 and, as described by Dr. Mark Rosker, Director of DARPA's Microsystems Technology Office (MTO), "Now in its second year of what we hope will be at least a five-year effort, it's a good time to reflect on what we're trying to do with ERI, where we're going, and how we're going to get there. This is a critical time in ensuring that we, in this country, have the ability to have access to secure and very, very capable electronics for both defense and non-defense applications."

Dr. Rosker became director of DARPA's MTO in April 2019, prior to which, he was deputy director of the Defense Sciences Office (DSO). He says he has "a little different perspective of where ERI should go." Although Rosker fully agrees with the stated objectives of the effort, he says he will probably move away from the use of the term "phases" when describing how their efforts are organized. "When I think about how electronics has developed over the last 40-50 years, I think of it as a series of waves. The first wave was really about geometric scaling. The second wave was about addressing problems having to do with the back end of the production line and the move toward copper interconnect --dominated more by packaging and interconnect than by the active devices. The third wave was where we started to see the limits of scaling and the need to move toward more interesting, complex devices, like Fin Field-effect transistor (FINFET) devices."

Today, Rosker says, "ERI is really about pushing innovation in the Fourth Wave," which to him means "moving past where we are today and the limitations we're seeing as we reach the end of scaling, into new areas that are really focused on many of the new things described for the ERI, such as 'differentiation,' and the fact that this is almost certainly associated with the exploitation of the 3rd dimension as a form of packaging, as well as increasing the amount of intelligence incorporated into microsystems that would include, but not be limited to, artificial intelligence (AI)."

The 2019 ERI Summit features a number of top-level speakers representing industry, the DOD and other institutions, including: Lisa Su, President and CEO of AMD; Steve Mollenkopf, CEO of Qualcomm; Thomas Caulfield, CEO of GlobalFoundries; John Kelly III, Executive Vice President at IBM; Bill Vass, Vice President of Technology at Amazon Web Services; John Neuffer, President and CEO of the Semiconductor Industry Association (SIA); and Dr. Lisa Porter, Deputy Under Secretary of Defense for Research & Engineering (DUSD(R&E)) – *J. Haystead*

SENATE FY2020 DEFENSE POLICY BILL ADVANCES

The Senate Armed Services Committee (SASC) has passed its version of the FY2020 National Defense Authorization Act (NDAA) and had sent it to the Senate floor for debate as this issue of *JED* went to press. In the committee report (116-48) accompanying the bill (S. 1790), the SASC discussed several budget items related to electronic warfare (EW), signals intelligence (SIGINT) and directed energy (DE) programs. Below are some of the highlights:

Electronic Warfare

In the procurement budget lines, several EW programs saw decreases for a variety of reasons. The SASC reduced the Navy's Surface EW Improvement Program (SEWIP) Block 3 procurement, which provides a new on-board radar jamming capability for surface combatants, by $62 million, citing the request as "early to need." This left the budget line with $360.2 million.

The Air Force's proposed plan to buy new F-15X aircraft, which would be equipped with the Eagle Passive Active Warning Survivability System (EPAWSS), led the SASC to recommend a reduction in EPAWSS procurement for existing F-15s. The Air Force's original request for $149 million in EPAWSS procurement was reduced by $67.2 million.

The SASC also trimmed the procurement budget for the RF Countermeasures (RFCM) system by $8.8 million. Air Force Special Operations Command is buying the RFCM system for its AC/MC-130J aircraft, but the Committee notes that the program is experiencing schedule delays "due to integration and compatibility issues with the technology." The reduction leaves AFSOC with $32.8 million for RFCM procurement. The committee also noted "…elsewhere in the Act, there is a symmetric increase to U.S. Special Operations Command's future vertical lift research and development efforts, a high priority unfunded requirement identified by the command."

One particularly interesting item in the committee report addressed Electronic Protection (EP) measures in military communications systems. The report stated, "The committee recommends a provision that would prohibit funding of any current or future Department of Defense (DOD) communications programs of record that do not meet certain resiliency requirements. The committee is concerned that, in the face of great power competition, the DOD has not assured servicemembers' ability to communicate and share data securely and consistently in a contested environment. The committee defines these program resiliency requirements as features that: 1) Deny geolocation of a transmission that would allow enemy targeting of the force; 2) Securely communicate classified information in a jamming environment of like-echelon forces; and 3) Utilize a waveform that is made available in the DOD Waveform Information Repository. The committee understands that there may be very limited cases where DOD communications equipment will be used to communicate in a garrison or peacetime situation and not in combat environments. Therefore, the provision would allow the Secretaries of the military departments to waive the aforementioned requirements for a system with a certification that the system does not require resiliency due to its expected use."

In a separate provision on multi-function, the report stated, "The committee is concerned about the ability of the Department of Defense to maintain its advantage in full spectrum operations in the future. Recent conflicts have highlighted our adversaries' increasing abilities to geolocate, jam, and intercept electronic communications, putting at risk the US military's ability to communicate and conduct effective command and control in contested environments. To better prepare for future combat operations against a near-peer adversary, the committee believes that the DOD needs to expedite testing of multi-domain capabilities and systems that provide distributed, shared, full-spectrum situational awareness and spectrum maneuver. This testing should include cognitive machine learning or artificial intelligence applications to assess new and unknown electronic signals in real-time. Such testing would also demonstrate advanced technologies, such as modern waveforms that are designed to be low-probability-of-intercept, low-probability-of-detection, and ultra-wideband radio frequency converged apertures that permit the U.S. to maintain spectrum dominance. These systems should also enable secure communications across networks with different security levels and between both legacy and advanced systems. Therefore, the committee directs the Secretary of Defense to provide the congressional defense committees with a briefing, no later than March 1, 2020, on the plan for the conduct of live testing of technologies and capabilities designed to permit secure full spectrum operations in the fiscal years 2020–2021 timeframe."

SIGINT

The SASC expressed more interest than usual in the DOD's SIGINT programs. For instance, the report stated, "The committee notes that the Chief of Naval Operations' unfunded priority list states that additional funding could provide for expansion of ship's signal exploitation space and installation of ship's signal exploitation equipment modifications on Flight I *Arleigh Burke*-class destroyers." The committee recommended an $8 million increase for procurement of the Ship's Signals Exploitation Equipment (SSEE) program, boosting the budget line to $202.8 million.

Elsewhere in the report, the committee noted the Air Force's efforts "…to develop an integrated, capability-focused SIGINT architecture and investment strategy. The committee observes that the investment has already produced significant advances in Air Force SIGINT capability, particularly within the medium-altitude RC–135 Rivet Joint program. The committee is also aware that some significant capability gaps exist against current threats and that the Air Force has not yet addressed diminishing industrial base issues with the high-altitude Airborne Signals Intelligence Payload program. Additionally, the Air Force has not yet achieved a unified enterprise for SIGINT processing, exploitation, and dissemination, despite having a distributed technical architecture within both the RC–135 Rivet Joint and Air Force distributed common ground system programs. Therefore, the committee directs the Secretary of the Air Force to provide a briefing to the congressional defense committees, no later than March 1, 2020, on how the Air Force is implementing its Next Generation Intelligence, Surveillance, and Reconnaissance Dominance Flight Plan in order to make Air Force airborne SIGINT data from the RC–135, U–2, RQ–4, MQ–9, and future SIGINT capabilities discoverable and available to the joint warfighter. The briefing shall address, among other things, cloud-based technologies and distributed crew concepts."

The SASC also encouraged Army Special Operations Command to pursue a new man-pack communications intelligence (COMINT) system. The report stated, "The committee is aware of expressed support by United States Army Special Operations Command (USASOC) for continued development of the Backpackable Communications Intelligence System (BPCS), an ultra-capable, low size, weight, and power, high-frequency direction finding system currently managed by the U.S. Army. The committee understands that BPCS performance was demonstrated at the Special Operations Forces Acquisition, Technology and Logistics (SOF AT&L) Technical Experiment 18–3 and encourages USASOC to continue working in close coordination with SOF AT&L and the Army to advance BPCS development and testing."

Directed Energy

The SASC also weighed in on several directed energy (DE) programs and test capabilities. It added $5 million for additional high-power microwave research noting "The committee supports increased research in high power microwaves as an element of an emerging set of directed energy technologies that support the National Defense Strategy and the priorities of the Under Secretary of Defense for Research and Engineering."

The SASC demonstrated a keen interest in high energy lasers for shipboard applications. Its report stated, "The committee is also encouraged by the Navy's plans to integrate the 60 kW High Energy Laser and Integrated Optical-dazzler with Surveillance (HELIOS) program into *Arleigh Burke*-class destroyers beginning in 2021. If the HELIOS effort succeeds, the committee believes there may be additional opportunities to integrate High Energy Laser (HEL) systems on large capital ships, including aircraft carriers and large amphibious ships, to increase the defensive capabilities and lethality of our carrier strike groups and expeditionary forces. If the Navy has continued positive results at increased radiated power, there may also be broader applications of laser weapons for providing capability for fleet air defense from more Navy vessels. Therefore, the committee directs the Secretary of the Navy to provide a briefing to the Senate Armed Services Committee, not later than October 1, 2019, describing the path forward for shipboard integration of HEL systems and the risk reduction plan to achieve improved technology and manufacturing readiness levels for such higher power systems. The committee also directs the Secretary to provide briefings on the progress of laser systems development and testing every 6 months through fiscal year 2021."

Another DE program the SASC wants to see expanded is the Low Power Laser Demonstrator (LPLD), which is currently being developed by the Missile Defense Agency for ballistic missile defense applications. The Committee Report stated, "The committee continues to support the Missile Defense Agency's Low Power Laser Demonstrator program and the development of a boost phase intercept (BPI) capability. Further, beyond BPI, a high-altitude laser weapon system, like those under development in the LPLD program, could have multiple applications and capabilities and could be adapted to be an effective countermeasure against other threats, including cruise, surface-to-air, air-to-air, and hypersonic missiles. The committee believes that existing lasers under development could be scaled up further to the higher power and beam quality levels needed to prosecute targets yet continue to have the low size and weight requirements that are critical to fielded systems. The Congress has recognized the need for this technology and provided increased funding in fiscal year 2019 with the intent of continuing the development of three technologies with the potential for scaling such lasers to the high power levels required for BPI and defense against other advanced threats."

As this issue of JED went to press, the SASC version of the NDAA bill was awaiting a vote in the full Senate. On the other side of Capitol Hill, the House Armed Services Committee had just completed its mark up of the bill and was voting on amendments. – *JED Staff*

IN BRIEF

The US Army's **Intelligence and Electronic Warfare Directorate (I2WD)** (Aberdeen Proving Ground, MD) has issued a Request for Information (RFI) seeking industry input "informing the technical approach to emerging signals intelligence (SIGINT), electronic warfare (EW), and cyber operations (CO) requirements at Echelons Above Brigade (EAB) to be addressed by a potential Extended Range (ER) materiel solution." The requested information includes concepts and recommendations "…for an optimized approach to integrating SIGINT, EW, and CO systems/capabilities that can operate in existing formations for Division, Corps, and Army Service Component Command areas of operation and depth in support of operations. The approach must support the commander's ability to task and control immediate intelligence, EW, and CO requirements, utilizing redundant communications as part of an integrated primary, alternate, contingency and emergency (PACE) plan to maintain connectivity to the larger mission command, intelligence, and cyber community in a disconnected, intermittent, limited bandwidth (DIL) environment." The RFI asks for responses covering a variety of sensing and effects at close range, (40-200 km), deep maneuver area (200-500 km) and deep fires area (500-1000 km). The contracting point of contact is Timothy B. Ward, (443) 861-4640, e-mail timothy.b.ward.civ@mail.mil.

world report

ARTIFICIAL INTELLIGENCE DISCUSSED AT EW EUROPE CONFERENCE

Artifical Intelligence (AI)-enabled EW systems were among the topics discussed at EW Europe conference in Stockholm in May. During the Plath Intelligence Workshop, which was held just before EW Europe commenced, several briefings broadly addressed the theme of the conference's second session, "Artificial (Signal) Intelligence – Can a Machine Think?" Presentations looked at AI from several perspectives, including voice biometrics, AI optimized workflows for acoustic intelligence operations, automatic relationship extraction from text, and how text data can be analyzed by "Psychological AI" to determine personality traits.

During the main EW Europe conference, which began the following day, Kyle Davidson of MDA in Canada provided an excellent overview in his presentation "Deep Learning and Electronic Intelligence." He described a classical ELINT approach and compared this to a Machine Learning (ML) approach. In this latter approach, the more data that is provided to train the neural network, the better the decision making will be. After showing a few examples, he wrapped up by stating that machine learning can offer significant gains in ELINT classification.

Another interesting AI-related presentation was delivered by Saab's Head of Research and Technology, Dr. Henrick Holter. In his discussion, he said the radar signal environment is becoming radically different from the way radars operated in the past. Today's radars are more agile and much more difficult to defeat with conventional jamming, which is why AI must be integrated into future EW system designs.

Dr. Holter began with an overview of the relationship between AI, Machine Learning (ML) and Deep Learning. DL is a subset of ML – really more of a technique – that applies algorithms to analyze data in order to detect patterns. DL is an extremely data hungry technology, Falk said, because DL-based algorithms typically get better as the system analyzes more data. Because of this reality, he explained, one of his biggest challenges is acquiring a large amount of valid and well organized EW and radar data.

Dan Pleasant of Keysight Technologies discussed another aspect of AI in his presentation on "Test and Evaluation of Cognitive EA Systems – Requirements for Future Test Systems." He explained the challenges of testing cognitive algorithms in real hardware, even though the cognitive algorithms are unpredictable by nature. He raised an important point, which is that the EW community needs to apply the same degree of innovation to testing cognitive EW systems as it does to developing them. – *J. Knowles*

UK STUDIES CONCEPTS FOR NAVAL RECOVERABLE OFFBOARD DECOY

The UK's Defence Science and Technology Laboratory (Dstl) has begun research to investigate a future recoverable offboard decoy system for anti-ship missile defense.

Both unmanned air vehicle (UAV) and unmanned surface vehicle (USV) carrier vehicles are being examined. The recoverable offboard decoy concept is seen as a potential replacement for the Royal Navy's now-retired Mk 251 Active Decoy Round.

The multi-rotor rotary-wing UAV carrier concept seen by *JED* would be designed to take a nominal 20-kg payload aloft for an endurance of 20-30 minutes. The system would be highly reactive, autonomous in operation and employ an auto land system for recovery.

