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August 2019

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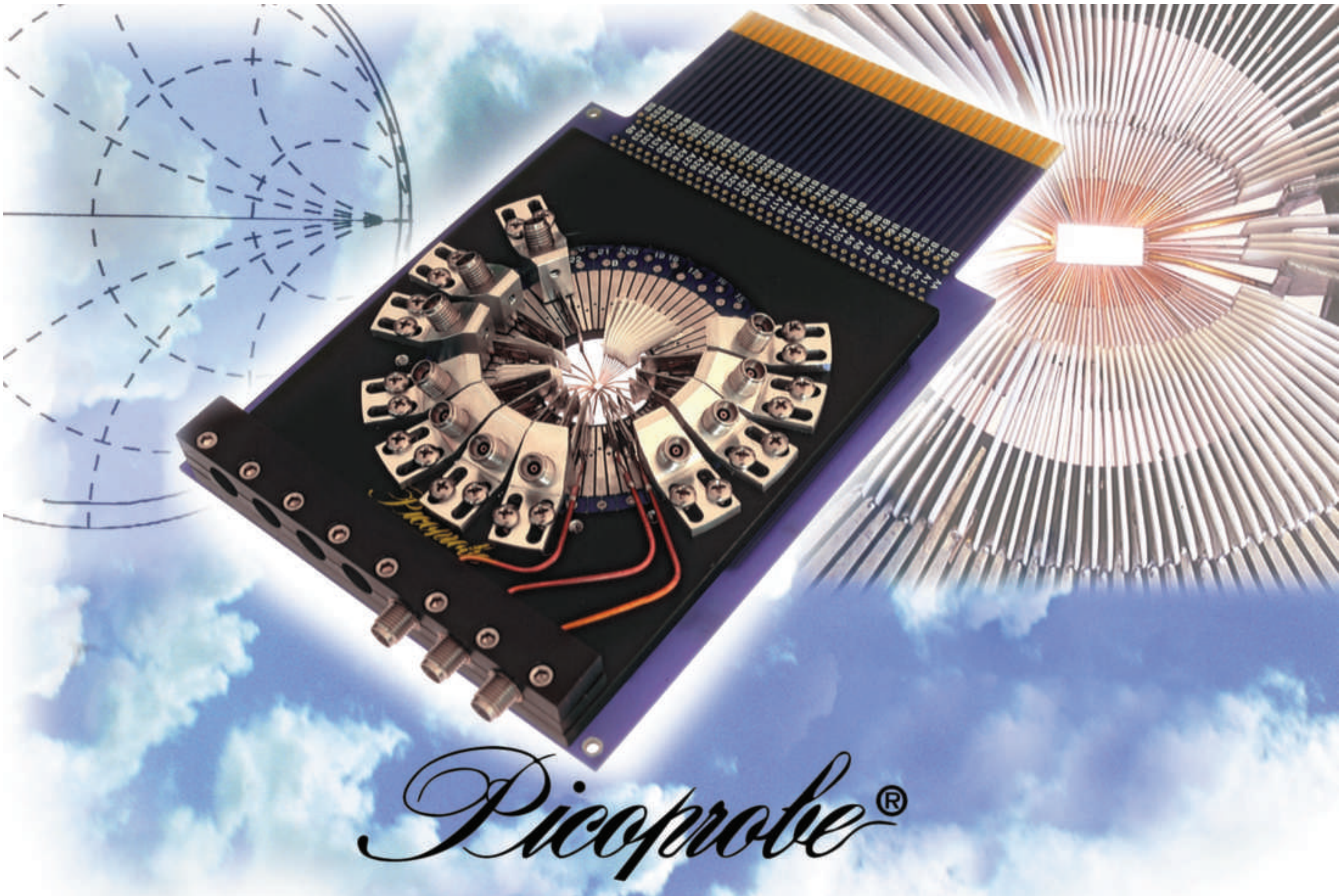

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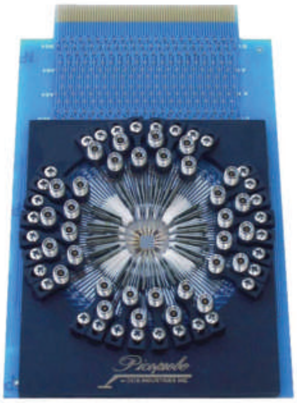

