Vol. 63 • No. 12

December 2020

Microwave® Journal

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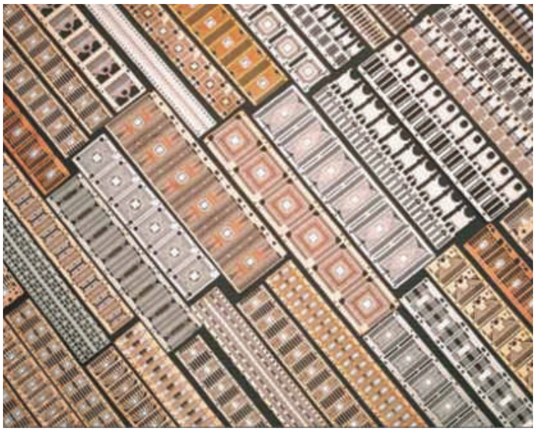

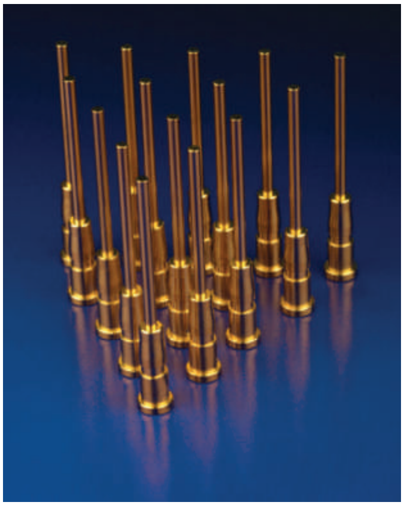

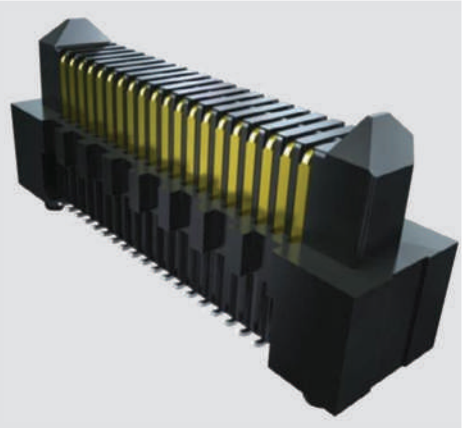

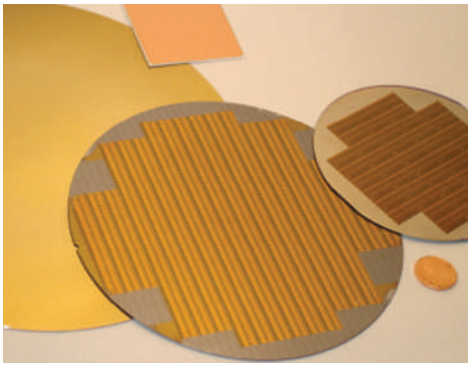

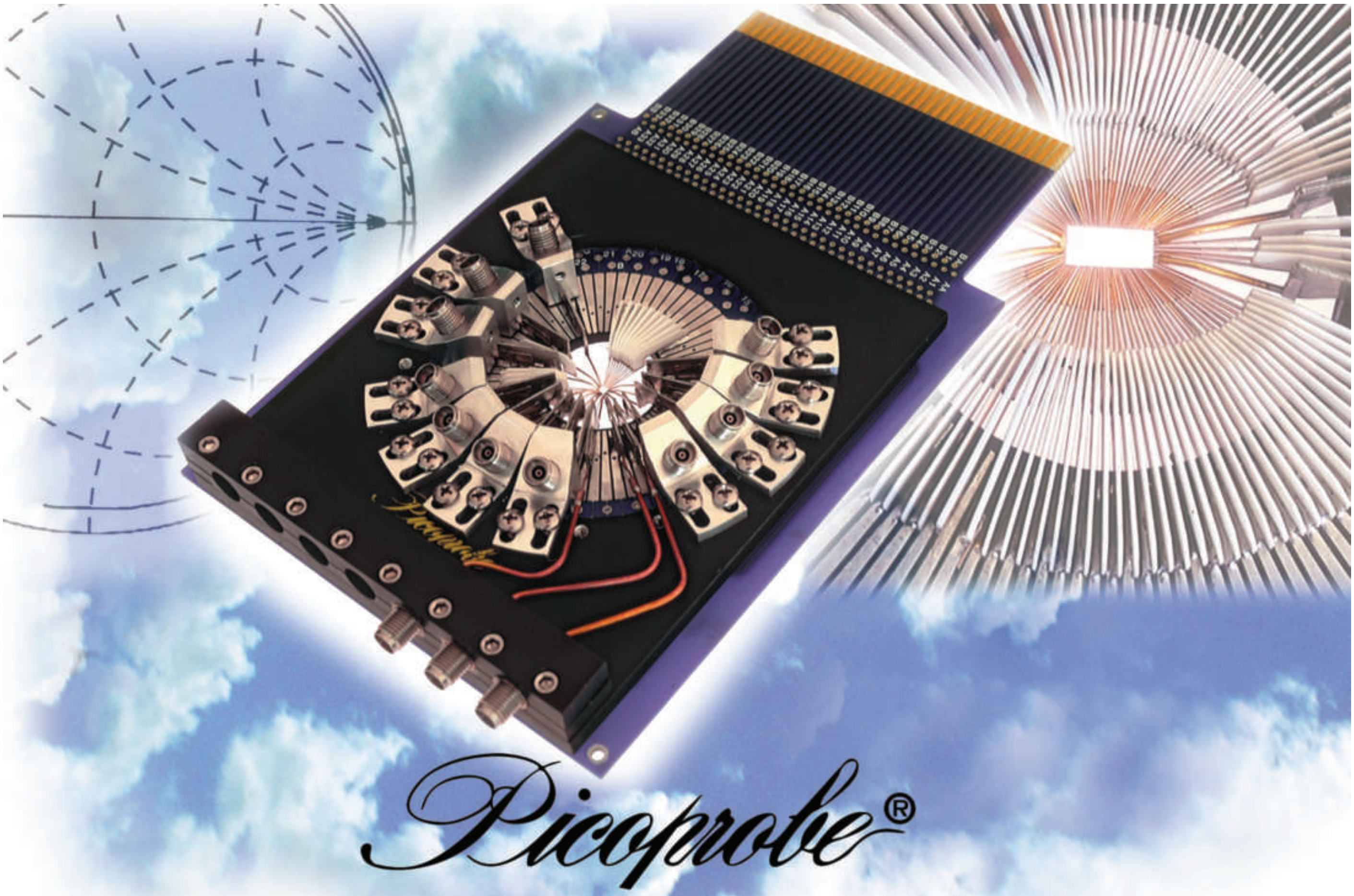

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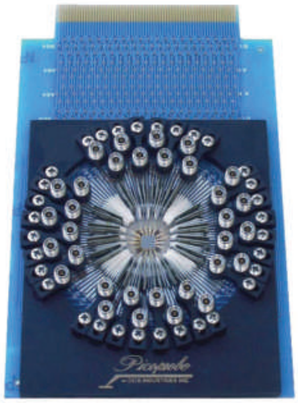

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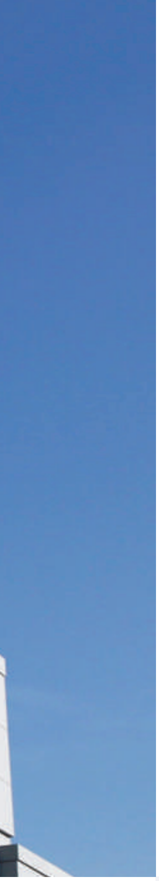

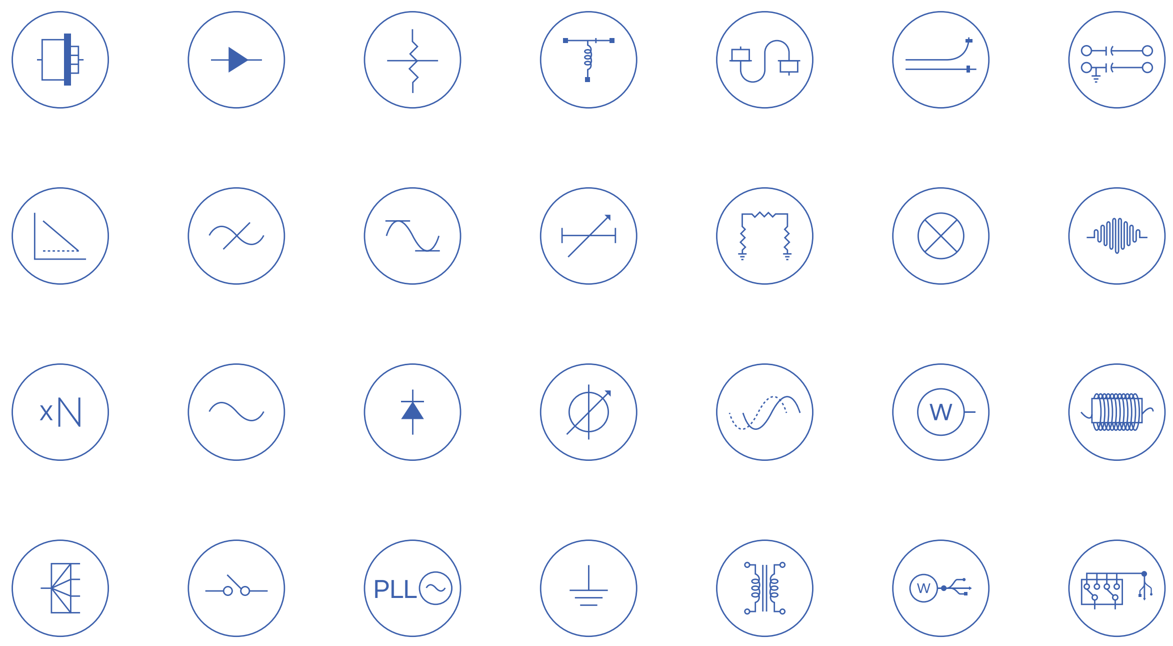

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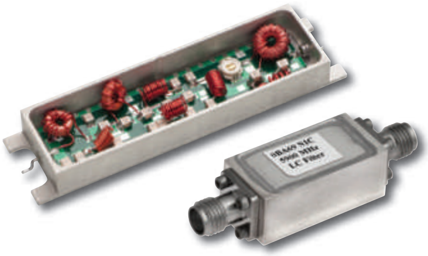
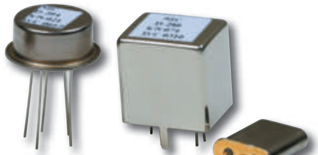
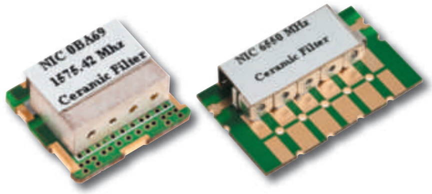


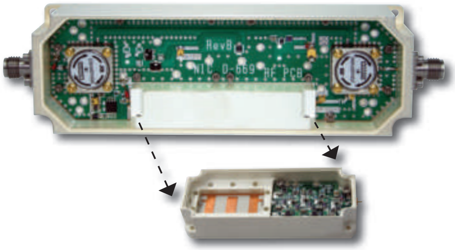
Discrete & Monolithic Crystal Filters



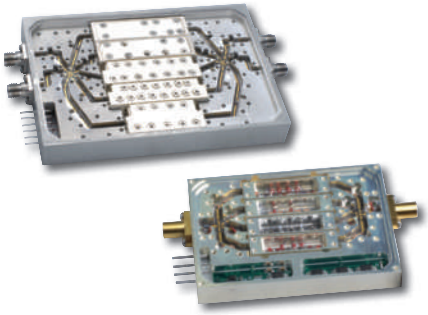
Ceramic Filters



Integrated Assemblies



Switch Filter Banks



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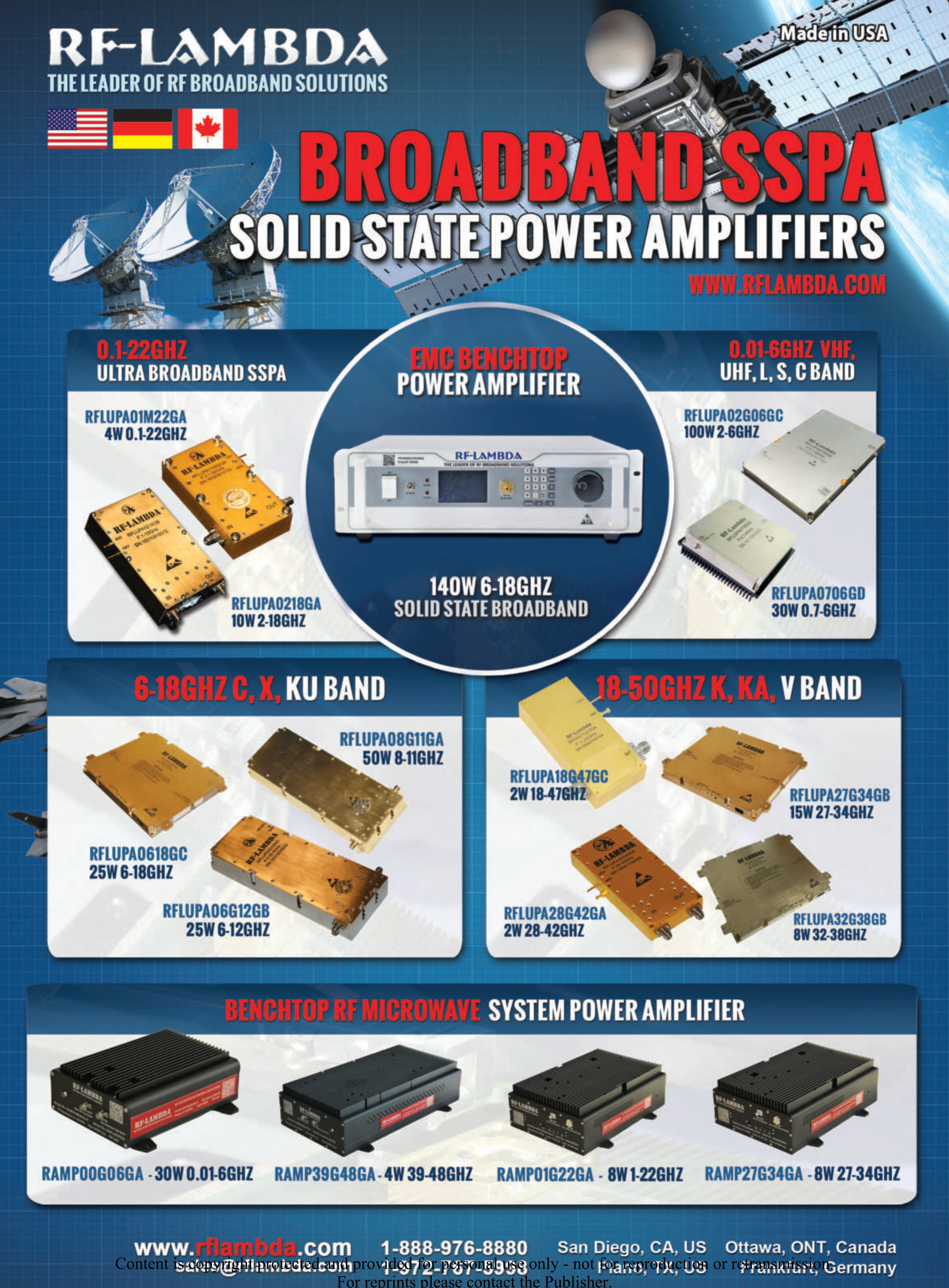

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Government & Military Electronics
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online spotlight

Look for this month's exclusive article online at mwjournal.com

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Technical Features

Editor's Note

Cover Feature

Special Report

EuMW 2020 Show Coverage

This month's cover:

This month's cover art was inspired by Van Gogh's iconic Starry Night painting along with this year's European Microwave Week show theme, "The Art of Microwaves." Vincent Willem Van Gogh was a Dutch painter who is among the most famous and influential figures from the Netherlands. The Cube SATs are an element that represent the Military & Government Electronics theme of our December issue. The Netherlands is also home to several R&D organizations related to aerospace activities which are featured in our cover story along with other local companies in the microwave industry.

63 YEARS OF PUBLISHING EXCELLENCE

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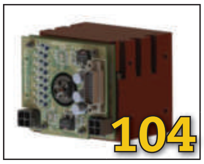

Product Features

Tech Briefs

2020 Editorial Index

A complete listing of 2020 *Microwave Journal* articles, organized by subject and indexed alphabetically by author, can be found at mwjournal.com/edindex2020.

Departments

Erratum: In our October Cover Feature, "Intensifying Technology Competition in the Acoustic Wave Filter Market" written by System Plus Consulting and Yole Développement, Figures 4 and 5 were reversed on page 26. To view the corrected version, please visit: mwjournal.com/articles/34710.

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Executive Interviews

Dean White, director of the defense and aerospace segment at **Qorvo**, discusses trends in the defense and space markets, how Qorvo is responding with technology and products and the company's recent SHIP program win.

Jeff Shealy, the founder, president and CEO of **Akoustis**, discusses the filter market opportunity which launched the company and the single crystal technology at the core of its better filter mousetrap.

Catch *Frequency Matters*, the industry update from *Microwave Journal*, microwavejournal.com/FrequencyMatters

WHITE PAPERS

- Copper Mountain Technologies — Measuring Millimeter Wave Materials for 5G and Advanced Sensing
- Keysight Technologies — Application Note: Easily Find Elusive Signal Faults with a Fault Hunter Infiniium EXR-Series Oscilloscopes
- Knowles — Wilkinson Power Dividers and Feed Networks: A Brief Overview
- NEL Frequency Controls, Inc. — App Note: Crystal Oscillator Based Clean-Up Modules
- Rohde & Schwarz — App Note: Basic RF Amplifier Measurements using the R&S® ZNB Vector Network Analyzer and "SMARTerCal"
- Teledyne e2v — On the way to RF Softwarization, Teledyne e2v Data Converters Push Digital Signal Processing Boundaries with Direct Access to Ka Band

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JANUARY

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10-15

VIRTUAL

The Defence, Security & Space Forum During European Microwave Week

VIRTUAL

Wednesday 13 January
08:30 to 14:30

A one-day focused forum addressing Space Situational Awareness. For details and to register, visit eumweek.com.

EuMW 2020 will be a virtual event this year while simultaneously planning for the next in-person event in London in October of 2021. EuMW 2020 includes the European Microwave Conference, the 15th European Microwave Integrated Circuits Conference and the 17th European Radar Conference. EuMW is organized by Horizon House on behalf of the European Microwave Association (Eu*MA*), an international non-profit association with a scientific, educational and technical purpose. The EuMW 2020 virtual event will begin on 10 January 2021 and run through 15 January 2021. Attendees can access conference sessions and visit the virtual booths until 5 February.

www.eumweek.com

11-14

VIRTUAL

The Consumer Technology Association (CTA) is reimagining how to connect exhibitors, customers, thought leaders and media from around the world while prioritizing health and safety. CTA is excited to share that CES 2021 will be an all-digital experience. For more than 50 years, CES has been the global stage for innovation. CES 2021 will continue to be a platform to launch products, engage with global brands and define the future of the tech industry. An all-digital CES 2021 will allow the entire tech community to safely share ideas and introduce the products that will shape our future. You'll be able to participate in all the awe-inspiring moments of CES wherever you are in the world.

www.ces.tech/planning-for-ces-2021.aspx

17-20

ARFTG

VIRTUAL

The ARFTG Microwave Measurement Symposium, which focuses on measurement techniques for accelerating the design of 5G circuits and systems, was scheduled for January 17-20, 2021 (co-located with Radio and Wireless Week) in San Diego, Calif., will be a virtual event. The program elements are expected to remain the same with some portions conducted live and others pre-recorded. Importantly, the main conference technical program will be intact, including: mmWave measurement techniques for communications and radars, mmWave antenna and OTA testing and test methods for the manufacture of mmWave and microwave component.

www.arftg.org/index.php/upcoming-conference/upcoming-conference-2

17-20

RWW

VIRTUAL

IEEE Radio & Wireless Week (RWW2021) consists of five related conferences that focus on the intersection between wireless communication theory, systems, circuits and device technologies. This creates a unique forum for engineers to discuss various technologies for state-of-art wireless systems and their end-use applications. RWW2021 will be held fully virtual on January 17-20, 2021.

www.radiowirelessweek.org

21

11am ET

VIRTUAL PANEL SESSION

Evolution of the RF Front End Virtual Panel

The smartphone RF front end has dramatically evolved over the last decade moving from a discrete amplifier and controller module to a complex module with duplexers/filters, switches, controllers and amplifiers that have to consider more than 1,000 frequency band combinations which will grow to more than 10,000 with 5G. This panel will discuss the evolution of the RF front end from 4G to 5G; the best current technologies for acoustic filters, switches, amplifiers and power management; will OpenRF work to reduce costs and improve performance; and what future mobile device RF front ends are expected to look like.

Organized by: Microwave Journal

mwjournal.com/virtualpanels

FOR DETAILS, VISIT MWJOURNAL.COM/EVENTS

Coming**Events**

CALL FOR PAPERS

CS MANTECH 2021
December 18, 2020

IEEE International Conference on Communications (ICC)
January 20, 2021

EDI CON China 2021
May 15, 2021

mwjournal.com

JANUARY

European Microwave Week (EuMW)
January 10–15 • Virtual
www.eumweek.com

CES 2021
January 11–14 • Virtual
https://www.ces.tech/planning-for-ces-2021.aspx

IEEE Radio & Wireless Week (RWW)
January 17–20 • Virtual
www.radiowirelessweek.org

96th ARFTG Microwave Measurement Symposium
January 17–20 • Virtual
https://www.arftg.org/index.php/upcoming-conference/upcoming-conference-2

FEBRUARY

International Conference on Computing, Communication, and Intelligent Systems (ICCCIS)
February 19–20 • Virtual
http://www.icccis.in/

MARCH

2021 IEEE Aerospace Conference
March 6–13 • Virtual
https://aeroconf.org/

EMV
March 23–25 • Stuttgart, Germany
https://emv.mesago.com/stuttgart/en.html

APRIL

IEEE WAMICON
April • Clearwater Beach, Fla. & Virtual
https://www.ieeewamicon.org/

DesignCon 2021
April 13–15 • San Jose, Calif.
https://www.designcon.com/en/home.html

2021 IEEE Conference on Technologies for Sustainability (SusTech)
April 22–24 • Virtual
https://ieee-sustech.org/

MAY

IEEE EMC+SIPI 2021
May 3–7 • Raleigh, N.C.
http://www.emc2021usa.emcss.org/

Space Tech Expo USA
May 10–12 • Long Beach, Calif.
https://www.spacetechexpo.com/

CS Mantech
May 24–27 • Orlando, Fla.
www.csmantech.org

JUNE

IEEE MTT-S IMS2021
June 6–11 • Atlanta, Ga.
https://ims-ieee.org/ims2021

Military Space USA
June 8–9 • Los Angeles, Calif.
https://www.smi-online.co.uk/defence/northamerica/milspace-usa

IEEE International Conference on Communications (ICC)
June 14–18 •Montreal, Canada
https://icc2021.ieee-icc.org/

MilSatCom USA
June 23–24 • Arlington, Va.
https://www.smi-online.co.uk/defence/northamerica/MilSatCom-USA

MWC Barcelona
June 28–July 1 • Barcelona, Spain
www.mwcbarcelona.com

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- Phased array radar and electronic warfare
- Electronic test and measurement systems

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What a Year – Glad to Put 2020 Behind Us

Pat Hindle, *Microwave Journal* Editor

2020 will go down in history as the most tumultuous year in modern time. From the COVID-19 virus to tense elections to trade disputes to social unrest worldwide. The impact of COVID-19 on the financial markets and reduced industrial activity will be felt for years to come. In the wireless industry, the roll out of 5G was slowed in the first half of this year but has roared back to near expected levels of activity.

Many trade shows were cancelled like Mobile World Congress Barcelona while others went virtual like the IEEE MTT-S International Microwave Symposium (IMS2020). The only trade show in our industry to take place in-person this year after COVID-19 was EDI CON China in Beijing. While attendance was light, this in-person event in China was a huge accomplishment, as China is one of just a few countries holding full-size events after the virus outbreak.

The hottest topic in our industry continues to be 5G as we saw the first stand-alone 5G and mmWave networks be deployed. 5G mmWave capabilities even showed up in the latest iPhone 12 and 12 Pro models proving it is becoming available in some areas. A related new trend in our industry is standardization or White Box as Open RAN became popular and the OpenRF Consortium was established for RF front end interface standardization. These standard interfaces promise lower cost, increased competition and reduced time to market but there are questions about if it reduces overall performance and innovation.

mmWave systems are becoming mainstream with the commercialization of low-cost phased arrays for SATCOM and 5G applications. Various companies are vying for the market using several different technologies. Wide use of high frequency silicon processes has greatly lowered the cost of devices and enabled the integration of the digital and control functions needed to realize advanced scanning and power saving techniques. This commercialization of phased arrays is also enabling new antenna technologies using metamaterials, dielectric resonators, LCD apertures, unique antenna shapes and spacings that improve efficiency, increase scanning angles and reduce costs.

With the 5G NR Release 16 finalized, 5G is further enabling Industry 4.0, connected/autonomous vehicles and smart cities. ABI Research expects the global Industry 4.0 market size to rise from $68 billion in 2018 to $205 billion by 2025 at a CAGR of 17 percent. The network providers are looking to these areas for larger growth initially for 5G rather than consumer data subscriptions. Autonomous vehicles, including drones and transportation vehicles, are an area of future growth with V2X communications being added to the 5G network via Release 16. Most of the Asian countries are leading in implementing smart cities as they connect services, people and vehicles to the network.

While President Trump waged war on Chinese companies like Huawei and ZTE, the new President Elect, Joe Biden, promises to be more business friendly internationally allowing companies to compete globally without government interference. We hope that it opens a new era of a more cooperative atmosphere between the U.S. and China (maybe even Russia) that will help and not hurt businesses internationally–but still maintain a fair and competitive market.

With some COVID-19 vaccines on the near horizon, we hope to see you at some events next year. We wish everyone a safe and successful future as we overcome COVID-19 and look forward to better years ahead.


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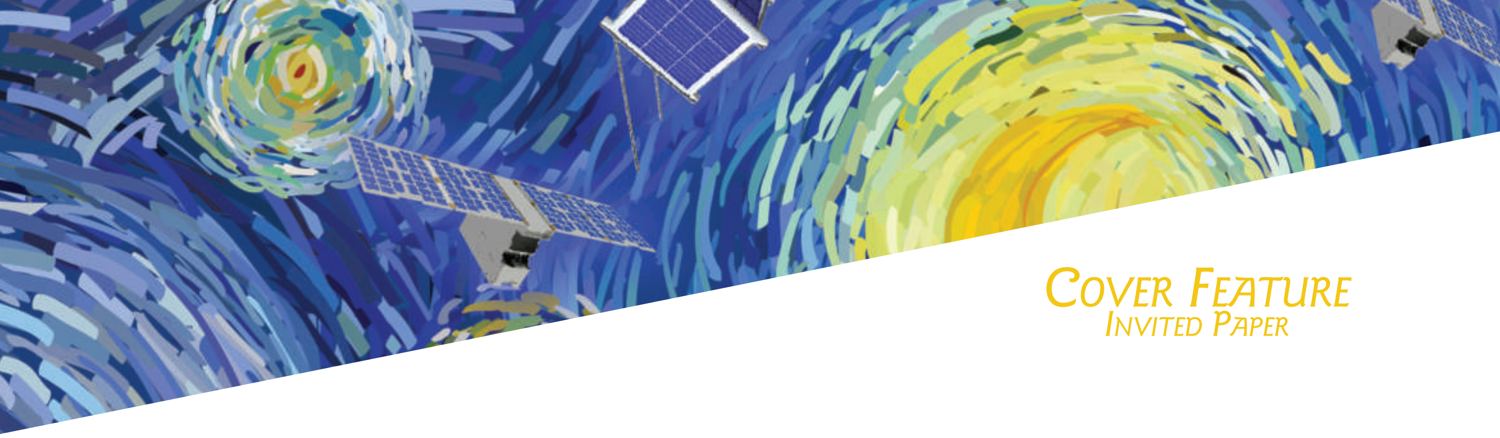


Benelux—At the Heart of Europe's Microwave Design Community and the EU Government Research Framework

Helen Duncan
MWE Media Ltd., U.K.

This year, European Microwave Week was to take place at a new location in the Netherlands—Utrecht, which is about 35 km south-east from the capital, Amsterdam. In common with its better-known neighbor, Utrecht has a network of picturesque inner-city canals and an attractive selection of shops and restaurants, as well as museums and ancient landmarks (some dating back as long ago as Roman times). However, due to the COVID-19 pandemic, it will take place virtually. The EuMW and Horizon House teams have selected a virtual trade show platform and are coordinating a full conference and engaging exhibition online.

The theme, **The Art of Microwaves,** continues to support the activities surrounding the event this year. In this article, we profile many of the RF/microwave companies and organizations shaping our industry. The Netherlands and surrounding region are the home to several government and space research organizations, fitting of our theme this month for EuMW and government/military electronics, plus many other semiconductor, test and software companies.

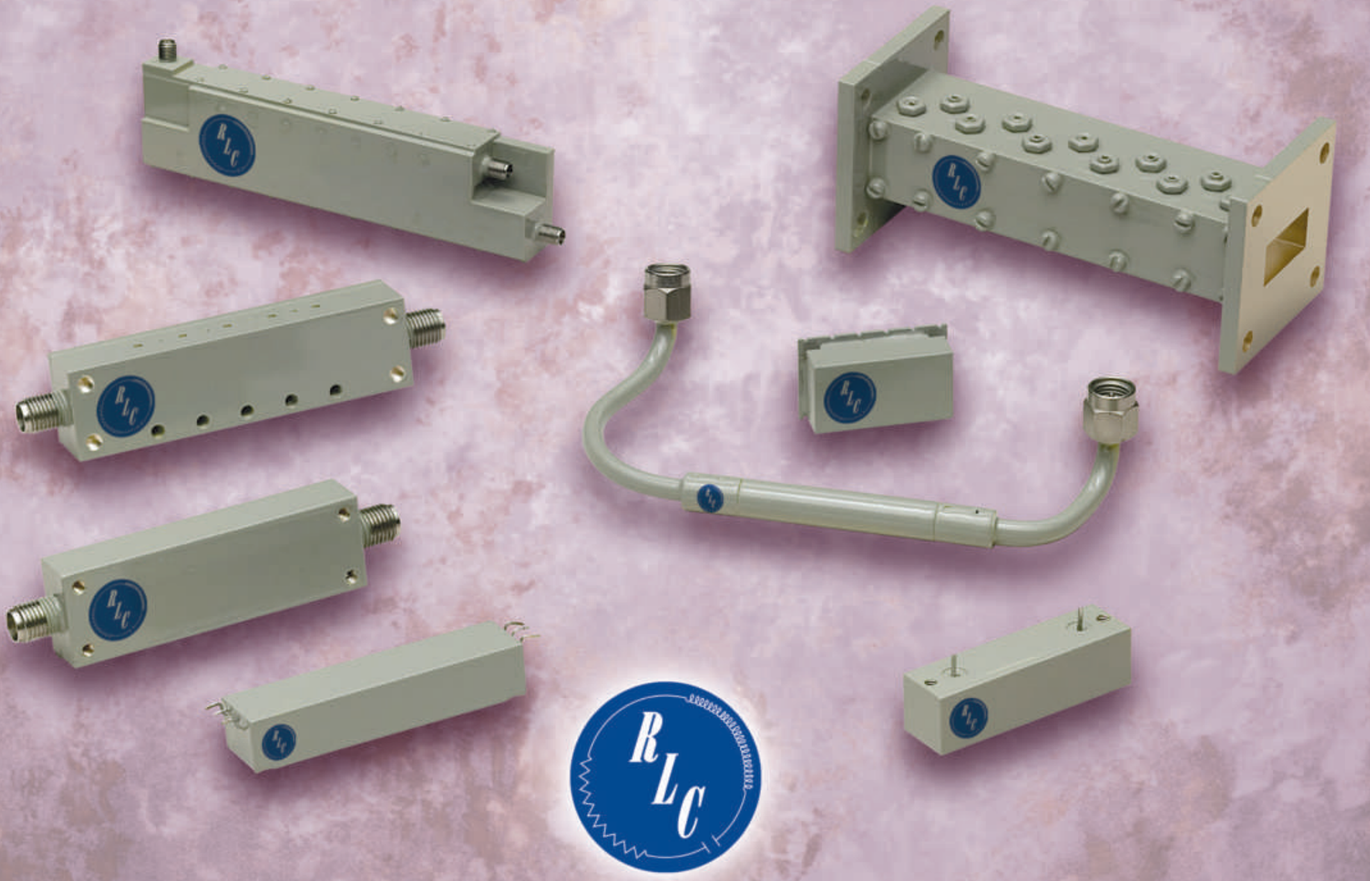
Economically, the Netherlands is part of the Benelux region, which also comprises Belgium and the tiny grand duchy of Luxembourg. The Treaty of the Benelux Economic Union was signed in 1958, and became operative in 1960, making Benelux the first free international labor market, with unrestricted movement of capital and services. These principles provided inspiration during the founding of the European Economic Community—now the European Union (EU)—effectively placing Benelux and its values at the heart of Europe.