Dstl's alternative concept is for a fully autonomous USV that would "ride shotgun" to the defended asset. Seen as easier to de-risk, this solution would offer several hours endurance. – *R. Scott*

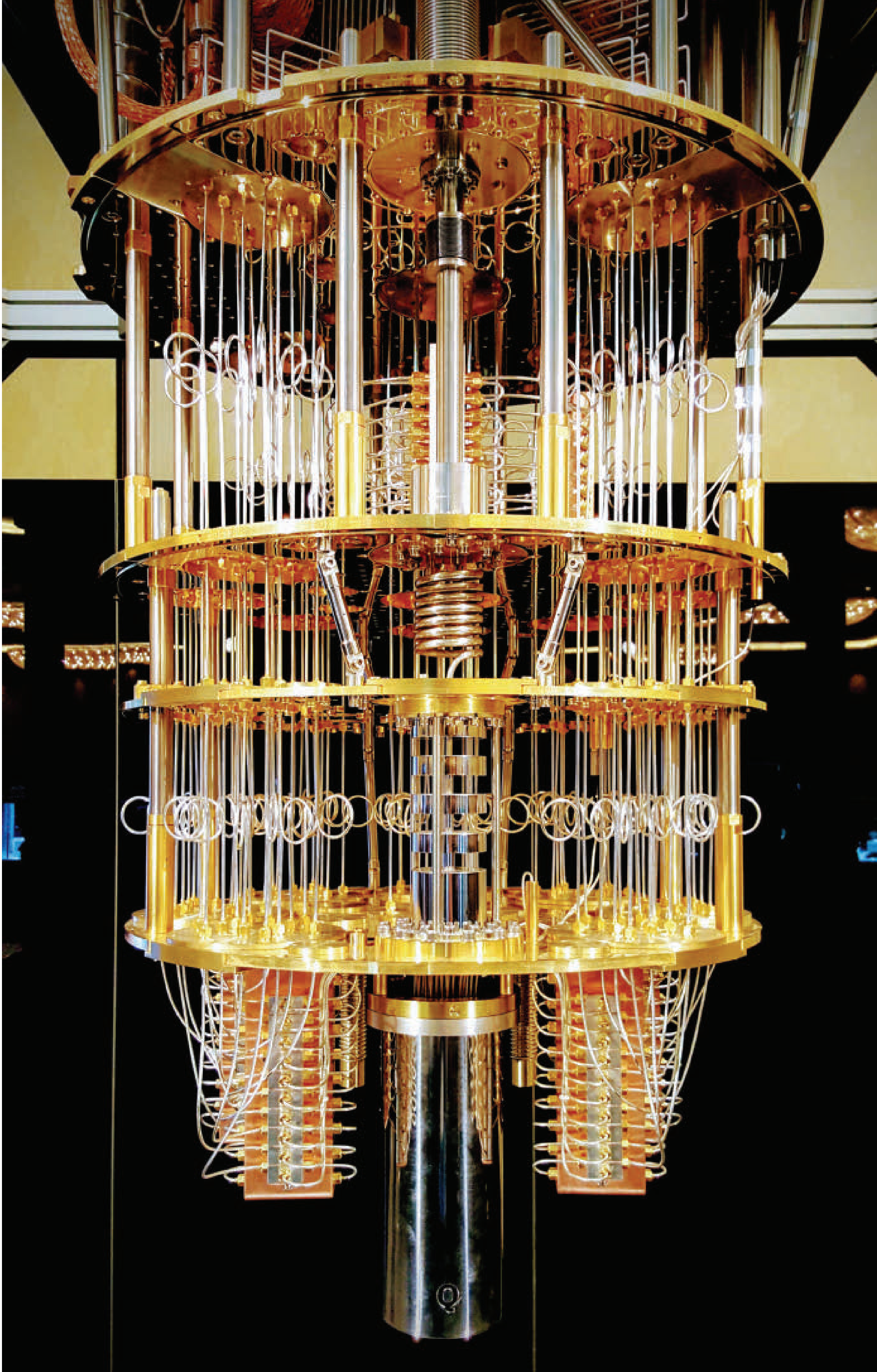
TERMA COMPLETES F-16 MISSILE WARNING, 3D AUDIO UPDATES FOR BELGIUM, NETHERLANDS

Danish systems and sensors house Terma has completed deliveries of missile warning system (MWS) and 3D-Audio upgrades for F-16 fighters operated by the Belgian Air Component and the Royal Netherlands Air Force, with systems now operational in both air arms.

The introduction of the pylon-mounted MWS – fitted with Hensoldt's AAR-60(V)2 MILDS F system – is enabled by the Terma PIDS+ pylon. The AAR-60(V)2 MILDS F installation comprises a total of six sensors and one processor (three sensors are installed in both the left-hand and right-hand PIDS+ pylons to provide almost full spherical coverage). The system processor is installed in the right-hand pylon.

The AAR-60(V)2 provides threat information to the Terma ALQ-213 Electronic Warfare Management System in the cockpit. The ALQ-213 selects and executes the most efficient dispense sequence in the PIDS+ pylon and/or in the fuselage. All of the original European Participating Air Forces nations – Denmark, Norway, the Netherlands, and Belgium – have now ordered Terma PIDS+ pylons and AAR-60(V)2 MWS for their F-16 fleets.

To further improve the pilot's situational awareness and reduce workload, the Belgian and Dutch F-16s have also received Terma's Aircraft Audio Management System (AAMS). Incorporating a 3D-Audio system, the AAMS system provides the pilot with a dynamically updated warning tone/cue in the true direction of the threat. In addition, the system also provides radio channel separation and noise reduction. – *R. Scott*



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Quantum Radar Sees the Light

By John Haystead

The first things anyone interested in the subject of quantum radar should know is that it is an extremely complex topic that many only discuss in the language of equations, it often involves physical science not yet established or understood, and in some ways it can actually be considered ethereal. But, positioned at the very leading edge of our scientific knowledge, with some of the world's greatest minds studying the subject, it is also one of the most significant technologies being pursued for military application, with the potential to supersede stealth in terms of its impact on the battlespace.

A truly in-depth discussion of the topic is well beyond the scope of this article and certainly beyond the cranial capacity of the author. Instead, what follows is an attempt to describe and explain the basic principles of the technology, its possible applications and benefits, some of the challenges that must be overcome to make it a reality, and the technological capabilities most likely to be actually realized and implemented in the foreseeable future.

ENTANGLEMENT

Any discussion of quantum radar technology begins with what are described as "entangled pairs" of photons, which are two photons, each of which can be in one of two quantum states of measurable physical properties (position, momentum, spin, polarization), but the state of each particle is dependent on (correlated with) the state of the other, even when they are separated from each other. Entangled photon pairs are commonly generated through a process called parametric downconversion, where a laser beam is passed through non-linear crystals (commonly beta barium borate). This approach is used to generate entangled photon pairs in the visible light range. For quantum radar application, these photons must be down-converted to microwave frequency. In the paper "Quantum-Enhanced Noise Radar," Chris Wilson, of Canada's Institute for Quantum Computing (IQC), at the University of Waterloo (Waterloo, Ontario), describes work done to directly produce entangled photon pairs in the microwave range using a superconducting circuit. Nondegenerate Josephson parametric amplifiers built as on-chip microwave circuits of superconducting aluminum are used as the quantum microwave source. One challenge in this process is that it must be done in an extremely cold cryostat (milli-Kelvin temperatures).

"In principle, with an entangled beam, what you can get back is the entire momentum vector of the target, not just its Doppler speed, but its entire momentum vector, all three dimensions and all three magnitudes of those dimensions of the target's motion."

THEORY VS REALITY

Beyond this point, the discussion of quantum radar gets quite a bit more variable, at least in the general media, where distinctly different interpretations or descriptions of the mechanism of quantum radar operation are often described. In one approach, the process begins when pairs of entangled photons are split apart with one of each pair sent directly along a path for storage (idler photons), while the partner photons are converted to microwave frequency (microwave photons) and transmitted toward a target as a conventional waveform. The premise is that, upon interacting with the target, the quantum state of the microwave photons will be altered in some way or ways (phase or polarity for example). A reflected return signal from the target is then received back at the source and the photons back-converted to their original frequency state, which can then be compared with that of their unchanged idler entangled pair to provide information about what they have encountered. Seems straightforward enough, in principle anyway.

However, there is another description of quantum radar theory that speaks of a "spooky-action-at-a-distance" link (a term coined by Albert Einstein) where one photon of a split, entangled pair is transmitted as a "photon beam," while its partner is saved. In this case, however, the transmitted photon somehow remains continuously and instantaneously in communication with its entangled pair, regardless of the distance between them. The transmitted photon does not return to its source for comparison with its saved partner, but the untransmitted photon will nevertheless also itself change in response to the environment seen by its entangled pair, thus providing information about possible targets that it encountered, without any known connection. Hence the "spooky" description.

However, as described by Dr. Ned Allen, Chief Science Officer, Lockheed Martin Corporation (Bethesda, MD), as part of a 2005 program out of DARPA's Strategic Technology Office (STO) looking at quantum radar concepts and ideas, Lockheed Martin examined this notion of "spooky-action-at-a-distance," which they referred to as "no-return radar." According to Allen, they determined that, "This is a flat-out violation of Einstein's theory of special relativity, and special relativity is far more confirmed and validated than quantum physics. After studying it for a while and pulling together a group of subject-matter experts from various universities and other top-level scientific entities, we did not look further at this, as we believed that it was not allowed under the laws of physics."

As a result of their quantum-enabled-radar project work, the Lockheed team defined two broad classes of quantum radar (referred to as QuDAR).

Today, however, Allen also recognizes that "physics is currently in a period of upheaval and a lot of those concerns are being revisited. Still, he notes that while "it's not clear that we understand enough physics today to actually rule this out completely, we're pretty confident that given the manifestations of physics that were accessible to us at the time, and still today, it would not be allowable."

QUANTUM RADAR CLASSES

As a result of their quantum-enabled-radar project work, the Lockheed team defined two broad classes of quantum radar (referred to as QuDAR) – Class 1 being where all the quantum effects were kept on board the transmitter/receiver for the radar, and Class 2, where a "quantum resource" (photon) is transmitted from Point A to Point B through a lossy medium (i.e., the atmosphere).

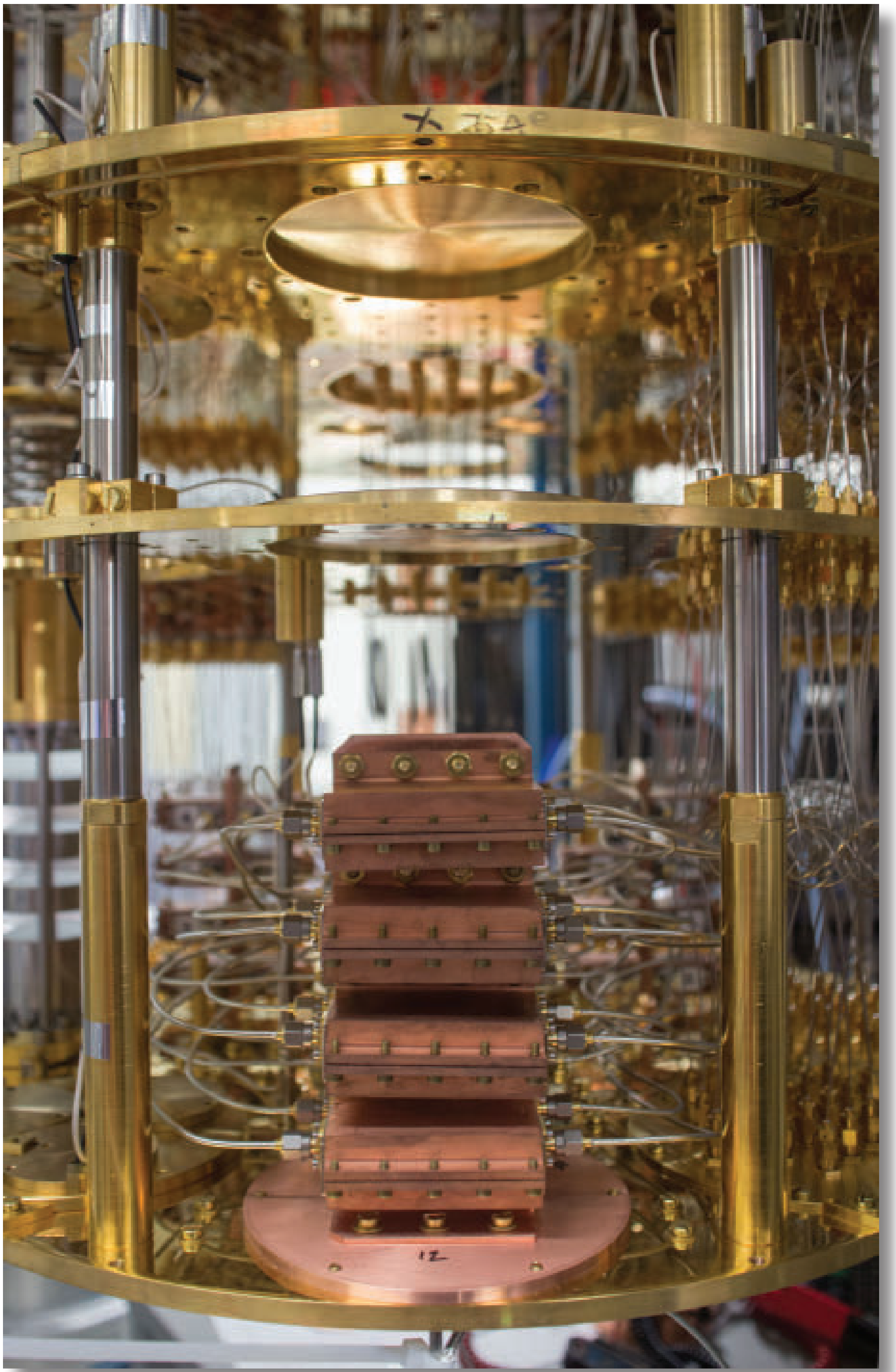
Allen says that Class 1 quantum radar is being developed today, "but it's not called quantum radar, but rather 'improvement in the sensitivity' of the electronics on board the transmit/receive module – for example a much better low noise amplifier." Jonathan Baugh, Associate Professor at the University of Waterloo IQC agrees, noting that "this is one of the near-term benefits from the development of 'quantum radar' systems with more sensitive detectors and quantum-inspired signal processing methods potentially being adapted to improve classical radar capabilities." Class 1 quantum radar technology can potentially have an impact on stealth target detection, since as pointed out by Allen, "from a mathematical standpoint, stealth is just a reduction in the radar cross section (RCS) of the target, and since it is signal-to-noise ratio (SNR) which determines whether a target is detectable, if you can increase the SNR by reducing the internal noise in the radar with a good quantum-enabled receiver/transmitter, you can detect smaller and smaller targets. Thus, a Class 1 quantum radar can potentially help defeat some approaches to stealth."

Class 2 quantum radars can be further distinguished in terms of the degree to which the entangled pairs (idler and transmitted photons) are expected to retain their coherence over time and distance. In one case, detected backscattered photons returning from a target will fully retain their coherence. This will allow the measurement of many more aspects of the target beyond just its existence and Doppler effect. As described by Allen, "The quantum interaction is essentially measuring the existence of the target along an infinite number of dimensions, not just amplitude and phase but an infinite number of attributes of the quantum device (photon) coming back. In principle, with an entangled beam, what you can get back is the entire momentum vector of the target, not just its Doppler speed, but its entire momentum vector, all three dimensions and all three magnitudes of those dimensions of the target's motion."

This is the much-hyped ultimate promise of quantum radar, because as observed by Allen, "If a fully-entangled quantum radar beam can indeed be successfully transmitted and received over a practical distance, it will essentially mean the defeat of stealth." But, not so fast, because as Allen continues, "In order to have a pure quantum radar capable of doing that, you need to solve the de-coherence problem, and the de-coherence problem is not easily solved." Decoherence is the loss of "quantumness," or coherent entanglement of the photon pairs, as the transmitted photon passes through a lossy medium, such as the atmosphere. Says Allen, "De-coherence is fundamentally related in profound ways that we don't really understand yet to the second law of thermodynamics, which if someone could find a way to overcome, would be very rich."

Meanwhile, the People's Republic of China (PRC) has made claims to having apparently largely overcome the decoherence problem. In 2016, the China Electronics Technology Group Corporation (CETC), the country's largest defense electronics company, reported it had tested a quantum radar with the capability to detect stealth aircraft at a range of 62 miles. It claimed that the experiment was conducted "in a real atmospheric environment," and "the detection ability of the system was proven to be over 100 kilometers (62 miles)." And, in November 2018, the PRC unveiled a prototype quantum radar that it claims can detect stealth aircraft in flight.

Allen isn't buying it. "Given that today, the argument continues (Einstein vs. Bohr) over whether quantum physics



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8th Annual AOC Pacific Conference

10-12 SEPTEMBER 2019

ASSOCIATION OF OLD CROWS

Honolulu, HI

Countering Coercion: The Role of Information Operations

The theme for the UNCLASSIFIED portion of the 2019 Pacific Information Operations Symposium, "Countering Coercion: The Role of Information Operations," examines the Indo-Pacific Information Environment (IE) to understand how coercion and malign influence diminish the effectiveness of deterrence. Following last year's symposium focus on how Information Operations could support effective deterrence, this year's theme will examine how comprehensive coercion undermines effective deterrence of adversaries and assurance of allies and partners. The symposium will examine how to counter the erosive effects of coercion and malign influence from weakening or negating friendly force inform and influence efforts, preserving confidence in the cohesion of our Alliances and national capabilities to defend sovereignty from multiple attack vectors.

CALL FOR PRESENTATIONS AND PAPERS

USINDOPACOM J39 and the Association of Old Crows (AOC) are soliciting original unclassified English language presentations and/or papers for the 8th Pacific IO Symposium / USINDOPACOM IO Symposium from subject matter experts in the United States, and Allied and partner militaries (or ministries of defense/security), as well as from academia and industry on the symposium theme. Presentations for the full symposium (September 10th and 11th) must be UNCLASSIFIED, or FOUO releasable to the invited Allied and partner militaries of Australia, Canada, Chile, France, French Polynesia, India, Japan, Korea, Malaysia, New Zealand, Philippines, Singapore, Taiwan, and the United Kingdom. Presentations for classified sessions at Camp Smith (October 11th) should be at the SECRET REL/FVEY level, or at higher classification for smaller U.S.-only break-out sessions. Presentations for the CLASSIFIED session are not bound by the theme for the UNCLASSIFIED portion and may cover IRC applications in both competition and war.