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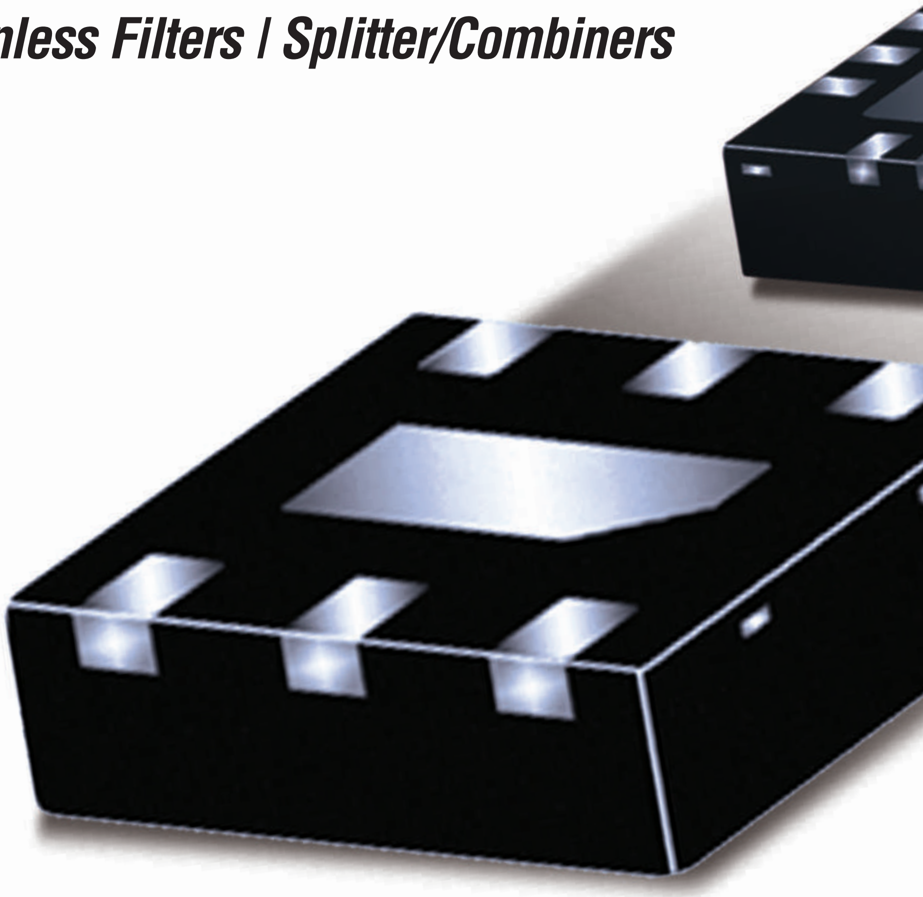

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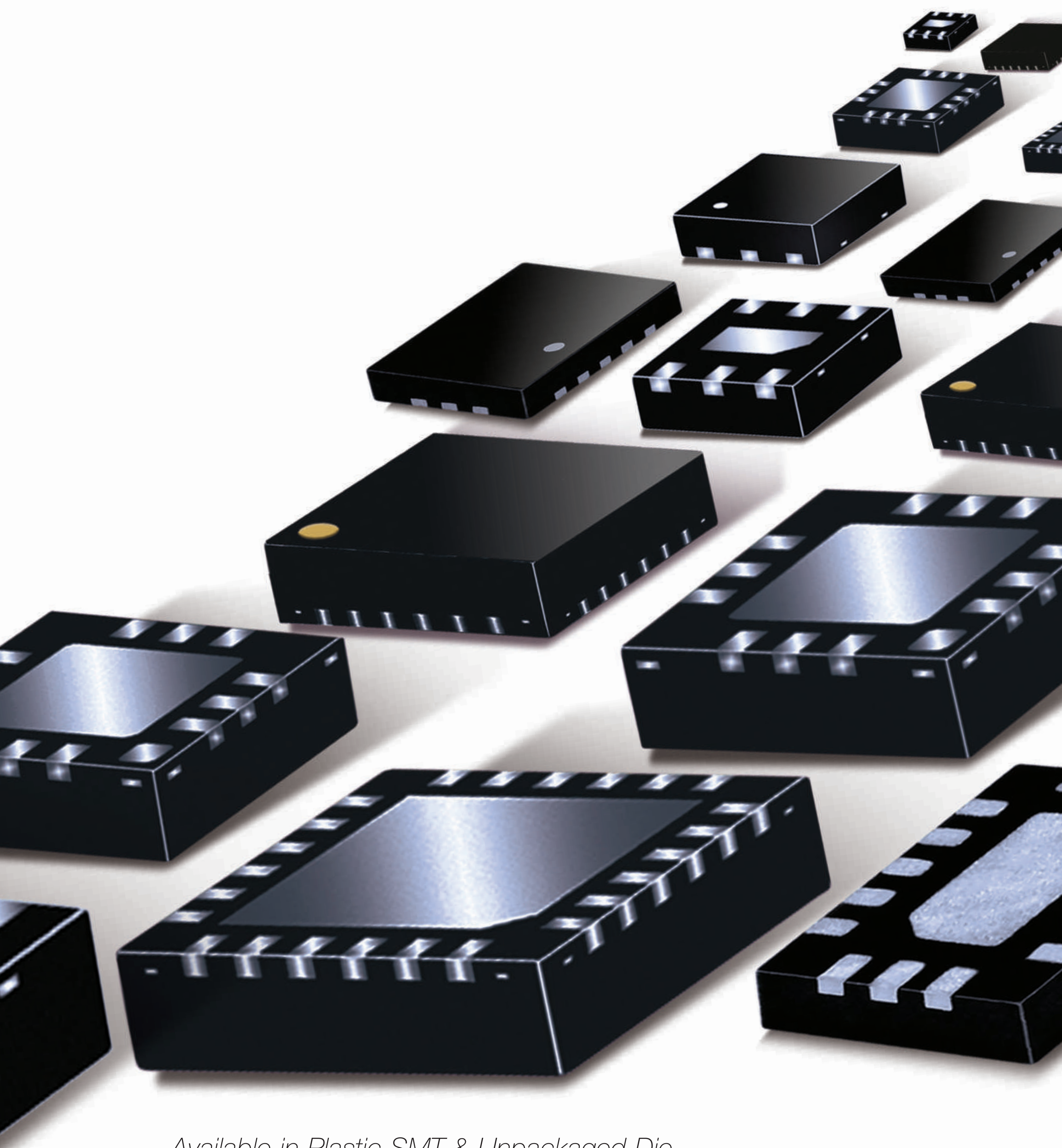