It also plays a key role in the government of the EU, as some of the committee meetings and plenary sessions of the European Parliament are held in Brussels, while its administrative offices are in Luxembourg, including those of CORDIS (Community Research and Development Information Service). CORDIS coordinates and disseminates the results from projects funded by the EU's framework programs for research and innovation, including Horizon 2020. Over the years, the pan-European framework programs have produced a wealth of innovation in RF and microwave technology, including work on compound semiconductor devices as well as on some of the fundamental technologies on which wireless and cellular technology has been built.

GOVERNMENT RESEARCH AND COLLABORATION

One of the most prominent participants in the Netherlands RF and microwave community is TNO, which in full stands for Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, an independent research organization based in The Hague, which employs over 3,400 professionals. TNO also plays a huge part in this European Microwave Week, as Frank van den Bogaart, principal consultant at TNO, is the president of the European Microwave Association and his TNO colleague, Frank van Vliet, is the EuMW 2020 general chair.

TNO's stated mission is to connect people and knowledge, to create innovations that boost the com-



petitive strength of industry and the well-being of society in a sustainable way. It is achieving this by focusing on driving change and improvement in nine socially driven areas, which include the built environment, sustainability, defense/safety/security, energy, healthy living, industry, ICT, strategic analysis and policy and transportation. Obviously microwave technology, specifically 5G, has a part to play in almost all of these end-use applications.

In October 2020, TNO and Columbia University posted a position paper that focuses on detection and response to oil- and gas-related methane emissions, which have been the subject of increasing focus on the part of industry and the public policy community. It addresses the significance of methane emissions for the climate, and the challenges of detecting and accurately quantifying methane emissions. It then explores the evolving capabilities of satellite-based methane detection and monitoring systems, which are expected to advance rapidly in the coming years, and can be especially powerful when used in concert with aerial and ground-based monitoring systems. It concludes with a discussion of the implications of the changing satellite detection landscape for the oil and gas industry, the finance and investment community and the realm of public policy.

In June 2020 it was announced that a fully-fledged 5G Standalone test network, which is more advanced than today's commercially available 5G networks, had been commissioned at TNO, to support innovations in the vertical sectors supported by 5G and beyond. The TNO 3.5 GHz 5G test network enables testing of advanced use cases such as augmented/virtual reality, high speed video connections, self-driving cars and drones, demonstrating latencies as low as 10 ms. The test network combines Ericsson's 5G base stations with a cloud-native open 5G core network based on Fraunhofer's Open5GCore, running on TNO's cloud platform in containers orchestrated by Kubernetes.

GOVERNMENT SPONSORED SPACE RESEARCH

The Netherlands' leading role in Europe means that it is also home to the **European Space Research and Technology Centre (ESTEC)** in Noordwijk, run by the European Space Agency (ESA). ***Figure 1*** shows a prototype 2.6 m diameter metal-mesh antenna reflector, produced as part of ESA's advanced techniques for mesh reflector with improved radiation pattern performance (AMPER) project. This represents a big step forward for the European space sector, because versions can be manufactured to reproduce any surface pattern that antenna designers require—something that was previously possible only with traditional solid antennas. This is needed so that large antennas that might be too bulky to fit inside a launcher fairing can be deployed in orbit. The basic paraboloid convex shape of a solid satellite antenna is distorted with additional peaks and valleys to contour the RF beam, typically to boost signal gain over target countries and minimize it beyond their borders, it was a challenge to reproduce this shaping using a mesh reflector design. This shaped mesh reflector design is based on tension members supported by a peripheral truss structure, which enables decoupling of the shaped surface and the structure—a design that can be implemented

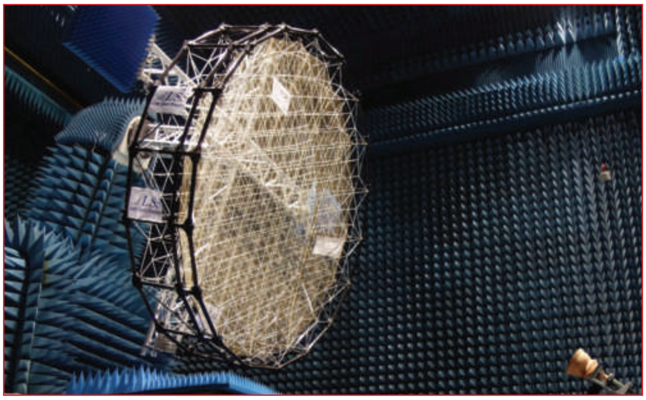


Fig. 1 Prototype 2.6 m mesh-reflector antenna being tested in ESA's Hertz chamber at its ESTEC technical center in the Netherlands.

for any size of reflector, for any frequency ranging from P-Band to Ka-Band, and for either deployable or fixed reflector technology.

Together with the **Netherlands Space Office (NSO)**, ESTEC also supports ESA's incubation program in the Netherlands, ESA BIC Noordwijk, which is a hub set up to nurture both novice and experienced entrepreneurs with technology ambitions in the field of space. Although there are 22 such centers throughout Europe, ESA BIC Noordwijk was the first to be established in 2003, since then it has supported more than 120 space startups. One of these is hiber—a network of small satellites that provides IoT connectivity with global coverage. hiber plans to deploy a constellation of CubeSats to provide low cost IoT services around the world (see ***Figure 2***).

SEMICONDUCTOR CLUSTER

Two of the major RF semiconductor companies in the Netherlands—NXP and Ampleon—were both originally spun out from Philips, the Eindhoven-based multinational giant that was once a leader across many sectors of consumer and professional electronics, but is now specialized in healthcare technology. The Philips legacy means there is a concentration of semiconductor expertise around Eindhoven and Nijmegen, which continues to foster new startups like Altum RF and Staal Technologies.

NXP's flagship design and manufacturing operations are located at the Eindhoven High Tech Campus in the Netherlands, where its R&D activities include the development of IP blocks, design tools and test and verification methodologies, as well as some product design. Most of the RF work, however, takes place in Nijmegen, where the ICN8 8-in. wafer fab—manufacturing over 500,000 wafers per year—is located, along with further R&D facilities. NXP's Smart Antenna Solutions team in Nijmegen is working on the development of mobile RF front end solutions. Its Automotive Radio team is also working at RF, making RF CMOS-based radio receivers and software-defined radio solutions.

At last year's European Microwave Week in Paris, NXP announced its RF Airfast power multichip module range for the development of massive MIMO (mMIMO) active antenna systems for 5G base stations. In October 2020 NXP announced that NEC had selected RF Airfast modules for use in a mMIMO 5G antenna radio unit for Rakuten Mobile, one of Japan's leading mobile network operators. The Airfast range includes LDMOS Doherty power amplifier modules, GaAs/SiGe pre-driver modules and receiver modules for cellular frequency bands from 2.3 to 3.8 GHz, with output power from 3 to 5 W. Designed with a common footprint across frequency and power, they can enable a fast time-to-market for OEMs and mobile network operators, as well as offering higher levels of integration to reduce power amplifier size, shorten design cycles and simplify manufacturing. This fall they announced the opening of a 6-in. GaN fab in Arizona in the U.S. to address 5G demand and expand their GaN portfolio of products.

Ampleon specializes in RF power devices, offering a range of discrete transistors, MMICs, pallets and modules in LDMOS as well as GaN technology for a range of applications, such as mobile broadband infrastructure, broadcasting, CO_2 lasers and plasma, MRI, particle accelerators, radar and air-traffic control, RF

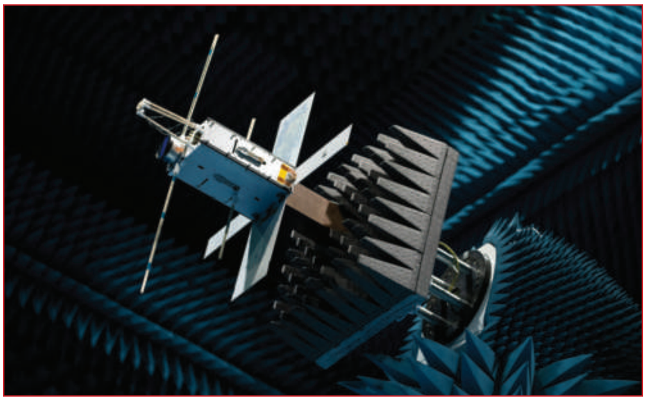


Fig. 2 An engineering model of a hiber CubeSat inside ESA's Hertz chamber at ESTEC in the Netherlands (courtesy of ESA).

ECONOMICAL APPROACH TO EXTEND EXISTING RF EQUIPMENT TO 5G mmWave

As new and innovative technologies for wireless communications continue to emerge and push into mmWave 5G bands, you must be able to adapt and enhance the lifetime of your existing RF systems to meet these new bands in an agile manner, while managing ever-tighter resources and budgets. Now, you can retain existing field, lab, and manufacturing test equipment, extend the life of your investment, and reduce time to market and costs when measuring 5G mmWave signals.

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cooking and defrosting, RF heating and plasma lighting. Ampleon was created in 2015 as a spinoff of the NXP/Freescale merger. Headquartered in Nijmegen, it has more than 1,650 employees worldwide. Its latest device is the BLF989E RF power transistor, which uses Ampleon's ninth-generation high-voltage (50 V) LDMOS process technology and is designed for use in UHF TV transmitters. With a peak power capability more than 1 kW, the BLF989E provides an average (DVB-T) output power of 180 W, shrinking the size of digital TV amplifiers by 20 percent. An ultra-wideband Doherty application circuit for the device enables it to achieve 50 percent efficiency and can cover the complete 470 to 700 MHz digital TV transmission band with a single amplifier, reducing service costs for broadcast network operators. It also works with digital pre-distortion to provide the high linearity required when transmitting digital TV signals with very low bit error rates.

Altum RF in Eindhoven is a relative newcomer to the RF and microwave semiconductor industry. Founded in 2019, it sells a range of bare die and packaged chips, including power amplifiers operating at E-Band (71 to 75 GHz and 81 to 86 GHz). In June 2020, Altum RF introduced its latest high efficiency linear amplifier for high data-rate applications such as mmWave 5G and 24 GHz ISM applications. Operating in the range 22 to 30 GHz, the ARF1010Q4 delivers 28 dB of linear gain and 36 dBm OIP3 at +20 dBm output. Packaged in a 4 × 4 QFN, it requires only a positive voltage supply, and can deliver 1 W output power at 26 GHz with 23 percent power added efficiency.

Staal Technologies (formerly Omniradar) is also based in Eindhoven. Its flagship product is the RIC60A 60 GHz single-chip radar, which is capable of detecting speed, range, shape and material over a range of 0 to 5,000 mm to an accuracy of 2 mm and a resolution of 21 mm. Power consumption is less than 1 W, making it suitable for battery powered devices for the IoT, including Smart City traffic monitoring and waste management, healthcare and collision avoidance and proximity sensing in robotics. The SiGe integrated circuit is packaged in a QFN44 package measuring 7 mm square, with integral antennas, and can be configured as either an FMCW radar or a Doppler radar. An integrated dual receiver provides angle-of-arrival measurement. It features I- and Q-receiver channels for identification of direction of motion and the transmit power amplifier, receive low-noise amplifier and IF amplifiers are all included.

SOFTWARE/TEST AND MEASUREMENT

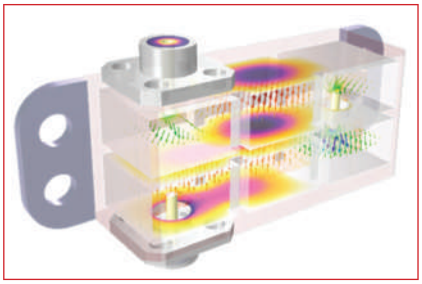
Another company with a major presence in the Netherlands is **COMSOL**, whose multiphysics simulation software can be used for modeling designs, devices and processes in all fields of engineering, including electromagnetics. COMSOL is headquartered in Stockholm and recently previewed its upcoming release of COMSOL Multiphys-

ics® version 5.6 that brings faster and more memory-efficient solvers, better CAD assembly handling, application layout templates and a range of new graphics features. For RF engineers, the RF Module and Wave Optics Module provide a new option for port sweeps, enabling faster computations of full S-parameters or transmission and reflection coefficient matrices. This functionality can be applied to the analysis of passive 5G components such as microwave filters with a large number of ports (see ***Figure 3***). A new modeling tool for approximate asymptotic scattering allows for quick far-field and radar cross section analysis for convex-shaped objects. A new set of postprocessing tools makes it easier to visualize and analyze polarization, with important applications for a variety of periodic structures including metamaterials for optics and microwaves. The new version of the Ray Optics Module includes faster ray tracing and specialized tools for scattering from surfaces and within volumetric domains.

The Benelux region is home to no less than four manufacturers of microwave absorbers, shielding materials and anechoic chambers. **Holland Shielding Systems** in Dordrecht, the Netherlands, makes a range of EMC and EMI shielding materials, Faraday cages and test enclosures and absorbers. **Comtest Engineering** in Zoeterwoude, the Netherlands, builds anechoic chambers, EMC test chambers and antenna test ranges for a wide range of industrial and research applications. Earlier this year, Comtest Engineering entered into a teaming agreement with **Amplifier Research (AR)** to provide a single testing solution for their EMC customers. The partnership combines AR's knowledge of high performance EMC instrumentation and Comtest's experience in constructing EMC chambers to provide a turnkey service, from design to completion of a fully operational test facility.

Dutch Microwave Absorber Systems (DMAS), also in Zoeterwoude, was founded by Bas de Groot, the managing director of Comtest, and is an independent supplier of high performance expanded polystyrene microwave absorbers suitable for anechoic and semi-anechoic chambers for both EMC and broadband microwave test. Unlike conventional polyurethane based absorbers, DMAS polystyrene absorbers do not need to include toxic fire-retardant chemicals.

Over the border in Westerlo, Belgium, **E&C Anechoic Chambers** has a long history, as part of Emerson and Cuming, in developing and manufacturing microwave absorbing



▲ Fig. 3 A multiphysics model of a cascaded cavity filter operating in the mmWave 5G band, including temperature changes and thermal stress.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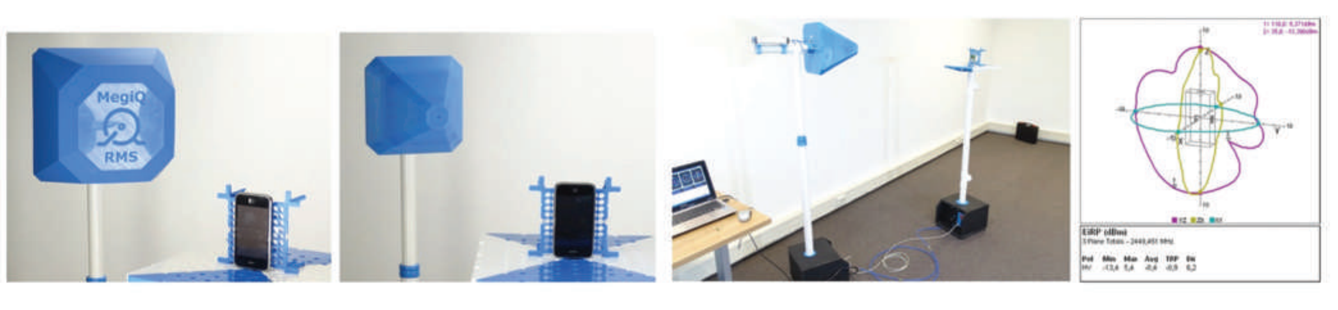


Fig. 4 **MegiQ compact 600 MHz to 6 GHz radiation measurement system compact test system.**

materials and anechoic chambers. It is now part of German group **Albatross Projects**, which itself plans and builds anechoic chambers.

Also related to antenna measurements, **MegiQ** in Eindhoven sells low cost VNAs and radiation measurement systems for communications systems up to 6 GHz. RMS-0660 (see ***Figure 4***), for example, is a compact 600 MHz to 6 GHz radiation measurement system compact test system that performs three-axis antenna radiation pattern measurements in relatively small non-anechoic spaces. The RMS system has an accuracy of ± 1 dB, with an additional uncertainty of 1 to 2 dB expected due to reflections. The repeatability of measurements is ±0.5 dB, with no user calibration required.

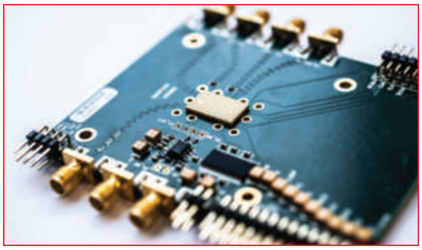
BELGIUM – A CENTER FOR CHIP INNOVATION

Leuven in Belgium is home to the headquarters of **IMEC**, a research and innovation hub whose mission is to provide infrastructure to connect bright minds internationally, across industry and academia. IMEC has 12 offices on three continents—six of them across Belgium and the Netherlands, with the others in the U.S. and spread across Asia Pacific.

At August's virtual IEEE RFIC conference, IMEC presented a mmWave motion detection radar at 60 GHz, integrated on a standard 28 nm CMOS process, that is optimized for vital sign monitoring and gesture recognition (see ***Figure 5***). Achieving 20 mm range resolution, the compact 4.15 mm^2 transceiver chip consumes only 62 mW of DC power, making it suitable for integration into small, battery powered devices. As an FMCW radar its high modulation bandwidth of 7.2 GHz gives it ultra-fine resolution suitable for 3D sens-

ing of finger motions, hand swiping and gestures. Its suitability has also been demonstrated for multi-target detection, heartbeat detection at a 5 m distance and accurate tracking of a pedestrian's position and velocity. A quick start-up time (1 µs) supports aggressive duty-cycling for further power reduction. A reference module design is available for the single-channel radar, including the antenna. In the rapidly growing field of eHealth, there will be a range of smart IoT applications this radar sensor could be used for, like baby monitoring, senior care, patient monitoring and sports performance, as well as more general applications like worker safety. This research received funding from the European Community's PRYSTINE project, which is aimed at developing sensors for safer autonomous driving.

Melexis, based in Ieper, Belgium, has a long-standing reputation for designing and developing



▲ Fig. 5 **IMEC's 60 GHz radar design, for vital sign monitoring and gesture detection.**

mixed signal ICs for low-power radio applications like RFID, wireless remote entry and industrial, scientific and medical applications. One of its most popular RF products is the MLX71122 multi-channel programmable FSK/FM/ASK double-conversion superheterodyne receiver IC for the 315, 433, 868 or 915 MHz ISM frequency bands.

Tusk IC is an IC design house based in Antwerp, Belgium, specializing in mmWave IC design. Its mission is to speed up the development cycle and reduce time-to-market for its clients, focusing on silicon mmWave circuit designs from 10 up to 300 GHz+ and beyond, with the ability to measure and validate prototypes up to 1.1 THz. Its experience ranges from transistor-level to packaging interface in advanced CMOS, SOI and SiGe processes. Tusk IC was founded in January 2018 as a spinoff from the ESAT-MICAS research group at KU Leuven, where the company's four founders had obtained their PhD degrees, specializing in mmWave CMOS integrated circuits and systems.

CONCLUSION

The position of the Benelux region at the heart of Europe, both geographically and administratively, has fostered its open and collaborative approach to government/scientific research and development, as evidenced by the success of the two main hubs, TNO and IMEC, as well as ESTEC for space-focused research. Furthermore, the lasting legacy of Philips Semiconductors has influenced a generation of new enterprises that are using a variety of mainly silicon-based chip technologies to power the smart applications of the 21st Century.■

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Analog Signal Generators	845	100 kHz to 12, 20 or 26.5 GHz	30 µs
	865	100 kHz to 6, 12.75, 20, 26 or 40 GHz	30 µs
Vector Signal Generator	875	10 MHz to 4, 6, 20 or 40 GHz	200 ns

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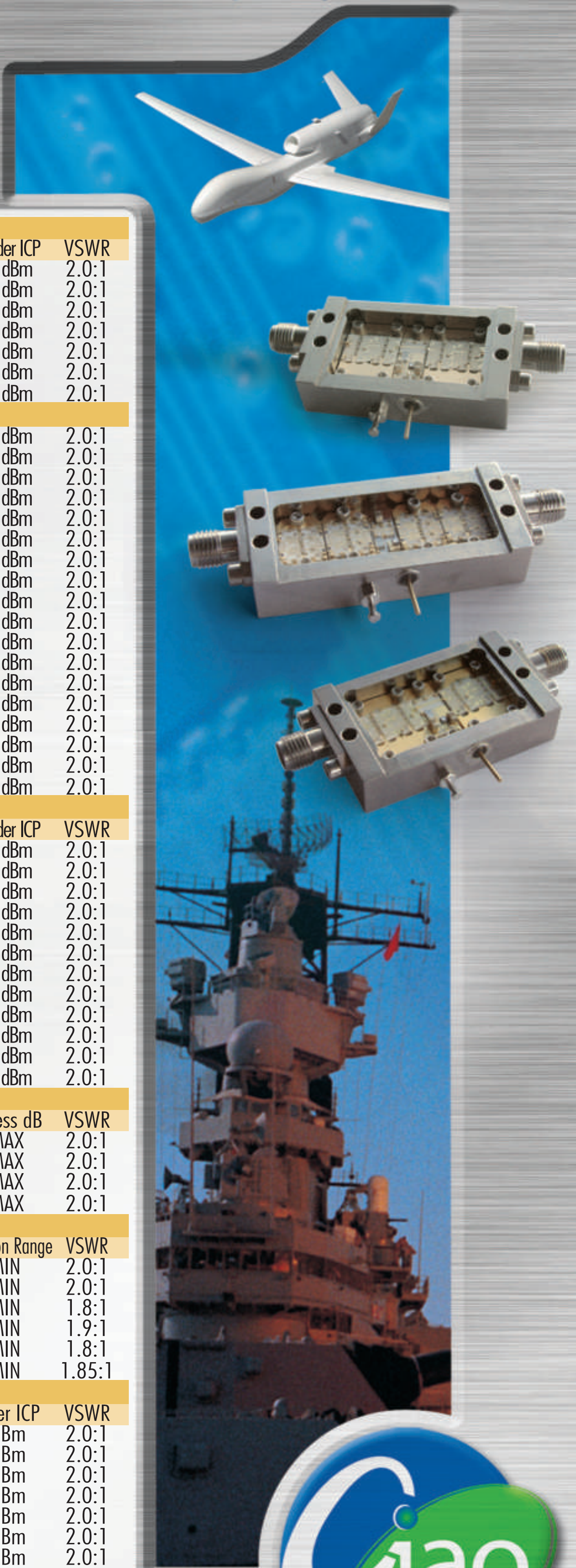

OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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StormBreaker Smart Weapon Approved for Fielding on the F-15 Eagle

Raytheon Missiles & Defense recently announced the StormBreaker® smart weapon has been approved for use on the F-15E by the U.S. Air Force's Air Combat Command. The fielding decision means that F-15E squadrons can now be equipped with StormBreaker and deployed for missions.

"StormBreaker delivers an unprecedented capability to pilots in the field," said Paul Ferraro, vice president of Raytheon Missiles & Defense's Air Power business. "The weapon gives airmen a significant advantage—the ability to strike maritime or land-based maneuvering targets at range in adverse weather." StormBreaker features an innovative multimode seeker that guides the weapon by imaging infrared, mmWave radar and semi-active laser in addition to or with GPS and inertial navigation system guidance.

"The weapon has proven itself in many complex test scenarios, against a variety of targets in extreme environmental conditions, and is now ready to fly," said Cristy Stagg, StormBreaker program director at Raytheon Missiles & Defense. "With its multimode seeker and datalink, StormBreaker will make adverse weather irrelevant."

StormBreaker's small size lets fewer aircraft address the same number of targets compared to larger weapons that require multiple jets. It can also fly more than 40 miles to strike mobile targets, reducing the amount of time that aircrews spend in harm's way.

The smart weapon's initial fielding on the F/A-18E/F Super Hornet for the U.S. Navy and integration for fielding on the F-35 Joint Strike Fighter are next for the program.

Source: Raytheon Technologies

Tempest: UK's Future Combat Aircraft

British engineers revealed some of the latest concepts in development for the Royal Air Force's (RAF) next-generation combat air system.

The pioneering technology is being delivered by Team Tempest, Leonardo, MBDA, Rolls-Royce and the RAF and involving hundreds of high-tech companies, SMEs and academia across the U.K.

Tempest is one of the U.K.'s most ambitious technological endeavors and is designed to deliver a highly advanced, adaptable combat air system to come into service from the mid-2030s. This next-generation combat aircraft, which forms part of a wider combat air system, will exploit new technologies as they evolve to respond to the changing nature of the battlespace, addressing increasingly high-tech and complex threats and conflict.

Experts from the Team Tempest electronics lead, Leonardo UK, are developing new radar technology capable of providing over 10,000 times more data than existing systems. The new sensor, called the 'Multi-Function Radio Frequency System,' will collect and process unprecedented amounts of data on the battlespace—equivalent to the internet traffic of a large city such as Edinburgh, every second. This huge volume of information, processed on-board, will give Tempest a battle winning edge in combat situations, with the ability to locate and target enemies well before they are targeted themselves.

Engineers at BAE Systems have begun flight testing cutting-edge concepts for Tempest's 'wearable cockpit' technologies, designed to provide pilots in the cockpit or operators on the ground with split-second advantage. The concept sees the physical controls seen in current aircraft cockpits replaced with augmented and virtual reality displays projected directly inside the visor of a helmet, which can be instantly configured to suit any mission.

BAE Systems has also been trialing 'psycho-physiological' technologies, including eye-tracking, to study the operator's physical and cognitive processes. The results of the trials will inform further development to better understand a pilot's cognitive behavior and processes relating to brain activity, psychological rhythms and eye movement to inform further development.

MBDA UK has embedded one of its human factors' engineers within this wearable cockpit team, ensuring early introduction of weapons concepts that exploit these future technologies. This close partnership approach between MBDA UK and BAE Systems will allow the companies to help collaborate at an early stage of the program, shaping how weapons systems information and operation are optimized for the pilot.

Rolls-Royce engineers have been developing advanced combustion system technology as part of the company's power and propulsion work. The combustion system is where fuel is introduced and burned to

Source: BAE Systems

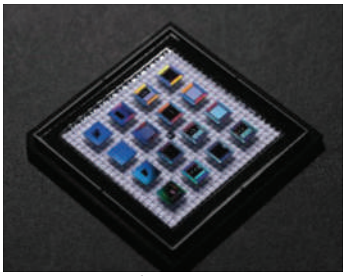
For More Information Visit mwjournal.com for more defense news.

release energy into the gas stream. Rolls-Royce has been exploring advanced composite materials and additive manufacturing as part of this work, producing lightweight, more power-dense components capable of operating at these higher temperatures.

These concepts are part of a wider research effort to develop technologies that could be used to create a next-generation combat air system for the U.K. Collectively, the Team Tempest partners are developing more than 60 technology demonstrations in the fields of sensing, data management and autonomy to prove world-leading processes and technologies.

Next-Generation Digital Antenna Passes Key Milestone

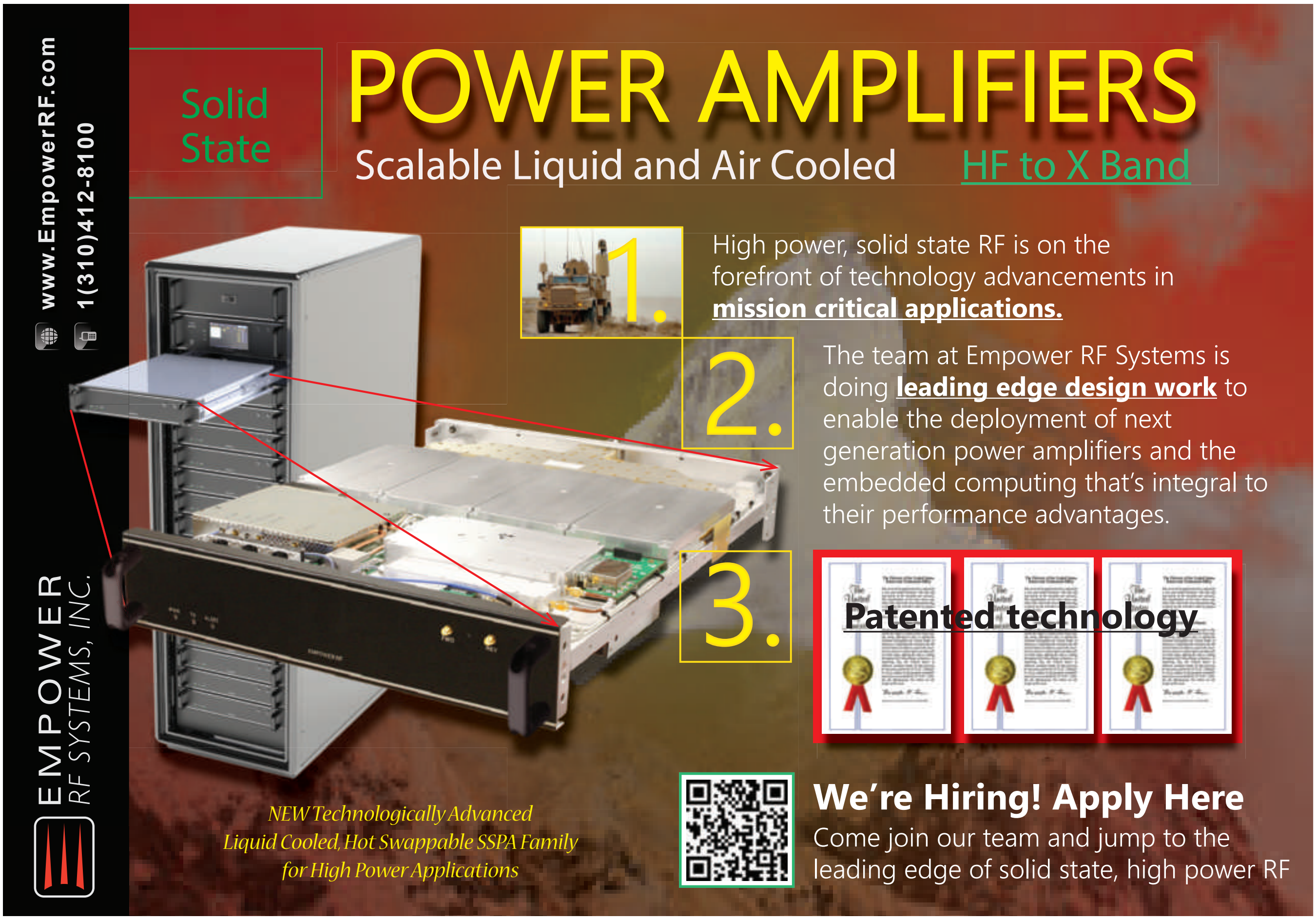
Aether Spy advances multi-function wideband digital active electronically scanned array (AESA) technology based on the advanced microelectronics created on the DARPA Arrays on Commercial Timescales program. It will develop the next generation of integrated circuits that include additional processing and key design features that enable the Department of Defense (DoD) trusted microelectronics strategy. The advanced devices will be fabricated and integrated into an advanced digital AESA to demonstrate a multi-function system capable of simultaneously performing multiple sensing, communication and electronic warfare functions.



Source: Northrop Grumman

"The advanced integrated circuits, digital AESA architecture and multi-function software developed on Aether Spy will become foundational building blocks for the next generation of multi-function RF systems supporting the future mission needs of the DoD," said William Phillips, director, multi-function systems, Northrop Grumman.

"This transition of digital AESA technology aligns well with the Air Force's digital engineering initiatives," said Thomas Dalrymple, technical advisor for Sensor Subsystems at the AFRL Sensors Directorate. "Aether Spy will enable significant improvements in surveillance and battle management missions in the future battlespace. The multi-function aspects are enabled by both software and hardware reprogrammability that will ensure this sensor will have operational impact for years to come."