Potential Speakers are invited to note the symposium sessions topics and specific areas of interest:

- Historical and current perspectives of how military IO contribute to counter-coercion.
- Case studies of PRC coercion and malign influence connected with hybrid warfare.
- Ally and partner perspectives on PRC and Russian coercion and malign influence actions.
- Opportunities for, and analysis of technical IRCs to compel a reduction in coercive actions, negate effects of adversary attempts at coercion, or increase adversary costs (financial or reputational) of continuing such attacks.

Please contact the Symposium Chair, Arthur Tulak, COL USA, Ret., via e-mail at Arthur.N.Tulak.ctr@pacom.mil if you are interested in speaking or want more information. Proposed presentations should be provided in the form of a brief synopsis, with the proposed title, and biographical information on the speaker.

Papers that are already completed (or nearly completed drafts) may likewise be submitted. Industry presentations that support the symposium theme may be submitted for either the UNCLASSIFIED or SECRET REL FVEY day. Company or product-focused briefs will not be accepted. The deadline for submitting is close of business **Wednesday, July 31, 2019**, but earlier is better.

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is a complete and adequate theory, the Chinese claims regarding their accomplishments in quantum radar appear to be not so well grounded as they might otherwise be if the physics had been settled."

In fact, Allen says it's not quite clear what the Chinese have actually accomplished, if anything. "My understanding (from open sources) is that the Chinese are just increasing the brightness of the radar so that they get some return that is to some extent useful, but they're just overwhelming the problem with brute force." Lockheed Martin is also conducting its own research work aimed at overcoming the de-coherence problem, but Allen says "We're doing the opposite of what the Chinese are doing. We're looking for an elegant solution that doesn't require brute force."

PHOTON FLUX

In addition to de-coherence, another challenge for quantum radars is that of photon flux – the number of entangled photons created and delivered per unit of time. As explained by IQC's Baugh, "Say you're sending out a photon once every nanosecond (a 1-GHz rate), but if only 1 in 1,000 or 1 in 10,000 is actually getting reflected back to you, then you're only detecting a photon once every millisecond or so. In order to build


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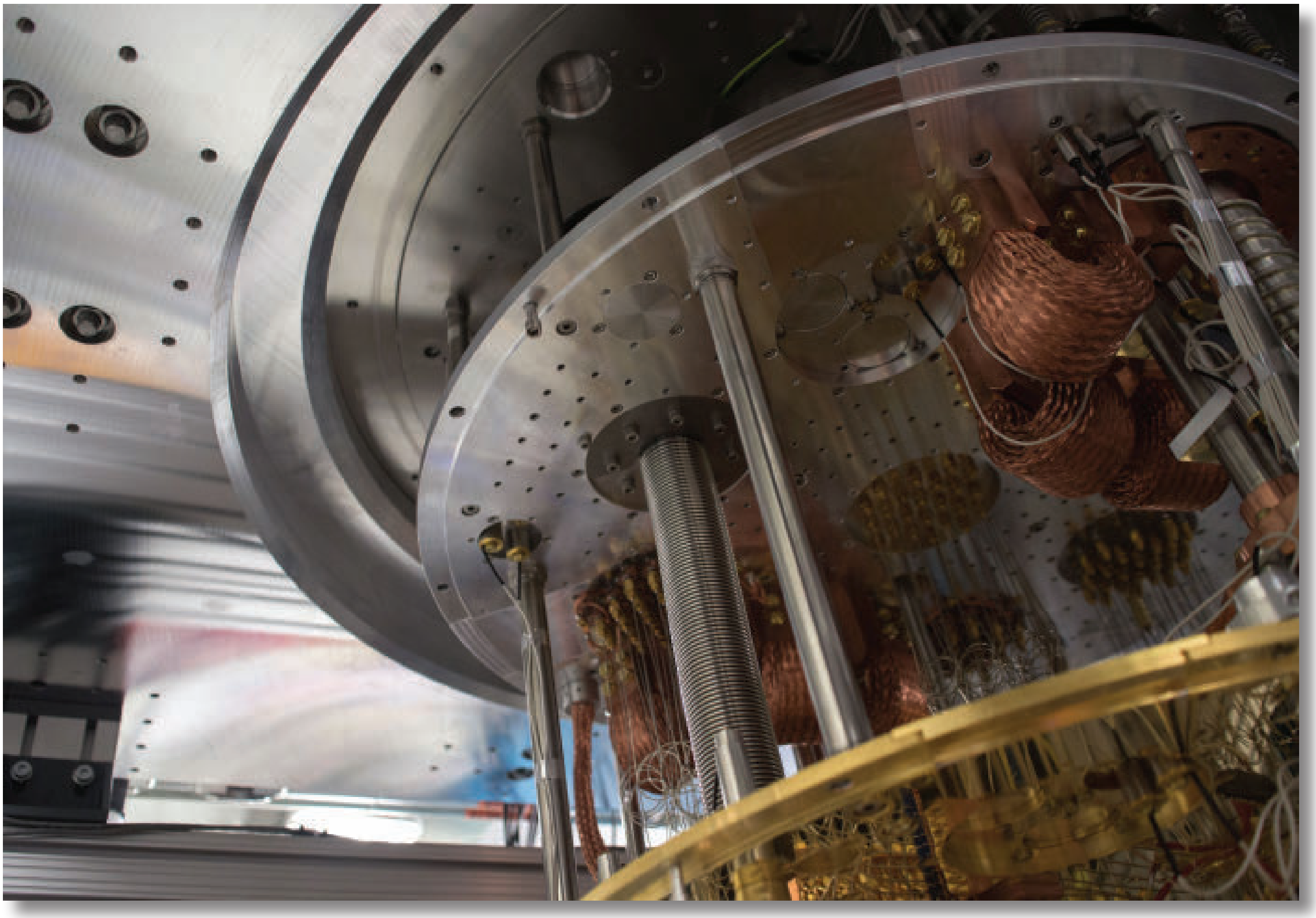


up a useful image, you really need to send out the photons very, very quickly so that you get enough information back in a reasonable amount of time."

Baugh is spearheading a research project with the Defense Research and Development Canada (DRDC) agency to develop an improved quantum light source, one of the applications of which would be quantum radar. The project is aimed at providing a "very-high-rate" signal of entangled photons and, although details of the approach aren't yet available, as the IQC has not yet published on the technology, Baugh describes it as "something like a semiconductor, nano-electronic device that operates at the single-electron level and allows you to convert an electrical signal into a photon or a pair of entangled photons." Since the source operates in the optical rather than microwave regime (approximately 850 nm – near IR, just at the edge of visible), the direct application of the capability will be lidar, but Baugh says "the idea is that eventually other groups around the world that are working on coherent quantum wavelength conversion from visible to microwave frequencies will be a pathway for our technology."

Although their source does also have to cooled, it's nothing near the degree of cooling required for microwave photon generation, and Baugh says they hope to demonstrate it working at 4 degrees Kelvin, the temperature of liquid helium, "which is a lot easier to deal with."

Thus far, Baugh's team have demonstrated the separate components involved, and they are now working to integrate them into a functional device. Baugh says that by the end of the summer, he expects they will be able to start characterizing "how good our single and entangled photon sources are."

QUANTUM ILLUMINATION RADAR

Today, in looking at the state of advancement and possible practical realization of quantum radar technology, the most promising approach, and that generally seen as the most realizable in the foreseeable future, is known as quantum illumination radar (QIR). With QIR, the returning transmitted photon of an entangled pair is not required to maintain its coherence with its idler partner in order to provide significant information about a target it has encountered.

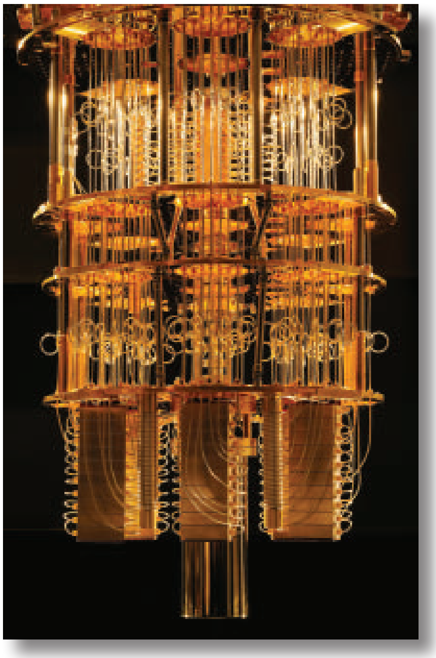
As explained by Bhashyam Balaji of the DRDC Radar Sensing and Exploitation group in his paper "Quantum Radar: Snake Oil or Good Idea?," "A fraction of the signal photons are received and can be correlated with the idler photon, and the surprising result is that the (original) entanglement provides significant benefits in sensitivity in low-SNR conditions. The result is rather remarkable, even in theory, as increased sensitivity in low-SNR regimes is a highly desirable goal, and entanglement and other quantum effects are usually fragile and not very robust against noise. This advantage accrues despite there being no (remaining) entanglement between the backscattered microwave photons collected from the target region and the retained idler beam."

As IQC's Jonathan Baugh describes, "the extent of decoherence that a photon beam will experience really depends on the kind of correlation that you're using. For example, polarization entanglement is very susceptible to decoherence." But, he points out that "You don't necessarily need to use that type of entanglement. Just using time correlation – the fact that you produce the two photons at essentially the same time allows you to throw out all the other photons from other time bins. It's not really entanglement anymore, but it's much more robust." Baugh notes, however, that the photon loss challenge will still have to be dealt with, "so effective range would be determined by how many photons are being absorbed or scattered in the atmosphere. Certainly, space-based applications would be better."

Overall, Baugh says QIR can provide a number of advantages over conventional radar. "Normally, with conventional radar, lidar, or any kind of remote sensing, you're sending a pulse of energy, which contains billions or trillions of photons. This is the classical approach of bouncing electromagnetic radiation off of an object, which when it comes back to your detector, allows you to measure the time of flight and calculate the distance to the object and, over time, to also calculate its velocity and direction. In contrast, QIR radar operates at the single-photon level, so you start with pairs of entangled photons that, because of the principles of quantum mechanics, have intrinsically stronger correlations than they would otherwise have. If the transmitted photon is reflected back, you can make a joint measurement of the two photons, which tells you whether those two photons were in fact initially correlated, allowing you to separate out any photons that were not correlated but may be just background noise. Since you're scaled down to very low power (single-photon) levels, quantum radar provides dramatic improvement in terms of SNR."

In addition, Baugh notes that another advantage of QIR is that, because of the "tiny" power levels that single-photon beams operate at, a QIR can provide detection while itself remaining undetected. "The target won't know it's being illuminated because the number of photons per unit time being used to detect it is so small that it would be almost impossible to measure. With QIR, you're talking 9-10 orders of magnitude lower power than conventional radars or lidar."

"De-coherence is fundamentally related in profound ways that we don't really understand yet to the second law of thermodynamics, which if someone could find a way to overcome, would be very rich."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Still, as emphasized by Baugh, "QIR radar will not replace conventional radar. Rather, the idea is to augment the capability in a particular regime where conventional radar is challenged, such as low SNR environments where you have a very strong background signal in the same frequency range that you want to use for detection, or you're trying to detect a stealth target, or if you want to make the detection itself stealthy."

In his 2018 paper, Bhashyam Balaji summed up the prospects for QIR as follows. "Quantum illumination radars can definitely be built…however, building a QIR will require a concerted and proper effort (i.e., radar engineering metrics) and suitable investment… There is much that is unknown in terms of optimal quantum radar design or optimal quantum signal processing, however, 'optimal should not be the enemy of the better.' These efforts will require radar engineers to master microwave quantum optics, but the payoff will be immense in niche, but extremely important, applications."

SPEAKER SPOTLIGHT

The Honorable Don Bacon
U.S. House of Representatives
NE-02 (Invited)

The Honorable Alan Shaffer
Deputy Under Secretary of Defense
for Acquisition and Sustainment

Lt Gen Robert Elder, USAF (Ret'd)
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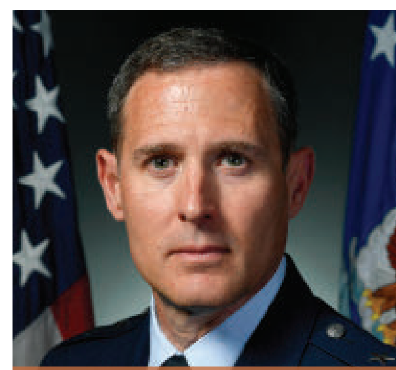

Major General David Krumm
Director of Strategic Plans, Office
of the Deputy Chief of Staff for
Strategic Plans and Requirements

SYMPOSIUM AGENDA

Building the EMS Enterprise

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View full descriptions of each agenda session at 56.crows.org

REGISTRATION INFORMATION

All Access Pass

The 'All Access Pass' includes access to General Sessions; access to all Symposium Sessions Monday–Wednesday; access to the Welcome Reception; access to the Exhibit Hall Monday–Wednesday, – including access to Innovation Stage programming, lunches and happy hours; First-Time Attendee Orientation; and access to all recorded Keynote Sessions and all briefings as released by the speakers. *Registration does not include access to AOC Annual Banquet or Professional Development Courses.*

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Industry (Non-Member)	$895	$995	$1095
Academia*	$445	$545	$645
Young Crows (35 and younger)*	$445	$545	$645
Government Civilian*	FREE	FREE	FREE
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THE INNOVATION STAGE RETURNS!

Due to your overwhelmingly positive responses, the AOC is proud to announce the Innovation Stage will be presented again on this year's Exhibit Hall floor! The Innovation Stage offers a series of short, dynamic and fresh perspectives that build upon the conversation surrounding this year's Symposium theme, "Building the EMS Enterprise." The ideas, aspirations, and knowledge shared on the Innovation Stage are intended to generate and exploit new ideas to solve problems and challenge participants to think differently about advancing our shared mission and common interests in EMS operations. Join us in the exhibit hall for these engaging and energizing conversations, specially crafted by global & industry leaders.