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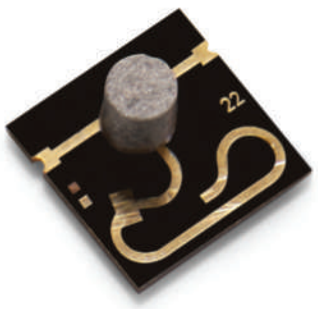

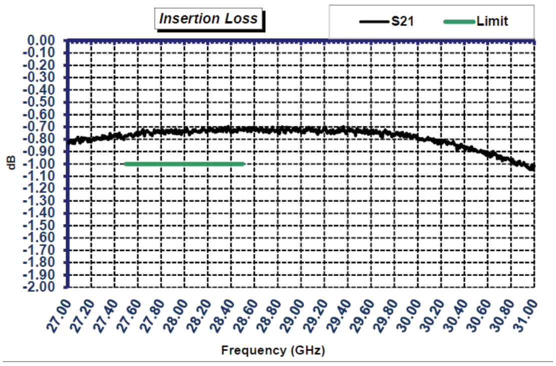

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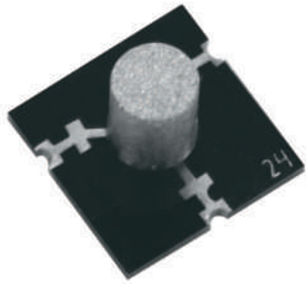

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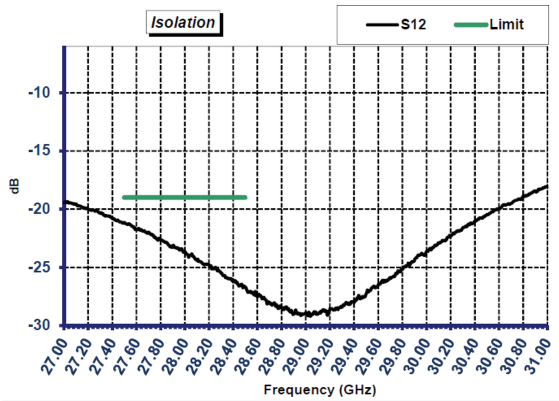