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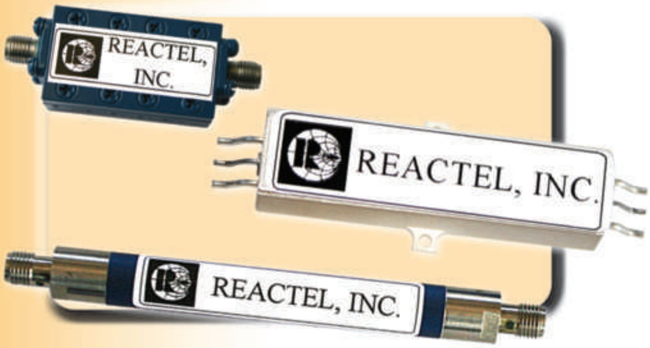

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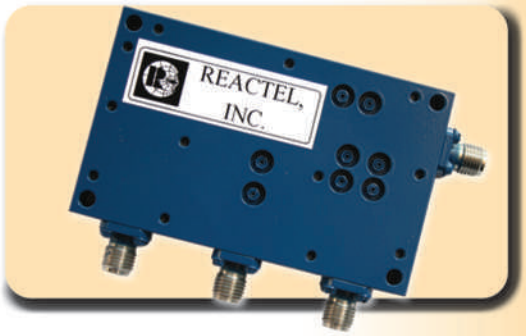
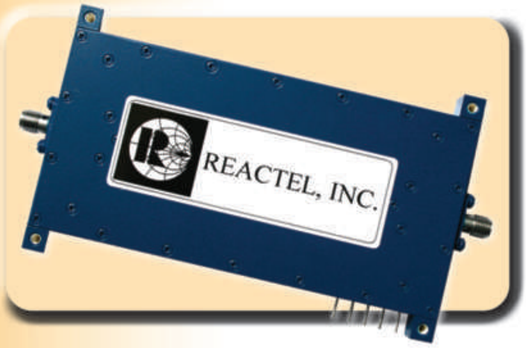


- **Multifunction Assemblies**



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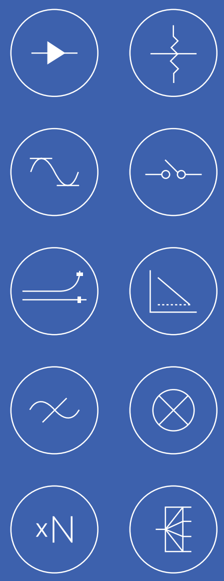
xN

New 5G Smartphone Teardowns Confirm Benefits of Radio System Integration

ABI Research, using the teardown expertise of System Plus Consulting, unpacked two 5G smartphones to confirm that smartphone original equipment manufacturers (OEMs) are extending fully integrated modem-RF system designs to support 5G and LTE implementations over their flagship devices. The teardowns analysis shows that Qualcomm's RFFE system design covers both sub-6 GHz mmWave 5G options, as well as LTE frequency bands, which will enable OEMs to cost-effectively integrate 5G with 3G/4G into complex form factors effectively. Such a fully integrated modem-RF system design is vital to drive wider adoption of 5G beyond the traditional smartphone market.

"Of particular interest in these teardowns is the use of mmWave modules, which are showing signs of increasing adoption as they aim to reach markets beyond North America. The use of these modules will be even more crucial for enabling new and complex form factor designs, such as foldable phones, to support mmWave access," stated David McQueen, research director at ABI Research.

> Affirms mmWave module use in ultra-thin foldable designs.

With 5G smartphone sales expanding rapidly, the RFFE has now replaced the modem/chipset as the largest revenue growth opportunity in the industry. "High design and RF components sourcing complexity are evident in 5G, so smartphone OEMs favor integrated system solutions to accelerate time to market while differentiating in terms of performance and overall power consumption," McQueen explained. "Optimizing integration between 3G/4G and 5G using a single supplier could not only provide a superior system design, enabling the production of cost-effective, smaller form factors and low-power consuming devices; but it also has the potential to support newer features, such as 5G carrier aggregation (CA) and dynamic spectrum sharing (DSS). Furthermore, 5G mmWave ecosystem momentum is gathering pace as the complexity of integration in smartphones is addressed through a fully integrated and miniaturized mmWave RF module design, which appears to have already matured enough to support ultra-thin foldable smartphone designs."

Handling the complexity of the entire cellular radio systems for OEMs can only be achieved if the modem-to-antenna system, as a whole, is taken into consideration, including co-existing mmWave/sub-6 RFFEs.

Early Deployments Indicate Open RAN is Maturing and Will Have 75% Market Share by 2030

The development of open radio access network (Open RAN) is gaining momentum. Network operators, new entrants, system integrators and application developers are working together to unlock the traditional integrated telco supply chain, which has up to now been dominated by a handful of large infrastructure vendors. ABI Research expects the total spending on Open RAN radio units (RUs) for the public outdoor macrocell network will reach US$69.5 billion in 2030, with cumulative unit shipments expected to reach 15.7 million. Meanwhile, the total revenue of Open RAN RUs for enterprise indoor small cell network will get reach as high as US$39.8 billion in 2030, with cumulative unit shipments expected to reach 205.5 million.

"The key benefits of Open RAN bring multi-vendor interoperability for innovations and reduce time to market for deploying new network functionality," said Jiancao Hou, 5G and mobile network infrastructure senior analyst at ABI Research. "Powered by network virtualization, Open RAN will help network operators and various industrial enterprise verticals enable network automation and intelligent radio resource control, therefore reducing network integration expenses and operational complexity." Moreover, "A robust ecosystem and supply diversity will remove fears and potential security threats to governments and network operators whose telco infrastructures were initially supplied by one or two big vendors, which has led to the unpredictable disruption of supply chains."

> Enables network automation and intelligent radio resource control.

Rakuten Mobile set a prime example to deploy Open RAN solutions. Moreover, Vodafone has also announced its first live Open RAN 4G site in the U.K. and partnered with Parallel Wireless. At the same time, TIP published a playbook to capture the learnings from the trial deployment in Turkey. Apart from those, many other network operators in collaboration with the vendor ecosystem are deploying and testing the solution, namely Dish Network in the U.S., Telefonica, Deutsche Telekom, Oranges and Turkcell in the EU and many other geological regions. The success of these deployment use cases will bring more network operators, new vendors and stakeholders into the marketplace to invest this new network approach.

"ABI Research expects that 2G/3G and 4G will be the mainstream focus of Open RAN in the next few years, while 5G Open RAN systems are being developed and matured. Advanced 5G features, including massive

For More Information Visit mwjournal.com for more commercial market news.

MIMO, DSS and wide-band CA, are still single-vendor solutions and will likely remain so for the immediate future," Hou stated. "On the other hand, several chipset vendors and new entrants are now creating development and processing platforms that will likely power the next wave of innovation in Open RAN."

In-Building Wireless Infrastructure and the Rollout of 5G Indoors will Exceed US$16 Billion by 2025

Distributed antenna systems (DASs) have become a vital component for in-building cellular coverage, especially in the U.S. and Asian markets. However, many legacy DASs are facing challenges incorporating 5G and increasing the overall capacity of the systems. To overcome these challenges, many mobile network operators (MNOs) are starting to transition from traditional in-building DASs to "5G-Ready" digital distributed radio systems (DRSs) due to technical and financial aspects and a smooth transition to 5G. According to a new report published by ABI Research, worldwide revenue for DASs will grow approximately 2.7x, from US$5 billion in 2019 to US$13.7 billion by 2025. Similarly, the consumer and enterprise small cells will generate a revenue growth of 2.6x from US$975 million in 2019 to US$2.6 billion by 2025.

> Initial deployment targets high-density venues such as stadiums and music halls.

"With the advent of 5G indoors, flexible solutions with advanced features and capabilities like DRS have gained greater participation in the market. These solutions change the way traditional DASs are designed and implemented due to their simplified and future-proofed architecture," said Johanna Alvarado, senior analyst at ABI Research. "The market opportunity for DRSs will grow in the following years, during which the solution is going to be adopted to address 5G upgrades for legacy DASs, as overlaid 5G systems, but also as the main indoor wireless solution for all venue sizes. DRSs will be largely adopted to address various wireless applications in the consumer and enterprise markets."

To cope with the pace of the technology changes in the mobile telecommunication industry, 42 percent of the interviewed vendors have merged/acquired new companies in a span of seven years. For example, CommScope acquired Airvana, TE Connectivity and Ruckus in the last five years, Corning acquired SpiderCloud in 2017 and Cobham acquired Axell Wireless in 2013. "It is clear that the DAS market is consolidating with vendors diversifying its product portfolios and entering new markets by acquiring new companies," concluded Alvarado.


Smith Chart Options
Sierpinski_C3_Triangle_Dipole_FFP

Around the Circuit

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Qorvo® has acquired Paris-based **7Hugs Labs S.A.S.**, a leading software provider for ultra-wideband (UWB) applications. The acquisition of 7Hugs Labs helps strengthen Qorvo's UWB product offering for smartphones and other devices that increase the accuracy of a host of new location and communication services. 7Hugs Labs was founded in 2014 and has been a trusted software partner for Decawave, which is now the UWB business unit within Qorvo's Mobile Product business. As part of Qorvo, the 35-member 7Hugs Labs team will help create complete UWB solutions for a broad ecosystem that is expected to reach billions of devices in the coming years.

Ticer Technologies announced that it has reached an agreement with **Materion Corp.** to acquire certain manufacturing assets from Materion's Large Area Coatings (LAC) Division in Windsor, Conn., effective January 1, 2021. Ticer will own and operate the vacuum deposition/sputtering production equipment, which will remain in place and continue to be operated by former staff of the Materion LAC operations, to be hired by Ticer. Processes, equipment and raw materials will continue to be the same during the ownership transition. The high quality TCR® thin-film resistor copper foil products offered by Ticer will remain unchanged.

Pacific Defense announced the acquisition of **Spear Research**, a Nashua, N.H.-based technology company focused on electronic warfare, signals intelligence and autonomous networked sensor systems. Spear Research brings an experienced and innovative team of engineers with core competencies in RF engineering, advanced signal processing, autonomous command and control and system integration. The Pacific Defense platform, including Spectranetix and Perceptronics, brings rapid adoption of best of breed capabilities into AI/ML enabled high performance radio frequency based systems, and Spear is a key enabler to delivering full scale, low risk solutions to the U.S. Department of Defense (DoD) and select international customers.

Curtiss-Wright Corp. announced that it has completed the acquisition of **Pacific Star Communications Inc.** for $400 million in cash. PacStar is a provider of secure tactical communications solutions for battlefield network management, including commercial off-the-shelf-based rugged, small form factor communications systems and its proprietary "IQ-Core® Software" integrated network communications management software. The acquisition establishes Curtiss-Wright as a critical supplier of advanced tactical and enterprise network communications solutions supporting a broad spectrum of high priority U.S. military force modernization programs.

COLLABORATIONS

Indium Corp. and **RENEX Group** have formed a strategic partnership for the service of their PCB and engineered solder materials in Poland. The partnership with RENEX, one of Poland's largest and longest-operating technology suppliers in the country, expands Indium Corp.'s existing market reach in Poland as it continues to deliver world-class products and technical service including solder paste, preforms, ribbon, flux, wire, kits, sphere and thermal interface materials. RENEX has been serving Poland's electronic industry with machines and materials as well as tech expertise, being an IPC and ESA training center, for the past 30 years. Its network of 150 dedicated employees, along with its Technology Center, provides deep process and quality training sessions.

GLOBALFOUNDRIES® (GF) and **Soitec** announced a multi-year supply agreement for 300 mm radio frequency silicon-on-insulator (RF-SOI) wafers. Building on the long partnership between the two companies, this strategic agreement secures the supply of wafers that will allow GF to further expand its critical role in providing solutions for the next-generation mobile phone market. The agreement was finalized earlier this week in a virtual signing ceremony with leadership from both companies. The primary driver of this wafer supply agreement is the growth of GF's most advanced RF-SOI solution, 8SW RF SOI.

BT and **EE** customers are set to benefit from Ericsson 5G radio access network (RAN) connectivity following the company's selection as BT's 5G RAN provider in the U.K. capitals London, Edinburgh, Belfast, Cardiff and other major cities. This announcement marks a significant strengthening in the BT-Ericsson strategic partnership, and builds on BT's selection of Ericsson to provide the company's next-generation cloud-native dual-mode 5G Core earlier this year, making Ericsson the end-to-end 5G partner for BT. Once the deployment is completed, Ericsson will manage around 50 percent of BT's 5G traffic. The expanded partnership creates exciting opportunities for collaboration on the next generation of 5G products and services.

Eurofins Digital Testing, a leader in end-to-end quality assurance and testing services, and **Rohde & Schwarz** are working closely together to give customers access to the latest high speed signal analysis and compliance testing tools using the R&S RTP164 high performance oscilloscope. These will give Eurofins a competitive edge in testing high speed interoperability. They will further provide certification services for high speed communications technologies including USB. To enter this cooperation with Rohde & Schwarz was an easy decision for Eurofins, as both share common values as companies.

For More Information — For up-to-date news briefs, visit mwjournal.com

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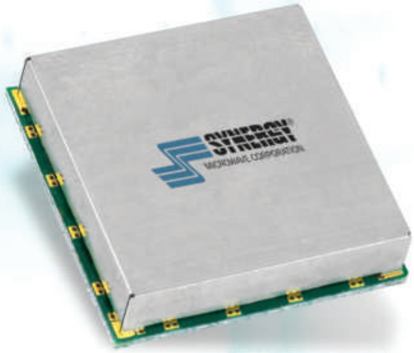

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HFSO745R84-5	745.84	0.5 - 12	+5 VDC @ 35 mA	-147
HFSO776R82-5	776.82	0.5 - 12	+5 VDC @ 35 mA	-146
HFSO800-5	800	0.5 - 12	+5 VDC @ 20 mA	-146
HFSO800-5H	800	0.5 - 12	+5 VDC @ 20 mA	-150
HFSO800-5L	800	0.5 - 12	+5 VDC @ 20 mA	-142
HFSO914R8-5	914.8	0.5 - 12	+5 VDC @ 35 mA	-139
HFSO1000-5	1000	0.5 - 12	+5 VDC @ 35 mA	-141
HFSO1000-5L	1000	0.5 - 12	+5 VDC @ 35 mA	-137
MSO1000-3	1000	0.5 - 14	+3 VDC @ 35 mA	-138
HFSO1200-5	1200	0.5 - 12	+5 VDC @ 100 mA	-140
HFSO1600-5	1600	0.5 - 12	+5 VDC @ 100 mA	-137
HFSO1600-5L	1600	0.5 - 12	+5 VDC @ 100 mA	-133
HFSO2000-5	2000	0.5 - 12	+5 VDC @ 100 mA	-137
HFSO2000-5L	2000	0.5 - 12	+5 VDC @ 100 mA	-133

** Package dimension varies by model. (0.3" x 0.3" to 0.75" x 0.75")*

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ACHIEVEMENTS

Analog Devices Inc. (ADI) announced that its ADIS16505 MEMS inertial measurement unit (IMU) has received the **Electronics Industry Award for Automotive Product of the Year**. The ADIS16505 is a 6DoF IMU capable of precision measurement of all rotational and linear motion of a platform, even under the harshest and most dynamic conditions. It is the first autonomous grade IMU available in a surface mount package, enabling its use within any land, air or sea vehicle which can benefit from accurate positioning information.

Beep, a Florida-based autonomous mobility-as-a-service provider, announced they will deploy the first autonomous shuttles at Yellowstone National Park with the National Parks Service (NPS) in May 2021. The pilot program will test multi-passenger, electric automated vehicle platforms to provide visitors a safe, innovative and eco-friendly transportation alternative while exploring Yellowstone. Beep will work in concert with both NPS Park Planning, Facilities and Lands Directorate, the Department of Transportation and Yellowstone National Park to safely plan, deploy and operate two autonomous shuttles in the Canyon Village.

Samsung has started research and development on Distributed FD-MIMO, which has the potential to become the next generation of radio technology. With Distributed FD-MIMO, Samsung aims to continue the innovation stream and achieve better performance and come up with another success story similar to FD-MIMO to take the industry forward to the next level. FD-MIMO (also known as massive MIMO, hyper MIMO and very large MIMO) is the use of a large number of antennas, tens, hundreds and thousands, to dramatically increase the throughput and energy efficiency to a multitude of communications devices.

CONTRACTS

General Dynamics Electric Boat, a business unit of **General Dynamics**, announced that the **U.S. Navy** has awarded it a $9.474 billion contract modification option for construction and test of the lead and second ships of the Columbia class, as well as associated design and engineering support. Electric Boat is the prime contractor on the Columbia program, which will replace the aging Ohio class of ballistic missile submarines. Electric Boat will perform about 78 percent of the construction of the Columbia class and recently shifted the program to full-scale construction at the company's manufacturing complex in Quonset Point, R.I.

Altamira Technologies Corp., delivering innovative, mission-focused analytics and engineering solutions to the U.S. national security community, announced that the company has been awarded a $950,000,000 ceiling indefinite-delivery/indefinite-quantity contract for the maturation, demonstration and proliferation of capability across platforms and domains, leveraging open systems design, modern software and algorithm development in order to enable Joint All Domain Command and Control (JADC2). This contract is part of a multiple award multi-level security effort to provide development and operation of systems as a unified force across all domains (air, land, sea, space, cyber and electromagnetic spectrum) in an open architecture family of systems that enables capabilities via multiple integrated platforms.

Comtech Telecommunications Corp. announced that its **Mission-Critical Technologies** group, which is part of Comtech's Government Solutions segment, received $2.8 million in additional orders from the **Federal Government** for its Joint Cyber Analysis Course (JCAC) Training solutions. The $68.0 million contract has been funded $63.0 million to date. The Mission-Critical Technologies group is focused on ensuring its customers are able to successfully carry out their mission, whether that be communicating in an austere environment on land or at sea, launching or tracking a satellite or protecting the cyber security posture of their network.

Fitbit announced it has been selected by the **U.S. Army Medical Research and Development Command (USAMRDC)** to receive nearly $2.5 million from the DoD through a Medical Technology Enterprise Consortium (MTEC) award to advance development of a wearable diagnostic capability for the early detection of a COVID-19 infection. As part of the award, Fitbit is working to initiate a prospective study with Northwell Health's Feinstein Institutes for Medical Research to validate a Fitbit COVID-19 early detection algorithm. The award is part of MTEC's efforts to help keep military personnel healthy and fully operational.

L3Harris Technologies has been awarded a firm-fixed price contract to missionize three new King Air 350ER aircraft for the Canadian manned airborne intelligence, surveillance and reconnaissance (CMAISR) project. The aircraft will be delivered to the **Canadian Department of National Defence (DND)** as a Foreign Military Sale managed by the U.S. Army, Program Executive Office Aviation, Fixed Wing Project Office. The CMAISR project will provide the DND with a rapidly deployable, airborne intelligence, surveillance and reconnaissance capability for its deployed operations, ensuring an innovative, flexible and interoperable force. The aircraft will feature a suite of L3Harris systems, including full-motion video sensors, a mission management system and communication datalinks.

Scientists at **HRL Laboratories** are working on a project that could result in a disruptive improvement in radar, electronic warfare and communications capabilities. If they are successful, the W-Band, nitrogen-polar (N-polar) GaN low-noise amplifier could be the industry's first such device, launching a new generation of defense-oriented electronics applications with a possible improvement of four times the output power in W-Band over HRL's existing technology. Sponsored by the Office of Naval Research, the initial project aims to demonstrate design, fabrication and functional testing of a N-polar GaN mmWave integrated circuit that will enable the first W-Band amplifier using the advanced semiconductor material.


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We bring next-gen technologies to every system we touch. From radio frequency and autonomous systems, to electronic warfare and communications, our electronics elevate every aperture.
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Around the **Circuit**

Akoustis Technologies Inc. announced that it has been awarded a new, multi-year direct-to-phase 2 (DP2) contract from **DARPA** to further develop Akoustis' technology through the development of a Piezo MEMS process design kit (PDK) for the company's proprietary and patented XBAW™ process. The DP2 program of the Small Business Innovation Research contract will be dedicated to developing a general purpose PDK that will enable bulk acoustic wave (BAW) and other similar MEMS structures to be designed and fabricated using the company's state-of-the-art XBAW™ process.

PEOPLE

▲ *Ee Huei Sin*

Keysight Technologies Inc. announced that **Ee Huei Sin**, head of Keysight's General Electronics Measurement business, has been promoted to lead the Electronic Industrial Solutions Group, effective immediately. Huei Sin takes over from Gooi Soon Chai who has led the business since 2015. Going forward, Chai will continue to lead Eggplant, the test automation software company Keysight acquired in June 2020, as well as Keysight's Order Fulfillment and Information Technology groups—all of which are key strategic functions for the company. Huei Sin joined the company in 1992 and has held a variety of global positions, including functional and business roles.

▲ *Steve Gotwalt*

▲ *Fred Firoozeh*

Steve Gotwalt joins the **Richardson Electronics – Power & Microwave Technologies** team with over 25 years of experience in the RF and microwave market and will be expanding accounts in the South Central U.S. region. Steve joined Texas Instruments where he spent 15 years in design, development and production. Based in Los Angeles, Calif., **Fred Firoozeh** brings more than 20 years of sales and application engineering experience for both the power and RF and the Microwave and Communications markets. Fred's career has been extensive with many roles such as senior and regional field application engineer, and regional sales manager for both OEMs and distribution in the western U.S.

▲ *Wendy Tirollo*

TRM Microwave Owner/CEO **Wendy Tirollo** was awarded the 2020 Business Excellence Award in the Manufacturing category for small organizations from NH Business Review. The annual awards recognize New Hampshire's top business executives for their imagination, industriousness, innovation and achievements. The apitech™

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- Gain Equalizers and Phase Shifters
- Adapters, Connectors and Accessories
- Surface Mount Attenuators, Terminations, Resistors

Around the Circuit

18th-annual Business Excellence Awards ceremony, honoring all recipients, was held virtually. This year marks 10 years since Wendy took the helm of TRM Microwave, a defense and aerospace manufacturer. Under the mentorship of her husband and TRM's former CEO and founder Tony Tirollo, Wendy found her own leadership style as she prepared to lead the company forward in the wake of Tony's long-term health concerns and passing in 2016.

REP APPOINTMENTS

Laird Performance Materials and **TTI Inc.** have reached an agreement whereby TTI will promote and sell Laird's full line of engineered products throughout North America. Most of the leading names in electronics are served by Laird, a global manufacturer of innovative thermal interface materials, electromagnetic interference shielding materials or magnetic ceramic solutions, RF/microwave absorbers, precision and structural metals and integrated solutions.

AGC Nelco America Inc. announced that effective immediately, they have partnered with **East Coast Electronic Material Supply LLC** and **East Coast Electronic Material Supply Canada Inc.** ECEMS will become the North American distributor for AGC Nelco America's laminate and prepreg materials.

PLACES

Cadence Design Systems has announced the opening of a new European R&D Centre of Excellence in Cork, Ireland, to further expand local computational software development. Over the next three years, Cadence expects to create approximately 150 new engineering positions in Cork, facilitating customer design advancement in emerging consumer, hyperscale computing, 5G communications, automotive, aerospace, industrial, mobile and healthcare application areas. Cadence already has a well-established Shared Services Centre in Dublin, Ireland, with senior finance, engineering and IT roles. The new Cork site broadens the company's international presence and its role as Cadence's international headquarters. The company plans to accelerate hiring in Cork immediately.

BAE Systems is investing more than $100 million to build a state-of-the-art facility in Cedar Rapids, Iowa. The facility will support the company's newly acquired Navigation & Sensor Systems business, which makes mission-critical military GPS products. The new building will bring the company's local design and production employees from multiple locations into a single center of excellence with modern manufacturing, engineering and office space. The facility will improve operational efficiency, optimize production and enhance the company's ability to deliver high quality military GPS products to the warfighter. At the heart of the project is a 278,000-square-foot, build-to-suit factory and research and development center that will be located on a 32-acre site at 7825 6th Street SW in Cedar Rapids.


Ka-Band AESA Technology
Cobham Advanced Electronic Solutions
leverages decades of aerospace and defense system design expertise by introducing an integrated high-power Ka-Band Active Electronically Scanned Array (AESA) Antenna system:
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• Aperture to data capability for mmWave arrays
• Flexible and scalable low cost systems
• Built for rugged defense environments
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Welcome to the 23rd European Microwave Week

Frank van Vliet, EuMW 2020, General Chair

For complete coverage of the EuMW 2020 conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show coverage at mwjournal.com/eumw2020.

We are excited to host the European Microwave Week from the Netherlands, the country where it all started in 1998, when three conferences merged into the 'Microwave Week.' This turned out to be a strategic and very successful move: 22 years later this week has grown into the RF/ microwave event in Europe.

The organization of the 23rd European Microwave Week has experienced turbulent times. The Corona virus has swept across the globe, and not even moving the conference has allowed us to escape the stringent measures on traveling and meeting in person that affects so many of us these days. At the time of writing, we have just installed a fully virtual conference week, preserving the entire scientific program.

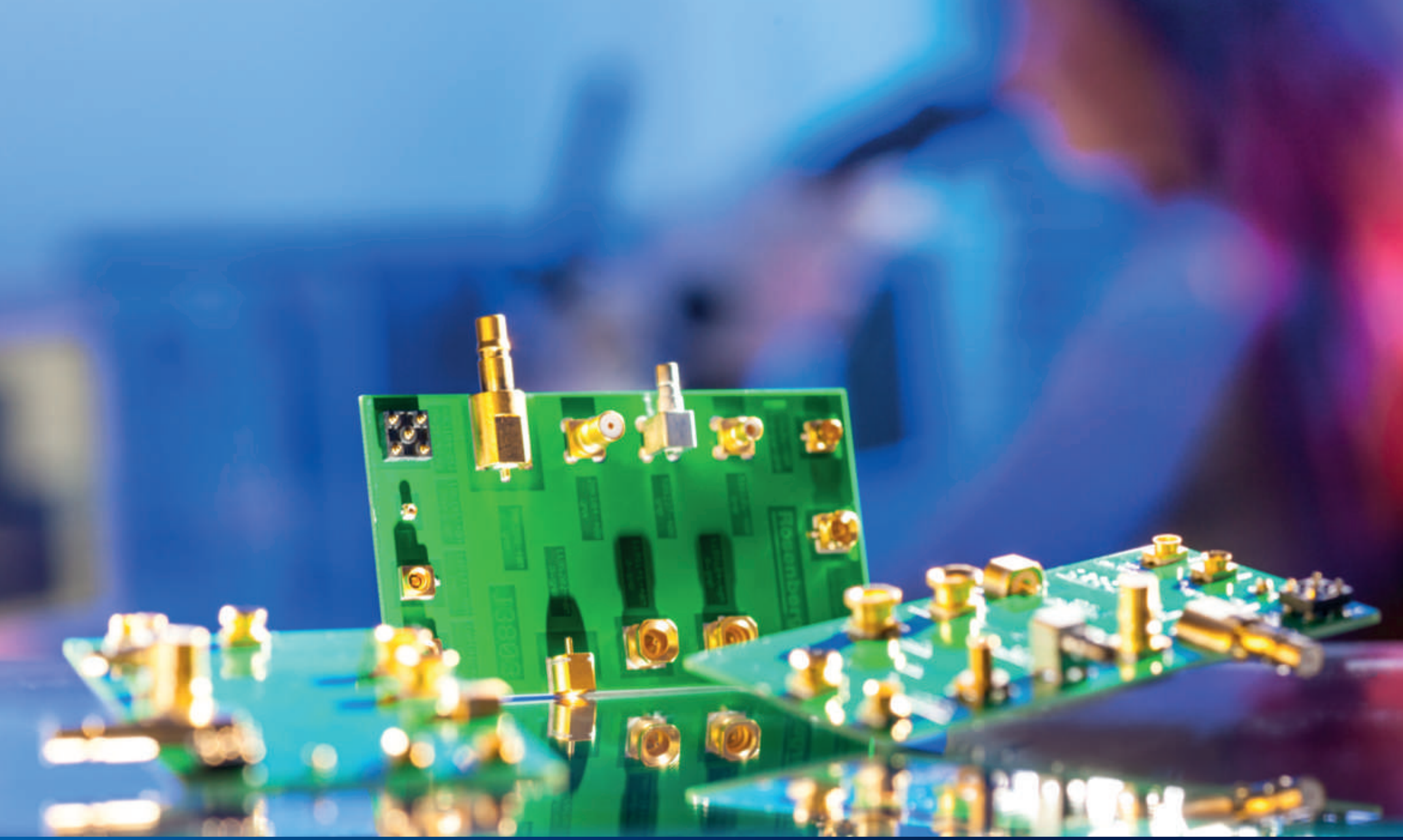
The European Microwave Week will take place from January 10-15, and we are working very hard to exploit all the benefits that a virtual conference can bring. Do not get me wrong: We value that real-life, person-to-person interaction so much that we went to great lengths to keep it in place, but now that the week will be entirely virtual. We have embraced all the good things that a virtual conference can bring. We will prepare the workshop and short course material as videos well ahead of the conference week, so that you can be optimally prepared for the live workshop sessions. We will keep all the scientific content online for several weeks after the conference. There is an integrated mobile app and streaming video platform. The tradeshow and conferences are seamlessly integrated and so are the live and on-demand sessions. The week will be different, no doubt, but a very good experience, nonetheless.

To me, the week can be summarized in four words: Learn, meet, enjoy and explore!

LEARN

This week represents the state-of-the-art in RF, microwaves and radar. Academia and industry will present over 400 scientific talks. Although this is more than any individual can absorb, it guarantees that—if you work in this field—you can pack your week with relevant insights and new developments. Keeping all this material available for a longer period resolves the conflicts of coinciding talks that inevitably occur at such a busy event.

EuMIC, EuMC and EuRAD: The European Microwave Integrated Circuits Conference, the European Microwave Conference and the European Radar Conference together



form the scientific heart of the Microwave Week. Keynote speakers from around the globe will inspire our audience; semiconductors that literally work up to a THz, dedicated sessions on Teaching Microwave Engineering, a Focus Day on (Active) Array Antennas, there is just too much to name it all here. EuMC, the oldest of the conferences involved, will be celebrating its 50th anniversary, which is the reason for the golden crown over this year's logo.

Short courses will get you up to speed for new topics and workshops will bring you all the new developments for those already working in the field. Exchange ideas with colleagues from academia and industry. Stay skilled in a world that is changing at an unprecedented rate. Check out the extensive program at eumweek.com so you do not miss anything.

MEET

This week is where our entire community meets. Meet, to interface with all the relevant industries at the largest microwave and radar tradeshow, this tradeshow alone is more than worth the visit! Stop by the EuMA booth and become a member. That is the first step to get involved in volunteering: do so for a few years and suddenly realize that you actually know all the famous names in microwaves and radar. Meet, to learn before things even get published. Meet old friends to catch up, meet to make new friends that last a lifetime. And female talent can meet their peers and get together during the Women-in-Microwaves event. The virtual exhibition will have text chat and video conferencing capabilities so you can interact with anyone. At each booth you can download information, view videos or listen to a technical presentation at some of the major sponsors.

ENJOY

Utrecht is a historic place that welcomes visitors warmly. Visit the city at a later stage to enjoy its canals, churches, modern and ancient art, its famous music scene, century-old restaurants, bars and nightlife. An online experience cannot replace the real one but take some time to visit the Catharijneconvent (www.catharijneconvent.nl), the Centraal Museum (www.centraalmuseum.nl) and the Rietveld Schröderhuis (www.rietveldschroderhuis.nl), to name few. Over 3,000 years of history leaves its traces through an immense wealth of cultural events and historic richesse. Take some time to enjoy these, online.

EXPLORE

Browse through the program to learn about the student activities including the famous Tom Brazil Doctoral School of Microwaves, the different fora (the Defence, Security and Space Forum on Space Situational Awareness; the Automotive Forum, this year particularly on waveforms and AI in automotive radar; and the new 5G Forum that bridges the gap between business and technology), a workshop on Quantum Computing for Electronic Engineers, there is something on 5G virtually in every time-slot, there is just too much to list it all.

This week is so packed with science and fun, we are sure that when it is over, you will be anxiously waiting for the next edition. And the good news is that this will arrive in less than nine months, in London. See you online in January!

Frank van Vliet, EuMW 2020 General Chair

EuMW 2020: Going Virtual for the First Time

Pat Hindle
Microwave Journal Editor

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EuMW 2020 was originally scheduled to take place this fall in Utrecht, the Netherlands and was delayed until January 10-15 in an attempt to still hold the event in-person. While the Covid-19 virus has continued to take hold around the world restricting travel and making it unsafe for an in-person event in Europe. The organizers, EuMA and Horizon House, were well prepared for this scenario and have organized a full virtual event that will take place on the same days and times as the scheduled physical event, January 10-15, plus will be on demand for three weeks after the event ends.

The event still holds onto its identity with the theme of "The Art of Microwaves" as represented on our cover with Van Gogh's famous Starry Night painting enhanced with Cube SATS representing the Military & Government Electronics theme of the issue. The Netherlands is rich in artistic history with Van Gogh and Rembrandt being two of the many famous painters from the country. The country is also home to several R&D organizations related to aerospace activities which are featured in our cover story along with other local companies in the microwave industry.