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TECHNOLOGY SURVEY

A SAMPLING OF COMINT AND COMMUNICATIONS ESM RECEIVERS

By John Knowles

US ARMY

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

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

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

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

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

COMINT AND COMMS ESM RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	DYNAMIC RANGE	MOD TYPES	SUPPORT DF
ASELSAN; Ankara, Turkey; +90-312-592-10-00; www.aselsan.com.tr							
V/UHF DF Receiver	Superhet/Digital	20 MHz - 6 GHz	40/5/1 MHz	-110 dBm (6.25 kHz FFT Res.) -120 dBm (250 Hz FFT Res.)	125 dB	AM, FM, CW, LSB, USB, I/Q	Phase coherent operation for DF
HF DF Receiver	Superhet/Digital	2-30 MHz	2 MHz, 25 kHz, direct sampling	-115 dBm (1 kHz FFT Res.)	125 dB	AM, FM, CW, LSB, USB, I/Q	Phase coherent operation for DF
MEERKAT - V/UHF Pocket Receiver	Superhet/Digital	20 MHz - 6 GHz	80 MHz	-105 dBm (12.5 kHz FFT Res.)	125 dB	AM, FM, CW, LSB, USB	*
BAE Systems; Richardson, TX, USA; +1 972-699-8580; www.baesystems.com							
RXR6322/ RXR6422	Superhet/Digital	0.1 MHz - 6 GHz	10, 40 or 80 MHz	-114 dBm (25 kHz)	144 dB (AGC) >80 dBc Single Tone SFDR across entire tune range with tone at -1 dBFS.	Pre-D, AM, FM, CW, SSB	Amplitude and phase interferometry (N-channel and Commutated Baseline) DF. TDOA and FDOA geolocation.
SYS6408	Superhet/Digital	0.1 MHz - 6 GHz	10 or 80 MHz	-114 dBm (25 kHz)	144 dB (AGC) >80 dBc Single Tone SFDR across entire tune range with tone at -1 dBFS.	Pre-D, AM, FM, CW, SSB	Amplitude and phase interferometry (N-channel and Commutated Baseline) DF. TDOA and FDOA geolocation.
Boger Electronics; Baden-Württemberg, Germany; +49 7525 923820; www.boger-electronics.com							
AFAS-3500	Digital monitoring receiver with analog scanning rf-frontend; BO-35 wideband receivers	10 kHz - 3.5 GHz	10 MHz, 2 MHz for I/Q streaming	-120 dBm with 10 dB S/N	115 dB	AM, FM, USB, LSB, I/Q; automatic classification of PSK (2-16), OQPSK, FSK, OFDM	Supports third party DFs
AFAS-18000	Digital monitoring receiver with analog scanning rf-frontend; BO-35 wideband receivers	10 kHz - 18 GHz	10 MHz, 2 MHz for I/Q streaming	-120 dBm with 10 dB S/N	115 dB	AM, FM, USB, LSB, I/Q; automatic classification of PSK (2-16), OQPSK, FSK, OFDM	Supports third party DFs
Chemring Technology Solutions; Romsey, Hampshire, UK; +44 1794 833000; www.chemring.co.uk							
AGSv3	Digital	100 kHz - 3 GHz	40 MHz	*	*	AM, FM,SSB, IQ, others, programmable	Yes
MCDWR16I	Direct digitisation SDR	100 kHz - 30 MHz	4 independent freq. channels, each ≤ 1.25 MHz	NF: 12 dB	>113 dB instantaneous (3 kHz BW, 0dB SNR, no AGC)	AM, LSB, USB, FM, CW, IQ	Super-resolution, N channel coherent
Chordell Systems Ltd.; Oxford, UK; +44 1865 784384; www.chordell.com							
WOLVERINE	Digital	0.5-18 GHz	17.5 GHz	CRLB +0.2 dB	<90 dB	All, voluntary and involuntary	FDOA, TDOA, PDOA
ALAETHIA	Digital	0.5-18 GHz	2 GHz	CRLB +0.2 dB	<100 dB	All, voluntary and involuntary	FDOA, TDOA, PDOA
CommsAudit; Cheltenham, UK; +44 1242 253131; www.commsaudit.com							
CA7851	Dual conversion, superhet	20 MHz - 6 GHz	100 MHz digitized bandwidth (full stare)	12 dB typ.	Single-tone, inst. spurious-free dynamic range (in normal mode): 65 dB typ., 60 dB min. (20 MHz - 120 MHz); 80 dB typ., 70 dB min. (120 MHz - 6 GHz)	VITA49 IQ output	TOA, TDOA, FDOA
CA7851-5	Dual conversion, superhet	20 MHz - 6 GHz	100 MHz digitized bandwidth (full stare)	12 dB typ.	Single-tone, inst. spurious-free dynamic range (in normal mode): 65 dB typ., 60 dB min. (20 MHz - 120 MHz); 80 dB typ., 70 dB min. (120 MHz - 6 GHz)	VITA49 IQ output	5-channel super resolution DF

CHANNELS	POWER (W)	SIZE (HxWxL in/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
8	< 340 W	19 in. x 4U x 370 mm	Air, shp, grd-mob	25 kg	WB and NB DF/surveillance/monitoring operations; digital spectrum, NB I/Q, WB IF, audio stream outputs; 2 DDR channels
8	< 340 W	19 in. x 4U x 370 mm	Air, shp, grd-mob	25 kg	MIL-STD-810, MIL-STD-461, MIL-STD-704 compliance; Built-in-self test capacity; Platform-optimized direction accuracy (DF) performance
1	*	80 x 35 x 140 mm	Man-pack, air, shp, grd-mob	0.6 kg	WB surveillance/monitoring operations; Digital spectrum, NB I/Q, audio stream outputs; DDR channel for demodulation and I/Q data
2 RF channels and 32 Independent DDR channels.	72 W max 45 W min depending upon user FPGA use.	3U VPX - 1-in. pitch or 0.975 H x 3.95 -in. W x 8.25" L "brick" style form factor.	Air, grd-mob, grd-fix, shp, sub, LEO space	1.4 lbs	VITA 65 OpenVPX with VITA 67.2 Blind-mate RF connectors. VITA 49.2 Radio Transport over PCI-E and 10 GigE. Phase coherent across multiple modules. High-sensitivity, low phase noise.
8 RF and 256 DDR	400 W max	19-in. rackmount chassis 1U 1.75 H x 19 W x 24 L -in.	Air, grd-mob, grd-fix, shp, sub, LEO space	35 lbs	(4) Sub-octave preselected superheterodyne tuner and digital receivers in a 19" rackmount chassis. VITA 49.2 Radio Transport over 10 GigE fiber or copper.
Configurable (up to 4 RX-channels per processing unit)	Config. dep.	Config. dep.	Air, grd-fix, grd-mob, shp	Config. dep.	*
Configurable (up to 4 RX-channels per processing unit)	Config. dep.	Config. dep.	Air, grd-fix, grd-mob, shp	Config. dep.	*
2 (1 for monitor, both for DF)	< 17 W	81 x 173 x 251 mm	Grd-fix, grd-mob	2.5 kg	*
≤9, expandable to ≤18 (dual-unit configuration) and higher (multi-device configuration)	35 W	2U x 19-in. rack	Grd-fix	5.25 kg	Multi-site networking for simultaneous position fixing.
1 or 4	15 KW	52 x 22 x 40 in.	Grd, shp, air, sub	200 kg	Comms and ESM.
1 or 4	2 KW	24 x 7 x 7 in.	Air	18.1 kg	Comms and ESM.
1 > 1024 DDC channels	28 W typ.	41 x 145 x 241 mm; (1U - 1/2 rack)	Air, grd-fix, grd-mob, shp	2.2 kg	13 band sub octave preselector; 1PPS & 10 MHz reference inputs; <1.5 ms tuning speed.
1 > 1024 DDC channels	150 W typ.	4U - 241 mm (depth)	Air, grd-fix, grd-mob, shp	22.4 kg	Sub-octave preselector; 1PPS & 10 MHz reference inputs; extremely stable group & absolute delays.

COMINT AND COMMS ESM RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	DYNAMIC RANGE	MOD TYPES	SUPPORT DF
CommsAudit; Cheltenham, UK; +44 1242 253131; www.commsaudit.com *cont'd.*							
CA7801-8	*	1.5 MHz - 30 MHz	28.5 MHz digitzed bandwidth (full stare)	10 dB typ.	Second order SFDR -80 dBc typ (in low noise mode)	VITA49 IQ output	8-channel super resolution DF
CRFS Inc.; Chantilly, VA, USA; +1 571-321-5470; www.crfs.com							
RFeye® Node 50-8	Superhet	9 kHz - 8 GHz	Up to 50 MHz	Typ. noise figures: 5.5 - 9 dB from 9 kHz - 8GHz	155 dB with AGC & switched LNA	CW, AM, FM, SSB, DSB, LSB, USB, PM, Noise, ASK-n, BPSK, MSK, FSK, PSK-n, OPSK, QAM-n, V.29-n, IQ	AOA, POA, TDOA
RFeye® Node 100-8	Superhet	9 kHz - 8 GHz	Up to 100 MHz	Typ. noise figures: 5.5 - 9 dB from 9 kHz - 8GHz	155 dB with AGC & switched LNA	CW, AM, FM, SSB, DSB, LSB, USB, PM, Noise, ASK-n, BPSK, MSK, FSK, PSK-n, OPSK, QAM-n, V.29-n, IQ	AOA, POA, TDOA
RFeye® Node 100-18	Superhet	9 kHz - 18 GHz	Up to 100 MHz	Typ. noise figures: 8.5 - 13 dB from 9 kHz - 18 GHz	155 dB with AGC & switched LNA	CW, AM, FM, SSB, DSB, LSB, USB, PM, Noise, ASK-n, BPSK, MSK, FSK, PSK-n, OPSK, QAM-n, V.29-n, IQ	AOA, POA, TDOA
CyberRadio Solutions; Mt. Airy, MD, USA; +1 301-676-2652; www.cyberradiosolutions.com							
NDR358	Superhet/Digital Microwave	20MHz - 6 GHz	80 MHz	-100dBM	>120 dB with AG	VITA49 IQ output	Supports phase and amplitude DF as well as T/FDO geolocation techniques
NDR562	Superhet/Digital Microwave	20 MHz - 18 GHz	500 MHz	*	>120 dB with AG	VITA49 IQ output - Also includes AM, FM, CW, USB and LSB demodulators	*
NDR584	Superhet/ Microwave	0.1-18 GHz	500 MHz	*	>120 dB with AG	*	Supports phase and amplitude DF as well as T/FDO geolocation techniques
D-TA Systems; Ottawa, Ontario, Canada; +1 613-745-8713; www.d-ta.com							
DTA-3380	Scanning transceiver	1 MHz - 8 GHz	80 MHz	115 dBm (-)	80 dB	Large list of analog and digital modulation and transmission mode recognition	Yes
RFvision1-Supermini S/W	Portable Scanning transceiver	20 MHz - 6 GHz / 1 MHz - 8 GHz for Supermini W	40 MHz / 80 MHz for W	115 dBm (-)	80 dB	Large list of analog and digital modulation and transmission mode recognition	Yes
Digital Receiver Technology Inc., a Boeing Company; Germantown, MD, USA; +1 301-9160-5554; www.drti.com							
44xx Family	Digital	2 MHz - 3 GHz	40 MHz continuous inst. RF bandwidth per channel	*	*	DSP demodulation, application specific AM, FM, CW, USB, LSB	Compatable with DRT DF sub-systems
120xC/1183C	Digital	0.2 MHz - 6.5 GHz	*	*	*	DSP demodulation, application specific AM, FM, CW, USB, LSB	Compatable with DRT DF sub-systems
1301C+	Digital	2 MHz - 3 GHz	120 MHz continuous inst. RF bandwidth - 40 MHz per tuner	*	*	DSP demodulation, application specific AM, FM, CW, USB, LSB	Compatable with DRT DF sub-systems

CHANNELS	POWER (W)	SIZE (HxWxL in/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
1 > 1024 DDC channels	240 W typ.	4U - 241 mm (depth)	Air, grd-fix, grd-mob, shp	24.6 kg	GigE (SFP Module) control port; 10 GigE (SFP+ Module) data port; GPIO Port (FPGA controlled); Config. DSP resources (XilinX ZynQ SoC).
1 channel with 3 switchable full BW inputs	25 W typ.	74 x 200 x 192 mm	Air, grd-fix, grd-mob, shp, sub	2.4 kg	Receiver phase noise: ≤-130 dBc/Hz @ 20kHz offset at 1GHz input.
1 channel with 3 switchable full BW inputs	25 W typ.	74 x 200 x 192 mm	Air, grd-fix, grd-mob, shp, sub	2.4 kg	Receiver phase noise: ≤-130 dBc/Hz @ 20kHz offset at 1GHz input.
1 channel with 3 switchable full BW inputs	40 W typ.	74 x 200 x 192 mm	Air, grd-fix, grd-mob, shp, sub	2.4 kg	Receiver phase noise: ≤-126 dBc/Hz @ 20kHz offset at 1GHz input.
8	175 W	19 W x 1.75 H x 18 D in.	Air, grd-fix, grd-mob, shp, sub	22 lbs	On-board Kintex UltraScale series FPGA used for channelizer, VITA-49 formatter, data multiplexer and 10 Gigabit Ethernet Digital IF data interfaces. Two modes of operation: Receiver and Fast Scan mode.
1	100 W	19 W x 1.75 H x 18 D in.	Air, grd-fix, grd-mob, shp, sub	22 lbs	Tuner has 1 GHz analog IF output with selectable bandwidths of 500, 320 and 200 MHz. Integrated high dynamic range 14-bit ADC to digitize 500 MHz wide IF at a 1344 Msps sample rate.
4	40 W	Single Slot 3U VPX	Air, grd-fix, grd-mob, shp, sub	2.5 lbs	Each channel provides 1 GHz analog IF output with 500 MHz instantaneous bandwidth. Channels can tune independently and phase coherently, and multiple units can be combined for phase coherent operation.
Up to 16	20 W/Ch	1U/2U 19-in. rack	Air, grd, shp, sub	15 kg for 8 Ch	Phase coherent and independent tuning.
Up To 2	140 W	3/4 ATR	Air, grd, shp, sub	8.1 kg	Phase coherent and independent tuning.
12 half-duplex	10-13 W	1.3 x 3 x 6.8 in.	Air, grd-manpack, grd-mob, grd-fix, shp, sub	1.59 lbs w/o battery; 2.44 lb w/ battery (full DF manportable system is < 20 lb)	Dismounted, OTM, LLVI operations, and mob. PTT collection missions; 1 man transportable package: based on the DRT44xx family of handheld SDR.
12C - 816 half-duplex (32 channels per WPM3); 1183C 336 half-duplex (32 channels per WPM3)	12C - 1143 W; 1183C - 650W	12C - 4U 19-in. rack mount chassis; 1183C 7 in. H x 13 in. W x 11.5 in. D	Air, grd-manpack, grd-mob, grd-fix, shp, sub	12C - 70 lbs; 1183C 45 lbs	Mult. slots that can be config. to any combination of turners, processsors; comes w/ DF antenna options.
48	37-83 W	3 x 7.9 x 13.32 in.	Air, grd-mob, grd-fix, shp	12 lbs	Comes with DF antenna options; geolocation; mult. interfaces 10 MHz ref, battery, 10/100 baseT erhernet.

COMINT AND COMMS ESM RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	DYNAMIC RANGE	MOD TYPES	SUPPORT DF
Elbit Systems EW and SIGINT – Elisra; Holon, Israel; +1-972-3-5577278; www.elisra.com							
TSR 2040	Superhet	100 kHz - 3 GHz	Up to 340 kHz	AM: 10 dB at 6 kHz BW; FM: 17 dB at 1 5 kHz BW; CW: 10 dB at 500 Hz BW	130 dB	AM, FM, SSB and CW	Yes
TSR 2300	Superhet	20 MHz - 6 GHz	Analog: 50 MHz; Dig: 40 MHz, 20 MHz and 10 MHz	10 kHz: -105 dBm; 50 kHz: -98 dBm; 100 kHz: -95 dBm; 300 kHz: -90 dBm	120 dB	AM, FM, ISB, USB, SSB and CW	Amplitude, phase interferometer and time of arrival
TSR 3300	Direct sampling	1.5-30 MHz	According to sub-octave filters or 28.5 MHz full band	-105dBm for AM @ 6KHz IF, m = 50%, (S/N)/N = 10dB, -113 dBm for SSB @ 3KHz IF, (S/N)/N = 10dB	140 dB	AM, FM, USB, SSB and CW	Amplitude, phase interferometer
Elettronica Group; Rome, Italy; +39 06 41541; www.elettronicagroup.com							
ELT/332	Digital, superhet	HF/VHF/UHF	Up to 80 MHz	-110 dBm (SNR=10 dB; BW=12,5KHz)	110 dB	Analog and digital signals	Multichannel correlative-interferometer; high performance config has 5 RF channels for DF
ELT/1001	Digital, superhet	VHF/UHF	40 MHz	-110 dBm (BW=8KHz) @ receiver input	100 dB	Analog and digital signals	Multichannel correlative-interferometer
Elta Systems Ltd; Ashdod, Israel; +972-8-857-2312; www.elta.co.il							
ELK-7036 Wideband V/UHF COMINT/DF Family	*	20 MHz - 3 GHz	5 MHz	*	120 dB	AM, FM, CW, FSK, PSK	Yes
ELK-7038 Wideband HF COMINT/DF Family	*	0.5-30 MHz	2 MHz	*	90 dB	AM, FM, CW, FSK, USB, LSB	Yes
ELK-7073 Microwave COMINT System	*	0.5-18 GHz	*	*	*	AM, FM, PSK, FSK/FM, 8PSK	*
Enablia S.R.L.; Rome, Italy; www.enablia.com							
TitanSDR	Direct sampling software radio	0.009-32 MHz	312.5, 625, 937.5, 1250, 1562.5, 1875, 2187.5 kHz	-116 dBm (0.34 μV) SSB at S+N/N=10dB, 15MHz, 2.4 kHz BW	>108 dB (SFDR)	USB, LSB, AM, NBFM, CW, eUSB, eLSB, FSK, IQ	No
Epiq Solutions; Schaumburg, IL, USA; +1 847-598-0218; www.epiqsolutions.com							
Matchstiq S10	SDR	45 MHz - 6 GHz	Up to 56 MHz	<8dB typical noise figure	60 dB SFDR typical	GMSK, QPSK, OFDM, others	*
Matchstiq Z2	SDR	45 MHz - 6 GHz	Up to 56 MHz	<8dB typical noise figure	60 dB SFDR typical	GMSK, QPSK, OFDM, others	*
Sidekiq X4 VPX Blade	SDR	1 MHz - 6 GHz	Up to 400 MHz	<8dB typical noise figure	75 dB SFDR typical	GMSK, QPSK, OFDM, others	All channels phase coherent capable
The Espy Corporation; Austin, Texas, USA; +1 512-261-1016; www.espy.com							
teamSENTINELmicro	Superhet with SDR dig channelizer	20 MHz - 6 GHz	64, 128, 192, 256 MHz	-110 dBm	>90 dB	AM, FM, CW, SSB, IQ, and others	Correlative interferometer DF, TDOA and FDOA, JCID 4.2 Node-Compliant