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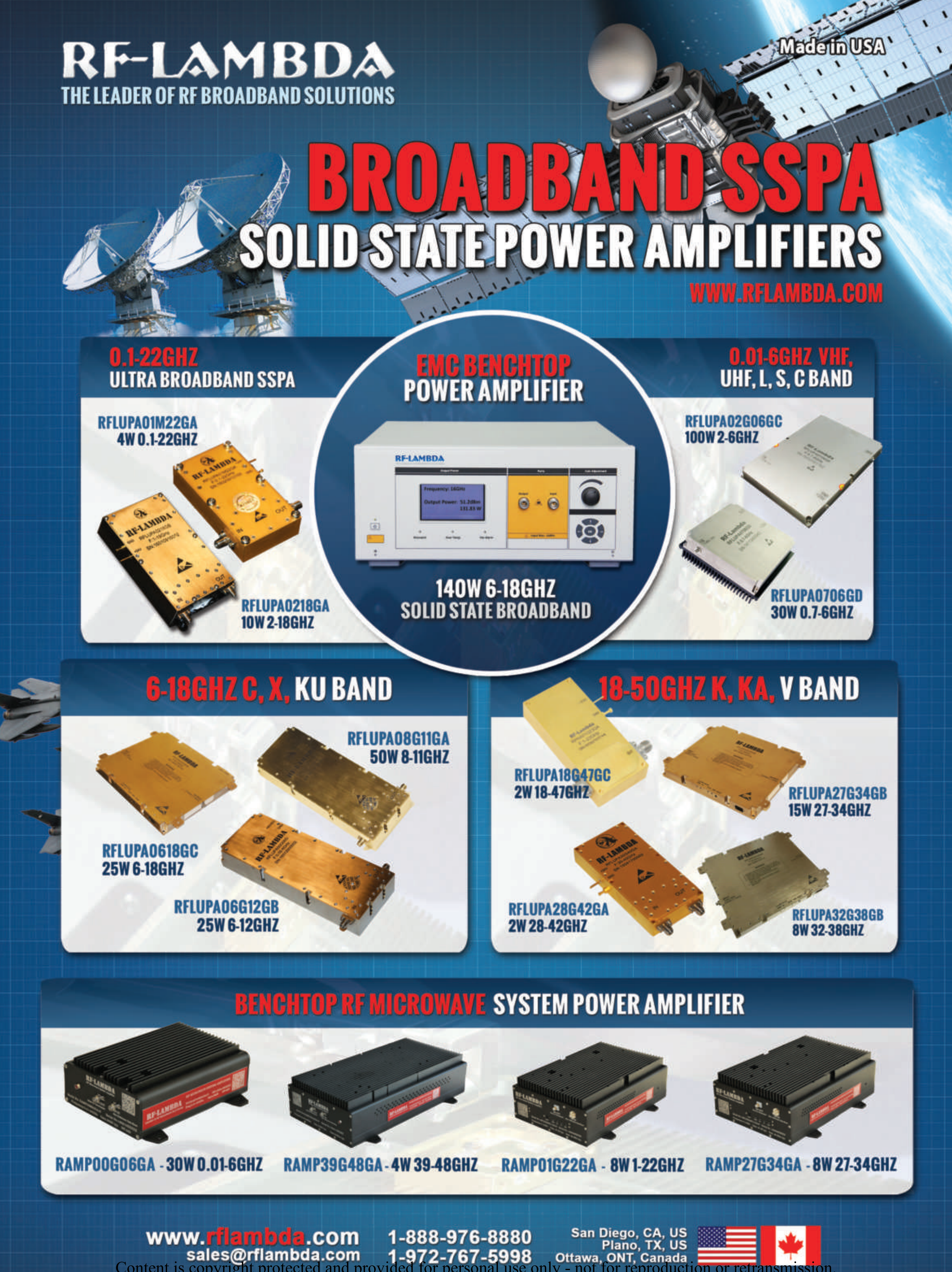

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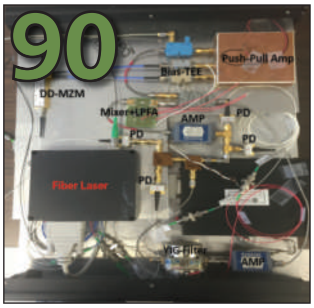

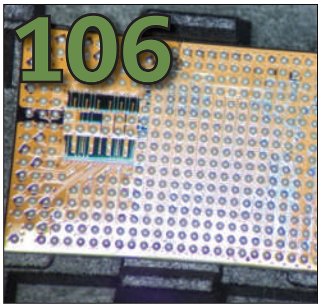

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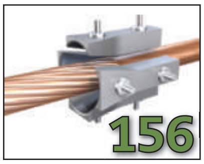

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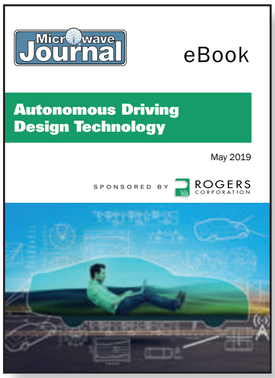

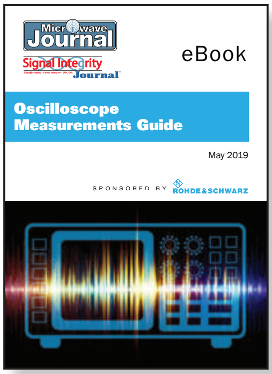

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Executive Interview

Mario Narduzzi, director of Keysight Technologies Services Marketing, discusses KeysightCare, with its various levels of service, and how it benefits test and measurement engineers in various industries.