The European Microwave Week is made up of three conferences: The European Microwave Conference (EuMC) January 12-14, 2021,

▲ Fig. 1 Virtual lobby mock-up for EuMW 2020.

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Fig. 2 3D virtual stand example for EuMW 2020

The European Microwave Integrated Circuits Conference (EuMIC) January 11-12 and The European Radar Conference (EuRAD) January 13-15. EuMC is Europe's premier conference on microwave, mmWave and terahertz devices, systems and technologies. This is the 50th edition of Europe's largest conference that covers a broad range of high frequency related topics, from materials and technologies to integrated circuits, systems and applications. The EuMIC conference is jointly organized by the GAAS® Association and EuMA. It is the premier European technical conference dealing with microwave integrated components whether based on silicon, III-V materials or photonics. It has established itself as a key contributor to the success of the overall European Microwave Week and remains the largest scientific event in Europe related to microwave integrated circuits. The EuRAD conference is in its 17th year and covers future trends in the fields of radar research, technology, system design and applications.

There are also special areas of focus that are organized as forums. There is the Defence, Space and Security Forum that will focus on Space Situational Awareness topics this year with experts from industry and government. The 5G Forum will host a mix of technical presentations from industrial experts that will address 5G strategic and market needs including how these can be met with technology solutions. The Automotive Forum will feature technical experts from the automotive industry throughout the whole supply chain. The speakers will present their views on special technical solutions as well as regulatory and strategic market issues.

The European Microwave Week was started in the Netherlands in 1998 and today it continues to be the largest event of its kind in Europe. This will be a unique year in that it is the first time the event is held virtually, so the Netherlands will also be the first EuMW event to go online. The organizers will record most of the sessions and play them online during their scheduled times of the physical event, holding to the original plan for the conferences. Each session group will be followed by a live question and answer period where attendees can address questions to the presenters in real time. The advantage of being an online event is if you cannot make the time of any sessions, you will be able to view it on demand for about three weeks after the event takes place, until February 5. Most sessions will be presented virtually except for panels and group forums since it is more difficult to coordinate these with people from around the world in different time zones.

The virtual event will re-create the feeling of attending in-person. The opening and closing sessions of EuMC, EuMIC and EuRAD, including the keynotes, will take place in the virtual auditorium which can be accessed right from the lobby of the event (see ***Figure 1***). From the lobby, attendees can enter the auditorium, lounge and two exhibit halls. Exhibit Hall 1 will contain the larger company stands that are represented in 3D virtual stands (see ***Figure 2***), and Exhibit Hall 2 will contain the smaller company stands as standard virtual stands. Some of the virtual stands will be exact representations of the stand design that was planned to be built onsite as the original CAD drawings and graphics will be used to prepare the virtual stand.

In the exhibition, attendees can view/download company information about how to design and test products plus learn about new products via brochures, datasheets and other types of literature. They can also listen to company presentations and training sessions for those companies that offer them in the conference. Videos will also be available for demos and additional information along with the ability to text or video chat with company representatives. Attendees can also utilize Zoom, MS Teams, WebEx and other video conferencing tools to meet virtually, if provided by the companies. The virtual platform has many advanced capabilities to replicate the in-person event as much as possible. There will also be a Meeting Lounge for attendees and exhibitors to meet and discuss topics of interest plus make appointments to see the stand's products and presentations with company experts.

Please join us for the first virtual EuMW event January 10-15. The virtual platform will re-create many of the activities and opportunities for learning and networking like the physical event, but we do hope to see you in-person in about nine months for EuMW 2021, taking place in London. While virtual events have come a long way in the past year, it is not a replacement for in-person trade show events which we hope will resume later in 2021.

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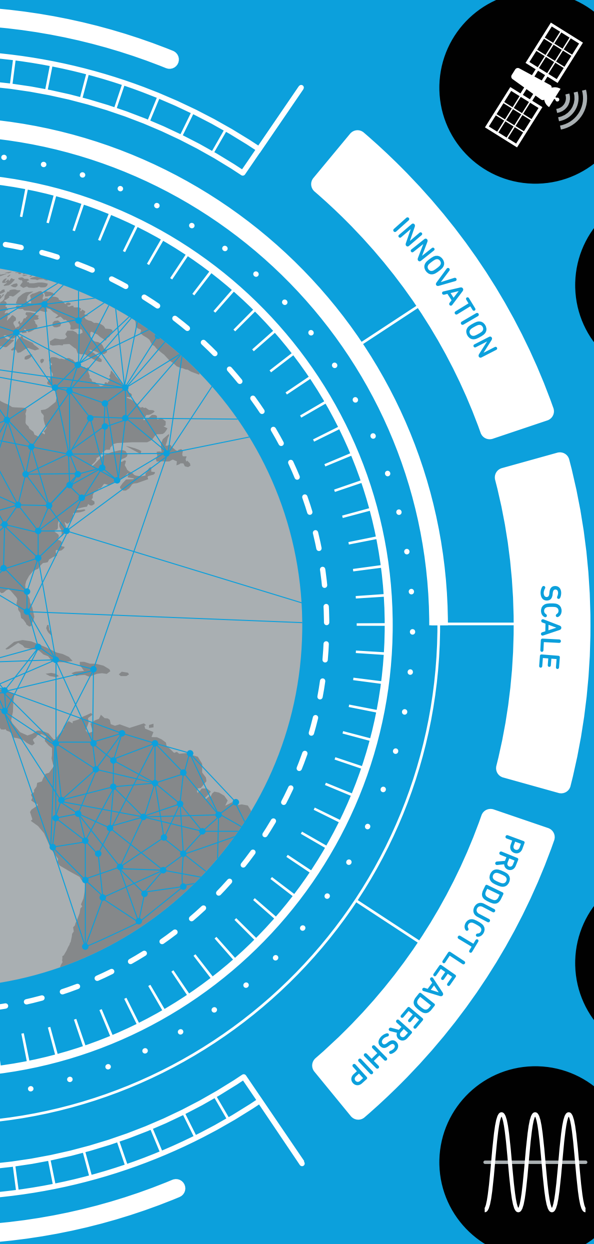

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INVITED PAPER

AI and Machine Learning Redefine the EW Landscape

Nancy Friedrich
Keysight Technologies, Santa Rosa, Calif.

This past September, a panel at the AFCEA/INSA Intelligence and National Security Summit delved into the race for artificial intelligence (AI). According to the Signal article, "AI Looms Large in Race for Global Superiority," panelists discussed the various approaches to AI research and applications among the U.S., Russia and China.[1]

According to Margarita Konaev, research fellow at the Center for Security and Emerging Technology, "Russia trails China and the U.S. in all metrics of AI. However, its military is leading the country's efforts to catch up in key areas, most of which involve military applications." Konaev listed three of Russia's investment focuses: military robotics and unmanned systems, electronic warfare (EW) capabilities and information warfare. Noting the country's quick pace when it comes to experimentation, she said, "They're quick to test, and they learn limitations under operational conditions."

China's AI strategy was covered by Elsa Kania, an adjunct senior fellow for technology and national security at the Center for a New American Security. "China has made no secret of its goal to lead the world in AI, and the military, in particular, has seen greater progress than expected. This includes a long list of applications such as suicide drones, autonomous weapon systems, EW, cyber operations, wargaming, data analytics and situational awareness," she said.[1]

By comparison, the U.S. invests the most time and energy evaluating how AI will impact the EW domain by exploring issues like ethics. According to Col. P.J. Maykish, USAF, who serves as the director of analysis for the National Security Commission on Artificial Intelligence, "Ethics is a major consideration for U.S. AI development. It comes down to three issues: civil liberties, human rights and privacy." China and Russia do not share those concerns to the same extent. As a result, Maykish recommends a "coalition of nations focused on common values." He also warns that the U.S. should not disregard rising AI and machine learning (ML) developments from other nations, which could be further in development than others realize.[1]

It is obvious that AI and ML are quickly gaining traction in EW. They provide clear advantages in the electromagnetic (EM) spectrum, which is increasingly congested and contested. As threats and countermeasures evolve, ever more complex battles are being fought for spectrum dominance. Systems that respond to threats or countermeasures without human intervention, continuously learning from those responses, are more likely to prevail.

UNDERSTANDING THE LINGO

As more discussion and progress focus on AI and ML, more confusion seems to arise around seemingly interchangeable terms: cognitive and adaptive versus AI and ML. Responsive threats did exist before AI and ML were implemented, often labeled as cogni-

tive and adaptive. Although people use these terms interchangeably, many levels of adaptability exist. Most of them do not come near the capabilities of cognitive EW. Using ML, cognitive EW systems can enter an environment with no knowledge of the adversary's capabilities and rapidly understand the scenario. Doing something that makes the adversary's system react, they evaluate its response and develop an effective response suited for the adversary's system.

In contrast, adaptive solutions cannot rapidly grasp and respond to a new scenario in an original manner. For instance, an adaptive radar can sense the environment and alter transmission characteristics accordingly, providing a new waveform for each transmission or adjusting pulse processing. This flexibility allows it to enhance its target resolution, for example. Many adversary systems require only a simple software change to alter waveforms, which adds to the unpredictability of waveform appearance and behavior, making military forces struggle to isolate adaptive radar pulses from other signals, friend or foe.

AI and ML are often used interchangeably, creating confusion around how each one impacts EW systems. Making the distinction, Dan Pleasant, a Keysight solutions architect, says, "Many people use the terms differently, but to me it's AI—although more properly called cognitive—if it learns and is autonomous. That means it does not necessarily do the same thing every time for an identical stimulus, because it has learned from prior experience. It's ML if it has a neural net built into it that's been trained. However, the use of ML does not necessarily mean that it's cognitive. The neural network may be static and unchangeable. If it's static, it's not AI, it's not cognitive."

In EM spectrum operations, the goal is to respond immediately. All those systems are now software controlled and reconfigurable on the fly. They can change what they are doing at a moment's notice and choose from a multitude of modes. With AI and ML, machines can perform smarter tasks using capabilities like signal recognition. They continuously learn from data, from every conflict, determining ways to be more effective, so they prevail against future countermeasures. This evolution occurs without the need for human interaction; the computer decides how to alter behavior. When tested or engaged, these threat systems learn from that experience. They modify future behavior, which means the computer decides the next steps. Due to the system's unpredictable behavior, even the people responsible for the system cannot foretell its exact behavior.

As threat systems advance with ML technology, they will adapt and alter their behavior or course of action at an increasingly rapid rate. If a radar is trying to track a jet, for example, the adversary's countermeasures may stop it from succeeding. Using ML, that radar would repeatedly try new approaches to achieve success. Today's machines possess intelligence that is an order of magnitude higher than a human expert in EW, learning from data that continues to aggregate.

SHIFTING TIMELINE

ML and AI greatly impact the ways EW systems are developed and their functionality. Pleasant points to the example of how a jammer technique is typically created for a new radar.

"You first have to make a recording of the radar signals—very hard in its own right, because people try not to let you record them. Once you get a recording, you send it to a team of people who look at the radar signal and try to understand what the radar is doing. Then they figure out how you would disrupt it with a jammer and implement the new technique in software or FPGA hardware. Finally, they must do extensive testing and get the solution deployed in the field, where people can use it. The whole process can easily take a year or more," he says.

The software-driven capabilities of modern radars can completely change what the radar does in an instant. Thus, militaries can no lon-

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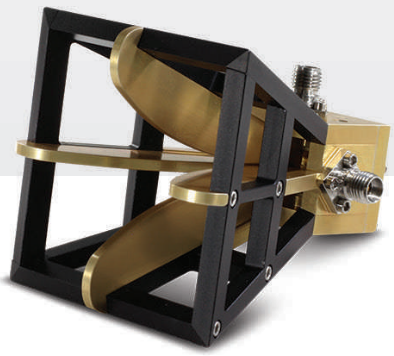

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Fig. 1 Notional interface depicting the vast collection of data from EW sensing and monitoring equipment.
Source: Shutterstock.

Fig. 2 Soldiers will increasingly monitor EW system responses, rather than making decisions.
Source: Shutterstock.

ger afford the year or so it previously took to respond to a radar. Pleasant states, "If you're going to be interacting with a system that can change on the fly, you have to change on the fly, too. It must be instantaneous, and people cannot be involved. People are much too slow. If you're trying to jam a radar, the jammer needs to figure out how to jam that radar. Plus, the radar—if it figures out it's being jammed—needs to know immediately what to do about it and flip to some other mode, change frequency, etc."

PRIORITIZING COMMUNICATIONS

One common way to gain an advantage in EM spectrum operations is to disable communications. An Army EW soldier, for example, must differentiate between the vast amounts of data streamed from battlefield sensors (see ***Figure 1***), deciding what constitutes enemy activity, such as jamming or interference, and what can be ignored. To reduce this cognitive burden and boost multi-domain operations, the Army Rapid Capabilities and Critical Technologies Office (RCCTO) is leveraging AI to prioritize incoming data rapidly and precisely.

According to the article "Artificial Intelligence Improves Soldiers' Electronic Warfare User Interface," "The RCCTO is partnering with soldiers from the 1st SBCT at Fort Wainwright, Alaska, who are using the new technology against operational scenarios. Their feedback will help improve effectiveness of the capability as the Army integrates it into EW systems. The new expert learning AI prototype uses AI that is trained to reduce or eliminate common low-level tasks performed by EW soldiers. It also simplifies the user interface of the battle management system. The tool saves time by decluttering the user interface and enhancing soldiers' ability to zero in on whether the emitter is from a 'red' or enemy source, is a 'blue' or friendly force signal, or just 'gray' noise."[2]

The Army RCCTO partnered with the Army's Project Manager Electronic Warfare & Cyber (PM EW&C) and the Combat Capabilities Development Command's C5ISR Center to develop the AI tool. An operational pilot is planned with a select forward deployed unit later this year. Within the last year, the Army revealed that it has delivered new EW prototype systems to satisfy an operational needs statement from U.S. Army Europe. According to the Army, soldiers with select units are using the equipment to implement electronic protection for their own formations, to detect and understand enemy activity in the EM spectrum and to disrupt adversaries through electronic attack effects. These systems are interim solutions, designed as a bridge until the programs of record, including the EW

Planning Management Tool, can be fielded.

BOOSTING INTELLIGENCE GATHERING

Beyond radar and communications, military units grapple with intelligence gathering and improving situational awareness. The Pentagon recently divulged a plan to use AI tools to gain a battlefield advantage. Under the Joint Artificial Intelligence Center's joint warfighting initiative, C4ISRNET noted it is developing algorithms to provide armed services and combatant commands with AI tools. The goal is to accelerate decision-making.

In the article "How does the Pentagon's AI center plan to give the military a battlefield advantage?" C4ISRNET said, "the center is 'specifically focused' on working to harness AI to link together systems involved in the intelligence gathering phase to the operations and effects piece of all-domain operations."[3] The goal is to connect the varied platforms, creating an end-to-end system that enables actionable visibility of intelligence.

The C4ISRNET article quotes Department of Defense Chief Information Officer Dana Deasy, "The JAIC is also working on an operations cognitive assistant tool to support commanders and 'drive' faster and more efficient decision-making through AI-enabled predictive analytics." Some obstacles may hinder this effort. For example, success will demand changes in user behavior, as the various services branches need to collect and share data at increased levels, and they will need to prioritize data differently. Adequate data storage and development platforms are also critical to the development of AI, putting emphasis on the need for cloud technology.

KEEPING PACE WITH EW EVOLUTION

Whether it is communications, radar or another system, anything implementing ML and AI brings up interesting questions about knowing how it will perform (see ***Figure 2***). Typically, test systems apply a stimulus to the system under test. The ideal testing process generates known results, so it is easy to verify performance. If a system is cognitive, however, and learns and changes from time to time, there is no way to know in advance exactly what it will do. So, how can you tell? Did it pass? Did it fail? Did it do the right thing? For radars and jammers, the test can put the jammer signal all the way through the radar processing and examine the outcome determining if the jammer fooled the radar, for example. Ultimately, test systems and other performance and support systems must be able to learn and adapt ahead of the EW systems to be able to gauge their responses and performance.

EW operations have always resembled a chess game in this way. A new system, such as a radar, is developed. Countermeasures are created in response, leapfrogging beyond the radar. Then, new radar technology is designed. The pace of development traditionally was very slow. Now, machine algorithms will dictate the pace. With the implementation of ML and AI, systems are closer to learning and responding instantaneously. Ultimately, the goal is to have autonomous systems that can learn and make their own decisions. Using these systems, forces want to attain the increased intelligence and learning/response capabilities to prevail in EM spectrum operations. Having more complete knowledge of the environment—whether it is friendly, neutral or adversarial—provides the path to superiority in the contested spectrum environment.■

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Open RAN: Reality or Illusion?

Bill McKenney
Analog Devices, Wilmington, Mass.

Since its inception, the idea of open radio access network (RAN)—its promise and viability—has created some debate. Many see open RAN as an avenue for expanding the limited ecosystem for communications infrastructure and an opportunity for the U.S. to establish a 5G network using more domestic technology. Others, however, are skeptical that an open ecosystem can deliver the complex integration that is required for state-of-the-art 5G networks or realize the much-lauded potential of open RAN.

As 5G networks continue to be activated across the world, Analog Devices is working with customers to develop solutions from base stations to radios, supporting businesses and suppliers of all sizes. And, within each customer interaction we hear real excitement for the potential and possibilities of open RAN, and a deep willingness to tackle the challenges ahead. We believe that, through continued partnership, the telecom industry will realize the promise of open RAN and unleash three areas of significant opportunity.

First, by opening up the RAN infrastructure and creating interoperability, we will see an influx in innovation. More specialized companies will emerge to address leading edge applications which will, in turn, create more growth in currently underserved markets. Open RAN creates the flexibility needed for innovation to come from not just a single supplier, but from multiple parties, expanding opportunities for new services within the network. With interoperability at the higher system level, open RAN will create more functional solutions that enable additional types of network deployments.

Second, this boon to innovation will create more vendor security. Over the past 20 years, market and industry conditions drove significant consolidation leaving operators few options. In an open RAN system, more vendors can supply critical components to the network without needing to deliver an entire network solution, creating an environment that fosters supplier diversity.

Third, virtualized RAN (vRAN) is a key element of open RAN in which RAN will run as software on the cloud. This will allow all parties to benefit from the cost efficiencies of a virtualized network. Early deployments of vRAN demonstrate a lower operating expense and greater flexibility, creating further opportunity for innovation. Importantly, this lower op-ex creates scalability that has the potential to improve network access in geographic areas that have not historically enjoyed the latest and greatest network technology.

Every game-changing innovation has hurdles and challenges, but for us the benefits of open RAN are clear. It will enable flexible and multi-vendor deployments, faster innovation, automated operational network functions and more. In short, it's a way for us to optimize and extend the true potential of 5G.

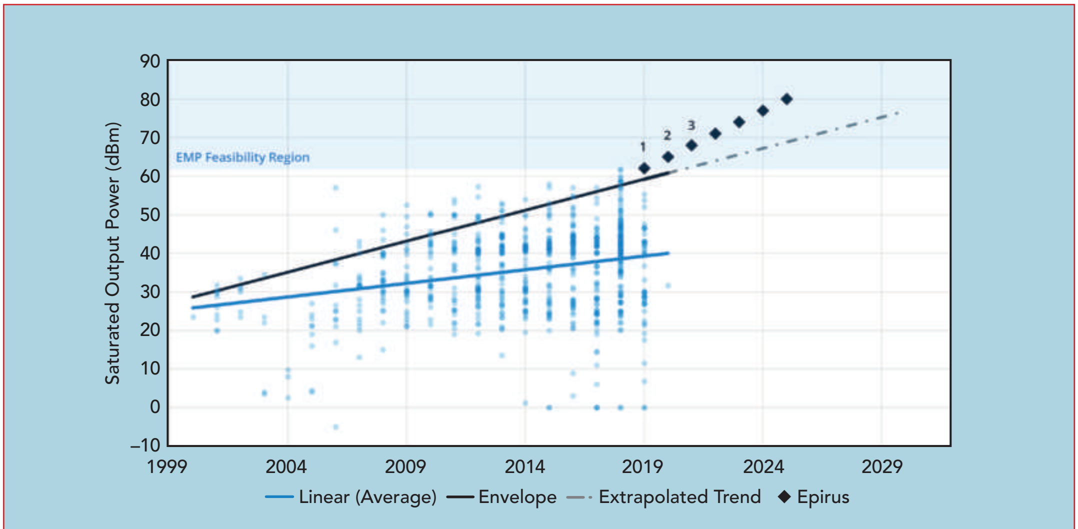
INVITED PAPER

Solid-State Power Density Enabling Unprecedented EMP Capabilities

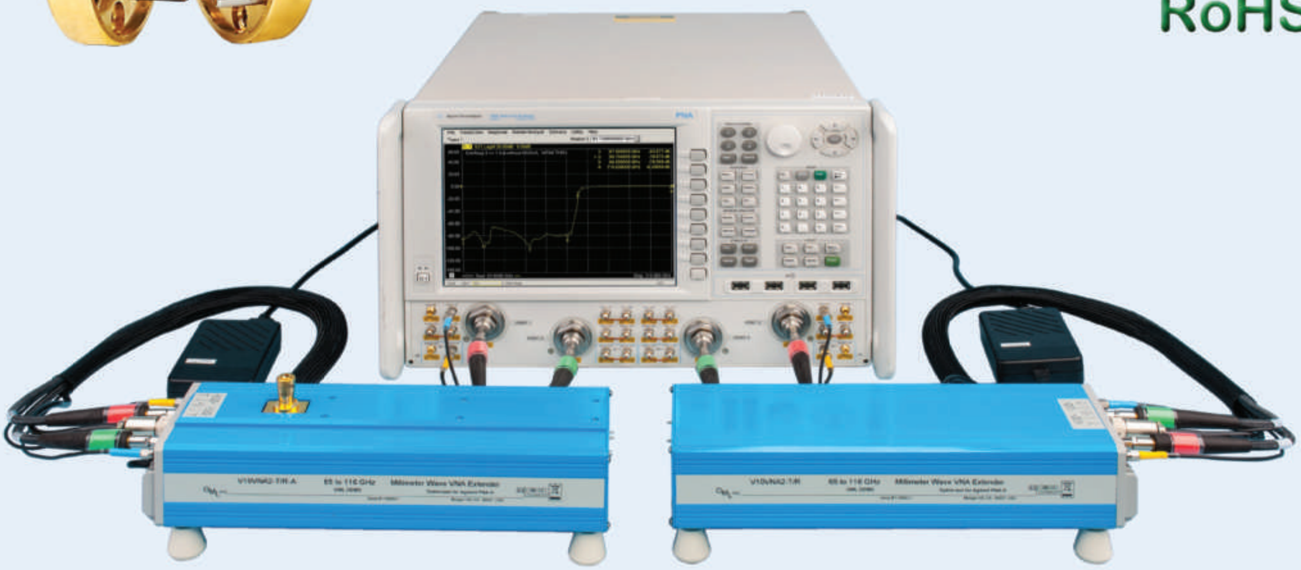
Bo Marr and Bill Dower
Epirus, Hawthorne, Calif.

Solid-state RF amplifier power density has been exponentially increasing for decades and will continue this trend for many decades. It has just reached levels sufficient for commercial and tactical software-controllable electromagnetic pulse (EMP) applications. This article focuses on the history, the underlying physics and future trends.

As the world becomes saturated with electronics and electronic systems built for both altruistic and nefarious purposes, providing an altruistic operator with control over device functionality in a hostile environment is necessary. There is a growing need for "electronic safe zones" (ESZ), for example, as professional sports, entertainment venues, airports, government facilities, oil pipelines, nuclear sites, critical infrastructure and mass gatherings are threatened by attack from emerging AI-driven unmanned aerial systems. A lack of ESZs threatens our right to privacy. The ubiquity of sensor electronics, including the omnipresence of cameras, where the activities of large portions of the world's population are constantly monitored,



▲ Fig. 1 20-year trend of saturated power output for silicon, GaAs, SiGe, InP and GaN PAs operating below 4 GHz.



and the trillion-device IoT, where microphones record millions of hours of conversations, are disturbing developments. From wayward autonomous vehicles to computers infected by viruses, the need for ESZs is apparent. A commercially viable EMP capability provides a means for establishing an ESZ. This article discusses advances in the enabling solid-state RF power amplifier (PA) electronics.

SOLID-STATE PA POWER DENSITY

The future of solid-state RF PAs is the future of wireless technology itself. Without these devices, none of the technology that is so intertwined with our day-to-day lives is possible. As the need for wireless devices has grown, so too has the power density of the enabling devices.

Figure 1 shows the trend of RF PA device output power over the last 20 years.[1] The saturated power (P_{sat}) from more than 900 silicon and III-V PAs operating in the 0.1 to 4 GHz range shows an exponentially increasing P_{sat}. Analyzing the data yields two trends: the overall average and the "envelope" average of the five highest PAs from a given year. This envelope line represents the trend for the increase in power density, showing that P_{sat} values have increased from about 25 dBm in 2000 to 60 dBm in 2019, a linear increase of more than 3,000× in less than 20 years. This equates to 1.8 dB per year, about a 50 percent increase in output power per year. Projecting this trend into the future, the power density of these solid-state devices will double about every 20 months.

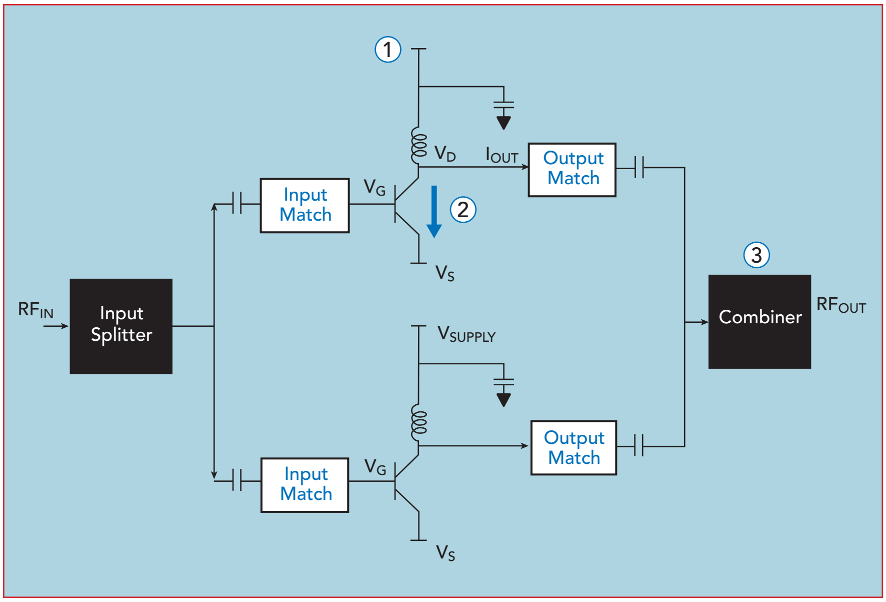


Fig. 2 Elements of the PA architecture expected to provide significant gains in RF output power.

The Epirus points on the plot reflect both integrated and printed circuit form factors being developed by Epirus. Based on EMP system design calculations, Epirus' first 63 dBm output power device in 2019 had sufficient power density to make commercial EMP feasible, and Epirus expects the output power density to double every 12 months. 69 dBm devices now being developed will achieve the power the envelope line trend predicts in 2026. By 2025, Epirus expects its saturated power capability to reach 80 dBm.

GENERALIZED PA MODEL

How will the exponential increase in solid-state output power continue? ***Figure 2*** shows a simplified solid-state PA circuit, indicating three areas enabling improvements in the RF power, designated 1, 2 and 3. Accompanying these, the authors rec-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ognize the need for improved thermal management, through cooling technologies and other proprietary techniques. Emerging cooling technologies to solve the thermal issues have been well documented.[2]

Using simplifying approximations, the RF output power of a PA is defined by:

$$P_{out} = \left(\sum_{i=1}^{n} P_i\right) - P_{loss} \quad (1)$$

$$P_i = I_{RFout,i} \cdot V_{D,i} \quad (2)$$

$$I_{RFout} \propto I_D \quad (3)$$

Equation 1 shows the power output as the sum of the powers from n RF devices, minus the loss through any combining circuits. Equation 2 shows the power through the i^{th} device is a function of the drain voltage, V_D, and the current to the RF load, I_{RFout}. I_{RFout} is proportional to the drain current, given by Equation 3. In an RF device, the drain current creates the negative cycle in the sinusoidal voltage signal going out to the RF load.

The following sections discuss each of the areas that will enable continuing improvements in PA output power.

Power Combining

One opportunity for increased RF output power comes from the power combining of multiple devices (see "3" in Figure 2). The revolution that has occurred and will continue in this area is due to chip scale combining, high breakdown voltage combiners and combining in three dimensions using 3D heterogeneous integration techniques.[3] Multiple semiconductor devices can be combined with chip scale circuit topologies to increase power density at the module level, using 90 degree hybrid circuits or microstrip-based Gysel combining. Hybrid circuits have the advantage that reflected power is handled with an isolation port and significantly reduces high VSWR and the risk of failure seen by the device.

Several topologies can be scaled to an arbitrarily large number of device ports, the only limitation the voltage in the circuits can withstand before breakdown. Combining technologies with high-power III-V materials enable very high power levels at the integrated circuit. There are losses that occur in splitting and combining the RF signals that must be considered, as well as impedance matching network losses. Large RF bandwidths require multiple matching network stages or RLC circuits, while a narrower bandwidth reduces the number of matching circuits and the loss.

Breakdown Voltage

A second opportunity to increase the RF output power is raising the breakdown and supply (i.e., drain) voltages of the RF transistor (see "1" in Figure 2). Increasing the drain voltage enables a larger voltage swing, increasing the output power of the amplifier. This also requires higher breakdown voltage: if the drain voltage, V_D, comes close to or exceeds the breakdown voltage, V_b, it normally destroys the transistor.

Breakdown voltage is typically determined by the device material. For example, GaAs semiconductors, the precursor to GaN, have breakdown voltages in the range of 7 to 20 V, while the theoretical breakdown of GaN devices can be 1,000 to 3,000 V, depending on the specific "on" resistance of the device.[4,5] ***Table 1*** shows the breakdown field, which is proportional to the breakdown voltage of several semiconductor materials used for PAs. Raising the operating voltage of the power transistor also requires higher breakdown voltages for the passive components connected to the drain node; however, this is generally not a problem.

Transistor Current

The third opportunity to increase PA output power is by increasing the transistor drain current (see "2" in Figure 2). A generalized equation for the drain current through a solid-state device is

$$I_{ds} = W\mu q n_s(x)\frac{dV(x)}{dx} \quad (4)$$

TABLE 1

SEMICONDUCTOR BREAKDOWN FIELDS[6] (10^6 V/CM)

Si	GaAs	GaN	Diamond	AlN
0.3	0.4	3	5	8.4

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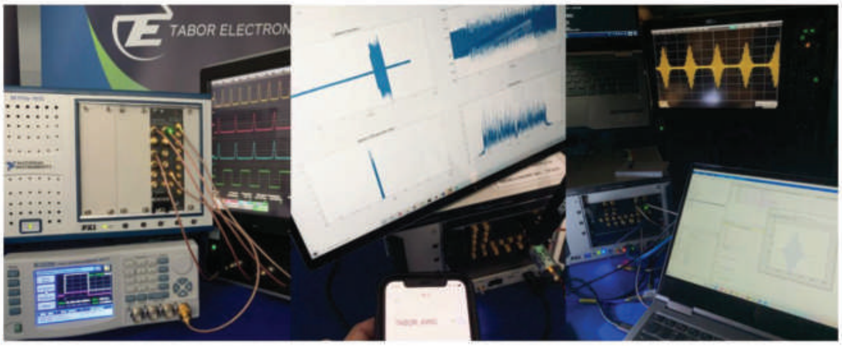

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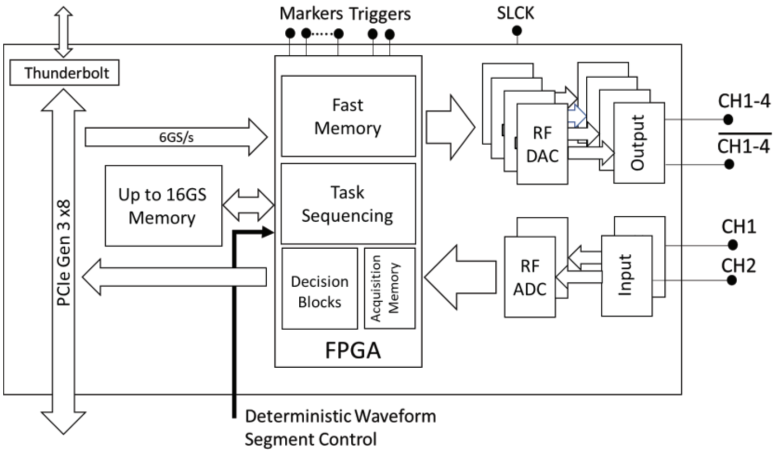

Block Diagram Overview

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The saturated drain current under specific boundary conditions[7] is given by Equation 5. There are many models to describe the drain current of HEMT devices using both empirical and theoretical approaches to determine the saturation current. The authors recognize this is a significant research area and decided to use the model by Charfeddine et al.[7] for this discussion, recognizing there are different forms of this expression.[8,9] Equation 5 gives a sufficient general approximation for the expected power gains. For RF power amplification, the drain current of a HEMT device that operates in the saturation region is thus:

$$I_{dsat} = W\mu C E_{sat}\left(V_{gs} - V_{th} - V_{dsat}\right) \quad (5)$$

where V_{th} is the threshold voltage, V_{gs} the gate voltage and V_{ds} the drain bias. The terms C and E_{sat} are the capacitance per unit area of the device and the E-field[10] within the device at saturation, respectively.