CHANNELS	POWER (W)	SIZE (HxWxL in/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
2 channels for DF; up to 8 channels for COMINT	25 W max.	Standard long PCI card	Air, grd-fix, grd-mob, shp, sub	*	*
1 - 7	60 W	14 x 19 x 23.5 in.	Air, grd, shp, sub	*	*
1 - 7	60 W	14 x 19 x 23.5 in.	Air, grd, shp, sub	*	*
5 DF channels + additional independent COMINT channels (opt.)	500 W (depending on COMINT channels)	Receiver 6U (depending on COMINT channels); mounts in standard 19-in. rack	Grd, naval, air	50 kg (depending on COMINT Channels)	Communication ESM; COMINT; signal demodulation; signal analysis, recording, decoding. Scalable and modular COMINT capability.
3-5 DF channels + additional independent COMINT channels (opt.)	250 W	1/2 ATR	Air, UAV	15 kg	Compact, highly efficient, airborne qualified.
*	*	*	Air, grd-fix, grd-mob, shp	*	*
*	*	*	Air, grd-fix, grd-mob, shp	*	*
*	*	*	Grd-fix, grd-mob	*	*
Wideband channels: 4; narrowband channels: 40	15 W	5.2 cm x 24.3 cm x 14.5 cm	Grd-fix	3.2 kg	*
1 RX, 1 TX (2 RX opt)	8 W typical	4.41 x 1.65 x 1.13 in.	*	5.6 oz	Integrated FPGA, quad-core Linux computer; platform development kit available.
1 RX, 1 TX	2.5 W typical	3.44 x 2.40 x .49 in.	*	3.1 oz	Integrated FPGA, dual-core Linux processor, pre-select filtering; platform development kit available.
4 RX, 4 TX	11 W typical for tuner	6.17 x 3.53 x 1.06 in.	*	19 oz	Integrated FPGA, quad-core processor, pre-select filtering; platform development kit available.
1, 2, 4	From 500 W	12 x 23 x 31 in.	Air, grd-fix, grd-mob, shp, sub	From 60 lb	Integrated operator GUIs, built-in wideband recording (from 10-hours by 64 MHz), multiple SDR NB receivers, and support for multi-sensor operations and networks.

COMINT AND COMMS ESM RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	DYNAMIC RANGE	MOD TYPES	SUPPORT DF
The Espy Corporation; Austin, Texas, USA; +1 512-261-1016; www.espy.com *cont'd.*							
teamSENTINELnano	Superhet with SDR dig channelizer	20 MHz - 6 GHz	22.5 MHz	-105 dBm	>75 dB	AM, FM, CW, SSB, IQ, and others	TDOA and FDOA, JCID 4.2 Node-Compliant
teamSENTINEL V/UHF	Superhet with SDR dig channelizer	20 MHz - 6 GHz	88, 176, 352, 528, 1056 MHz	-105 dBm	>75 dB	AM, FM, CW, SSB, IQ, and others	Correlative interferometer DF, TDOA and FDOA, JCID 4.2 Node-compliant
FEI-Elcom Tech, Inc.; Northvale, NJ, USA; +1 201-767-8030; www.elcom-tech.com							
MT-6500	Quad Channel	2-18 GHz	1GHz (2GHz)	-100 dBm	1 MHz/80 dB	*	Common synth LO
SIR-3200-40/80	Superhet, IF sampling SDR	20 MHz - 3 GHz	40 MHz/80MHz	-103 dBm	20 kHz/90 dB	AM, FM, PM, SSB, IQ	Common synth LO
SIR-4100	Superhet, IF sampling SDR	0.1-26.5 GHz	40/80 MHz, 1 GHz	-100 dBm	1 MHz/80 dB	AM, FM, PM, SSB, IQ	Common synth LO
General Dynamics Mission Systems; Annapolis Junction, MD, USA; +1 240-456-5500; www.gd-ais.com							
DFSR-3000 Compact DF system	PLL superhet SDR	2-30 MHz for HF; 20-1, 200 MHz for V/UHF	50 kHz	0.35 uV/12 db SINAD	70 dB	FM, AM and SSB	Pseudo Doppler
WolfScout - Tactical Collection Package (TCP-1)	SDR	500 Hz - 30 MHz	190 kHz	-127 dBm at 500 Hz BW	>100 dB	FM, AM, SSB, LSB, USB, 2-FSK, 4-FSK, 8-FSK, BPSK, QPSK, 8-PSK and others	Paired w/ DFSR-3000 compact DF system (pseudo Doppler)
Wolftrap	Superhet dig channelizer	2 MHz - 20 GHz	60 MHz	-114 dBm at 30 kHz BW	100 dB	FM, AM, SSB, suppressed carrier, pulse position, OOK, 2-FSK, 4-FSK, 8-FSK, BPSK, QPSK, 8-PSK, QAM, OQPSK and others.	Amplitude and phase N-channel DF using MUSIC algorithm
GEW Technologies; Pretoria, South Africa; +27 12 421 6216; www.gew.co.za							
SKYSCAN7X Wideband DF System	Superhet, SDR	1 MHz - 6 GHz	Up to 80 MHz	<-115 dBm, resolution dep	*	DF on all modulation types (specific focus on classification and DF of commercial drones)	Watson Watt/TDOA
MRR8001C Wideband and Monitor Receiver	Superhet, SDR	500 kHz - 9 GHz	Up to 80 MHz	-125 dBm, mode dep	Up to 140 dB	SSB, CW, AM, FM, dig I/Q	High speed interface to DF's available
GRX700 Multi-Channel Wideband Monitor Receiver	Superhet, SDR	9 kHz - 9 GHz	Up to 320kHz	-125 dBm, mode dep	*	SSB, CW, AM, FM, dig I/Q	High speed interface to DF's available
Herrick Technology Laboratories, Inc.; Manchester, NH, USA; +1 603-624-5750; www.herricktechlabs.com							
HTLv-C-19	RX/TX, superhet, SDR	2.0 MHz - 20 GHz	80 MHz, per channel	*	*	FA, PTT, dPTT, Pulse	Yes
HTLw	RX/TX, superhet, SDR	20 MHz - 18 GHz	1 GHz, per channel	*	*	FA, PTT, dPTT, Pulse	Yes
HTLx	RX/TX, superhet, SDR	2.0 MHz - 18 GHz	80 MHz, per channel	*	*	FA, PTT, dPTT, Pulse	Yes
Horizon Technologies; London, UK; +(44) 2036 089996; www.horizontechnologies.eu							
Flying Fish 3rd Generation (SD)	*	L-Band	*	*	*	Thuraya, Inmarsat, IsatPhone Pro	*

CHANNELS	POWER (W)	SIZE (HxWxL in/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
1	250 W	4 x 17 x 12 in.	Air, grd-fix, grd-mob, shp, sub	20 lb	Laptop-based, integrated operator GUIs, built-in wideband recording (22.5 MHz by 16-hr storage), multiple SDR NB receivers, and support for multi-sensor operations and networks.
8, 16, 24, 48	From 500 W	From 4U, 19 in. rack	Air, grd-fix, grd-mob, shp, sub	From 60 lb	Built-in wideband recording (from 7-hours to multiple days), multiple SDR NB receivers, and support for multi-sensor operations and networks.
2 or 4	120 W	19 in., VPX, Module	Air, grd, shp	*	*
2 - 4	120 W	19 in. , 2U	Air, grd, shp	*	*
single	120 W	19 in., 2U	Air, grd, shp	*	*
1	12 W	Receiver processor: 3.1 x 6.2 x 7.7 in.	Grd, shp	*	*
1 channel for monitoring; 1 channel for DF	14 W per channel	*	Grd	*	*
5 - 8	50 W	10 RU standard rack mount chassis (17.5 x 19 x 21 in.)	Grd	*	*
3	< 55 W	*	Grd-fix, grd-mob, shp	< 10 kg	*
1 wideband channel plus 32 DDCs	< 100 W	2U x 19 in. x 440 mm	Grd-fix, grd-mob, shp	< 16 kg	*
uU to 6 indepent receivers (dep on config.)	< 100 W typ. (dep on config.)	2U x 19 in. x 400 mm	Grd-fix, grd-mob, shp	< 13 kg	*
2 - 32 channels	1950 W max.	23 x 15 x 7.75 in.	Air, grd-mob, grd-fix	Chassis, w/o modules: 68 lbs Fully Loaded: 95 lbs	Ruggedized 3U VPX signal interception and collection system designed to detect, DF and demodulate FA, PTT, dPTT and Pulse emitters.
4	120 W typ.	2.06 H x 4.0 W x 8.0 D in.	Air, grd-mob, grd-fix	4.0 lbs	Signal interception and collection device designed to detect, DF and demodulate FA, PTT, dPTT and Pulse emitters.
4	80 W typ.	1.6 H x 3.5 W x 8.0 D in.	Air, grd-mob, grd-fix	2.9 lbs	Signal interception and collection device designed to detect, DF and demodulate FA, PTT, dPTT and Pulse emitters.
64	AC PSU External: 90V - 264VAC; DC PSU Internal 28V	392 x 371 x 240 mm	Air	16 kg	Analyzes Thuraya, IsatPhone Pro traffic simultaneously.

COMINT AND COMMS ESM RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	DYNAMIC RANGE	MOD TYPES	SUPPORT DF
Indra Sistemas, S.A.; Madrid, Spain; +34-916-271-162; www.indra.es							
IN/TSD-900	Preselected superhet wideband dig.	1-30 MHz	800 kHz	-112 dBm	125 dB	*	Correlative interferometry, Watson-Watt
IN/TSD-1000	Preselected superhet wideband dig.; direct sampling HF	20 MHz - 6 GHz	80 MHz (30 MHz in HF)	-105 dBm (-112 dBm in HF)	120 dB	IQ data	Correlative interferometry (Watson-Watt in HF)
Innovationszentrum Telekommunikationstechnik GmbH (IZT); Erlangen, Bavaria, Germany; +49-9131-4800-100; www.izt-labs.de							
IZT R3000/R3200; IZT R3301/R3302; IZT R3410/R3411	Dual-conversion superhet	9 kHz - 18 GHz	25 MHz	-120 dBm (SNR=10 dB; BW=3 kHz)	170 dB (AGC)	FM, AM, USB, LSB, I/Q	Correlative interferometer, Watson-Watt, TDOA
IZT R5010	Dual-conversion superhet	20 MHz - 6 GHz	60 MHz 80 MHz 120 MHz	-120 dBm (SNR=10 dB; BW=3 kHz)	170 dB (AGC)	*	TDOA
IZT R5506/R5509	DF/Digital DF	R5506: 1 MHz - 6 GHz; R5509: 100-500 MHz	60 MHz	*	*	*	Super Resolution DF, Correlative interferometer, TDOA
iRF - Intelligent RF Solutions; Sparks, MD, USA; +1 443-310-2814; www.irf-solutions.com							
iWR-6500/ WIDERAIL	Superhet; stepped sweeper	450 MHz - 26.5 GHz, up to 44GHz	500 MHz @ 1 GHz IF; 100 MHz @ 140 MHz IF	>90 dB @ 1 MHz	65 dB, STSFDR	AM, FM, LOG, QAM, BPSK, QPSK, 8-PSK, 4-FSK, SSB	Yes
SMR-7522/LiteRail	Superhet; stepped collection	800 MHz - 26.5 GHz, up to 44GHz	95 MHz @ 140 MHz/ 160 MHz IF	94 dB @ 1 MHz	50 dB min., STSFDR	BPSK, QPSK, SQPSK, 8-PSK, QAM, FM-FDM, MSK, 2-FSK, 4-FSK, FM, AM, SSB, pulse position, suppressed carrier, etc.	Yes
SMR-5550i	Superhet, set-on receiver	500 MHz - 20 GHz	100 MHz at 140 MHz & 1 GHz IF outputs	-99 dBm in 1 MHz IF BW	84 dB in 1 MHz IF BW	FM, AM, SSB, pulse position, suppressed carrier, etc.	No
Jordan Electronic Logistics Support; Amman, Jordan; +96 279 667 9716; www.jels-tech.com							
Signal Sniper	Channelized w/ dig receiver	50 MHz - 6GHz	50 MHz	-100 dBm @ 10 MHz BW	60 dB	AM, FM, PM, DSB, SSB, NBFM	No
Keysight Technologies, Inc.; Santa Rosa, CA, USA; +1 800-829-4444; www.keysight.com							
M939x PXIe Vector Signal Analyzers	SDR (FFT)	9 kHz - 50 GHz	160 MHz	Noise Figure 12 dB	DANL -120 to -157 dBm/Hz	None	No
M99xx Field Fox Handheld Analyzers	Multiple. In Spectrum Analyzer Mode it uses SDR (FFT)	30 kHz - 50 GHz	100 MHz	Noise Figure 8 dB	DANL -91 to -154 dBm/Hz	AM, FM, others	No
N6841A RF Sensor	SDR (FFT)	20 MHz - 6 GHz	20 MHz for FFT, local IQ; 1.9 MHz for IQ stream	-120 dBm to 110 dBm	>110 dB	AM, FM, others	Yes, TDOA and power-based geolocation

CHANNELS	POWER (W)	SIZE (HxWxL in/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
3	230 W	19 in. x 6U x 570 mm	Grd-mob	26 kg	Fix frequency and frequency hoppers signals pre-classification.
3; up to 8	600 W	19 in. x 6U x 640 mm	Air, grd-mob, shp	47 kg	Fix frequency, frequency hoppers and DSSS signals pre-classification HF.
1	43 -160 W, depending on model	model dependent	Grd-mob, grd-fix, shp, sub	R3000/R3200: approx. 10-12 kg; R3301/R3302: approx. 15-17 kg; R3410/R3411: approx. 5-7 kg	Mobile, rugged or rack-based; multichannel operation; high linearity; Gigabit LAN interface
1	100 W	1U x 19 in. x 560 mm	Grd-mob, grd-fix, shp, sub	Approx. 10-12 kg	Six independent digital downconverters; real-time spectrum calculation; large internal buffer memory
R5506: 6; R5509: 9	R5506: 200-250; R5509: 300 W	R5506: 292 x 205 x 270 mm; R5509: 265 x 300 x 360 mm	Grd-mob, grd-fix, shp, sub	R5506: approx. 13 kg R5509: approx. 19 kg	Digitization close to the antenna; simultaneous processing; optional independent monitoring channel; applicable for drone detection and air traffic control
Single	45 W	1.6 H x 5.5 W x 10 D in.; CD-ROM enclosure	Air, grd-fix, shp, sub	<5 lbs	SDR housed in rugged mini chassis, designed to support SIGINT collection, N-channel DF, user programmable FPGA resources available on-board.
Single and dual channel	25 W	1.6 H x 5.5 W x 10 D in.	Air, grd-fix, shp, sub	3.5 lbs	LiteRail receiver housed in rugged mini CD-ROM enclosure, supports OFDM/ PCM satellite backhaul and COMINT applications.
Not channelized	100 W for single receiver	1.75 x 17 x 20.16 in.; mounts in standard 19-in. rack	Air, grd-fix, shp, sub	22 lbs	General purpose microwave collection receiver w/ superior phase noise and signal fidelity.
4	*	40 x 40 x 12 cm	Grd-mob	*	Support automatic jamming system.
1 channel (multiple channels can be added to PXI chassis)	140 W	52 x 11 x 84 cm	*	5.6 lbs	PXI modular hardware, requires chassis and controller, not included in these specifications.
1	14 W typ.	6.4 x 29.3 x 18.7 cm	Air, grd-fix, grd-mob, shp, sub	7.1 lbs	IP52 rated enclosure.
1 channel for monitoring, w/ 2 antenna inputs (up to 8 narrow band DDCs)	30 W max; 25 W typ.	5.4 x 24.2 x 29.2 cm	Air, grd-fix, grd-mob, shp, sub	7.7 lbs	IP67 rated enclosure (for ingress of dust and water). Linkage to Signal Surveyor 4D and 89601B VSA software.