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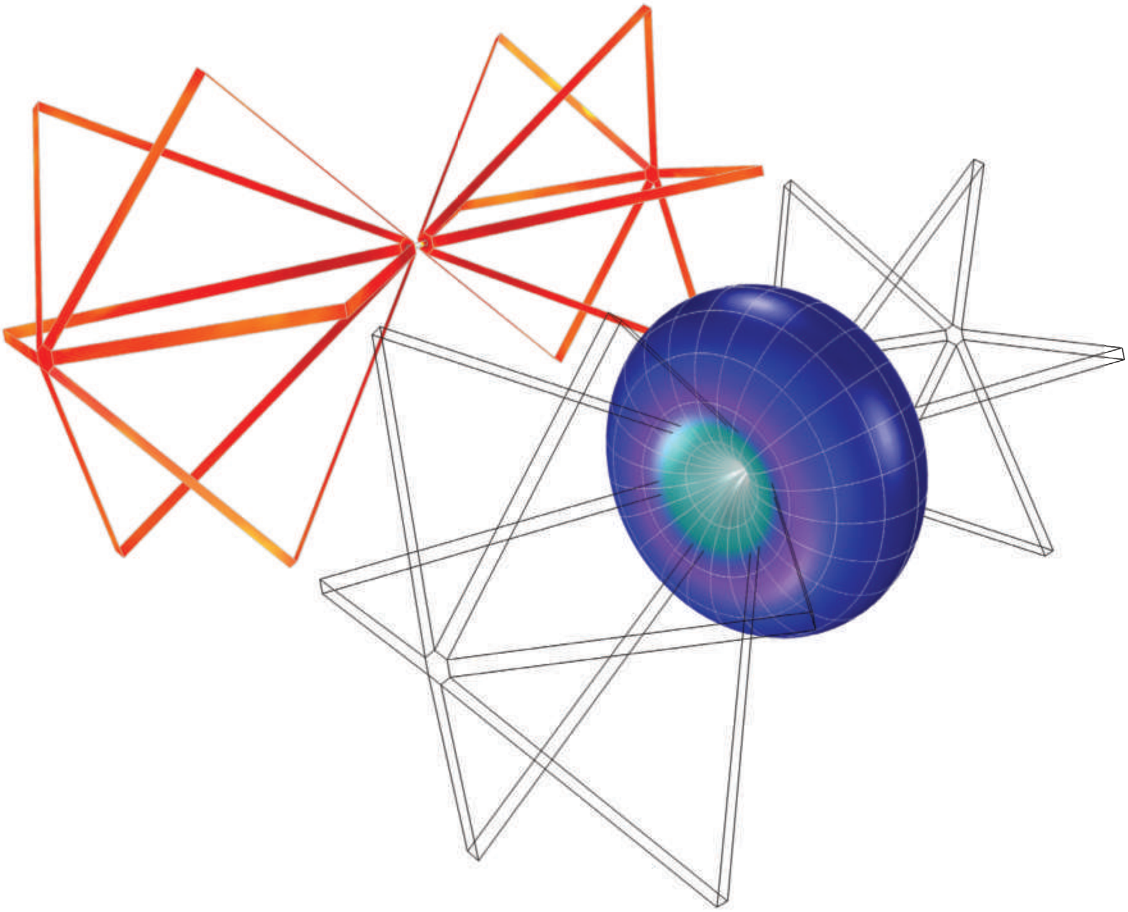

Visualization of the electric field norm and far-field radiation pattern of a biconical frame antenna.

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9-12

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Call for Papers Deadline

GOMAC Tech 2020

GOMACTech is accepting abstracts covering technical topic areas such as Radiation Hardened Technologies, Designs and Systems; Trusted, Assured and Cyber-Secure and Microelectronics; Power Electronics and Emerging Power Technologies; and Emerging Technologies. **www.gomactech.net**

16-21

ROME MMXIX METAMATERIALS
Rome, Italy

Metamaterials 2019 will bring together the engineering, physics, applied mathematics and material science communities working on artificial materials and their applications in electromagnetism/optics, acoustics/mechanics, transport and multi-physics. **http://congress2019.metamorphose-vi.org/**

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5G ANTENNA SYSTEMS
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94th ARFTG Microwave Measurement Symposium

27

Call for Papers Deadline

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9/29-10/4

EuMW 2019
Paris, France

The European Microwave Week (EuMW), bringing industry, academia and commerce together, is a six day event, including three cutting edge conferences and one exciting trade and technology exhibition featuring leading players from across the globe. EuMW 2019 provides access to the very latest products, research and initiatives in the microwave sector. It also offers you the opportunity for face-to-face interaction with those driving the future of microwave technology. **www.eumweek.com**

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Coming**Events**

CALL FOR PAPERS

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September 27

IEEE IMS2020
December 4

IEEE IMBioC 2020
January 31, 2020

WAMICON 2020
February 7, 2020

EuMC 2020
February 7, 2020

IEEE AUTOTESTCON 2020
February 15, 2020

95th ARFTG Microwave Measurement Symposium
February 16, 2020

ITC 2020
March 13, 2020

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AUGUST

IEEE AUTOTESTCON 2019
August 26–29 • National Harbor, Md.
https://2019.autotestcon.com/

ESC Silicon Valley 2019
August 27–29 • Santa Clara, Calif.
http://escsiliconvalley.com/