Increasing the current comes from several areas, with new materials beyond GaN potentially providing up to an order of magnitude increase.[11] Improvements such as electron mobility and gate capacitance, μ and C, will depend on future device materials. However, an approach that does not require materials engineering is to increase the periphery of the device, W.

It is critical that these improvements maintain the same or increase drain voltage. GaAs, for example, has improved electron mobility but significantly degraded breakdown voltage. The important parameter, then, is the transconductance or gain of the semiconductor device, g_m; the transconductance is the change in drain current as a function of the applied voltage, defined as

$$g_m = \frac{\delta I_{dsat}}{\delta V_{gs}} \quad (6)$$

Increasing the gain of the semiconductor device increases the RF output power at a given drain voltage. Materials and larger device peripheries can increase the transconductance. As three dimensional and integrated circuit technologies improve, channel depth will also increase drain current.

The gate capacitance, C, is inversely proportional to the cutoff frequency, f_T:[12]

$$f_T = \frac{g_m}{2\pi CWL} \quad (7)$$

where L is the transistor channel length. As the RF frequency of the device increases, the capacitance of the device must decrease, which ultimately lowers I_{dsat}, the drain current at saturation, and decreases the RF output power. Higher output power can be achieved at lower microwave frequencies using semiconductor devices like GaN.

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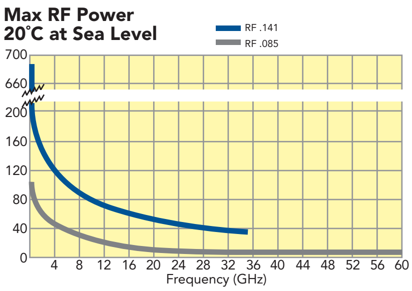

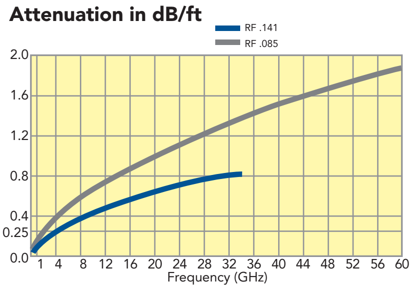

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CONCLUSION

Improvements are being developed to increase the saturated output power of RF transistors by several orders of magnitude. The key areas are devices with higher breakdown and drain voltages and current, with increased integrated circuit power combining. The next generation of products leveraging these high-power, solid-state amplifiers has the potential to revolutionize commercial and government EMP applications. Considering the historical overview discussed here, solid-state electronic power density has been on the rise for decades, with substantial increases to come.■

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Low RCS Microstrip Patch Antenna Using Artificial Magnetic Conductors and Defected Ground Structure

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University of Electronic Science and Technology of China, Chengdu, China

A new design reduces the radar cross section (RCS) of a microstrip antenna by using artificial magnetic conductors (AMCs) and a defected ground structure (DGS). RCS reduction is achieved by phase cancellation. Compared with the traditional method of only AMC loading, simultaneous AMC and DGS loading reduces the monostatic RCS at low frequencies, while gain is significantly improved. 10 dB RCS reduction is from 8.19 to 15.84 GHz (63.7 percent) and maximum gain enhancement is 3.7 dB at 10 GHz.

Antenna RCS is an important component of total RCS on a low observable platform. The requirement that its own radar wave is transmitted and received, however, makes antenna stealth difficult. A microstrip antenna is widely used in communication systems due to its small volume, light weight, low profile and ability to conform to a surface. In recent years, several methods have been proposed to reduce microstrip antenna RCS, one of which uses metamaterials.

Because the reflection phase difference between electromagnetic band gap (EBG) structures and perfect electrical conductors is 180 degrees at resonance, their reflected waves cancel. RCS reduction is obtained by partially distributing the EBG substrate around the antenna patch, at the cost of antenna radiation performance.[1] For wideband antenna RCS reduction, when the phase cancellation units are replaced by two different AMCs and arranged in a checkerboard configuration, 180 ± 37 degree phase difference can be achieved over a wider frequency range.[2-4] The structure of a frequency-selective surface (FSS) can also be used to reduce antenna RCS, but it is usually limited to out-of-band reduction.[5] To reduce both in-band and out-of-band antenna RCS simultaneously, the FSS structure is often combined with other methods, like loaded microstrip resonators[6] and EBGs.[7]

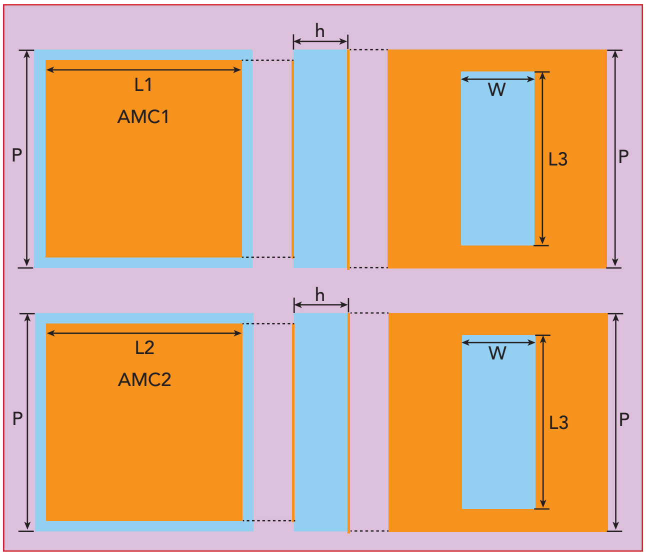

Fig. 1 AMC1 and AMC2 dimensions (mm): P = 5, h = 1.575, L1 = 4.9 and L2 = 3.6.

This work reduces antenna RCS by using AMCs. Different from previous work, a DGS is incorporated into the antenna design. A DGS is commonly used to improve antenna performance by reducing mutual coupling,[8, 9] broadening impedance bandwidth[10] and suppressing cross-polarization.[11-13] In this design, an AMC structure is combined with a DGS to reduce the antenna RCS at low frequencies and simultaneously improve gain.

AMC DESIGN

A conventional AMC structure is composed of periodically arranged metal patches on the upper surface, with an intermediate medium and metal ground. According to the equivalent LC resonant circuit, reducing the AMC center frequency with appropriate patch dimensions does not guarantee its bandwidth once the substrate thickness is determined. The center frequency is assumed to be the frequency corresponding to 0 degree reflective phase, and the bandwidth is the frequency range of the reflective phase from -90 to +90 degrees. Etching a DGS on the ground plane introduces additional inductance, which reduces the center frequency without changing the size of the upper patch, leaving the bandwidth unchanged. As shown in ***Figure 1***, square patches of different sizes are selected as the AMC units, AMC1 and AMC2. The substrate material is Rogers RT5880 (ε_r = 2.2), and the ground plane is etched with a rectangular aperture.

Figure 2 shows the reflection phase of AMC1 with different aperture widths and polarizations. The case w = 0 mm corresponds to a conventional AMC, with L3 set to 3 mm. As expected, the etched aperture on the ground plane has a large influence on the AMC phase characteristics. The center frequency decreases with increasing aperture width, especially when the polarization direction is parallel to the direction of w. ***Figure 3a*** shows the reflection phase of two AMCs with w = 2 and 0 mm for different polarizations. Because the AMC phase characteristics are related to polarization, the phase difference curves for

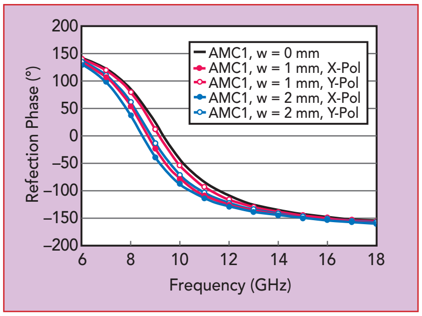

Fig. 2 AMC1 reflection phase vs. frequency, aperture width and polarization.

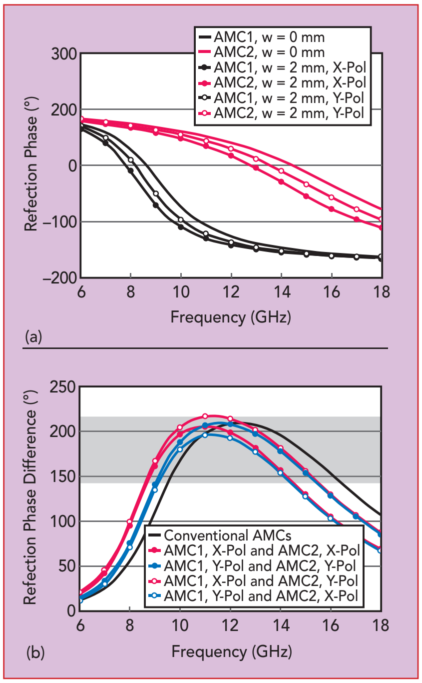

Fig. 3 Reflection phase (a) and reflection phase difference (b) of the AMC units.

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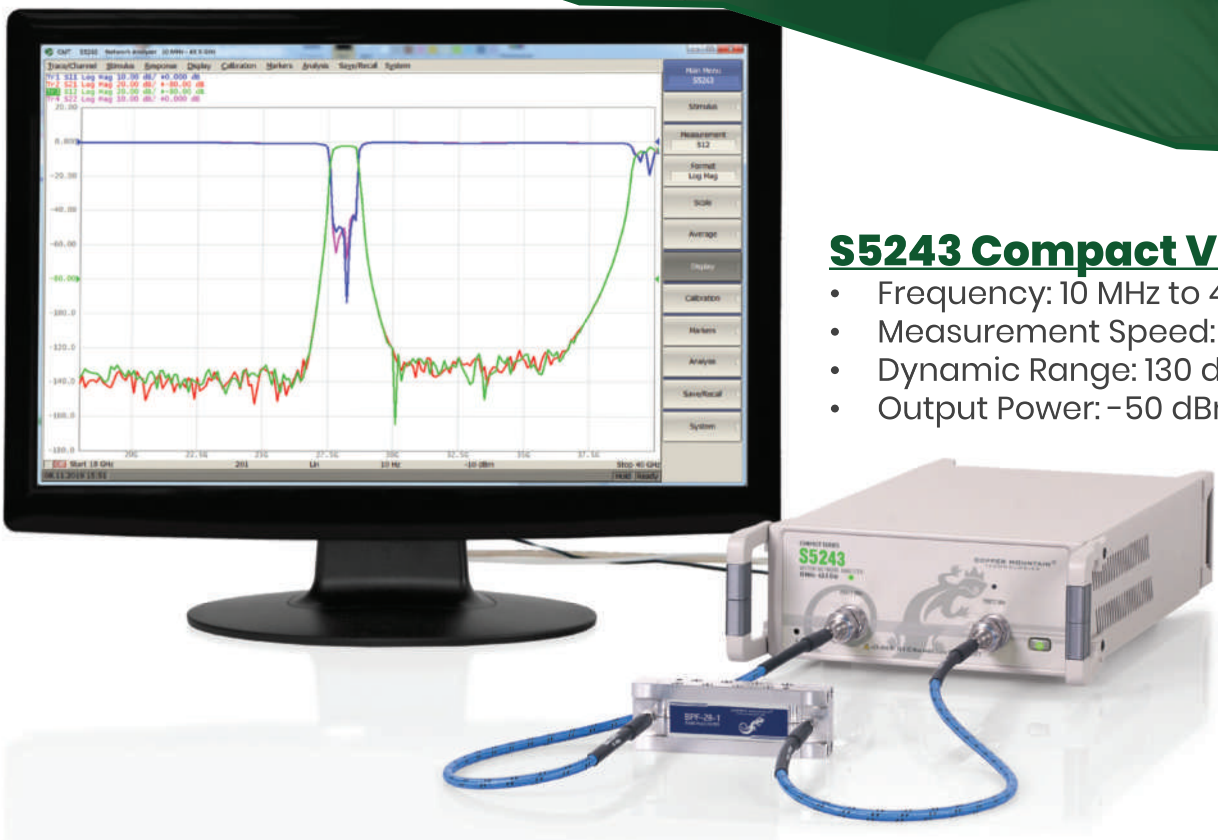

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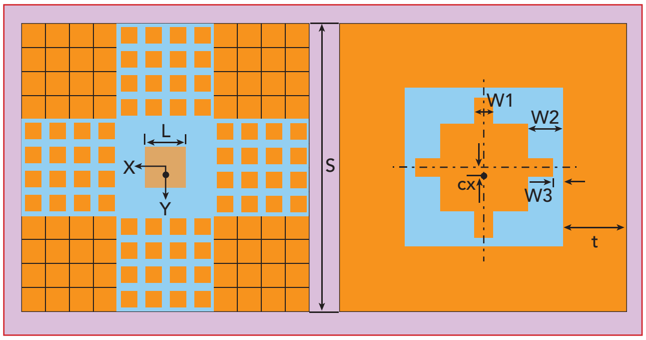

▲ Fig. 4 **Prototype antenna dimensions (mm): S = 60, L = 8.6, cx = 1.7, W1 = 4, W2 = 9.2, W3 = 2 and t = 16.5.**

different cases are shown in ***Figure 3b***. The effective phase difference band of two different conventional AMCs spans 9.52 to 16.43 GHz, while the maximum AMC and DGS aperture band spans 8.61 to 15.47 GHz. The bandwidth is almost unchanged and the phase difference curve moves lower in frequency with the etched aperture on the ground plane.

ANTENNA DESIGN

The substrate material for the prototype antenna (see ***Figure 4***) is the same as that of the AMC, and it is fed by a coaxial cable. The AMC is placed around the antenna patch in a checkerboard configuration, and the symmetric DGS is etched on the ground plane. DGS dimensions are optimized to achieve the maximum cross-polarization suppression in the H-plane without affecting the co-polarized gain and impedance bandwidth, defined as $|S_{11}| < -10$ dB. As mentioned, the DGS structure reduces the AMC center frequency near the patch.

Simulated $|S_{11}|$ is plotted in ***Figure 5a***. Antenna 1 is the antenna loaded with conventional AMCs, antenna 2 represents this work and an unmodified patch antenna is a reference. The resonant frequencies and impedance bandwidths of the three antennas are only slightly different. The simulated gain of antenna 2 is significantly higher than that of antenna 1 from 9 to 11 GHz, the maximum gain enhancement compared to the reference antenna is 3.7 dB at 10 GHz (see ***Figure 5b***). The simulated antenna 1 patterns almost coincide with the reference antenna patterns, while the main beam of antenna 2 is narrower, indicating higher directivity (see ***Figure 6***).

At normal incidence, the simulated monostatic RCS of the antennas is shown in ***Figure 7***. Compared to antenna 1, with loaded conventional AMCs, the RCS of antenna 2 decreases at low frequencies and rises at high frequencies, because the effective phase difference bandwidth moves lower in frequency with the DGS. Compared to the reference antenna, antenna 1 shows >10 dB RCS reduction from 10.2 to 17.11 GHz (50.5 percent bandwidth); the 10 dB RCS reduction band represented by this work (antenna 2) is from 8.19 to 15.84 GHz (63.7 percent) except for a few points. Although the >10 dB RCS reduction bandwidth is slightly lower than reported by Zheng et al.[2] (65.2 percent from 8.8 to 17.3 GHz) and Yao et al.[4] (67 percent from 13.4 to 26.9 GHz), antenna 2 achieves RCS reduction at low frequencies and significantly improves the antenna gain. The maximum gain reported by Zheng et al.[14] is enhanced by 4.9 dB, but with only 55.1 percent relative reduction bandwidth (9.6 to 16.9 GHz). Both radiation and scattering characteristics have been improved in this design compared to the results reported in the literature.

MEASUREMENTS

To verify the simulations, a prototype of the antenna 2 (see ***Figure 8***), as well as an antenna loaded with conventional AMCs and a conventional patch, were measured with a Keysight E8363B vector network analyzer. As shown in ***Figure 9***, while the resonant frequencies of antennas 1 and 2 are higher and the bandwidths slightly larger, the performance is similar to the simulation. Normalized radiation patterns


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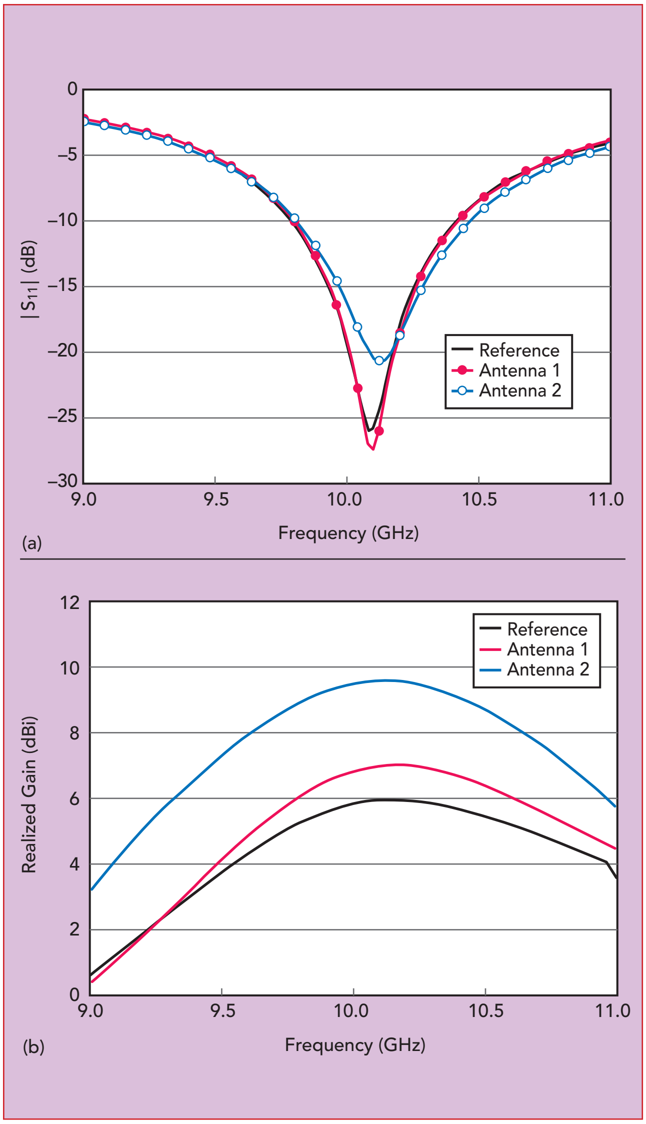


Fig. 5 Simulated $|S_{11}|$ (a) and realized gain (b) vs. frequency.

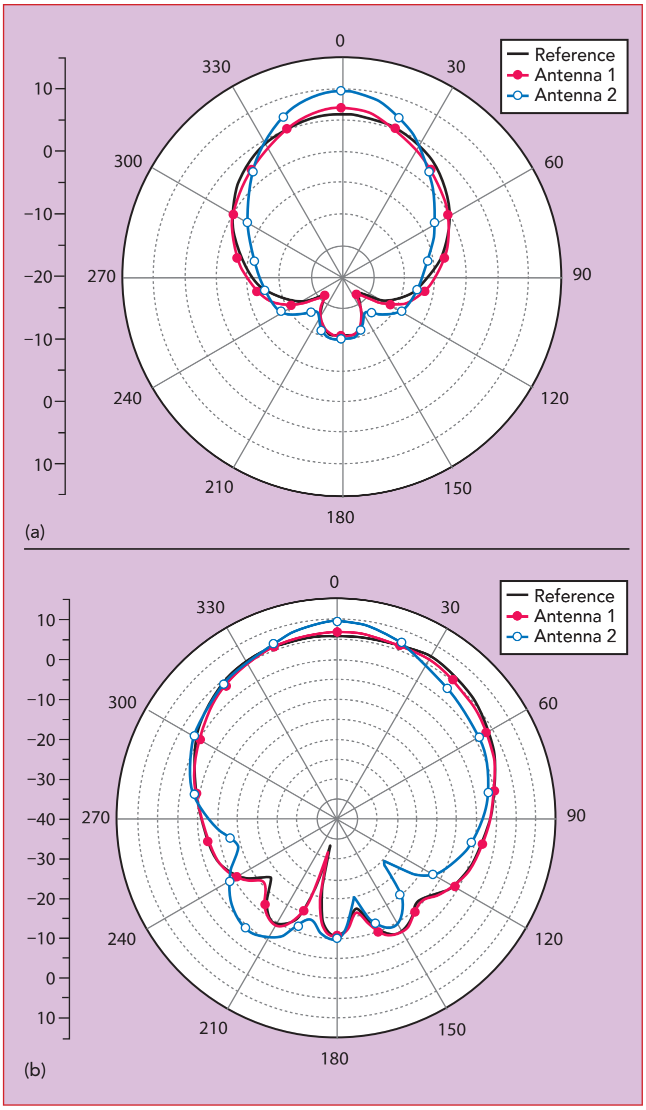
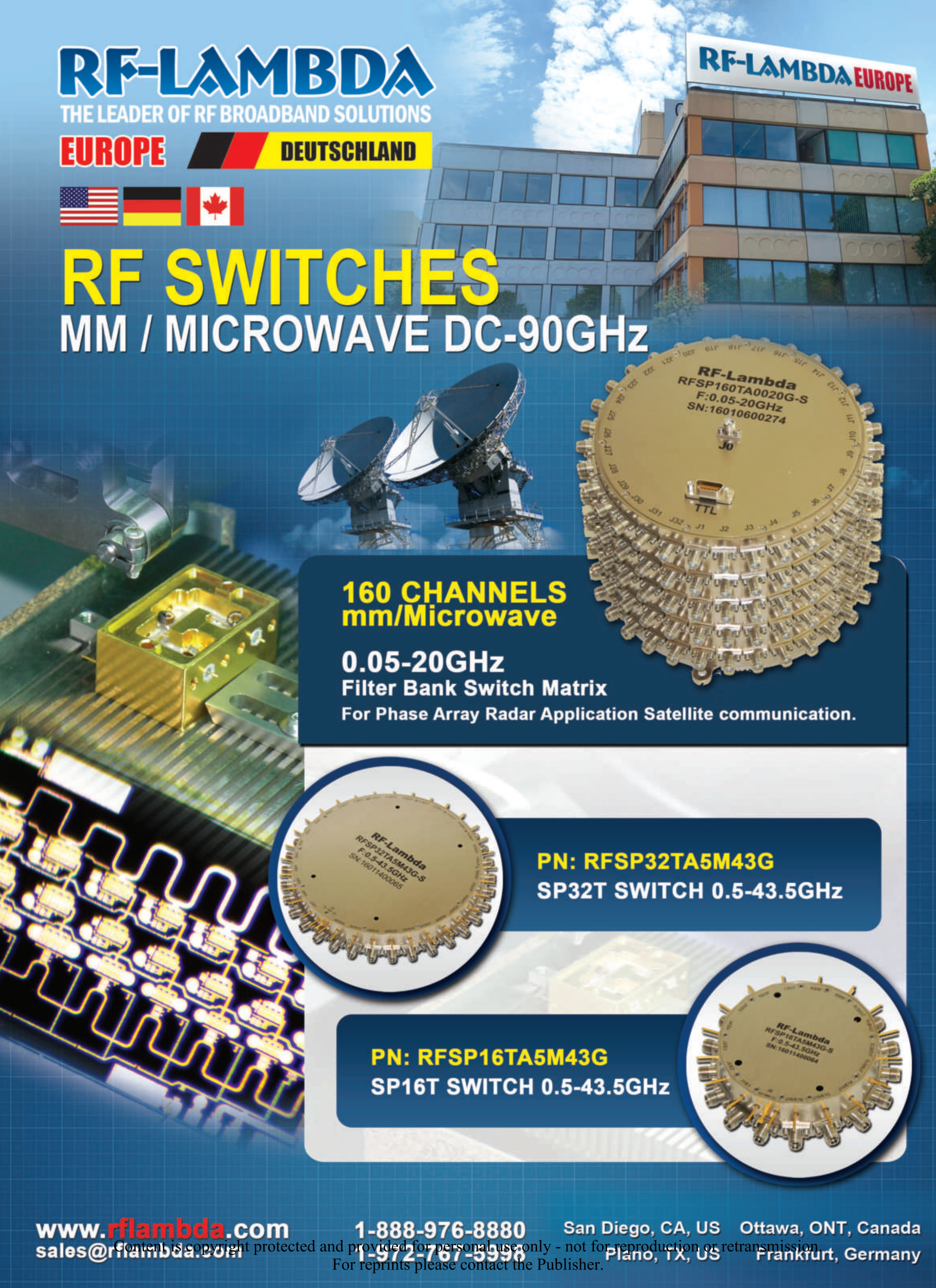


Fig. 6 Simulated xoz (a) and yoz (b) plane radiation patterns at resonance.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are shown in ***Figure 10***. As predicted by the simulation, antenna 2 has slightly improved directivity. The monostatic RCS at normal incidence is shown in ***Figure 11***. Like the simulation, antenna 2 demonstrates a larger RCS reduction at lower frequencies than antenna 1 and a significant reduction compared to the reference, which agrees with the simulation.

CONCLUSION

RCS reduction of a patch antenna and gain improvement were achieved with simultaneous AMC and DGS

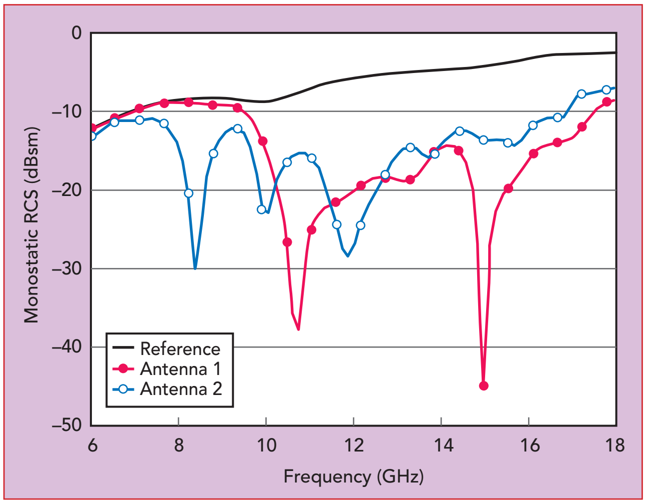


Fig. 7 Monostatic RCS vs. frequency.

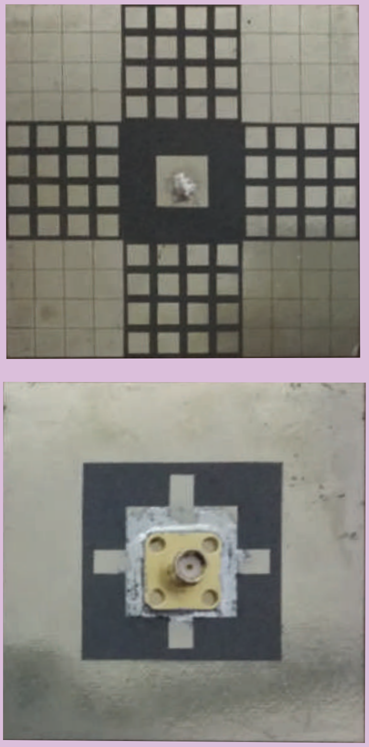
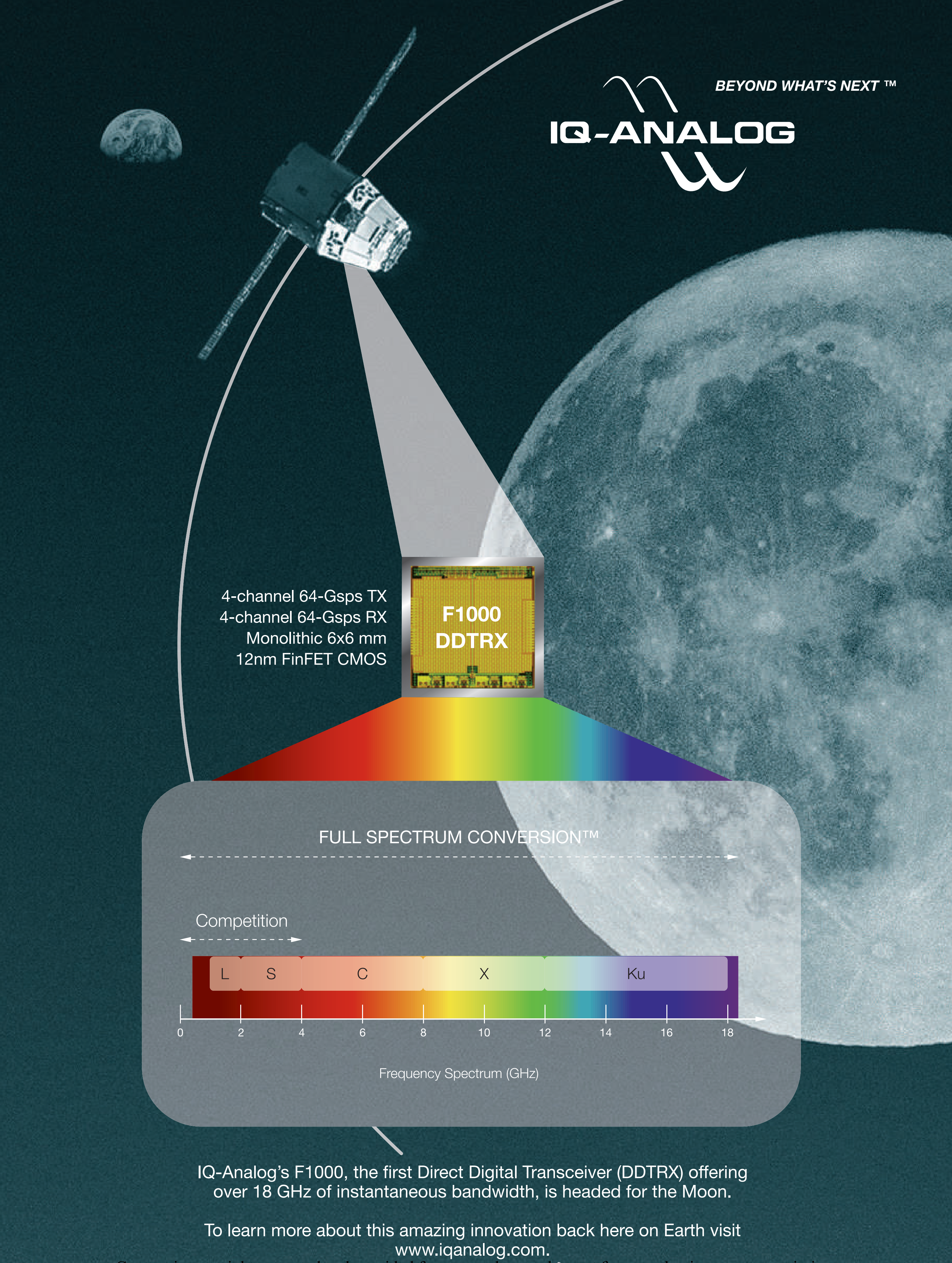


Fig. 8 Antenna 2 prototype.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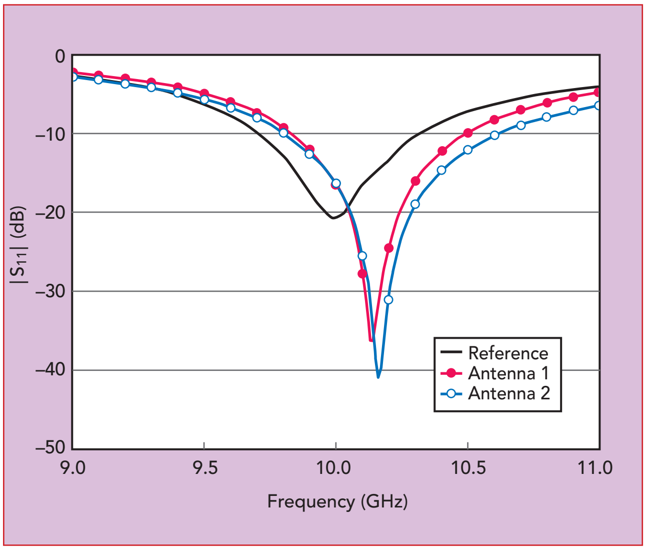

Fig. 9 Measured $|S_{11}|$ vs. frequency.