COMINT AND COMMS ESM RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	DYNAMIC RANGE	MOD TYPES	SUPPORT DF
L-3 Communications - Linkabit Division; San Diego, CA, USA; +1 800-331-9401; www.l-3com.com							
MD-405A	Superhet	100 kHz - 2 GHz	Up to 200 KHz	FM: 200 KHz, 12 dB SINAD 3.2 uV. AM: 6 kHz, 12 dB SINAD 1.5 uV. SSB/CW: 3 kHz. 10 dB SINAD 0.4 uV.	*	FM, AM, SSB, CW	Single-channel interferometer
MD-407	Superhet	2 MHz - 6 GHz	10 MHz upgradeable to 20 MHz per channel (3 total)	FM: 200 kHz, 12 dB SINAD 2.5 uV. AM: 6 kHz, 12 dB SINAD 1.8 uV. SSB/CW: 3 kHz, 10 dB SINAD 0.3 uV.	130 dB including gain and attenuation	FM, AM, USB, LSB, CW, ISB	HF LVHF: 2 channel amplitude comparison DF VHF, UHF: 2 channel interferometer
L-3 Communications - TRL Technology; Tewkesbury, Gloucestershire, UK; +44 1684 278700; www.trltech.co.uk							
SMARTSCAN MEWS	Superhet	2 MHz - 3 GHz	40 MHz	*	*	AM, FM, SSB and CW	Correlative interferometry
Leonardo DRS; Germantown, MD, USA; +1 301-948-7550; www.leonardodrs.com/SignalSolutions							
SI-9150 Polaris	Superhet	2 MHz - 6.2 GHz	Selectable bandwidths 1 kHz to 85 MHz I/Q data stream or 40 MHz analog	13 dB NF, -122 dBm sensitivity @ 10 kHz BW	81 dBc SFDR in a 10 KHz BW	16-bit VITA 49 I/Q data streaming selectable 1Ksps to 256 Msps per channel	N-channel coherent or full independent tuning
SI-9170A Sparrow	Superhet	20 MHz - 18.25 GHz	500 MHz	15 dB NF	-2 dBm input 1 dB compression point	*	Phase coherent up to N-channels
SI-9172/3 Vesper	Superhet	3 MHz - 6.2 GHz	Selectable bandwidths, 100 MHz, 30 MHz & 15 MHz	13 dB NF, -122 dBm sensitivity @ 10 kHz BW	88 dBc SFDR in a 10 KHz BW	VITA 49 packetized digital IF via Aurora transport protocal	N-channel coherent or full independent tuning
LS Telcom AG; Lichtenau, Germany; +49-7227-9535-600; www.lstelcom.com							
FMU 318w (Fixed monitoring unit)	Superhet/digital	9 kHz - 18 GHz	Up to 40 MHz	*	*	AM, FM, CW, LSB, USB, DSB.	Yes, DF Time Travel® (Automatic amplitude based full-band live and past DF)
PPU 318w (Protected portable unit)	Superhet/digital	9 kHz - 18 GHz	Up to 40 MHz	*	*	AM, FM, CW, LSB, USB, DSB.	Yes, DF Time Travel® (Automatic amplitude based full-band live and past DF)
Mercury Defense Systems, unit of Mercury Systems, Inc.; Cypress, CA, USA; +1 866-627-6951; www.mrcy.com							
MDS ISR System	DF	30 MHz - 3 GHz	20 MHz	-122 dBm (25 kHz BW)	65 dB (25 kHz BW)	*	Yes, amplitude, phase, TDOA
Midwest Microwave Solutions Inc.; Hiawatha, IA, USA; +1 319-393-4055; www.mms-rf.com							
MSDD-6600-D	Dual channel scanning superhet with digitizer	30 MHz - 6 GHz	40 MHz	-117 dBm (12.5kHz RBW)	>100 dB	I/Q, AM, FM, pre-D, Spectral	TDOA, FDOA, time stamping
RX-26GLX-D	Dual channel scanning superhet with digitizer	30MHz - 26 GHz	80 MHz	-116 dBm (12.5kHz RBW)	>100 dB	I/Q, pre-D, Spectral	TDOA, FDOA, time stamping
RX-6400	Four channel scanning superhet with digitizer	30 MHz - 6 GHz	40 MHz	-116 dBm (12.5kHz RBW)	>100 dB	I/Q, AM, FM, pre-D, Spectral	TDOA, time stamping

CHANNELS	POWER (W)	SIZE (HxWxL in/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
1 DF, 2 monitor	9.5 W typ.	5.2 x 11.5 x 12.2 in.	Air, grd	*	*
3	≤ 20 W (when fully operational)	13 x 9.3 x 3.7 in.	Air, grd	11.5 lbs (not including battery)	Designed to MIL-STD-810F.
3	44 W	14 x 24 x 29 cm	Grd-mob	*	*
4 tuners with at least 8 sub-band tuners	32 W (digital); 16 W (analog)	3 x 2.5 x 5 in. (digital); 3 x 1.7 x 5 in. (analog)	*	<4 lb	Tactical
2 channels phase coherent	46 Watts conduction cooled	3U VPX	*	2 lbs.	Wideband microwave, 0.4 degrees RMS SSB integrated phase noise
SI-9173 up to 8 Rx & 1 Tx; SI-9172 up to 4 Rx & 1 Tx	111 W & 50 W	6U VPX & 3U VPX	*	4.5 lb	Highly configurable with multiple channels.
Dual-receiver option available (Monitoring sweep mode + DF in parallel)	*	52 x 21 x 37 cm	Grd-fix	27.5 kg	DF sweep mode, co-channel signal resolution, TDoA geolocation (min. 3 receivers needed), PDoA geolocation, Automatic Violation Detection (AVD).
Dual-receiver option available (monitoring sweep mode + DF in parallel)	*	42 x 25 x 56 cm	Air, grd-fix, grd-mob, shp	15 kg	Fully integrated portable COMINT system (receiver, processor, storage, remote comm modem), automatic DF live or based on stored data.
2	5 W	0.82 x 3 x 5.5 in.	Air	12 oz	PAN/SDU displays, JICD 4.2 compliance, < 3 deg RMS AOA error.
1 RF, up to 56 DDR	15 W	0.97 x 3.25 x 5.4 in.	Air, grd, shp, sub	18 oz	User programmable, phase coherent operation, VITA-49.
2 RF, up to 16 DDR	24 W	1.7 x 4.1 x 6.9 in.	Air, grd, shp, sub	48 oz	User programmable, phase coherent operation, 1GE and 10GE, VITA-49.
4 RF, up to 2 DDR	35 W	2.0 x 3.8 x 7.0 in.	Air, grd, shp, sub	40 oz	User programmable, 1GE and 10GE, VITA-49.

COMINT AND COMMS ESM RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	DYNAMIC RANGE	MOD TYPES	SUPPORT DF
Narda Test Solutions GmbH, an L-3 Communications Company; Pfullingen, Germany; +49 7121-9732-0; www.narda-sts.com							
NRA-6000 RX	Superhet wband dig	9 kHz - 6 GHz	Frequency domain: 10 Hz - 20 MHz; Time domain: 100 Hz - 32 MHz	<-140 dBm; RBW = 10 Hz	160 dB	FM, AM, CW, USB, LSB, I/Q	Yes, Narda-IDA antennas
SignalShark Handheld 3310	Preselected superhet/realtime	8 kHz - 8GHz	25 Hz - 40 MHz	NF: 12 dB typ. w/o preamp	IP2 40 dBm, IP3 14 dBm typ. @ 0 dB ATTN.	AM, Pulse, CW, ISB, USB, LSB, FM, PM, or I/Q. VITA49 IQ output	AOA, POA, TDOA Automatic DF Antennas; Handheld Directional Antennas
SignalShark Remote 3320	Preselected superhet/realtime	8 kHz - 8GHz	25 Hz - 40 MHz	NF: 12 dB typ. w/o preamp	IP2 40 dBm, IP3 14 dBm typ. @ 0 dB ATTN.	AM, Pulse, CW, ISB, USB, LSB, FM, PM, or I/Q. VITA49 IQ output	AOA, POA, TDOA Automatic DF Antennas
PLATH GmbH; Hamburg, Germany; +49 (0) 40-237-34-0; www.plath.de							
Radio Direction Finder DFP5130	Watson-Watt, direct sampling	0.5-30 MHz	29.5 MHz analog, 12.288 MHz digital @ 125 Hz freq. resolution	-139 dBm (min. detectable signal)	169 dB (SFDR2 105dB)	*	Yes (also in scan mode)
Radio Direction Finder DFP5135	Watson-Watt, direct sampling	0.5- 30 MHz	29.5 MHz analog, 29.5 MHz digital @ 125 Hz freq. resolution	-139 dBm (min. detectable signal)	169 dB (SFDR2 105dB)	*	Yes
SIR 2115	Superhet	20 MHz - 3 GHz (opt. from 9 kHz - 6 GHz)	80 MHz @ 1 kHz freq. resolution	-135 dBm	165 dB	AM, FM, SSB via SW-Modul on PC	*
QinetiQ; Farnborough, Hampshire, UK; +44 (0) 1684 894750; www.qinetiq.com							
ASX Family of COMINT/DF Systems	*	20-500 MHz	40 MHz	*	*	NFM, WFM, AM, USB, LSB, CW	Yes
Radixon Group (WiNRADiO); Melbourne, Australia; +61 3 9417 3417; www.winradio.com							
G35DDCi	Direct-sampling	1 kHz to 45 MHz	32 MHz	-121 dBm (0.2 uV)	111 dB min.	Analog, digital	*
G39DDC(i/e)	Superhet	9 kHz - 3.5 GHz	6 MHz	-122 dBm (0.18 uV)	87 dB min.	Analog, digital	*
G65DDCe	Direct-sampling	1 kHz - 88 MHz, 118-190 MHz	64 MHz	-121 dBm (0.2 uV)	111 dB min.	Analog, digital	*
Raytheon Applied Signal Technology, Inc.; Sunnyvale, CA, USA; +1 408-749-1888; www.raytheon.com							
Model 570X SIREN	Superhet	411-495 MHz, 824-849 MHz and 869-894 MHz	1.23 MHz	-102 dBm	84 dB	Modern signal	TOA
Model 660 HYDRA Airborne COMINT Payload	Dig channelizer	20 MHz - 3 GHz	200 MHz	-100 dBm	90 dB	FM, AM, LOG and pulse	8-element phase interferometer
Model 680 RAIDER High-Capacity Signal Surveillance System	Dig channelizer	20 MHz - 3 GHz	200 MHz	-100 dBm	90 dB	FM, AM, LOG and pulse	External DF subsystem
Rohde & Schwarz GmbH; Munich, Germany; +49-89-4129-0; www.rohde-schwarz.com							
R&S®DDF®550 Wideband Direction Finder	Superhet and DDR	300 kHz - 3 GHz	80 MHz	1-10 μV/m typ.	150 dB w/ 40 dB attn (1 dB steps)	AM, FM, PM, pulse, I/Q, USB, LSB, CW, ISB	HF: amplitude (Watson-Watt); VHF/UHF/SHF: phase (correlative interferometer)
R&S®EB500 Monitoring Receiver	Superhet and DDR	20 MHz - 3.6 GHz; (opt. from 9 kHz - 26.5 GHz)	20 MHz	<-126 dBm	150 dB w/ 40 dB attn (1 dB steps)	AM, FM, PM, pulse, I/Q, USB, LSB, CW, ISB	HF: Amplitude (Watson-Watt); VHF/UHF/SHF: Phase (correlative interferometer)

CHANNELS	POWER (W)	SIZE (HxWxL in/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
1	< 20 W	1U x 19 in. x 14.3 in.	Grd-fix, grd-mob, shp	< 5 kg	I/Q and audio streaming, 10 MHz ref input, antenna control, level meter, multi-channel power, scope mode.
1	< 35 W	230 × 335 × 85 mm, 9.06 × 13.19 × 3.35 in.	Grd-fix, grd-mob, shp	Approx. 4.1 kg / 9.04 lbs (with one battery)	Win10 open plattform for 3rd party applications, Integrated Heat Map, 4 inputs, up to 50 GHz/s, POI 3,125 μs, ITU compliant, SCPI , IP52/67 rated.
1	< 35 W	RU, 43.5 × 220 × 204 mm, 1.71 × 8.66 × 8.03 in.	Grd-fix, grd-mob, shp	Approx. 2.1 kg / 4.63 lbs	Win10 open plattform for 3rd party applications, Integrated Heat Map, 4 inputs, up to 50 GHz/s, POI 3,125 μs, ITU compliant, SCPI, Stand-alone and 19-in. rack.
3	~250 W	3 HU x 19 in. x 605 mm	Grd, shp	~15.3 kg	*
5 x 3	~1400 W	4 HU x 19 in. x 605 mm	Grd	~40 kg	All over DF-ing of HF range.
1 channel	~200 W	1 HU x 19 in. x 490 mm	Grd, shp	10 kg	Ultra fast scan with 100 GHz/s, complete IQ stream (4x 20 MHz), 20 DDC simultaneously (inside the 80 MHz Bandwidth).
*	*	Varies	Air	*	Optional 20 MHz - 3 GHz coverage; AS3 for tactical UAVs and helos; AS4 for MALE and HALE UAVs; AS5 for business jets.
3	*	8.57x3.87x0.7 in	*	1.1lbs/0.5kg	Ext. clock in/out.
2	*	8.57 x 3.87 x 0.7 in. (PC card); 6.5 x 3.8 x 2.3 in. (external USB version)	*	1.1lbs/0.5kg (PC card); 1.75lbs/0.805kg (external USB version)	Ext. clock in/out.
3 or 32 channels	*	6.5x3.8x2.3 in	*	1.8lbs/0.8kg	Ext. clock in/out.
1 duplex	12 W	1.23 x 5.6 x 8.2 in.	Air, grd	*	*
8	250 W	7.5 x 7.6 x 19.6 in. 3/4 ATR chassis	Air	*	*
8	250-300 W	5.25 x 19 x 24 in.	Grd	*	*
1	400 W (depending on config.)	42.6 × 17.6 × 45 cm	Air, grd-fix, grd-mob, shp, sub	*	*
1 + 3 DDCs	40-120 W	21.3 x 13.2 x 45 cm	Air, grd-fix, grd-mob, shp, sub	*	*