SEPTEMBER

PCB West 2019
September 9–11 • Santa Clara, Calif.
www.pcbwest.com/

EDI CON Online
September 10–12
www.ediconoline.com

Metamaterials 2019
September 16–21 • Rome, Italy
http://congress2019.metamorphose-vi.org/

TWST/5G Antenna Systems
September 26 • New York City, N.Y.
https://antennasonline.com/

EuMW 2019
September 29-Oct. 4 • Paris, France
www.eumweek.com/

OCTOBER

COMSOL Conference 2019 Boston
October 2–4 • Boston, Mass.
www.comsol.com/conference/boston

AMTA 2019
October 6–11 • San Diego, Calif.
https://amta2019.org/

2019 IEEE International Symposium on Phased Array Systems and Technology
October 15–18 • Waltham, Mass.
http://array2019.org/

ITC 2019
October 21–24 • Las Vegas, Nev.
www.telemetry.org/

MWC 2019 Los Angeles
October 22–21 • Los Angeles, Calif.
www.mwclosangeles.com/

56th Annual AOC International Symposium & Convention
October 28–30 • Washington, D.C.
http://56.crows.org

NOVEMBER

2019 IEEE BiCMOS and Compound Semiconductor Integrated Circuits and Technology Symposium (BCICTS)
November 3–6 • Nashville, Tenn.
https://bcicts.org

IEEE COMCAS 2019
November 4–6 • Tel Aviv, Israel
www.comcas.org/

Global MilSatCom 2019
November 5–7 • London, U.K.
www.smi-online.co.uk/defence/uk/global-milsatcom

MILCOM 2019
November 12–14 • Norfolk, Va.
https://events.afcea.org/MILCOM19/Public/enter.aspx

Space Tech Expo Europe 2019
November 19–21 • Bremen, Germany
www.spacetechexpo.eu/

DECEMBER

IEEE IMaRC 2019
December 5–7 • Mumbai, India
https://imarc-ieee.org/

65th Annual IEEE International Electron Devices Meeting (IEDM)
December 7–11 • San Francisco, Calif.
https://ieee-iedm.org/

Asia Pacific Microwave Conference 2019
December 10–13 • Singapore
https://apmc2019.miceapps.com/client/sites/view/SP8f993

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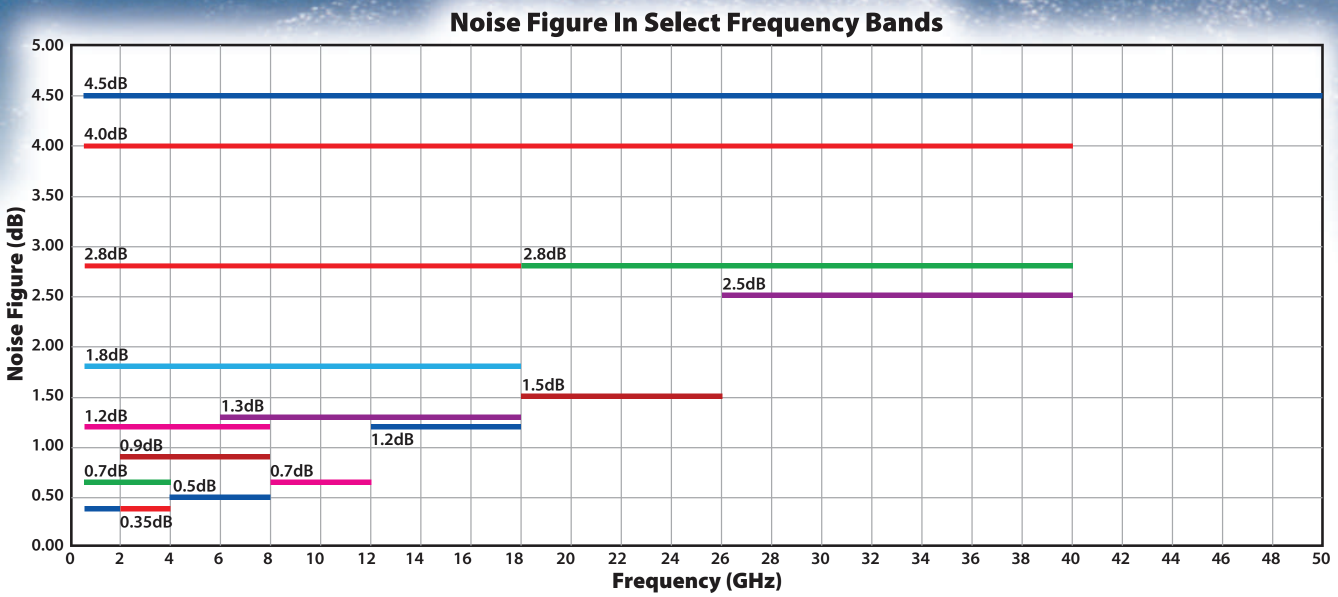
Has Amplifier Performance or