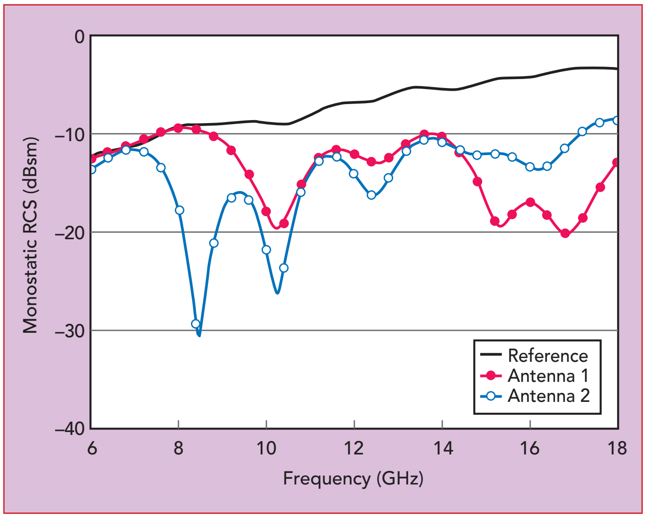

Fig. 11 Measured monostatic RCS vs. frequency, at normal incidence.

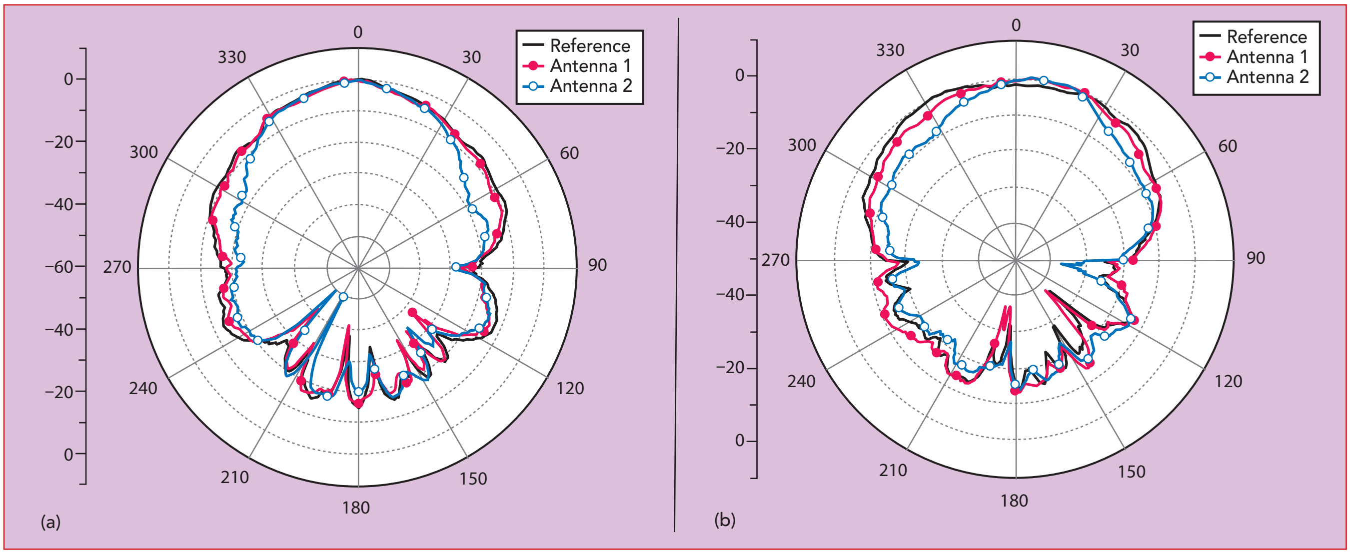

Fig. 10 Measured and normalized radiation patterns in the xoz (a) and yoz (b) planes.

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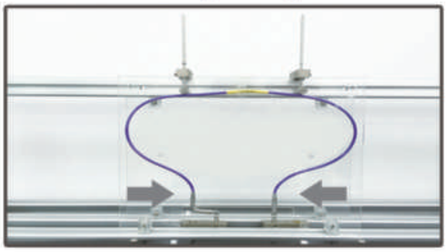

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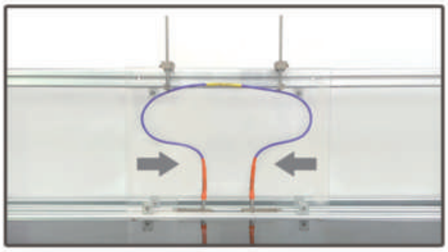

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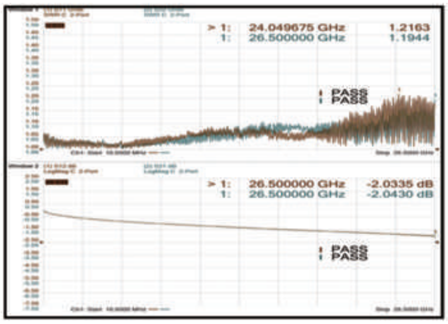

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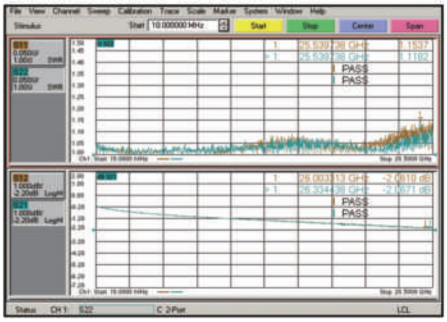

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loading. For normal incident waves, reflections are cancelled on the antenna surface for better RCS reduction at lower frequencies. AMC and DGS loading provide a solution to the conflict between gain enhancement and RCS reduction, and RCS reduction is achieved without altering the patch design.■

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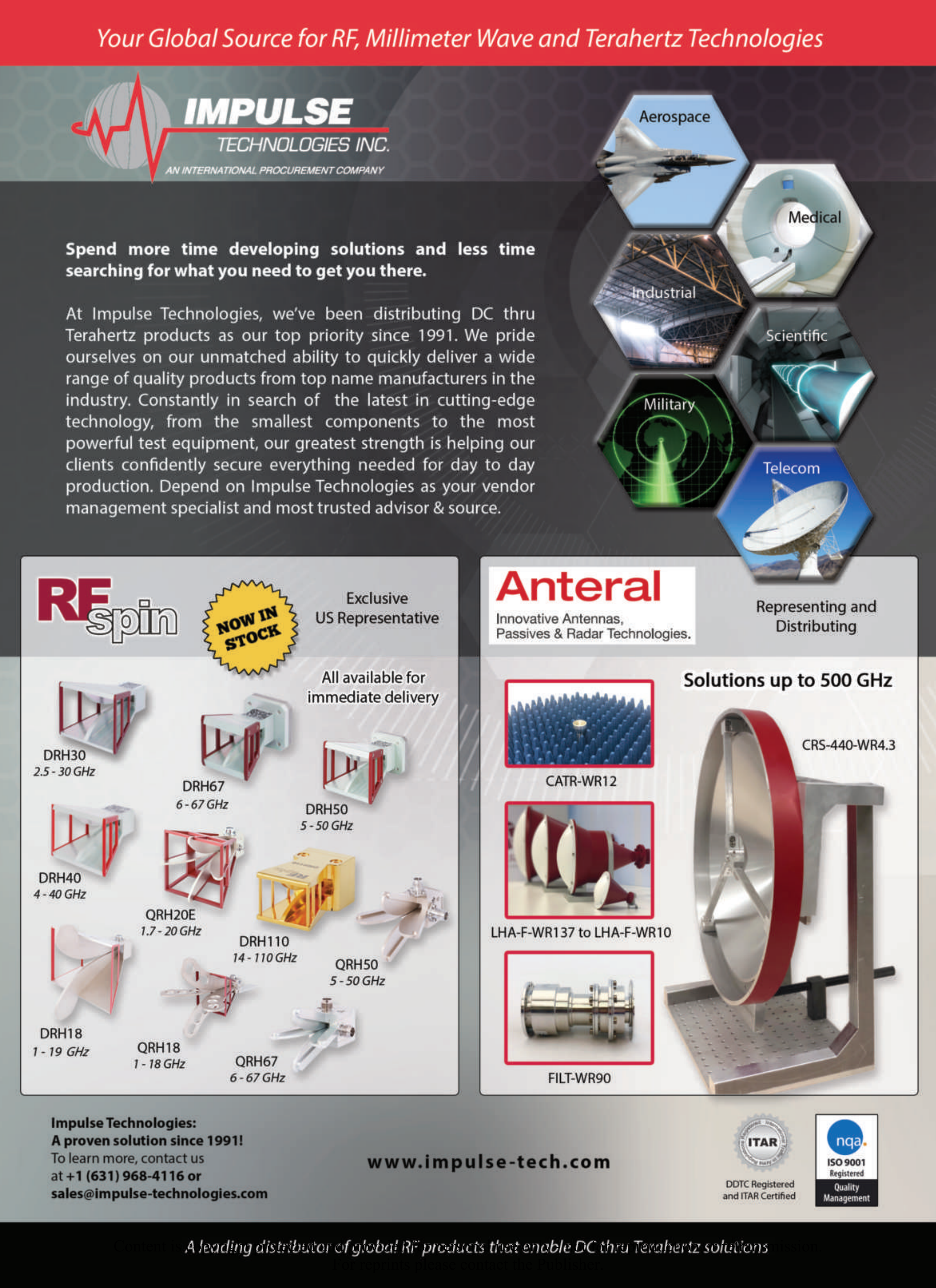

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28 and 38 GHz Colpitts Oscillator MMICs With Low Phase Noise, High-Power and High DC-to-RF Efficiency

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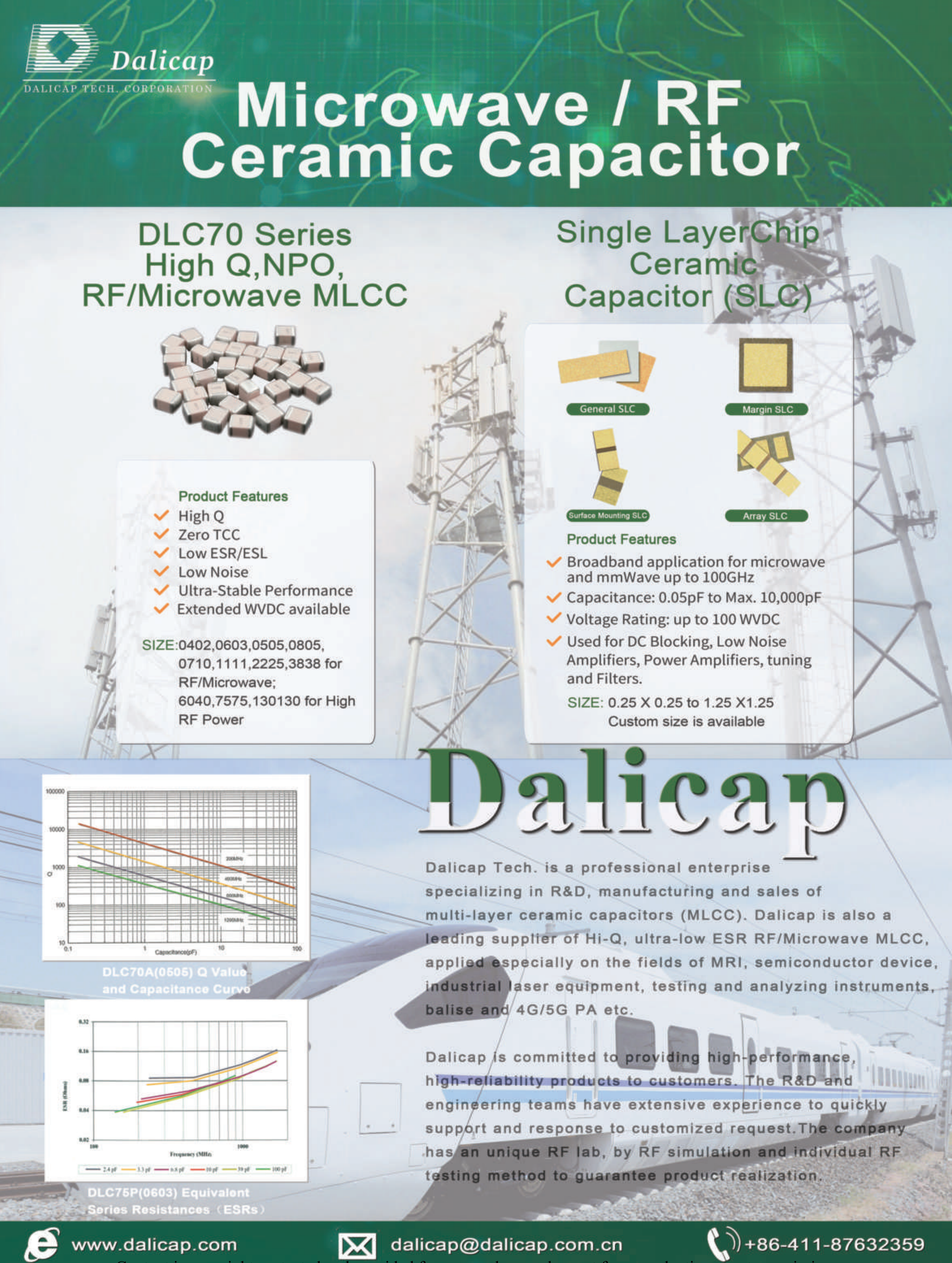
Two MMIC oscillators at 28 and 38 GHz, respectively, were fabricated with a 0.15 μm GaAs enhancement-mode (E-mode) PHEMT process using a Colpitts topology modified for high frequency performance. For higher output power and better efficiency, a T-shaped network on the load side was optimized for output matching. The 28 GHz oscillator delivered an output power of 16.7 dBm with a DC-to-RF efficiency of 24.3 percent, while the 38 GHz oscillator delivered an output power of 10.6 dBm with a DC-to-RF efficiency of 10.3 percent. Measured phase noise at 1 MHz offset was -115.8 dBc/Hz at 28 GHz and -110.4 dBc/Hz at 38 GHz.

mmWave frequency sources with low phase noise, low-power dissipation and sufficient output power are essential elements of wireless communication systems. Because heterojunction bipolar transistors (HBTs) exhibit lower device 1/f noise compared with high electron mobility transistors (HEMTs), they are often used for low phase noise oscillators.[1] Many results have been reported for Ka- and K-Band oscillators fabricated with GaAs or SiGe HBTs,[2,3] however, these oscillators have either high DC power consumption or insufficient output power. HEMTs can deliver greater power at higher oscillating frequencies,[4] with several Ka-Band HEMT MMIC oscillators reported.[5-7] The E-mode PHEMT is suitable for modern wireless communications due to its single supply voltage and low knee voltage.[8]

In this article, we discuss the design and performance of two Ka-Band oscillators designed on the same 0.15 μm GaAs E-mode PHEMT process. High DC-to-RF efficiency and low phase noise were obtained. To achieve high oscillating frequency, a modified Colpitts topology was adopted and a T-shaped output matching network was used to achieve higher output power and efficiency. With this approach, oscillators at 28 and 38 GHz delivered 16.7 and 10.6 dBm output power and high DC-to-RF efficiencies of 24.3 and 10.3 percent, respectively. The modified Colpitts topology enables a low gate voltage bias without influencing oscillation start-up. This results in lower gate shot and 1/f noise, reducing their contributions to the oscillator's phase noise. The measured phase noise at 1 MHz offset was -115.8 dBc/Hz at 28 GHz and -110.4 dBc/Hz at 38 GHz.

MMIC PROCESS AND CIRCUIT DESIGN

The circuit design was based on the 0.15 μm GaAs E-mode PHEMT devices on a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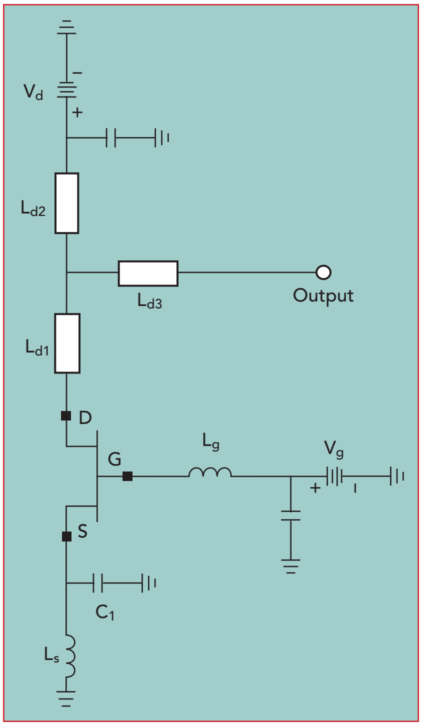

Fig. 1 Colpitts oscillator.

process offered by WIN Semiconductors Corporation. The E-mode PHEMT device typically exhibits a maximum oscillation frequency, f_{max}, of 150 GHz and a current gain cutoff frequency, fT, of 80 GHz when biased for maximum DC transconductance of ~1,000 mS/mm. The threshold voltage for the devices is ~0.25 V. The MMIC process includes slot vias, thin film resistors, metal-insulator-metal (MIM) capacitors, spiral inductors and microstrip transmission lines.

A Colpitts topology was used for the oscillator (see ***Figure 1***). The inductive elements L_g and L_s were achieved using short microstrip lines less than λ/4 and the capacitance, C_1, was realized with an open microstrip line or MIM capacitor. For a traditional lower frequency Colpitts oscillator (see ***Figure 2a***), the resonator is typically formed by C_1 and L_g. For the high frequency oscillators described here, an additional inductance, L_s, was introduced to improve performance (see ***Figure 2b***). In this design, the internal gate-source capacitance of the transistor, C_{gs}, serves as C_2.

Using an ideal transconductance model, the circuits were analyzed under small-signal conditions to understand the effect of L_s (see ***Figure 3***). The input impedance of the model in Figure 3a is

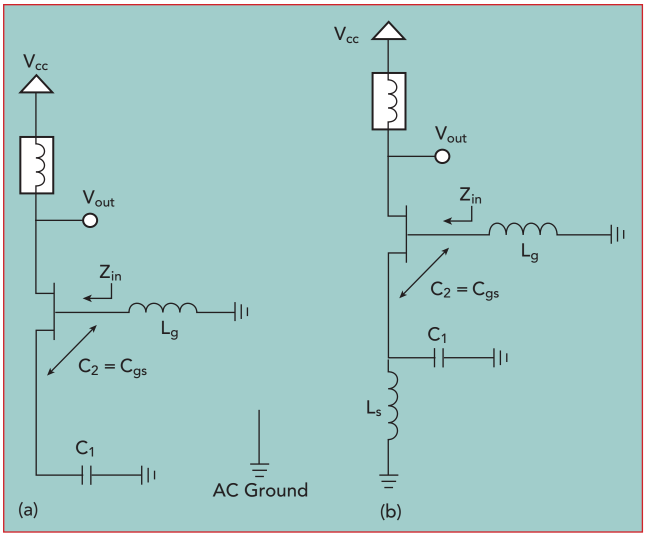

Fig. 2 Traditional low frequency Colpitts design (a), modified for better high frequency performance (b).

$$Z_{in} = -\frac{g_m}{4\pi^2 f^2 C_1 C_2} - j\frac{1}{2\pi f}\left(\frac{1}{C_1}+\frac{1}{C_2}\right) \quad (1)$$

where the negative real part of Z_{in} corresponds to the negative resistance. The value of negative resistance is smaller at higher frequencies. From Figure 3b,

$$Z_{in} = -\frac{g_m}{4\pi^2 f^2 C_1 C_2 - \frac{C_2}{L_2}} - j\left(\frac{1}{2\pi f C_2}+\frac{1}{2\pi f C_1 - \frac{1}{2\pi f L_S}}\right) \quad (2)$$

In the mmWave band, $4\pi^2 f^2 C_1 C_2 > 4\pi^2 f^2 C_1 C_2 - C_2/L_s > 0$. With L_s included, the negative resistance is boosted at higher frequencies, which improves oscillation start-up and enables higher efficiency. From Equations 1 and 2, the imaginary part of Z_{in} is a capacitive reactance. To create oscillation, an externally connected inductive component at the gate terminal, L_g, pairs with the opposite reactance of the PHEMT device.

The HEMT device cells had 2 × 100 μm and 2 × 50 μm gate widths at 28 and 38 GHz, respectively, and were biased at V_{ds} = 4 V and V_{gs} = 0.45 V. Since the added L_s enhances the negative resistance, the transistor can be biased at a lower gate voltage and drain-source current without inhibiting the conditions for oscillation. This enhances efficiency and reduces the gate shot and 1/f noise, achieving lower oscillator phase noise.[9]

The load design was optimized for higher output power and better DC-to-RF efficiency. Theoretically, maximum output power is realized with complete reactive compensation, so an inductive load was employed to compensate the capacitive device output reactance. A λ/4 transmission line was not used as the RF choke in the supply path; instead, the microstrip line L_{d2}, shorter than λ/4, was employed as the inductive element (see Figure 1). The T-shaped network $L_{d1\text{-}d3}$ serves as output matching at the load side to achieve better power and efficiency. In this way, the circuit structure was simplified since the matching lines also provide the bias.

The circuit was simulated using Keysight's Advanced Design

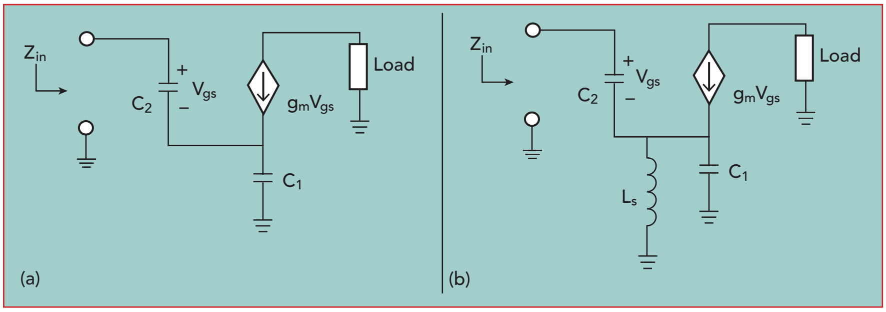

Fig. 3 Small-signal models of the low frequency (a) and high frequency (b) designs.

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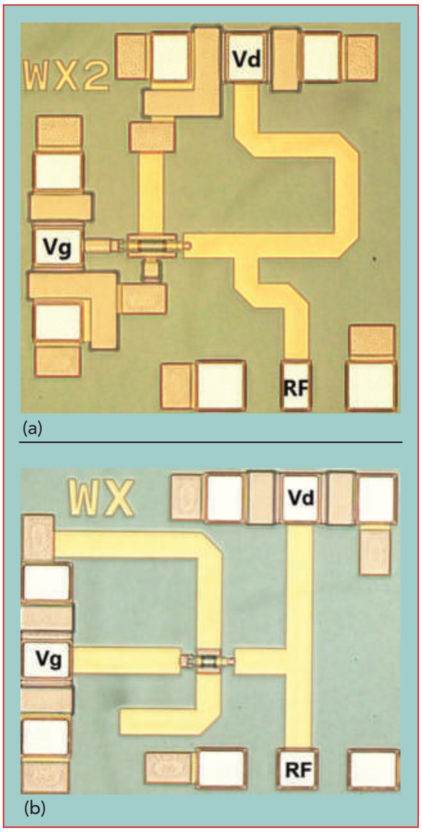

▲ Fig. 4 **28 GHz (a) and 38 GHz (b) oscillator MMICs.**

System, first using small-signal analysis to determine the oscillating frequency. Then, harmonic balance and transient analyses were performed to determine the output power. Finally, the layout was simulated and optimized using the Momentum 2.5D planar electromagnetic simulator. The harmonic balance simulation predicted the 28 GHz oscillator would achieve an output power of 17.9 dBm with an efficiency of 29 percent, and the 38 GHz oscillator would achieve an output power of 12.4 dBm with an efficiency of 17 percent.

EXPERIMENTAL RESULTS

The two MMICs are shown in ***Figure 4***. The 28 and 38 GHz MMIC sizes are 750 μm × 760 μm and 740 μm × 640 μm, respectively, including the DC and RF probe pads.

The E-mode PHEMT oscillator MMICs were fully characterized on-wafer at room temperature using a Keysight N9030A PXA signal analyzer. Measuring the 28 GHz oscillator, a 6 dB attenuator was added to protect the analyzer from high output power. For the 38 GHz measurement, the attenuator was not needed. The cables and probes had 3.3 dB loss at 28 GHz and 3 dB loss at 38 GHz; the two MMICs were measured with different cables, which is why the cable loss at 38 GHz is lower. Accordingly, the measured output power values at 28 and 38 GHz were corrected by 9.3 and 3 dB, respectively, to account for the loss of the attenuator, probes and cables.

Figure 5 shows the measured spectrum of the two oscillators into a standard 50 Ω load. For the 28 GHz oscillator, an uncalibrated output power of 7.4 dBm corresponded to an actual output power of 16.7 dBm, compensating for the attenuator, cable and probe losses. For the 38 GHz oscillator, an uncalibrated output power of 7.6 dBm corresponded to an actual value of 10.6 dBm. With dissipated powers of 192 and 112 mW, respectively, the DC-to-RF efficiencies were 24.3 and 10.3 percent. The measured phase noise was -115.8 dBc/Hz at 1 MHz for the 28 GHz oscillator and -110.4 dBc/Hz at 1 MHz for the 38 GHz design (see ***Figure 6***).

Generally, an oscillator's performance is evaluated by the figure of merit, FOM:[10]

$$FOM = L(\Delta f) - 20\log(f_0 / \Delta f) + 10\log(P / 1mW) \quad (3)$$

where $L(\Delta f)$ is the phase noise at offset frequency Δf, f_0 is the oscillation frequency and P is the power dissipation. The calculated FOMs of the 28 GHz and 38 GHz oscillators at 1 MHz are -181.9 dBc/Hz and -181.7 dBc/Hz, respectively.

SUMMARY

mmWave MMIC oscillators at 28 and 38 GHz were developed using a 0.15 μm GaAs E-mode PHEMT process. The oscillators demonstrated excellent efficiency and phase noise performance with sufficient RF output power to drive a mixer without a buffer amplifier. DC-to-RF efficiency and phase noise performance was state-of-the-art for GaAs-based oscillators operating at this frequency. The performance of several published free-running GaAs-based oscillators is compared with these designs in ***Table 1***. This work demonstrates the potential of GaAs E-

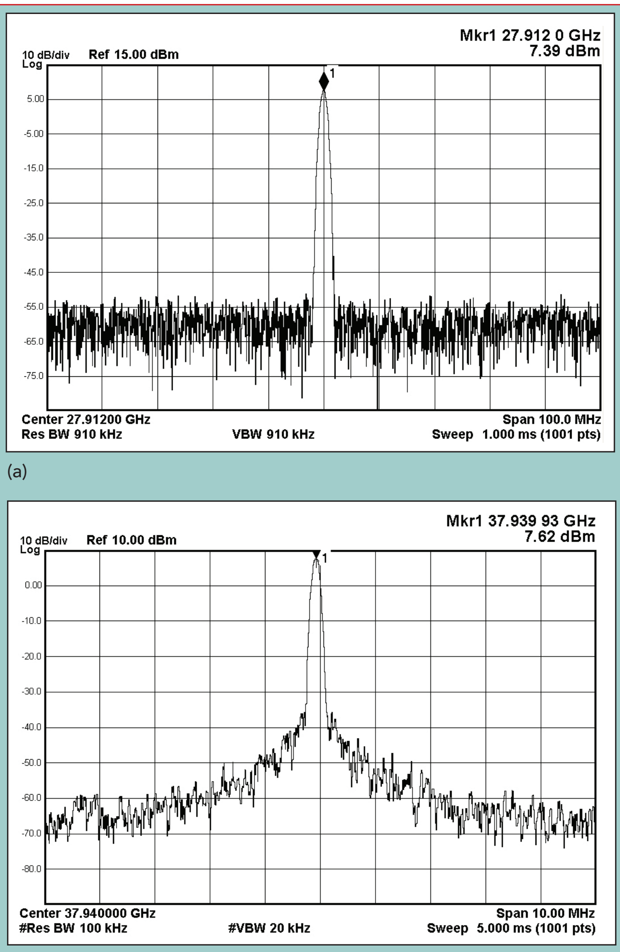

Fig. 5 Measured spectrum of the 28 GHz (a) and 38 GHz (b) oscillators.

mode PHEMT technology for high performance mmWave sources in wireless communication systems.

ACKNOWLEDGMENT

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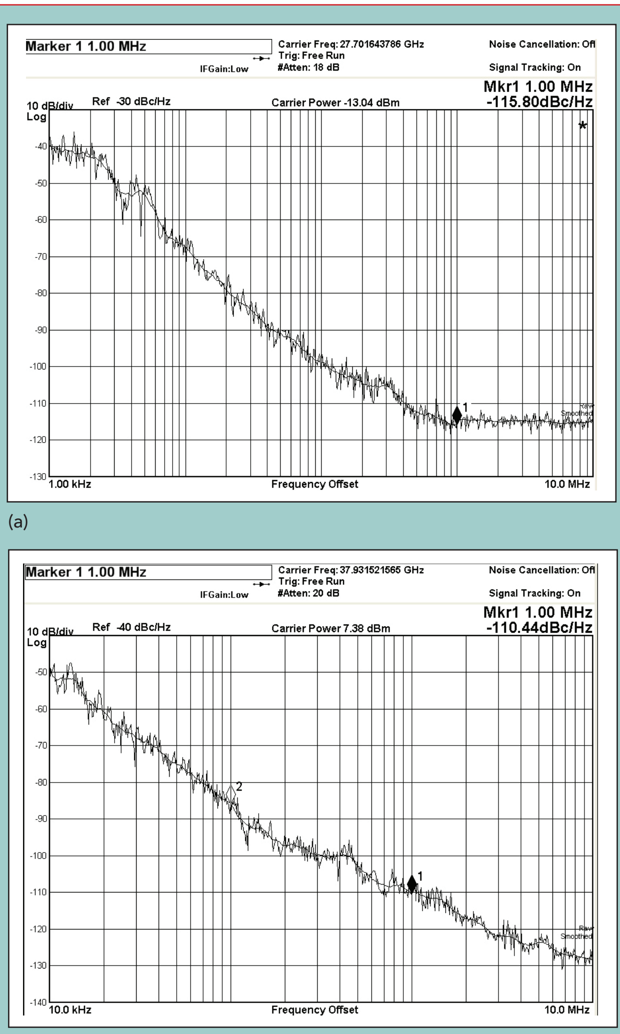
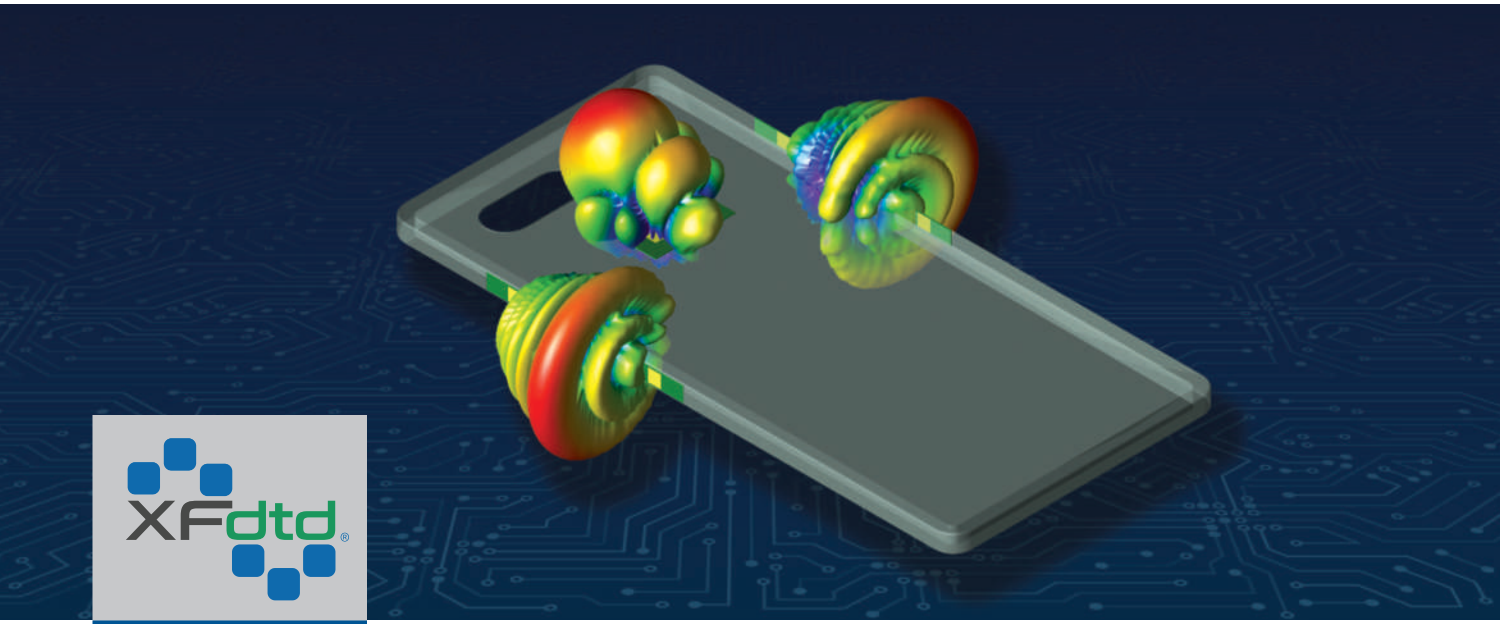
Noise Differential Voltage Controlled Oscillator Using a 0.5 μm E/D-pHEMT Process," *IEEE Microwave and Wireless Components Letters*, Vol. 19, No. 7, July 2009, pp. 467–469.
11. H. Y. Chang, C. H. Lin, Y. C. Liu, W. P. Li and Y. C. Wang, "A K-Band High Efficiency High Power Monolithic GaAs Power Oscillator Using Class-E Network," *IEEE Microwave and Wireless Components Letters*, Vol. 27, No. 1, January 2017, pp. 55–57.
12. C. C. Chiong, H. Y. Chang and M. T. Chen, "Ka-Band Wide-Bandwidth Voltage-Controlled Oscillators in InGaP-GaAs HBT Technology," *Proceedings of the 3rd European Microwave Integrated Circuits Conference*, October 2008, pp. 358–361.