COMINT AND COMMS ESM RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	DYNAMIC RANGE	MOD TYPES	SUPPORT DF
Rohde & Schwarz GmbH; Munich, Germany; +49-89-4129-0; www.rohde-schwarz.com *cont'd.*							
R&S®ESMD Widband Monitoring Receiver	Superhet and DDR	20 MHz - 3.6 GHz; (opt. from 9 kHz - 26.5 GHz)	20 MHz, 80 MHz versions (upgradeable)	<-126 dBm	150 dB w/ 40 dB attn (1 dB steps)	AM, FM, PM, pulse, I/Q, TV, USB, LSB, CW, ISB	HF: Amplitude (Watson-Watt); VHF/UHF/SHF: Phase (correlative interferometer)
Saab Medav Technologies GmbH; Erlangen, Germany; +49-9131-583-0; www.saab.com/saabmedavtechnologies							
ARS-Compact	Direct sampling receiver	9 kHz - 30 MHz	Up to 30 MHz	NF < 10 dB	SFDR > 90 dBc @ BW=30 MHz	More than 200 analog and digitial transmission methods	Yes
CCTNG-D2	Direct sampling	9 kHz - 30 MHz	Up to 24 MHz	< -128 dBm (500 Hz BW/ 10 dB SNR)	156 dB (incl. AGC)	AM, FM, CW, LSB, USB and more	Watson-Watt, interferometer and hyperbolic position finding
CCTNG-D4	Direct sampling, double conversion superhet	9 kHz - 3 GHz	Up to 24 MHz	9 kHz-30 MHz: < -128 dBm (500 Hz BW/ 10 dB SNR); 20 MHz - 3 GHz: < -123 dBm (500 Hz BW/ 10 dB SNR)	9 kHz - 30 MHz: 156 dB; 30 MHz - 3 GHz: 133 dB (incl. AGC)	AM, FM, CW, LSB, USB and more	Watson-Watt, interferometer and hyperbolic position finding
Sagax Communications; Budapest, BP, Hungary; +36-30-172-0718; www.sagaxcommunications.com							
SRS-3000	HF: direct samplig V/UHF: IF sampling superhet search and intercept digital receiver	HF: 9 KHz - 36 MHz V/UHF: 20 MHz - 3 GHz	36 MHz	-120dBm @ 10dB S/N with 1KHz resolution	124 dB	Energy detection, amplitude spectrum, bearing spectrum	Amplitude (Wattson-Watt)
SRM-3000	HF: direct samplig V/UHF: IF sampling superhet monitoring and collecting digital receiver	HF: 9 KHz - 36 MHz V/UHF: 20 MHz - 3 GHz	200 KHz	-120dBm @ 10dB S/N with 1KHz resolution	124 dB	Energy detection, amplitude spectrum, bearing spectrum	Amplitude (Wattson-Watt)
Seqtor Denmark A/S; Grenaa, Denmark; +45 8632 6300; www.Seqtor.com							
Mentor	Direct Conversion	25 MHz – 3 GHz in 10 KHz steps	100 KHz / 500 KHz / 2 MHz / 10 MHz	-90 dBm	70 dB	None, RSSI only	No
AUTOR	Direct Conversion	25 MHz – 3 GHz in 10 KHz steps	100 KHz / 500 KHz / 2 MHz / 10 MHz	-90 dBm	70 dB	None, RSSI only	No
Silver Palm Technologies; Ijamsville, MD, USA; +301-874-0065; www.silverpalmtech.com							
SP-8385 SDR	Superheterodyne with SDR	20 MHz - 6 GHz	4 MHz (software definable up to 40 MHz)	-86dBm for 10db snr in 4MHz bandwidth	80 dB	AM, FM, Log	Could be added in SDR FPGA load
SP-8344 Quad VPX Tuner	Superheterodyne with SDR	20 MHz - 6 GHz	Up to 40 MHz	-76dBm for 10db snr in 40MHz bandwidth	80 dB	Can be added in SDR load	Could be added in SDR FPGA load
SP-1342 Quad Tuner	Superheterodyne with SDR	20 MHz - 6 GHz	Up to 40 MHz	-76dBm for 10db snr in 40MHz bandwidth	80 dB	Can be added in SDR load	Could be added in SDR FPGA load
Southwest Research Institute (SwRI); San Antonio, TX, USA; +1 210-522-2517; www.swri.org							
HFW-2400	Digital	VLF through low VHF	Full band stare	*	*	*	DF (vector match), SSL
MBA-460	Digital, superhet	2 MHz - 6 GHz	20- 80 MHz	*	*	PSK, MSK, FSK, QAM, SSB, FM and others	DF (vector match), T/ FDOA

CHANNELS	POWER (W)	SIZE (HxWxL in/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
1 + 4 DDCs	100-250 W	17.6 x 42.6 x 45 cm	Air, grd-fix, grd-mob, shp, sub	*	*
Up to 100	350 W	19 in. rack with 4 RU and 70 cm depth	-Land: vehicles, fixed installation -Surface vessels -Submarine	35 kg	Interactive or fully automated operation (detection, classification, production); wideband signal and result recording; remote operation; scalabale.
3 RF paths for DF w/ Watson-Watt; 5 or 9 RF paths for DF w/ interferometer	50 W	1 RU x 19 in. x 560 mm	Air, grd, shp, sub	10 kg	4 DDC channels, IQ/FFT/PSD outputs, IP protocol supporting multicast/ broadcast.
3 RF paths for DF w/ Watson-Watt; 5 or 9 RF paths for DF w/ interferometer	50 W	1 RU x 19 in. x 560 mm	Air, grd, shp, sub	12 kg	4 DDC channels, IQ/FFT/PSD outputs, IP protocol supporting multicast/ broadcast.
1 independent RF input	<45 W	41 x 200 x 440 mm (1U half rack)	Grd-fix, grd-mob, portable	<5 kg	TCP/IP remote control and data/spectrum streaming, built-in DF processor, record and playback, channel scan, installed decoders, 10MHz REF IN, 12-20VDC operation.
4 independent RF input and 16 independent hw DDCs	<45 W	41 x 200 x 440 mm (1U half rack)	Grd-fix, grd-mob, portable	<5 kg	TCP/IP remote control and data/spectrum streaming, built-in DF processor, record and playback, channel scan, installed decoders, 10MHz REF IN, 12-20VDC operation.
1	0.4 W	1.28 x 3.05 x 6.0 in.	Air, grd-mob, grd-fix	Approx. 0.25 kg	Body worn spectrum analyzer/scanner for dismounted personnel; built-in solid state recorder and GPS that correlates the detected signal with position and time.
1	0.4 W	1.1 x 6.9 15 cm	Air, grd-mob, grd-fix	Approx. 0.15 kg	Spectrum analyzer and scanner functionality; detects RF activity from tactical radios, personal radios, cell-phones, SAT-phones.
1	< 15W	6 x 3.5 x 1.25 in.	Air, grd-mob, grd-mob, shp	1.0 lb	Designed as a software definable tuner/ receiver replacement for legacy systems.
4	< 50W	3U VPX - VITA 48.2 (6.3 x 4 x 1 in.)	Air, grd-mob, grd-mob, shp	1.4 lbs	Four highly integrated true Heterodyne tuners with a four channel IF digitizer. Kintex XC7K410T FPGA. Integrated GPS. VITA 67.3 RF backplane.
4	< 54W (9-16VDC)	7.75 x 5.75 x 1.635 in.	Air, grd-mob, grd-mob, shp	2.9 lbs	Four highly integrated true Heterodyne tuners with a four channel IF digitizer. Kintex XC7K410T FPGA. Integrated GPS.
8 to 24 (software channelization)	*	rack mountable	Grd, grd-mob, shp	*	N channel wideband DF server; multi-day delay memory; full spectrum DF visualization; automatic DF network tasking interface.
1 acquisition only, 2 DF (software channelization)	350 W	7.62 x 6.0 x 9.0 in.	Air, grd, grd-mob	30 lb., not including antennas	OpenVPX architecture for deployment on unpressurized airborne platforms and harsh shock and vibration environments.

COMINT AND COMMS ESM RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	DYNAMIC RANGE	MOD TYPES	SUPPORT DF
Southwest Research Institute (SwRI); San Antonio, TX, USA; +1 210-522-2517; www.swri.org *cont'd.*							
MBS-567	Digital, superhet	0.1 MHz - 6 GHz	30-320 MHz	*	*	PSK, MSK, FSK, QAM, SSB, FM and others	DF (vector match), T/FDOA
Spectranetix, Inc.; Sunnyvale, CA, USA; +1 408-982-9057; www.spectranetix.com							
MX-103E	Wideband SDR transceiver	20 MHz - 6 GHz	Dual 160 MHz	NF < 12 dB all bands	132 dB total	SDR	Yes, dual channel phase coherent
SX-430 SDR	Wideband SDR transceiver	1 MHz - 18 GHz	Dual 160 MHz	NF < 12 dB all bands	132 dB total	SDR, Any waveform up to 160 MHz wide	Yes, multi card phase coherency
Syncopated; Baltimore MD, USA; 410-707-7338; www.SyncopatedProducts.com							
DF-A2	Homodyne (zero IF), SDR channelizer	20 MHz - 6 GHz	0.2-50 MHz	-102 dBm	72 dB	OFDM, MPSK, MQAM, MFSK, DSSS, FH	Watson-Watt, phase
TCI; Fremont, CA, USA; +1 510-687-6110; www.tcibr.com							
TCI 803E HF/VHF/UHF Wideband DF System	Hybrid superhet; channelized analog/dig receiver	20 MHz - 8 GHz	4 or 40 MHz (dual BW receivers)	Antenna dependent	120 dB	DF on all modulations	Hybrid AOA/TDOA, AOA or TDOA
TCI 850 Blackbird HF/VHF/UHF/SHF Signal Collection and Analysis system	Hybrid superhet; channelized analog/dig receiver	.009-8000 MHz	4 or 40 MHz (dual BW receivers)	-120 dBm at 1 kHz BW	120 dB	DF on all modulations	Optional Hybrid AOA/TDOA, AOA or TDOA
TCI Model 902	Dual channel or N-channel	0 - 30 MHz	28 MHz	-120 dBm (antenna-dependant)	90 dB SFDR	DF: all; collection: AM, FM, LSB, USB, I/Q	Yes (Dual channel interferometer, n-channel correlative interferometer, or n-channel super-resolution/MUSIC)
Tech Comm, Inc.; Ft. Lauderdale, FL, USA; 954-712-7777; www.techcommdf.com							
TC-5035C SAR/DF	Superhet	2-470 MHz	5 MHz	10 dB NF	100 dB	AM, FM, SSB, CW	2-470 MHz
TC-9300 COMINT/DF	SDR, digital DF processor	30 MHz - 6 GHz	22 MHz	-115dBm	120 dB	AM, FM, SSB, CW, 2500+ signal types 3rd party software	Yes, phase and magnitude, 30 MHz - 2 GHz, opt. to 6 GHz
TC-9320 COMINT/DF	SDR, digital DF processor	30 MHz - 6 GHz	22 MHz	-115dBm	120 dB	AM, FM, SSB, CW, 2500+ signal types 3rd party software	Yes, phase and magnitude, 30 MHz - 2 GHz, opt. to 6 GHz
Thales SIX-GTS ; Gennevilliers, France; +33 1 46 13 20 00; www.thalesgroup.com							
TRC 6200	DF and superhet receiver	0.3-30 MHz HF DF; 20 MHz - 3 GHz V/UHF DF; SHF Add-on as an option	30 MHz in HF; 40 MHz in V/UHF	-125 dBm in V/UHF	120 dB in V/UHF	DF: all	Interferometry and Watson-Watt
TRC 6460	DF and superhet receiver	20 MHz - 3 GHz V/UHF DF; SHF Add-on as an option	40 MHz in V/UHF	-128 dBm in V/UHF	120 dB in V/UHF	DF: all	Enhanced Vector Correlation
TRC 6500	Direct sampling	0.5-30 MHz	30 MHz	-125 dBm	120 dB	DF: all	High Resolution
Ultra Electronics Telemus; Ottawa, ON, CAN; +613 592-2288; www.ultra-telemus.com							
C-EAGLE	Superhet	10 kHz - 3 GHz	>30 MHz	>100 dBm	>80 dB	FM, AM, SSB, CW, DSB-SC, BFSK, MSK-type, BPSK, QPSK and others.	DF interferometer
MicroEAGLE	Superhet	20 MHz - 3 GHz	2 or 16 MHz, others opt	>100 dBm	>80 dB	FM, AM, SSB, CW, DSB-SC, BFSK, MSK-type, BPSK, QPSK and others.	DF interferometer

CHANNELS	POWER (W)	SIZE (HxWxL in/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
2 to 8 (>200 simultaneous receivers)	*	2 racks, scalable to 1	Shp, sub	*	Wideband automatic detection, classification and recording; tactical or strategic operations; data mining; complex signals analysis.
2 TX and 2 RX	15 W	0.84 x 3.1 x 4.3 in.	Air, grd-mob, grd-fix, shp, sub	0.25 kg	1/10Gbe, PoE, MORA compatible.
2 TX and 2 RX	45 W	3U VPX conduction cooled	Air, grd-mob, grd-fix, shp, sub	0.6 kg	2 x 16 bit ADC/DAC per channel, CMOSS/ SOSA/HOST.
2, 3	<20 W total	2.7 x 9.6 x 7.9 in.	Air, grd-mob, grd-fix, shp	6.5 lbs	Spectral sensing / signal detection; waveform recognition; collaborative comms (built-in transceiver).
2	<200 W	7 x 19 x 20 in.	Fix, grd, mobile, portable	*	*
1-3 (plus 92 DDCs)	<200 W	7 x 19 x 20 in.	Fix, grd, mobile, portable	*	*
2 or N-channel	300 to 1,000 W	Processors: 5 x 19 x 20 in. to 36 x 19 x 21 in. (configuration-dependant)	Fixed or mobile	Processors: 50 to 200 lbs (configuration-dependant)	Collection and integrated HF DF system; all DF results stored in database; N-channel opt.; super-resolution/MUSIC; post-facto processing
Single	40 W @ 120vac	3U rack	Grd-fix, shp	17 lbs	SAR application, 4-degree DF accuracy, SARSAT/COPAS/406 MHz EPIRB.
Single	26 W @ 12vdc	1 x 3 x 6 in. bricks airborne	Air, grd-mob, grd-fix, shp	16 lbs (with DF array)	4-degree DF accuracy, with Tech Comm 8000 Series DF arrays.
2	52 W @ 120vac	2U rack	Grd-fix, air, ship, mobile	28 lbs	4-degree DF accuracy, with Tech Comm8000.
2 DF channels in H/V/UHF	90 W	47 x 14 x 31 cm	Air, grd-fix, grd-mob, shp, sub	< 15 kg (without SHF add-on)	*
5 or 6 DF channels, plus 1 or 2 monitoring channels;	400 W	9U, 19 in.	Air, grd-fix, grd-mob, shp	40 kg	*
10	Depending on configuration	19-in. rack (dep on config.)	Grd-fix, grd-mob, shp	*	Spatial filtering.
1 - 4	Config. dep.	6u x EIA 19-in. rack x 24 in.	Air, shp	*	*
1 - 4	Config. dep.	1u x EIA 19-in. rack	Air, grd-mob	*	*

SURVEY KEY – COMINT AND COMMS ESM RECEIVERS

MODEL

Product name or model number

REC TYPE

Receiver type

- DDR = direct digital receiver
- DF = direction-finding
- dig = digital
- FFT = fast Fourier transform
- HF = high frequency
- IF = intermediate frequency
- LAN = local area network
- nband = narrowband
- PLL = phase-locked loop
- RF radio frequency
- SDR = software-defined radio
- superhet = superheterodyne
- wband = wideband

OP FREQ

Operating frequency in kHz, MHz or GHz.

INST BW

Instantaneous bandwidth (if different from operating frequency)

TYP INST SENS

Typical Installed Sensitivity

- RBW = resolution bandwidth
- SINAD = signal-to-noise-and-disåtortion
- SNR = signal-to-noise ratio

DYN RANGE

Total dynamic range

- AGC = automatic gain control
- SFDR = spur-free dynamic range

MOD TYPES

Modulation types it can process

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

SUPPORT DF

Does it support DF and with what technology?

- DDC = direct digital downconversion
- FDOA = frequency difference of arrival
- LO = local oscillator
- MUSIC = multiple signal classification
- SHF = super high frequency
- TDOA = time difference of arrival
- TOA = time of arrival

 # REC CHANNELS

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

PWR (in W)

Power dissipated in Watts per channel

- AC = alternating current
- DC = direct current

SIZE (in in/cm)

Size by height x weight x length, or diameter, in inches

- ATR = air transport rack
- PCI = peripheral component interconnect
- RU = rack unit
- VME = virtual machine environment

PLATFORM

Platform

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

WEIGHT

Weight in lb/kg

OTHER ABBREVIATIONS USED

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

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

AUGUST 2019 PRODUCT SURVEY: EW AND SIGINT ANTENNAS

This survey will cover antennas designed for electronic warfare (EW), communications intelligence (COMINT) and electronic intelligence (ELINT). Please e-mail JEDEditor@naylor.com to request a survey.

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New EA Techniques Part 6

Remote Jamming of Track via Missile Threats

By Dave Adamy

During the last two months, we have been discussing the dynamics of jamming track-via-missile (TVM) threats with self-protection jammers. This month, we will turn to the remote jamming of these threats.