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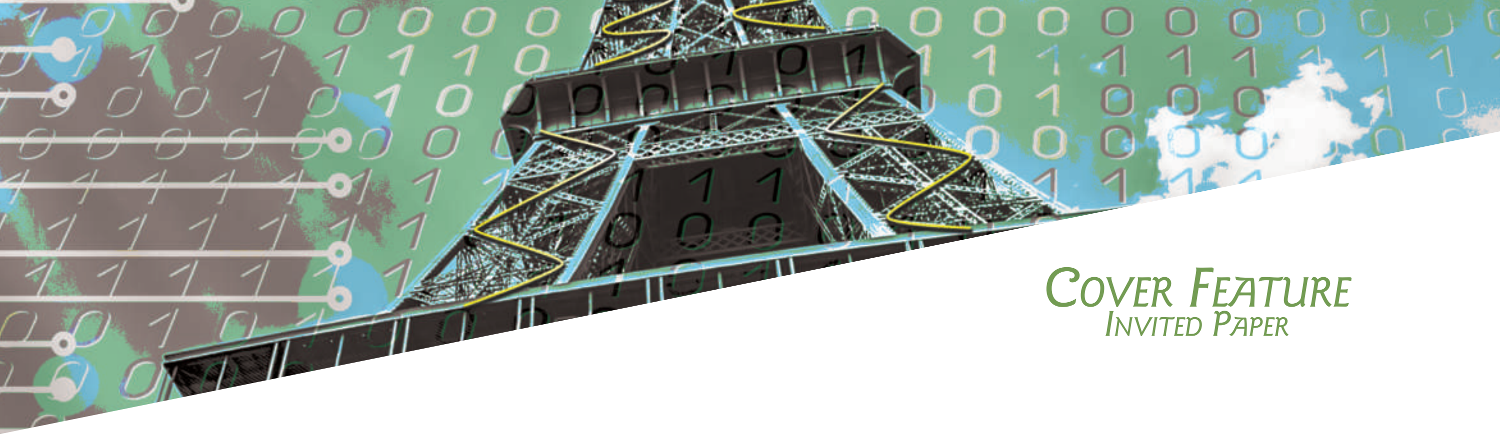

Du Pain, Du Vin, Du Fromage, Des Microondes:* EuMW En Route to the French Capital

Helen Duncan
MWE Media Ltd., U.K.

A review of the microwave and wireless industry in France ahead of EuMW 2019 in Paris.

At the end of September this year, European Microwave Week (EuMW) once again returns to France, but this time to a new venue—the newly refurbished Paris Expo Porte de Versailles. France has a thriving microwave industry, mainly focused on three clusters of high technology companies, which are centered around Paris, Toulouse, Grenoble and the Côte d'Azur (French Riviera) as shown in ***Figure 1***.

The main application sectors are aerospace and defense, plus a significant telecoms emphasis too. France also has a strong presence in the semiconductor industry, boasting both compound semiconductor and RF silicon fabs run by UMS, OMMIC, NXP Semiconductors and STMicroelectronics, as well as silicon on insulator (SOI) wafer production at Soitec in Paris, which also recently acquired GaN capability through its takeover of EpiGaN. The industry is supported by some highly respected universities, including XLIM, IEMN at Lille, Brive-la-Gaillarde, LAAS in Toulouse and ENSI at Caen.

**Some bread, some wine, some cheese, some microwaves.*

DEFENSE

Defense is a key market, and possibly the most dominant for RF and microwave technology in France. A number of companies have stressed the importance of maintaining French (or European) sovereign capability in components and subsystems that are proven in performance and reliability for defense applications. A growing concern about cybersecurity is cited as one of the reasons for keeping defense manufacturing as local as possible.

The French defense industry is dominated by **Thales**, which is Europe's largest defense electronics company and is a leading supplier of ground, sea and air surveillance radars to armed forces, both within Europe and worldwide. A large ecosystem of SMEs has built up in France to supply Thales, and there is a growing impetus to strengthen this local supply chain even further as the