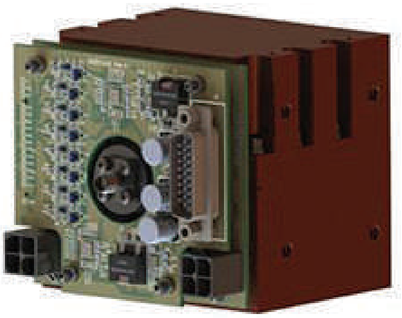


▲ Fig. 6 Measured phase noise of the 28 GHz (a) and 38 GHz (b) oscillators.

TABLE 1
COMPARISON OF PUBLISHED GAAS-BASED OSCILLATORS

Reference	Process	Frequency (GHz)	Pout (dBm)	Phase Noise @ 1 MHz (dBc/Hz)	Efficiency (%)	FOM
5	0.15 μm PHEMT	27.6	1.9	-109	1.5	-182.7
6	0.15 μm PHEMT	33.5	11	-88	2.1	-150.7
7	0.2 μm PHEMT	28.3	0.3	-98.5	7.1	-176.7
11	0.15 μm PHEMT	24	21	-106.3	19	-166.3
12	2 μm HBT	39	0	-103.8	1.2	-176
This Work	0.15 μm PHEMT	27.9	16.7	-115.8	24.3	-181.9
This Work	0.15 μm PHEMT	37.9	10.6	-110.4	10.3	-181.7





GaN PAs Deliver 100 W, 27–31 and 32–38 GHz

Qorvo, Inc.
Newbury Park, Calif.

Qorvo's new enhanced mmWave Spatium® amplifiers deliver unparalleled combining efficiency and bandwidth in a compact envelope for high performance applications such as satellite ground stations, 5G infrastructure, radar and electronic warfare. Using its latest GaN MMICs, Qorvo has developed two mmWave Spatium products, both in volume production:

- QPB2731, which provides 100 W output power from 27 to 31 GHz.
- QPB3238, which provides 100 W output power from 32 to 38 GHz.

These solid-state power amplifiers (SSPA) handle continuous wave (CW), pulsed and modulated RF waveforms, with two biasing options to best suit the application.

Like previous incarnations of Spatium technology, the mmWave Spatium employs a laminate-based antenna structure to spatially combine 16 elements in a quasi-transverse electromagnetic (TEM) coaxial environment. Theoretically, this results in an SSPA with 12 dB more power than the power from each MMIC.

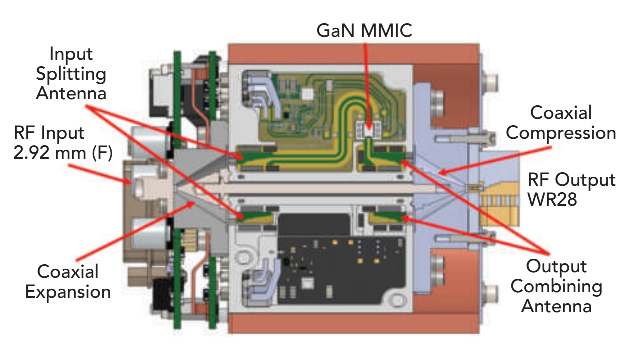


Fig. 1 Cross-section of the mmWave Spatium SSPA.

Before building the amplifier, Qorvo designed a passive structure to assess the performance of the combining network—constructed to duplicate the RF path of the amplifier without the MMICs. At the input, the RF signal enters through a 2.92 mm female connector, then physically expands in an oversized coaxial region to a laminate, endfire antenna array that splits the RF into 16 equal signals, each with a microstrip transmission line connecting to the input of the MMIC (see ***Figure 1***). In the passive structure, though, the microstrip line connects to another laminate antenna array that reverses the transitions at the input. In most cases, the output of a high-power amplifier (HPA) requires an output connection with suitable power-handling capability, such as WR28 waveguide. With this passive test structure, a 2.92 mm female connector was used at the output to make a broadband connection with a standard network analyzer.

Each laminate was bonded to a silver-plated copper blade, forming a 1/16th wedge when viewed along the major axis. AGC Taconic TLY-5Z was chosen as the core laminate material, as it exhibits a low permittivity (ε_r = 2.2) and relatively low loss tangent (tanδ = 0.0015 at 10 GHz), which contribute to the broadband, low loss performance of the antenna structures. Although the metallization on the passive laminate was covered with an IPC-compliant, immersion silver to prevent oxidation of the copper, the am-

plifier designs generally use gold metallization to be compatible with gold wire bond attachment to the MMICs.

The passive structure was designed and analyzed using ANSYS HFSS. The simulated insertion loss and return loss compared to the measured passive structure assembly are shown in ***Figure 2***. While small deviations between the measured (red lines) and simulated (blue lines) are seen, there is good correlation overall, and the observed performance is acceptable for amplifier development. The measured insertion loss reflects the loss of the entire RF path, i.e., both input and output. In the SSPA, the MMIC is placed toward the output, so more than 50 percent of the microstrip line is prior to the MMIC. Thus, a reasonable estimate of the output insertion loss is 0.67 dB, which yields a combining efficiency of 86 percent.

For the QPB2731 design, Qorvo's QPA2211 GaN MMIC was selected as the HPA. The QPA2211 is specified to provide 14 W saturated and 5 W linear CW output power, with 34 percent power-added efficiency (PAE) in CW operation (see ***Figure 3***). For the QPB3238N design, the TGA2222 GaN MMIC was selected as the RF HPA; it has a specified CW output power of 40.2 dBm saturated with 22.3 percent PAE from 32 to

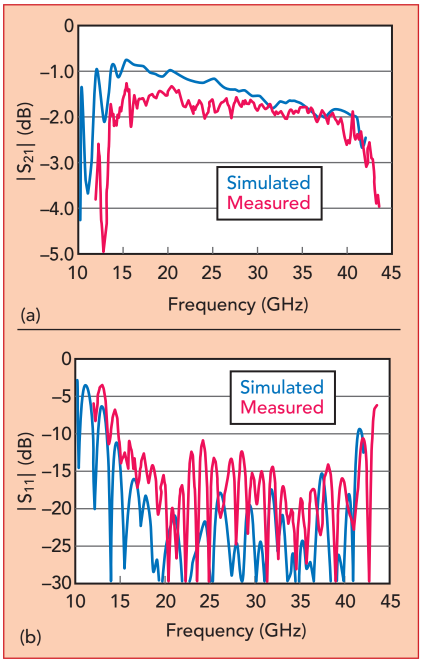


Fig. 2 Simulated vs. measured insertion loss (a) and return loss (b) of the passive assembly.

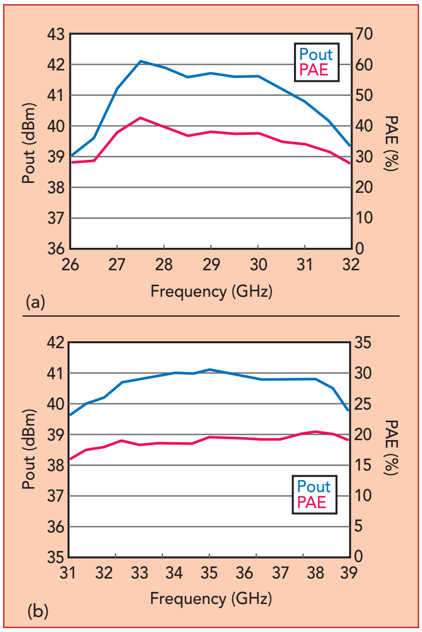


Fig. 3 Typical output power and PAE of the QPA2211 (a) and TGA2222 (b).

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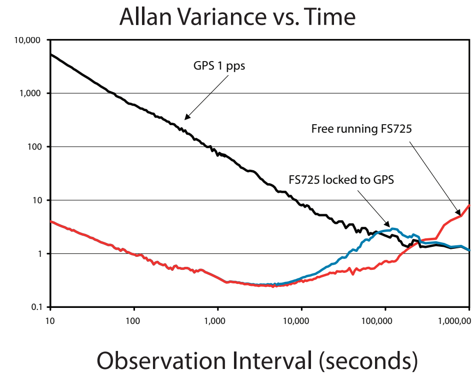

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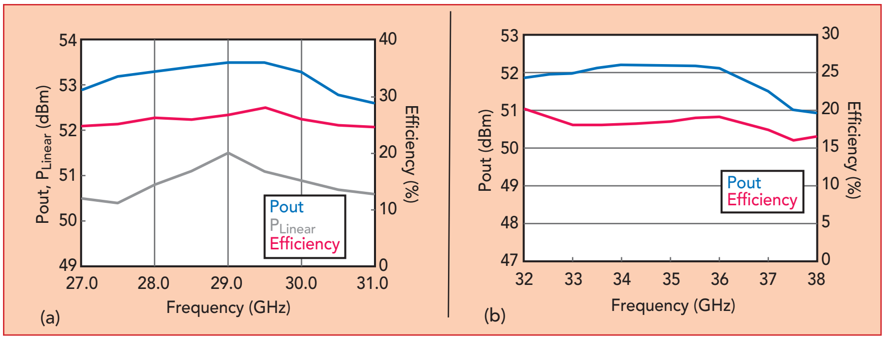

Fig. 4 Measured output power and drain efficiency of the QPB2731 (a) and QPB3238 (b) at 25°C clamp temperature.

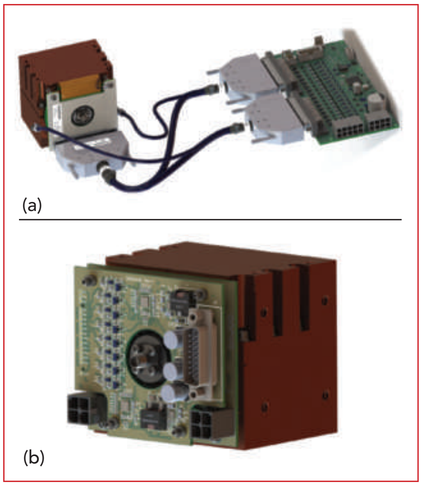

Fig. 5 The mmWave Spatium offers external (a) and integrated (b) bias configurations.

38 GHz and a die backside temperature of 25°C (also shown in Figure 3). Both devices use Qorvo's 0.15 µm GaN on SiC process (QGaN15).

Figure 4 shows the output power and drain efficiency measurements of the QPB2731 and QPB3238 SSPAs at a "clamp" temperature of 25°C. Note the different thermal reference points between the die and SSPA data. Operating at saturated power with a CW signal, self-heating may raise the backside temperature of the die more than 50°C above the clamp temperature of the SSPA. Therefore, Figures 3 and 4 do not show "apples to apples" comparisons; nonetheless, the figures show the mmWave Spatium platform performs well combining the power from the individual MMICs.

For ease of system integration, Qorvo offers two bias options for the mmWave Spatium products. The first has a separate bias card, operating remotely from the SSPA, containing a microcontroller to fully customize the amplifier for its operating environment (see ***Figure 5a***). The second option is more integrated, achieving a more compact physical profile (see ***Figure 5b***). Both solutions provide the required sequencing and gate voltage control for the GaN MMICs, so the user can power the SSPA by simply applying the prime voltage at the power connector.

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Qorvo, Inc.
Newbury Park, Calif.
www.qorvo.com/products/amplifiers/spatium

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Cable Assembly Family Extends Laboratory-Grade Measurements to 70 GHz

HUBER+SUHNER AG
Herisau, Switzerland

Our increasingly high-tech world relies on the capabilities of new generations of infrastructure, as society adopts 5G, autonomous cars, the IoT and Industry 4.0. To ensure these complex systems work as designed, the underlying components—antennas, semiconductor chipsets, passive components and high speed interfaces—require rigorous testing. With test and measurement, the best measurement setup is only as good as its weakest link, which is often the cable assembly used to connect the device being tested to the measurement equipment. Repeated connecting and disconnecting flexes the cable assembly and may damage the connectors. Even without damage, the phase and amplitude responses of the cable will change with movement and variation in the surrounding temperature. For fixed installations, RF/microwave cable assemblies are often damaged during equipment installation. Even when installed without damage, the cables are prone to amplitude and phase variation caused by system vibration and temperature changes.

Recognizing the importance of rugged, high performance cable assemblies for these applications, HUBER+SUHNER developed the SUCOFLEX® 500 series for RF and high speed digital test and measurement applications. Recently, HUBER+SUHNER added the 570S to the family, extending the frequency range to 70 GHz. SUCOFLEX 500 now comprises five cable assembly types with upper frequency coverage beginning at 26.5 and extending to 70 GHz when configured with compatible connectors (see **Table 1**). These cable assemblies assure precise, repeatable and reliable measurements in laboratories and other installations that require the highest quality and reliability.

The cables in the family share a common construction (see **Figure 1**), which makes them extremely flexible with zero spring back, so they are easy to handle and connect to equipment. As required for labo-

TABLE 1

SUCOFLEX PRODUCT FAMILY

Cable Type	526S	526V	550S	550S	570S
Maximum Frequency (GHz)	26.5	26.5	40	50	70
Connector (mm)	3.5	3.5	2.92	2.4	1.85
Typical Insertion Loss (dB/m)	1.63	3.63	3.41	3.87	6.48
Flex Lifetime (Cycles)	>100,000	>100,000	>100,000	>100,000	>20,000


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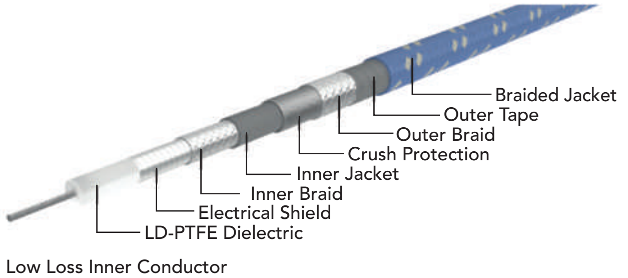

Fig. 1 **SUCOFLEX 500 cable construction.**

ratory-grade measurements, they have a stable phase response, high flex life, low insertion loss and excellent return loss (see ***Figure 2***). Amplitude, phase repeatability and stability are essential to achieving accurate laboratory measurements, which is used to assess the performance of multi-million dollar prototypes or decide to pass/fail at final manufacturing test. The members of the SUCOFLEX 500 family exhibit just ±0.05 dB amplitude change with cable movement or flexure, and the phase stability versus flexure is within ±3 degrees for the 26.5 GHz 526S cable assembly and ±8 degrees for the 70 GHz 570S. The cable assemblies have an operating temperature range from -55°C to +125°C, so they support measurements over temperature.

SUCOFLEX 500 assemblies are available in various lengths, with stock assemblies shipped within five working days and customized configurations within 10 working days. The cable assemblies can also be supplied matched to the same time delay within ±1 ps.

To assist customers specifying a cable assembly, HUBER+SUHNER offers several online tools: eCatalogue, RF assembly calculator and RF assembly configurator. The tools help designers identify suitable cables, configure cable assemblies with appropriate connectors, estimate electrical performance and compare the performance of various designs.

HUBER+SUHNER's SUCOFLEX 500 series offers excellent performance and good value. The newest addition, the 570S, is a precise, long-lasting connectivity solution that ensures extremely accurate mmWave measurements.

As RF, microwave and mmWave

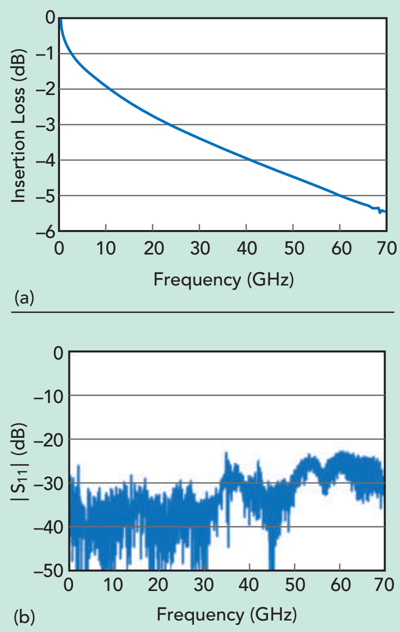

Fig. 2 **Insertion loss (a) and $|S_{11}|$ (b) of a 36 in. 570S cable assembly with 1.85 mm connectors.**

technology enables innovations such as 5G and IoT, testing remains essential to product development and manufacturing. Even with the adoption of over-the-air testing, cable assemblies remain an integral part of the test system and should be chosen from a supplier with a long heritage delivering high performance, rugged and reliable products. Since the late 1800s, HUBER+SUHNER has been providing products that help people connect, beginning with insulating copper wires supporting the adoption of electricity to today's world of RF/microwave and optical networks.

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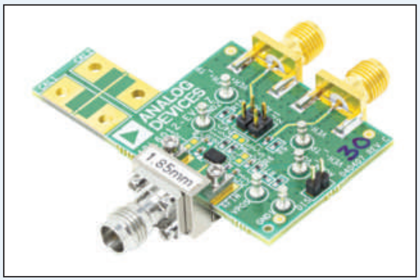

Wideband 2 to 67 GHz Envelope Detector

The ADL6012 is a versatile, broadband envelope detector that operates from 2 to 67 GHz. The combination of a wide 500 MHz envelope bandwidth and a fast 0.6 ns rise time makes the device suitable for a wide range of applications, including wideband envelope tracking, transmitter local oscillator leakage corrections and high resolution pulse (radar) detection.

The ADL6012 uses Schottky diodes in a two-path detector topology. One path responds during the positive half cycles of the input and the other responds during the negative half cycles of the input, achieving full wave signal detection. This arrangement presents a constant input impedance throughout the full RF cycle, preventing the reflection of even order harmonic distortion components back toward the source. This reflection is a well-known phenomenon of widely used, traditional, single-Schottky diode detectors. Detector response time at lower RF frequencies is also improved with symmetrical detection.

The response of the ADL6012 is stable over a wide frequency range and features excellent temperature stability. Enabled by propriety technology, the device independently detects the positive and the negative envelopes of the RF input. Even order distortion at the RF input due to nonlinear source loading is also reduced when compared to classic diode detector architectures.

The quasi differential output interface formed by the VENV+ and VENV− pins has a matched, 100 ohm differential output impedance designed to drive a 100 ohm differential load and up to 2 pF of capacitance to ground on each output. The output interface provides the detected and amplified positive and negative envelopes, which are level shifted using an externally applied voltage to the VOCM interface. This configuration simplifies interfacing to a high speed analog-to-digital converter. The ADL6012 is specified for operation from −55°C to +125°C and is available in a 10-lead, 3 × 2 mm LFCSP.

VENDORVIEW

Analog Devices
Norwood, Mass.
www.analog.com

Wideband Transceivers for 5G, Wi-Fi, UWB Test

The Proteus family of arbitrary waveform generators (AWG) from Tabor Electronics was designed to solve measurement challenges in physics, communications, radar/electronic warfare (EW) and automotive sensors. With a bandwidth to 4 GHz and a frequency range to 9 GHz, these instruments provide signal generation capability for 5G, Wi-Fi 6, ultra-wideband (UWB), wideband linear FM (LFM) and LiDAR. Additionally, the optional RF digitizer and on-board FPGA provide a fully closed-loop, real-time measurement system, which is why Proteus is defined as an arbitrary waveform transceiver (AWT).

The heart of the AWT is a performance FPGA, which controls all the operational modes of the instrument:

- Fast sequencing waveforms from memory
- Controlling the RF digital-to-analog converters with built-in I/Q modulators
- Acquiring wideband signals with the RF analog-to-digital converters.
- Performing high speed measurement processing using an FPGA decision block system
- Streaming high speed waveforms from an external computer or disk.

The Proteus system helps physicists by modifying control waveforms based on measurements, especially compensating for noise and decoherence. For RF engineers designing amplifiers for Wi-Fi 6, 5G and UWB, the ability to stimulate, measure, process and re-stimulate leads to faster, lower cost device characterization. For radar/EW, the high fidelity signal creation of the AWG can generate fine details of a threat signal. Combined with the AWT, the ability to receive, process and adapt the signal based on the environment or countermeasures enables testing and evaluating more realistic scenarios. This same capability makes the AWT well suited for automotive sensors such as radar and LiDAR.

The Proteus family is available in multiple channel configurations and form factors, from benchtop to PXIe.

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V15 Playlist Now Available on AWR.TV

This playlist highlights the V15 release of Cadence® AWR® software, including enhanced network synthesis, integrated TX-LINE calculator, new antenna measurements, faster EM meshing and new behavioral amplifier models, as well as user environment improvements.

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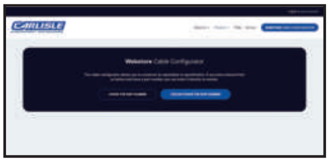
CIT Launches European Web Store



Carlisle Interconnect Technologies (CIT) announced that customers in the U.K. and Europe can now purchase RF microwave cable assemblies online directly from its Blackburn U.K. facility. The website's Cable Configurator feature allows customers to shop for and create their own RF assembly custom built for their specific application needs. Customers now have instant access to pricing information and can buy products online with direct shipping to their location. This new eCommerce offering simplifies the purchasing process and helps speed up turnaround times.

Carlisle Interconnect Technologies

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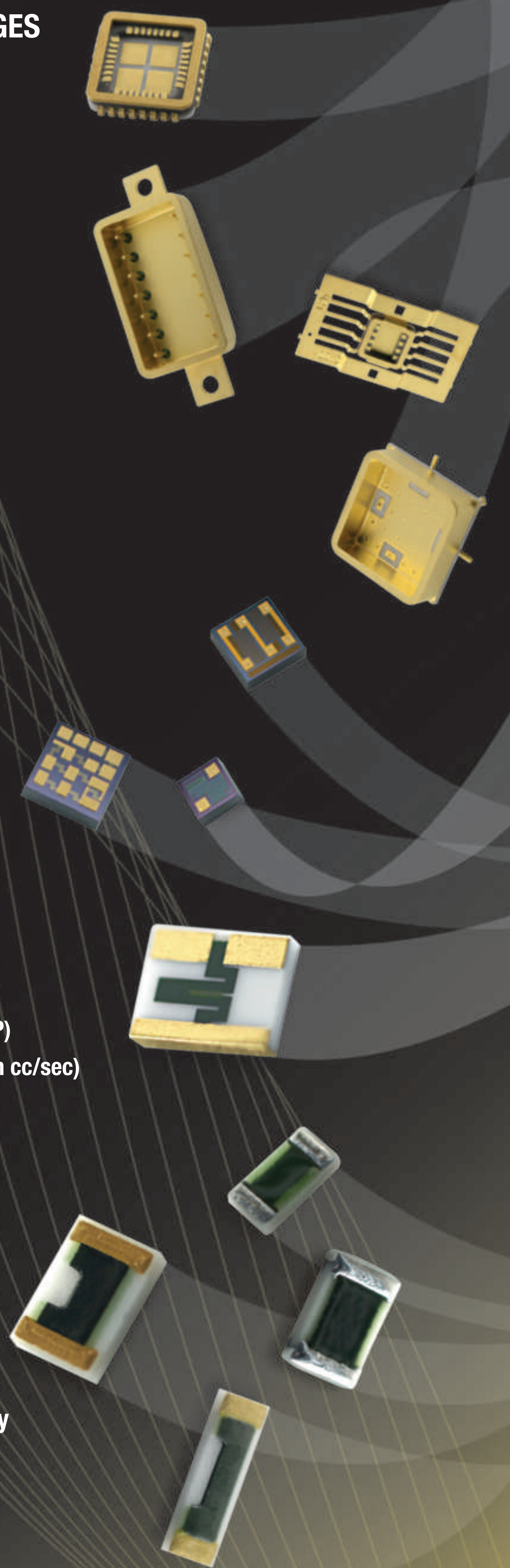

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RFE Develops Services Page

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RFE's website has greatly expanded its Services Page to highlight the breadth of RF and microwave component product capabilities in design and manufacture. Details now include a number of highly sought niche offerings with in-process photos. The principal message is a willingness to engage in a variety of flexible customer desired engagements. Underscoring this is a new page chronicling specific success stories. Whether looking for small start-up volume or a fully outsourced turnkey production solution, RFE is your partner of choice.

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hybridNETBOX, A Multi-Channel AWG and Digitizer in One Box

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Spectrum Instrumentation Corp. launched the "hybridNETBOX." This single LXI/Ethernet-instrument simultaneously generates, acquires and analyzes electronic signals in manual, automated or remotely controlled applications. Six models are available offering the choice of 2 + 2, 4 + 4 or 8 + 8 matched AWG and digitizer channels, with output- and sampling-rates of 40 and 125 MS/s. Take a look at the hybridNETBOX introduction video: www.spectrum-instrumentation.com/en/media.

Spectrum Instrumentation Corp.

www.spectrum-instrumentation.com

Research & Educational Kits

VENDORVIEW

The first of the University Project kits, UVNA-63, includes all the elements students need to build a fully functioning vector network analyzer, develop S-parameter algorithms and perform real-time measurements of two-port RF devices. The kit comprises Vayyar's high performance transceiver chip with a variety of RF components from Mini-Circuits, along with control software and a development environment for Python and MATLAB®. Mini-Circuits has expanded its collaboration with Vayyar to offer its second kit, VTRIG-74, a ready-to-use, 4D mmWave imaging and sensing application development platform.

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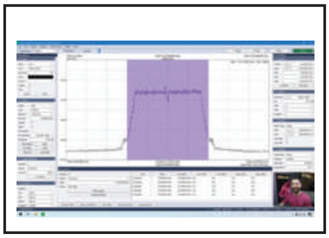
Channel Power and Adjacent Channel Power Measurements With Spike Software



This new video from Signal Hound discusses channel power and adjacent channel power measurements, their role in spectrum analysis and how you can use standard Spike™ software features to perform these measurements. Along with channel power, adjacent channel power ratio is commonly used to measure effects typical to transmitters such as non-linearities, spectral regrowth and other non-desirable emissions.

Signal Hound

http://signalhound.com/acp-video

Video: RF Gain Blocks for Space in Three Flavors

With the release of its new 10 GHz gain blocks for X-Band space and defense applications, Teledyne e2v HiRel now offers customers a standard "go to" amplifier solution that stretches from L-Band through X-Band. This standard amplifier solution offers design engineers a "flight qualified" solution that programs require and greatly simplifies the procurement process for components. The X-Band gain blocks are available in configurations of 13.6, 16.5 and 18.4 dB.

Teledyne Defense Electronics

https://www.teledynedefenseelectronics.com/

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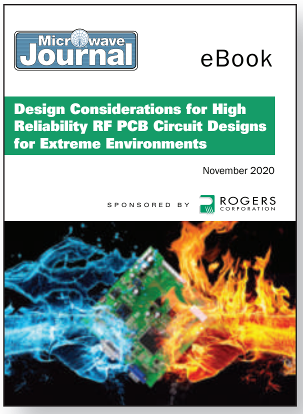

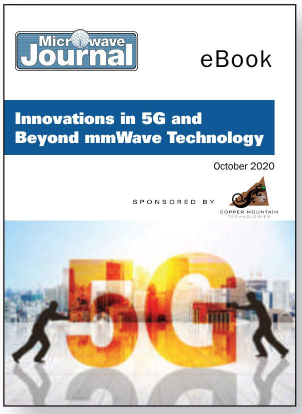

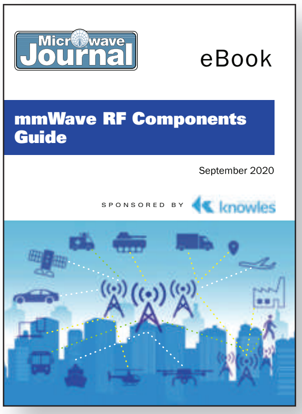

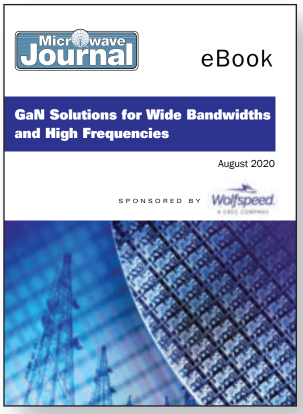

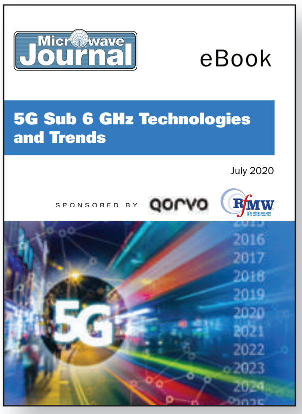

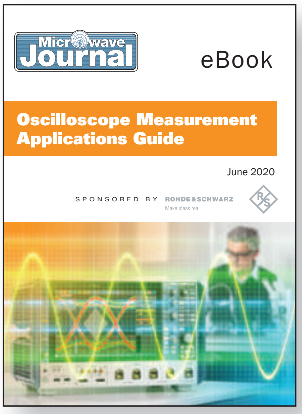

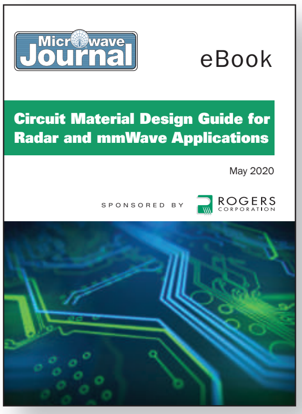

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VIRTUAL PANEL SERIES

Evolution of the RF Front End

January 21

The smartphone RF Front End has dramatically evolved over the last decade moving from a discrete amplifier and controller module to a complex module with duplexers/filters, switches, controllers and amplifiers that have to consider more than 1,000 frequency band combinations which will grow to more than 10,000 with 5G. This panel will discuss the evolution of the RF Front End from 4G to 5G; the best current technologies for acoustic filters, switches, amplifiers and power management; will OpenRF work to reduce costs and improve performance; and what future mobile device RF Front Ends are expected to look like.

Will Open RAN Work?

Now On Demand

Open RAN promises to lower network costs and barriers to entry to create competition through the standardization of hardware and software. But will this reduce the innovation in hardware and software design by dumbing down the systems? Will it increase security risks? Will it decrease economies of scale that the larger companies have developed? How would this effect RF component design and integration with system providers? What are the test challenges and can standard testing be implemented? This panel discusses and debates the pros and cons of Open Radio Access Networks from a components and sub-systems point of view along with testing challenges and solutions. The session will be moderated by Joe Madden of Mobile Experts.