As shown in **Figure 1**, there are three jamming targets: the tracking radar, the receiver in the missile, and the data link. Any or all of these targets can be jammed. In each case, we will show the J/S formula and the burn-through range formula. As in earlier jamming discussions, the formulas for stand-off and stand-in jamming are the same. These formulas are more complex than the self-protection jamming formulas because the ranges to the jammer and the target from the radar and missile are different. The receiving antenna gains are also usually different.

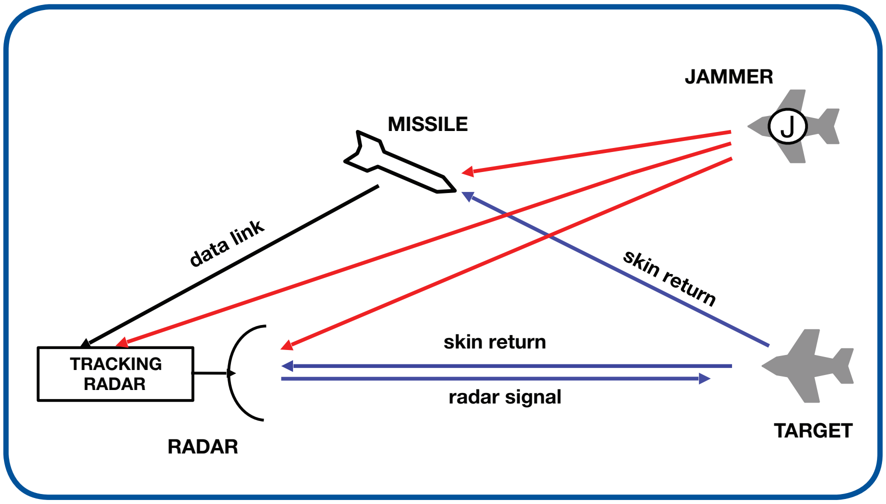

Figure 1. For remote jamming against a threat with a track-via-missile feature, the jammer must jam the tracking radar and also the missile receiver and/or the link from the missile to the radar.

REMOTE JAMMING OF THE TRACKING RADAR

Figure 2 shows the geometry for the remote jamming of the tracking radar and the missile receiver.

The formula for the jamming to signal ratio against the tracking radar is:

$$J/S = ERPJ - ERPS + 71 + GS - GM + 40 \log (RRT)\ 20 \log (RRJ) - 10 \log RCS$$

Where: *J/S* is the jamming to signal ratio in dB,

ERPJ is the effective radiated power of the jammer (toward the radar) in dBm,

ERPS is the effective radiated power of the radar in dBm,

GS is the side lobe gain of the radar antenna in dB,

GM is the main lobe boresight gain of the radar antenna in dB,

RRT is the range from the radar to the target in km,

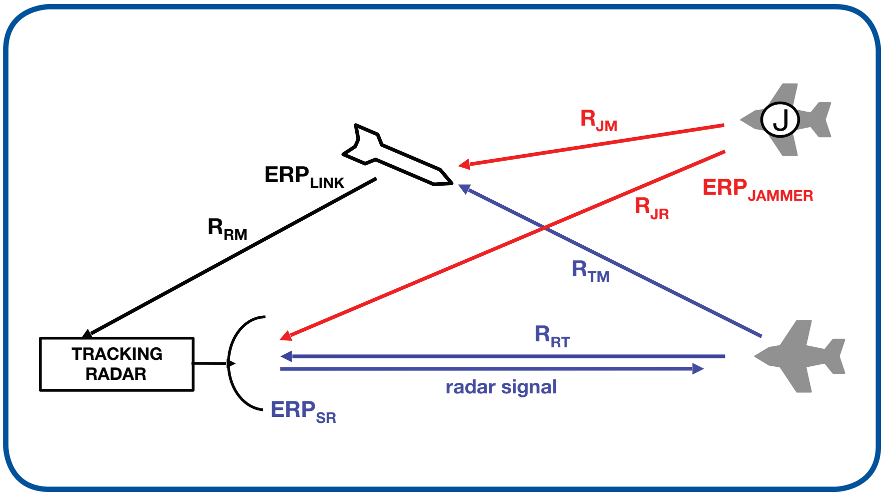

Figure 2. If the jammer only jams the tracking radar, the target aircraft is left vulnerable to targeting from signals received by the missile receiver and passed to the radar processor via the data link.

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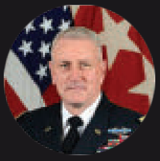
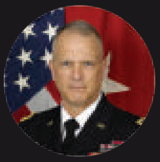


General John M. "Mike" Murray *(invited)*
Commanding General, US Army Futures Command



Brigadier General Robert M. Collins
PEO IEWS

The Honorable Dr. Bruce D. Jette *(invited)*,
Assistant Secretary of the Army for Acquisition, Logistics and Technology

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Contact Sean Fitzgerald, fitzgerald@crows.org, to learn more.

RRJ is the range from the radar to the jammer in km, and
RCS is the radar cross section of the target in m^2.

If we set the J/S to the minimum that can protect the target (arbitrarily set to 2 dB last month) and solve for the range from radar to target term, we get:

40 log (RRT) = ERPS - ERPJ - 71 + GM - GS +20 log (RRj) + 10 log RCS + J/S MIN

The formula for the burn-through range (RBT) is the radar-to-target range when the J/S is J/SMIN, so:

RBT = Antilog [(value of 40 log (RRT)) / 40]

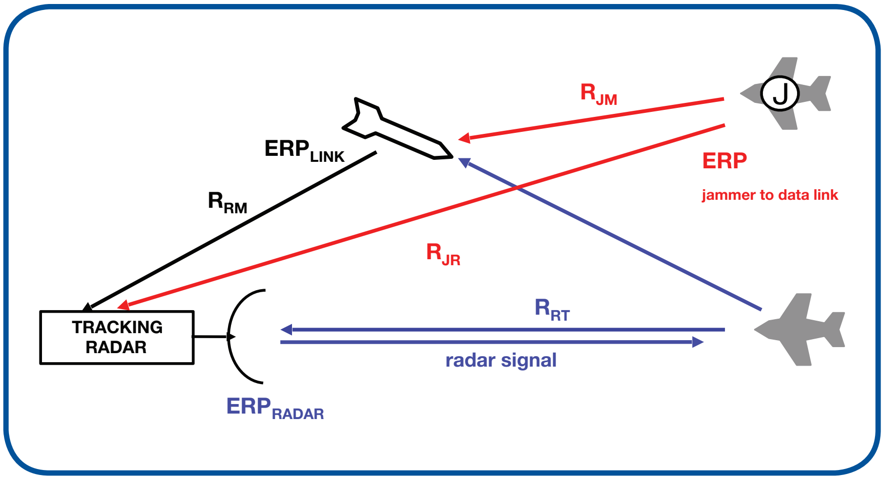


Figure 3. If the jammer jams the link, it performs communication jamming at the link frequency.

REMOTE JAMMING OF THE MISSILE RECEIVER

The formula for the jamming to signal ratio is:

J/S = ERPJM - ERPS +71 + GMS - GMM + 20 log (RRT) + 20 log(RTM) - 20 log (RMJ) - 10 log RCSB

Where: *J/S* is the jamming-to-signal ratio in dB,
ERPJM is the effective radiated power of the jammer (toward the missile) in dBm,
ERPS is the effective radiated power of the radar in dBm,
GMS is the side lobe gain of the missile antenna in dB,
GMM is the main lobe boresight gain of the missile antenna in dB,
RRT is the range from the radar to the target in km,
RMJ is the range from the missile to the jammer in km, and
RCSB is the bistatic radar cross section of the target in m^2

The burn-through range for tracking with the signal relayed through the missile is:

20 log (RRT) = ERPS - ERPJM - 71 + GMM - GMS - 20 log RTM + 20 log RMJ +20 log (RRJ) + 10 log RCSB + J/S MIN

The formula for the burn-through range (RBT) is the radar-to-target range when the J/S is J/SMIN, so:

RBT = Antilog [(value of 20log (RRT)) / 20]

REMOTE JAMMING OF THE DATA LINK

With careful observation, you will note that these formulas are the same as those given for self-protection jamming of the data link last month. However, last month the jammer was on the target. Now the jammer is remote from the target, as shown in **Figure 3.** You could argue that the jammer is now in the side-lobe of the link receiver. However, with a maneuvering missile, the link would need to have very wide antennas (as close to isotropic as practical). Thus, we can reasonably assume that the antenna gains don't change during the engagement.

The J/S formula for the jamming signal used against the data link is:

J/S = ERPJL - ERPL - 20 log (RJR) + 20 log (RMR)

Where: *J/S* is the jamming to signal ratio in dB,
ERPJL is the effective radiated power of the jammer against the data link in dBm,
ERPL is the effective radiated power of the data link transmitter in dBm,
RJR is the range from the radar to the jammer, and
RMR is the range from the missile to the radar in km.

REMOTE BURN-THROUGH RANGE FOR JAMMING THE DATA LINK

Solving this J/S equation for range at burn through gives:

20 log RMRBT = ERPL – ERPJL - 20log (RJR) + J/S Req

Where: *RMRBT* is the range term for the link propagation distance at which at the point the jammer is no longer effective (i.e., the "burn-through range").

Solving this equation for range at burn through gives:

RMRBT = Anti-log {(20 log RMRBT) / 20}

WHAT'S NEXT

Next month we will shift gears to talk about escort and modified escort jamming. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.

FEATURED LIVE COURSES

Introduction to Radar Systems

Kyle Davidson

Mondays, Wednesdays, & Fridays
13:00 – 16:00 EDT | July 29 – August 9
This course introduces the audience to radar systems in a military context, with a focus on search and tracking radars associated with modern day threats.

SPACE EW

Dave Adamy

Mondays, Wednesdays, & Fridays
13:00 – 16:00 EDT | September 4 – 20
In the eight sessions of this course, we will cover the nature of EW in space and go on to work practical EW problems appropriate to the space environment.

EW Modeling and Simulation

Dave Adamy

Mondays & Wednesdays
13:00 – 16:00 EST | March 2 – 25, 2020
This is a practical course in which the basic concepts and techniques of Electronic Warfare modeling and simulation are presented and applied to practical problems.

= Web Course, no travel required!

Airborne Expendables/UAS Capabilities and Potential

Dr. Patrick Ford

Mondays & Wednesdays
13:00 – 16:00 EDT | August 19 – 28
This course provides attendees with a strong foundation in expendables/sUAS, from basic airframe classes and capabilities, to EW potential, to the current FAA airframe and pilot certification/flight approval process.

21st Century Electronic Warfare, Systems, Technology, and Techniques

Dr. Clayton Stewart

Mondays, Wednesdays, & Fridays
13:00 – 17:00 EST | February 3 – 21, 2020
This course offers a comprehensive overview of modern electronic (EW) warfare systems, technology, and techniques.

Intermediate Electronic Warfare
EW EUROPE 2020

Dr. Clayton Stewart

Friday & Saturday | 08:00 – 17:00 BST
June 19 – 20, 2020 | Liverpool, UK
We will begin with a historical perspective and introduce use of radar, integrated air defense system, early EA functions and conclude with an overview of modern EA, ES, and EP.

WASHINGTON D.C. 56th AOC INTERNATIONAL SYMPOSIUM & CONVENTION

Fundamental Principles of Electronic Warfare

Dave Adamy
Saturday & Sunday
08:00 – 17:00 EDT | October 26 – 27

Advanced Principles of Electronic Warfare

Dave Adamy
Thursday & Friday
08:00 – 17:00 EDT | October 31 – November 1

Machine Learning for Electronic Warfare

Kyle Davidson
Saturday & Sunday
08:00 – 17:00 EDT | October 26 – 27

Electronic Countermeasures—Theory and Design

Kyle Davidson
Thursday & Friday
08:00 – 17:00 EDT | October 31 – November 1

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

DIXIE CROW EDUCATION FOUNDATION AWARDS SCHOLARSHIPS TO HIGH SCHOOL SENIORS

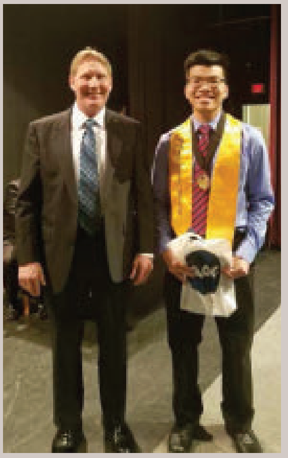
In May, the Dixie Crow Education Foundation awarded several scholarships to graduating high school seniors. Dixie Crow Chapter representatives presented the awards to each student at their schools.

Northside High School Scholarship Recipient: Kimberly Lopez

Perry High School Scholarship Recipient: Christopher Hamilton; Dixie Crow Chapter Representative: Rodney Brooks

Veterans High School Scholarship Recipient: Ryan Sant; Dixie Crow Chapter Representative: Matt Bryant

Warner Robins High School Scholarship Recipient: Makiyah Dee; Dixie Crow Chapter Representative: Mike Hopf



Houston County High School Scholarship Recipient: Christopher Saetia; Dixie Crow Chapter Representative: Ricky Westray

DIXIE CROW CHAPTER HONORS MEMORIAL DAY AT ANDERSONVILLE NATIONAL HISTORICAL SITE

The Dixie Crow Chapter commemorated Memorial Day by volunteering at The Andersonville National Historic Site in Andersonville, GA. Those who made the journey assisted the Boy & Girl Scout clubs along with the National Park Service Rangers with placing flags at the tombstones of fallen soldiers and feeding lunch to more than 300 volunteers, the largest crowd the Park Service has ever had.

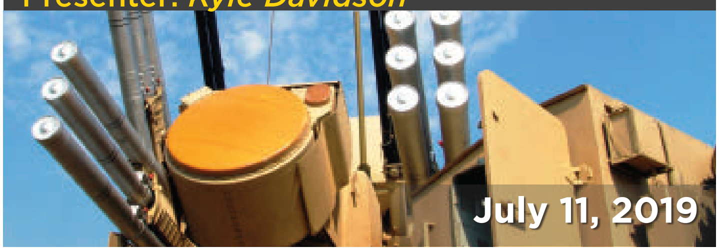
The Andersonville National Historic Site includes the National Prisoner of War Museum of the former Camp Sumter prisoner-of-war camp and the Andersonville National Cemetery.

Dixie Crow Chapter members in Attendance included: Mark and Martha Leslein, Robbie and Connie Edore, Tom Miller, James Miller, Debbie Koenig, Ron Herpst, Adam Delestowicz, Joe and Machelle Rhinerson, and Billy and Mary Ellen Gragg.

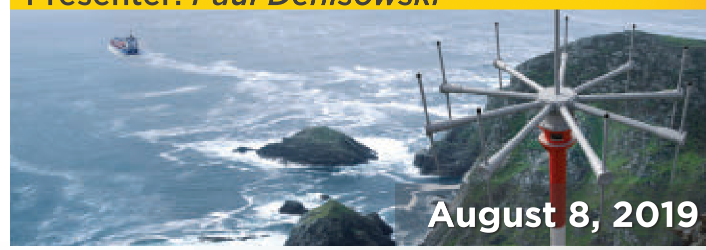
2019 AOC Virtual Series

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

Understanding Tracking Radars
Presenter: *Kyle Davidson*



An Introduction to RDF Methodologies
Presenter: *Paul Denisowski*



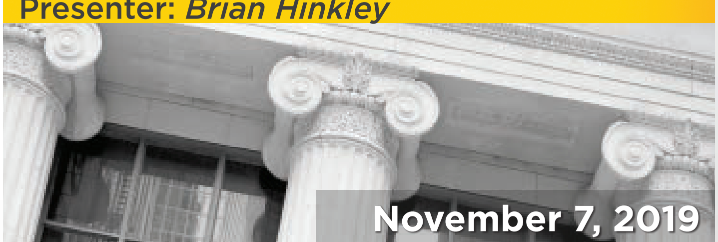
Evolving to the Next Generation of Multifunctional EW - Part II
Presenter: *Matthew Orr*

Intro to Machine Learning for EW
Presenter: *Paul Denisowski*

Achieving SWAP-C Benefits in EW Systems using Positive Gain Slope MMIC Amplifiers
Presenter: *Chris Gregoire*

RAF 100 Group and its EW Legacy
Presenter: *Thomas Withington*

The 3 Pillars of Electronic Warfare - Electronic Attack
Presenter: *Brian Hinkley*



The 3 Pillars of Electronic Warfare - Electronic Support
Presenter: *Brian Moore*

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

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