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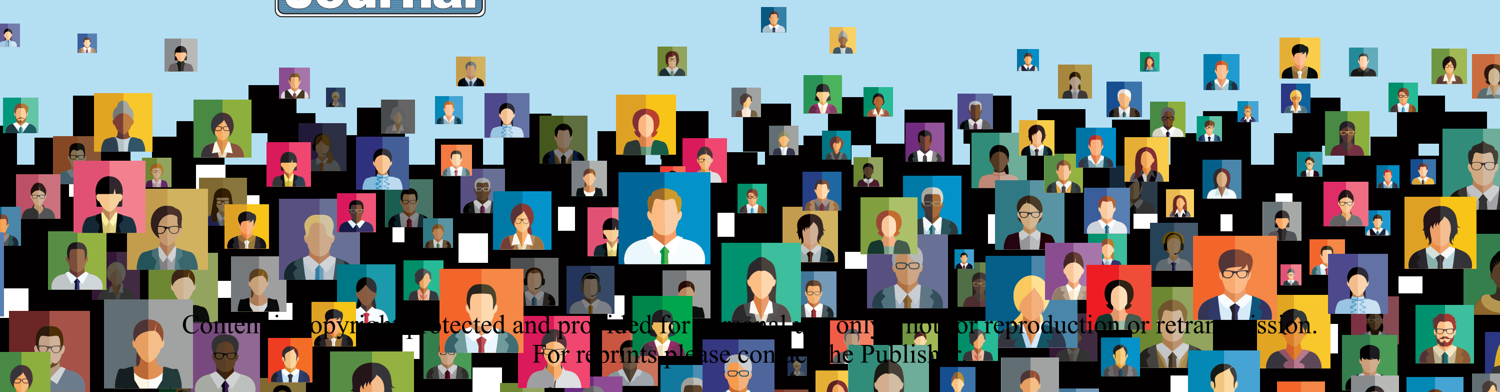

The 2021 Defence, Security & Space Forum

At European Microwave Week

EuMA

Microwave Journal

Wednesday 13 January – 08:30 to 14:30

A one-day focused Forum addressing Space Situational Awareness

Programme:

08:30 – 10:10 **EuRAD Opening Session**

10:50 – 12:30 **Space Situational Awareness**

Peter Knott, Director of Fraunhofer-FHR, Radar Sensors for SSA

Mohamed Abouzahra and Gregg Hogan, Haystack-MIT-Lincoln Laboratory, an emergency-response system supported by NATO

David Otten, Dutch Airforce, Space in the Dutch MoD, the current focus and activities of the Defense Space Security Center

12:40 – 13:40 **Strategy Analytics Lunch & Learn Session**

Space Situational Awareness in the New Space Era

Eric Higham, Strategy Analytics

13:50 – 14:30 ***Microwave Journal* Industry Session**

The Microwave Journal Industry Session will be made up of company presentation(s) that illustrate the technological innovation that industry is developing for Space Situational Awareness related topics.

Register online at www.eumweek.com

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COMPONENTS

Five-bit Digital Step Attenuator

VENDORVIEW

AM2010 is a wideband 31 dB five-bit digital attenuator covering the DC to 30 GHz frequency range in 1 dB steps. The positive control device provides low insertion loss, flat frequency response and low attenuation error over the operating temperature range of -40°C to +85°C. Packaged in a 4 mm QFN with internal 50 Ω matching, internal decoder circuitry and drawing less than 2 mA of current, the AM2010 is suited for low SWaP applications.

Atlanta Micro Inc.
www.atlantamicro.com

Full Band Mixers

VENDORVIEW

HASCO's full band mixers are designed using the best performance GaAs Schottky beam-lead diodes and balanced circuit configuration, offering excellent low conversion loss and great port to port isolation. The HWMX15-SFV full band mixer operates at a frequency of 50 to 75 GHz, IF frequency up to 10 GHz and typical conversion loss of 10 dB. HASCO's full line of full band mixers support waveguide band operations at frequency levels up to 110 GHz.

HASCO
www.hasco-inc.com/mmwave-mixers.html

1P8T RF Switch

Save time and budget with JFW's new commercial solid-state RF switch model 50S-2133 SMA. It is a self-terminating 1P8T RF switch that operates 20 to 5,000 MHz. Its solid-state design gives you the reliability and repeatability that automated RF testing requires. Its price and delivery gives you an economical automated RF testing choice.

JFW Industries Inc.
www.jfwindustries.com

Out-of-Band Emission Filter Solutions

VENDORVIEW

MCV Microwave offers a series of out-of-band emission filter solutions to handle interference in the commercial 700 and 800 MHz band. Filter solutions provide either a very narrow passband with sharp roll off and 40 dB rejection only 300 to 500 kHz away from the passband edge or a band reject filter having excellent notch performance. Dual MIMO with IP67 pole mount package operates between -20°C to +65°C and has been deployed successfully for B14 uplink and downlink frequency and B14/B13/ multiband radios.

MCV Microwave
www.mcv-microwave.com

Hybrid Combiner/Dividers

VENDORVIEW

High-power, 3 dB hybrid couplers useful in public safety applications for combining two transmitters to share one antenna or high-power splitting. Covering 350 to 570 MHz UHF Unique air-line construction provides lowest possible insertion loss while delivering high isolation (27 dB typ), exceptional VSWR (1.15:1 typ) and superior phase balance (3 deg maximum). Rated for 500 W (average and available with 7/16 DIN and Type N interfaces. Made in the U.S. with a 36 month warranty.

MECA Electronics Inc.
www.e-MECA.com

Directional Coupler

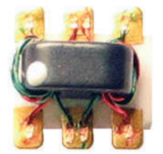
VENDORVIEW

Mini-Circuits' model ZCDC130E1653+ is a wideband directional coupler for a wide range of applications from 1 to 65 GHz. Well suited for mobile communications, satellite communications and test and measurement applications, the RoHS-compliant directional coupler features 13 dB typical coupling with ±0.9 dB typical coupling flatness across the full frequency range. The typical mainline insertion loss is 0.7 dB from 1 to 18 GHz, 1.3 dB from 18 to 40 GHz, 1.8 dB from 40 to 50 GHz and 2.3 dB from 50 to 65 GHz.

Mini-Circuits
www.minicircuits.com

Two-Way Splitter/Combiner

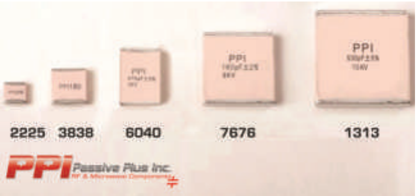
VENDORVIEW



Featuring 2.5 GHz bandwidth and 20 dB isolation for 50 ohm applications this low-cost miniature part is designed to split/ combine RF wideband signals while maintaining high RF performance. MiniRF offers highly repeatable performance with a low-cost surface mount package. These parts designed to operate over extreme temperature range -40°C to 85°C with minimal variation. Don't delay and have mismatched signals in your 5G system, contact MiniRF for samples.

MiniRF
www.minirf.com

Hi-Q High-Power Capacitors



Passive Plus Inc. (PPI) is known for their outstanding customer service, high quality product line, competitive pricing and quick delivery times. While other companies are pushing out their lead-times for product delivery, PPI is committed to being able to deliver your needs as quickly as possible. As PPI tries to keep a full inventory in stock, depending on the capacitor and quantities needed, delivery times can be stock to eight weeks.

Passive Plus Inc.
www.passiveplus.com

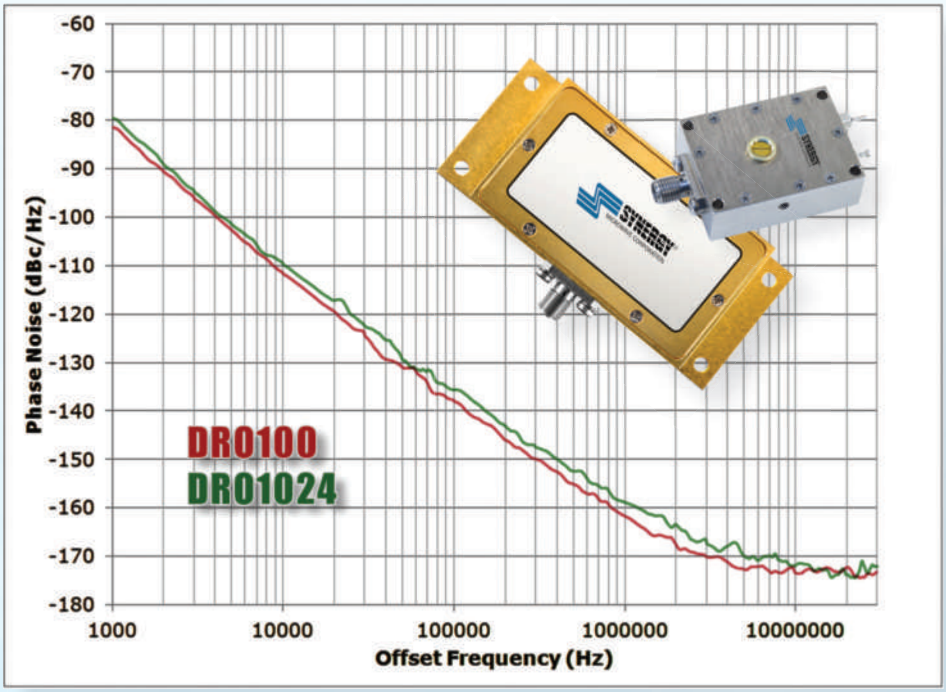
Dual RF Transceiver

Richardson RFPD announced the availability and full design support capabilities for a new dual narrow/wideband RF transceiver from Analog Devices Inc. The ADRV9002 is a highly integrated, RF transceiver that has dual-channel transmitters, dual-channel receivers, integrated synthesizers and digital signal processing functions. The IC delivers a versatile combination of high performance and low-power consumption required by battery-powered radio equipment and can operate in both FDD and TDD modes.

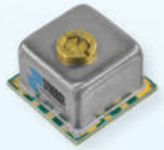
Richardson RFPD
www.richardsonrfpd.com

Exceptional Phase Noise

Dielectric Resonator Oscillator



Available In Surface Mount.



SDRO Series
0.75" x 0.75 x 0.53"

RoHS ***Patented Technology***

Model	Frequency (GHz)	Tuning Voltage (VDC)	DC Bias (VDC)	Typical Phase Noise @ 10 kHz (dBc/Hz)
Surface Mount Models				
SDRO800-8	8.000	1 - 10	+8.0 @ 25 mA	**-110**
SDRO900-8	9.000	1 - 10	+8.0 @ 25 mA	**-112**
SDRO1000-8	10.000	1 - 15	+8.0 @ 25 mA	**-107**
SDRO1024-8	10.240	1 - 15	+8.0 @ 25 mA	**-105**
SDRO1118-7	11.180	1 - 12	+5.5 - +7.5 @ 25 mA	**-104**
SDRO1121-7	11.217	1 - 12	+5.5 - +7.5 @ 25 mA	**-106**
SDRO1130-7	11.303	1 - 12	+5.5 - +7.5 @ 25 mA	**-106**
SDRO1134-7	11.340	1 - 12	+5.5 - +7.5 @ 25 mA	**-107**
SDRO1250-8	12.500	1 - 15	+8.0 @ 25 mA	**-104**
Connectorized Models				
DRO80	8.000	1 - 15	+7.0 - +10 @ 70 mA	**-114**
DRO8R95	8.950	1 - 10	+7.0 - +10 @ 38 mA	**-109**
DRO100	10.000	1 - 15	+7.0 - +10 @ 70 mA	**-111**
DRO1024	10.240	1 - 15	+7.0 - +10 @ 70 mA	**-109**
DRO1024H	10.240	1 - 15	+7.0 - +10 @ 70 mA	**-115**
KDRO145-15-411M	14.500	*	+7.5 @ 60 mA	**-100**

* Mechanical tuning only ±4 MHz

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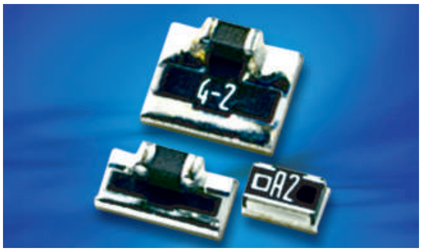
Mail: 201 McLean Boulevard, Paterson, NJ 07504

High-Power 18 GHz SPDT Switch

RLC Electronics announced the addition of a high-power 18 GHz SPDT switch with N connectors to its product capabilities. The switch can handle 1,000 W at 100 MHz, 200 W at 4 GHz and 125 W at 18 GHz, and provides high reliability, long life and excellent electrical performance characteristics over the frequency range (including high isolation).

RLC Electronics
www.rlcelectronics.com

Attenuators



There is one aspect of high frequency amplifiers with GaAs semiconductors that makes life difficult: their gain reduces with rising temperatures. Complex feedback circuits are normally necessary in order to compensate for this effect. Japanese manufacturer Susumu offers an elegant solution that is both simple and inexpensive: the thermo-variable attenuators in the product families, PXV1220S, PBV1632S and PAV3137S save space and reduce complexity. The chip attenuators contain a network of resistors with a temperature-variable attenuator, the characteristics of which compensate for the temperature drift of the GaAs component.

Susumu
www.susumu.co.jp

Downconverter/Tuner

Measuring 7.6” × 7.6” × 1.6” and weighing 3.7 lbs., the thinkRF™ D4000 RF downconverter/tuner features a compact design that makes it portable, versatile and easy to use for 5G analysis in any deployment scenario without adding significant size, weight and power requirements. With 500 MHz analog bandwidth, built-in local oscillators, pre-select filtering and single IF output, the D4000 RF Downconverter/Tuner extends the performance of lower frequency RF test equipment to 40 GHz economically.

thinkRF
www.thinkrf.com

CABLES & CONNECTORS

50 GHz and 70 GHz VNA Test Cables

VENDORVIEW

Fairview Microwave’s new high frequency VNA test cables display exceptional phase stability of ±6° at 50 GHz and ±8° at 70 GHz, as well as VSWR of 1.3:1 at 50 GHz and 1.4:1 at 70 GHz. The braided stainless steel armoring provides a rugged but flexible cable with a flex life exceeding 100,000 cycles. They are ideal for use in semiconductor probe testing, precise bench top testing, as well as lab/production testing where the need for a highly flexible, yet durable cable solution is required.

Fairview Microwave
www.fairviewmicrowave.com

Pin Screw-On Circular Multi-Coax Cable Assemblies

MIcable DC-6GHz eight-pin screw-on circular multi-coax cable assemblies are high density, blind mated eight-coax phase matched cable assemblies. They are an integrated, high performance easily connected solution. They have 1.0 dB/m maximum cable attenuation, 1.2:1 maximum VSWR, 75 dB minimum isolation and 6 degree maximum phase difference among channels at 6 GHz. The diameter of the plug circular connector is 31 mm, working temperature is -55° to +85°C. The applications include base station, antenna, switch matrices test and equipment connection.

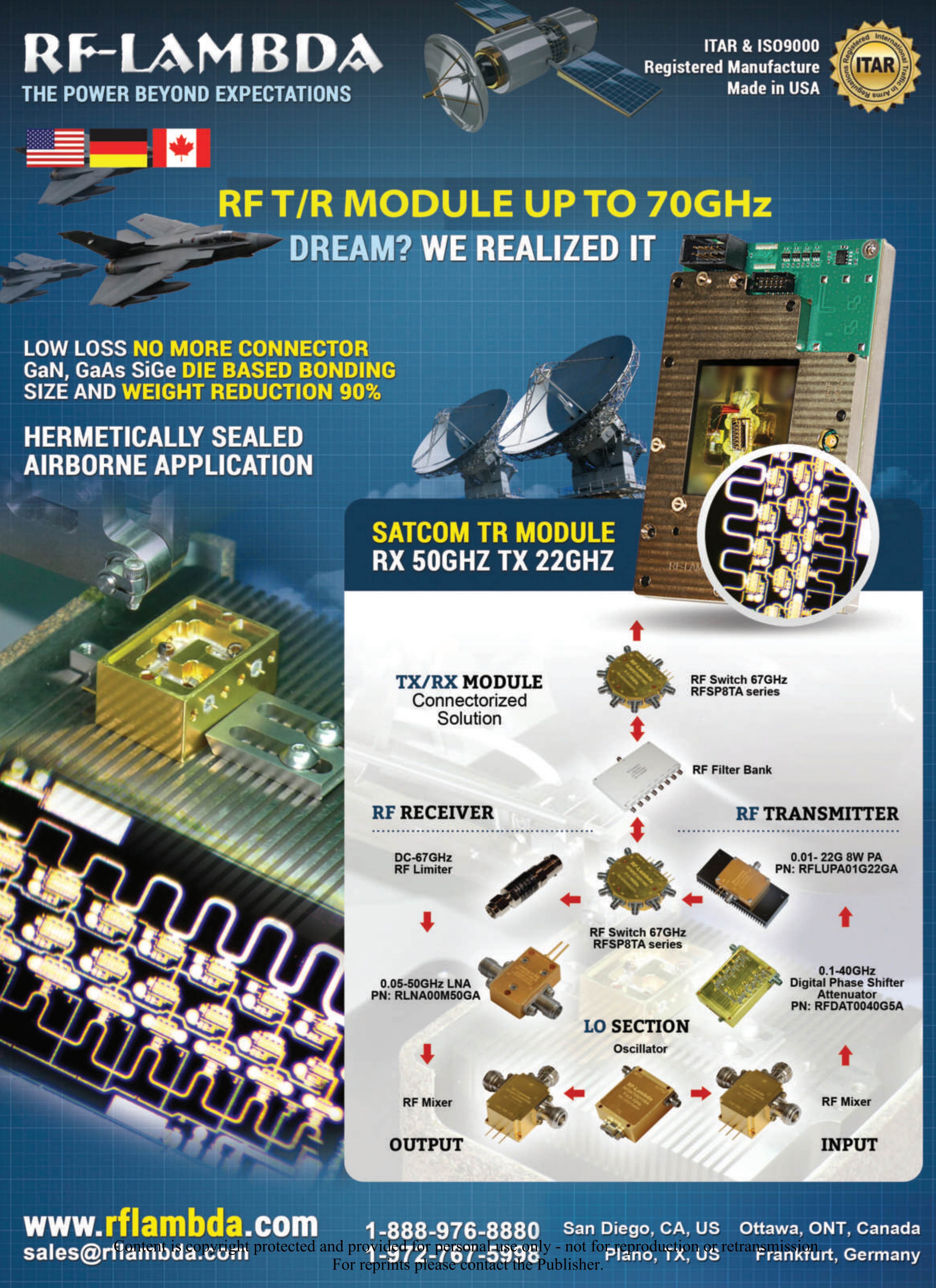
Fuzhou MIcable Electronic Technology Co. Ltd.
www.micable.cn

Field Replaceable Connectors

VENDORVIEW

Pasternack’s new field replaceable RF connectors include SMA, 3.5 mm, 2.92 mm, 2.4 mm and 1.85 mm types with two-hole and four-hole mounting configurations. Each connector utilizes a metal ring that grounds or mates with the component ground and will work with a range of different pin sizes. These types of connectors can be used on various sealed RF components as replaceable RF interconnects where the component has a pin exposed. The connector is attached to the wall of the component with screws and accepts the interface pin.

Pasternack
www.pasternack.com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THE POWER BEYOND EXPECTATIONS
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RF T/R MODULE UP TO 70GHz
DREAM? WE REALIZED IT
LOW LOSS NO MORE CONNECTOR
GaN, GaAs SiGe DIE BASED BONDING
SIZE AND WEIGHT REDUCTION 90%
HERMETICALLY SEALED
AIRBORNE APPLICATION
SATCOM TR MODULE
RX 50GHZ TX 22GHZ
TX/RX MODULE
Connectorized
Solution
RF Switch 67GHz
RFSP8TA series
RF Filter Bank
RF RECEIVER
RF TRANSMITTER
DC-67GHz
RF Limiter
0.01- 22G 8W PA
PN: RFLUPA01G22GA
RF Switch 67GHz
RFSP8TA series
0.05-50GHz LNA
PN: RLNA00M50GA
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Ottawa, ONT, Canada
Frankfurt, Germany

New**Products**

Standard Block Thread-In End Launch Connectors

Southwest Microwave has expanded its high performance solutions with new standard block thread-in end launch connectors, offering robust performance and 1:2:1 VSWR to 110 GHz for board thicknesses up to 100 mils. The connector's unique two-piece bottom clamp maintains the ground between the connector and the circuit board. Combining the bottom clamp with the solderless pin allows for ease of removal and greater reusability. The connector pin is designed with an interference fit to the circuit board trace, requiring no solder.

Southwest Microwave
www.southwestmicrowave.com

Precision Test Adapters

Withwave's precision test adapters are designed based on precision microwave interconnection technologies. This 1.85 mm (M) to 1.85 mm (M) right angle adapter is manufactured to precise microwave specifications and constructed with male gender on both sides. The precision microwave connector interfaces ensure an excellent microwave performance up to 67 GHz.

Withwave
www.with-wave.com

AMPLIFIERS

Broadband Amplifier

VENDORVIEW

The model 2500A225B is a solid-state, self-contained, broadband amplifier designed for applications where instantaneous bandwidth, high gain and linearity are required. The amplifier is air-cooled using internal self-contained liquid cooling for high performance and reliability. A stylish, contemporary enclosure allows for easy portability. The model 2500A225B, when used with a sweep generator, will provide a minimum of 2,500 W of RF power. Included is a front panel gain control which permits the operator to conveniently set the desired output level.

AR RF/Microwave Instrumentation
www.arworld.us

Solid-State Power Amplifier System

VENDORVIEW

Exodus AMP2107ADB-2 is a superb 1 to 18 GHz, 50 W amplifier system. This dual-band amplifier features 47 dB minimum gain, Type N female RF input, sample and RF output ports. Built-in VVA circuits for gain control local and remote functionality, designed for high reliability and ruggedness in a compact 4U chassis. This system is suitable for all industry testing standards requiring high power such as EMI/RFI general and specialized test equipment requirements.

Exodus Advanced Communications
www.exoduscomm.com

Low Noise Amplifier

VENDORVIEW

PMI model No. PE2-15-2R012R0-4R0-22-12-SFF is a low noise amplifier operating over the frequency range of 2 to 12 GHz. Typical gain of 15 dB; a typical noise figure of 4 dB; OP1dB +22 dBm minimum; VSWR (input/output): 2.0:1 maximum; DC voltage supply: +12 to +15 VDC; and DC Current Draw 250 mA maximum. Measured 231 mA. This model is supplied with SMA female connectors in a housing measuring 1.08" × 0.71" × 0.29".

Planar Monolithics Industries Inc.
www.pmi-rf.com

SYSTEMS/SUBSYSTEMS

Horizontal-mount OpenVPX Backplanes

Pixus Technologies, a provider of embedded computing and enclosure solutions, has announced new OpenVPX backplanes designed for horizontal-mount enclosures. The horizontal-mount backplanes can be placed into 1U-4U tall 19" rackmount OpenVPX enclosures. They provide enough space to have three 3U slots or one 3U and one 6U slot side-by-side. So, a wide range of configurations and size options are available. The backplanes are typically designed to support at least PCIe Gen3 speeds, but higher speed options are offered.

Pixus Technologies
www.pixustechnologies.com

ERAVANT

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FREQUENCY **MULTIPLIERS**

Active | Passive | X2 through X8 | 18 to 220 GHz

SAGE Millimeter is now Eravant, a change that renews our commitment to the millimeterwave industry. Since 2011, we have been delivering quality products and energizing the customer experience to respond to the next generation of RF engineers.

Active Frequency Multipliers

Active Frequency Multipliers with X2, X3, X4, X6 and X8 multiplication factors to cover the output frequency range of 18 to 110 GHz with full waveguide bandwidth operation, low harmonics/spurious emission, and high output power up to +30 dBm.

Uni-Guide™ based output connector offering better harmonic and spurious rejections with X2 and X3 multiplication factors covering the frequency range of 26.5 to 60 GHz. X2 and X3 available in Ka, Q and U Bands.

Passive Frequency Multipliers

Passive Frequency Multipliers with no required external DC bias. Offered in X2 and X3 multiplication factors to cover 26.5 to 220 GHz with low conversion loss, superior harmonic rejection and full waveguide operations.

Ultra 3U VPX Module Dynamic Engagement System

SPEC has expanded its tactical and range systems to include the ADEP T4000 Ultra 3U VPX Module Dynamic Engagement System, which pairs a 100 MHz to 20 GHz VPX transceiver with a digital signal processing board. The flight-qualified system can generate up to 4,000 false targets and a kinematic scenario programming environment. Includes features such as: multiple output channels for complex simulations, MTI and SAR simulation, 1 GHz instantaneous bandwidth, <60 dB dynamic range, and multiple resolution options.

Systems & Processes Engineering Corp. (SPEC)
www.spec.com

Modular POI

Tamagawa Electronics' Modular POI, composed of 16 in/2 out. The frequency configured from 700, 900, 1800, 2100 and +3500 MHz with the specified of GSM/WCDMA/LTE/5G systems and is suitable for IBS base station, cellular in-building network, MRT/metro and active DAS. Each modular unit is install-able/removable in 19" rack.In-loss 8.5 dB maximum, isolation 50 dBc minimum (inter band), 22 dB minimum (in band), 40 W maximum.

Tamagawa Electronics Vietnam Co. Ltd.
www.tmeleus.com

SOURCES

Phase Locked Oscillators

Eravant's phase locked oscillator line utilizes high performance DRVCO technology to generate high quality microwave signals. Externally referenced SOPs require a crystal oscillator to achieve exceptional phase noise performance. These oscillators are hermetically sealed and can operate from -40°C to +70°C to satisfy the rigorous environmental requirements.

Eravant
www.eravant.com

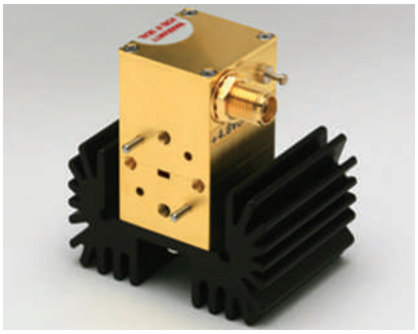
YH1300-33 OCXO

The YH1300-33 OCXO (oven controlled crystal oscillator), available at 50 MHz, features low g-Sensitivity to ≤7 × 10-10/g. Typical phase noise performance is -110 dBc/Hz at 100 Hz and -160 dBc/Hz at 1 MHz. For a limited time, Greenray is offering short lead-time availability for the YH1300-33. Key

features include a 5 V DC supply voltage, a miniature 20.3 × 12.7 mm DIP package and CMOS squarewave output.

Greenray Industries Inc.
www.greenrayindustries.com

94 GHz W-Band Gunn Oscillator



Spacek Labs model GW-940-FT is a cost-effective, high-power, W-Band Gunn oscillator. The center frequency is 94 GHz with ± 250

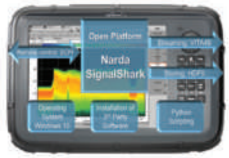
MICRO-ADS

MHz of bias-tunable bandwidth with other frequencies available. The output power is 20 mW minimum. Stability is 5 MHz/°C and a power stability of -0.04 dB/°C. This model incorporates an InP Gunn diode with an input bias of +5 V DC at 1A typ. Heat is dissipated with an integrated heatsink.

Spacek Labs
www.spaceklabs.com

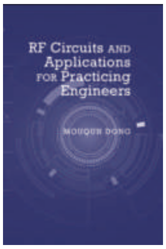
TEST & MEASUREMENT

High Performance Analyzer Without Limits



The SignalShark Real Time Spectrum Analyzer is designed to be an open platform. Its integrated powerful computer running Windows 10 eliminates limitations of traditional test instruments. So the SignalShark family communicates in standard languages like SCPI or VITA 49, while using and supporting the popular formats in common use in the scientific field. If additional software is required—for instance to connect additional sensors—users can run it directly on the analyzer, saving the need for an external PC.

Narda Safety Test Solutions
www.narda-sts.com



RF Circuits and Applications for Practicing Engineers

Mouqun Dong

This comprehensive resource explains the theory of RF circuits and systems and the practice of designing them. The fundamentals for linear and low noise amplifier designs, including the noise and S-parameters and their applications in amplifier designs and matching network designs using the Smith chart are covered. Theories of RF power amplifiers and high efficiency power amplifiers are also explained. The underpinnings of wireless communications systems as well as passive components commonly used in RF circuits and measurements are discussed. RF measurement techniques and RF switches are also presented. The book explores stability criteria and the invariant property of lossless networks and includes detailed theoretical treatments.

The basic concepts and techniques covered in this book are routinely used in today's engineering practice, especially from the perspective of printed circuit board-based RF circuit design and system integration. Intended for practicing engineers and circuit designers, this book focuses on practical topics in circuit design and measurement techniques. It bridges the gap between academic materials and real circuit designs using real circuit examples and practical tips. Readers develop a numerical feel for RF problems as well as awareness of the concepts of design for cost and design for manufacturing, which is a critical skill set for today's engineers working in an environment of commercial product development.

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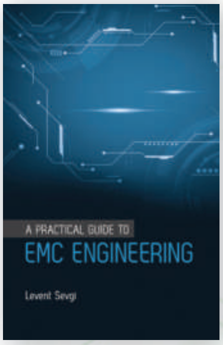

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FABS and LABS

Aaronia: From Handheld Spectrum Analyzers to International Summits

Surrounded by the bucolic farms of western Germany, not far from the borders with Belgium and Luxembourg, Aaronia's expansive glass A-frame headquarters is carved from the evergreen forest, the hub of a global business whose products are helping protect western governments in an uncertain and asymmetric world.

Aaronia's story begins with its founder, Thorsten Chmielus, who started his first business when he was 15. Curious and creative, an interest in PC games led Chmielus into programming and building electronic hardware. Like several well-known tech pioneers, he dropped out of graduate school to pursue his passion.

In 2003, Chmielus started Aaronia to build measurement instruments, initially the "HF-Detektor," a broadband RF meter. This evolved into spectrum analyzers and, in 2008, Aaronia was first to market what Chmielus says was a "real" handheld spectrum analyzer, achieving a record sensitivity of –170 dBm/Hz displayed average noise level.

This first analyzer expanded into the SPECTRAN lines of handheld and compact desktop analyzers, the latter with USB interfaces and software to control and display the measurements. In a competitive environment with many companies offering spectrum analyzers, Aaronia's approach, secured by patents, provides performance advantages confirmed by customers. Complementing SPECTRAN, the company expanded its portfolio to include antennas for direction finding and EMC testing, preamplifiers to improve analyzer sensitivity and signal and field generators for EMC and EMI testing.

Chmielus has always been interested in opportunities to combine Aaronia's products with custom software, creating unique solutions for customers. This blend of curiosity and creativity may have led to the most interesting—perhaps transformative—offering by the company: systems for detecting and jamming drones.

Aaronia detects drones by "sniffing" their RF signals using its antennas, real-time spectrum analyzer and monitoring software. To jam drones, it uses high-power antenna arrays that amplify and broadcast appropriate signals to swamp and disable the links controlling the drone. Combining its sensitive receiver with classification software using AI, the drone detection system, named AARTOS, provides 360 degree coverage out to 10 to 15 km. It can determine the type of drone as soon as it turns on, even before it begins flying.

Now in its sixth generation, AARTOS' capabilities have been tacitly endorsed by the number of international locations and events where it has been deployed: at Heathrow Airport, by the Austrian Army, at the 2018 NATO summit in Brussels and the 2018 meeting in Singapore between the U.S. president and North Korea's leader.

Building on the success of its spectrum analyzer products with AARTOS, Aaronia's revenue has grown some 30 percent per year for the past five years. To handle this and future growth, in 2018 the company expanded its facilities to some 40,000 square meters, providing ample space for research, product development, production, an EMC and calibration center and customer training facilities.

Thorsten Chmielus has not run out of creative ideas to explore. From first tinkering with early PCs in his bedroom to protecting international summits, he and Aaronia are on quite the journey.

https://aaronia.com/

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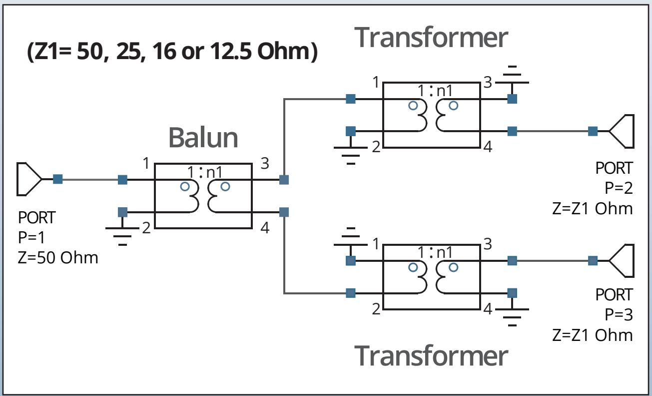
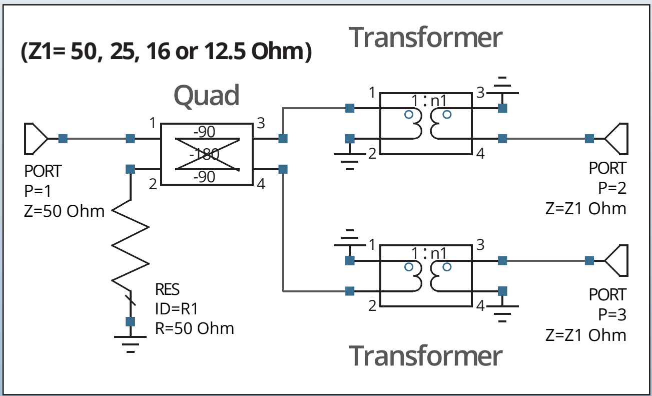
Balun - Transformer Assembly



Quad - Transformer Assembly



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