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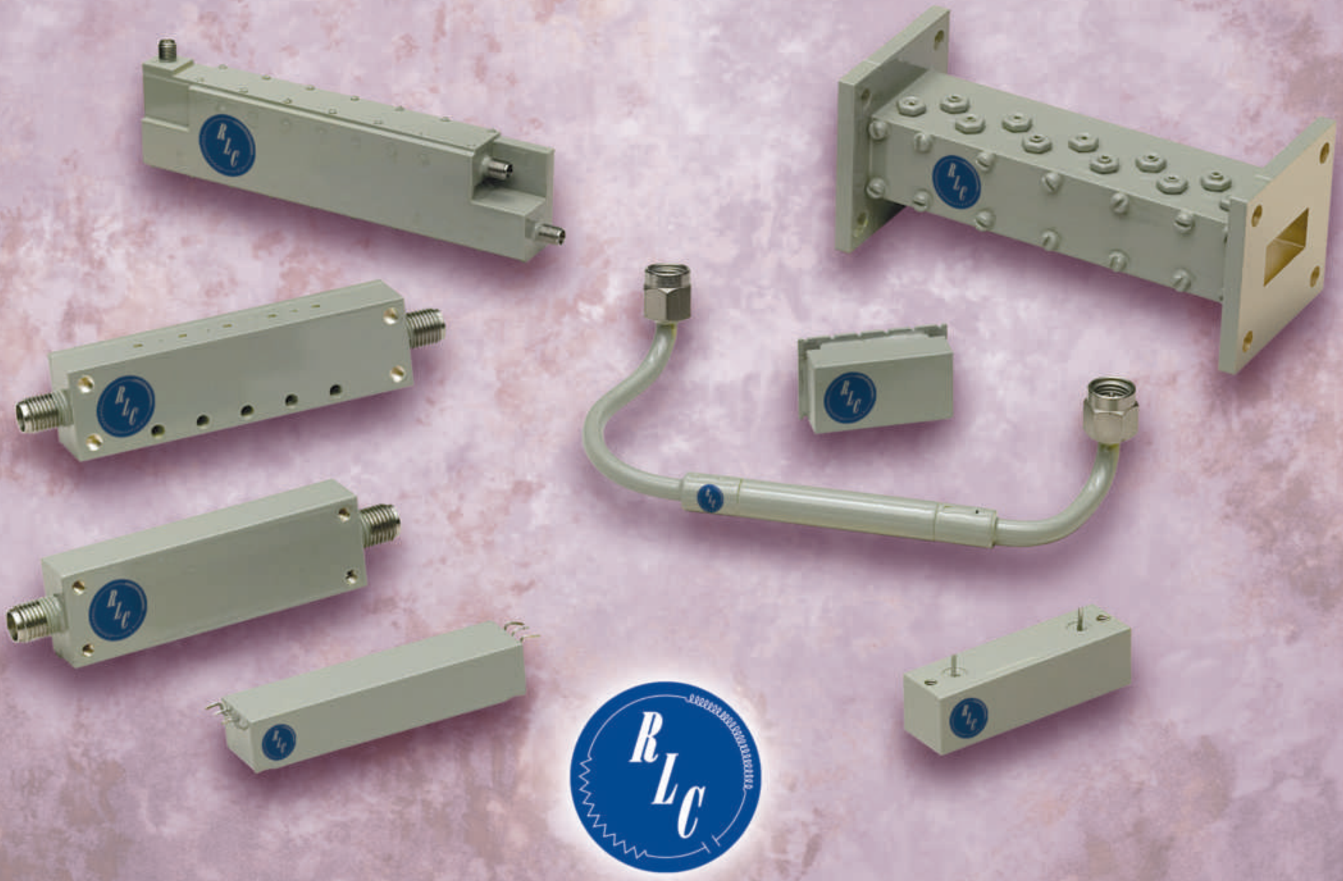

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▲ Fig. 1 **Locations of the main areas (in red) of microwave industry in France.**

climate within U.S. industry appears to be becoming more protectionist.

Dassault Aviation is a French defense and aerospace company with a long history. Part of the Dassault Group, it manufactures both military aircraft—including the Rafale—and business jets. At the 2019 Paris Air Show in June, Dassault and its industrial partner Airbus Defense & Space unveiled a full-scale model of a proposed next-generation stealth fighter—the Future Combat Air System—that is progressing towards a first demonstration phase for eventual deployment around 2040.

Another large company in this sector is Paris-based **Safran Electronics & Defense**, which specializes in avionics, helicopter controls and UAVs.

AEROSPACE

Aerospace represents a large sector of the French industry, particularly in the region of Toulouse, where Airbus has its French headquarters. **Thales Alenia Space**, based in Cannes, is a joint venture between Thales (67 percent) and Leonardo (33 percent), and is a leader in Earth observation satellites, based on high resolution optical and radar payloads that cover military, dual and civilian missions, including intelligence gathering and mapping, as well as meteorology, oceanography and climatology. It is also involved in space exploration missions to Venus, Mars, Titan and to asteroids and comets within the Solar System, and in the development of satellites for the Galileo European navigation system. In a consortium with Maxar Technologies, Thales Alenia Space has recently been selected as one of two contractors for the design phase of the Telesat LEO satellite constellation, with the aim of designing an end-to-end communications system, including satellites, landing stations, user terminals, operations centers and ground network.

Nearly 48,000 people are employed in France by **Airbus**, whose headquarters is located in Toulouse, where the final assembly of its commercial jet airliners—the A320, A330, A350 and A380 families—takes place. Other sites in the country for aircraft manufacture are in Saint-Nazaire, Nantes, Marignane (near Marseilles) and Paris-

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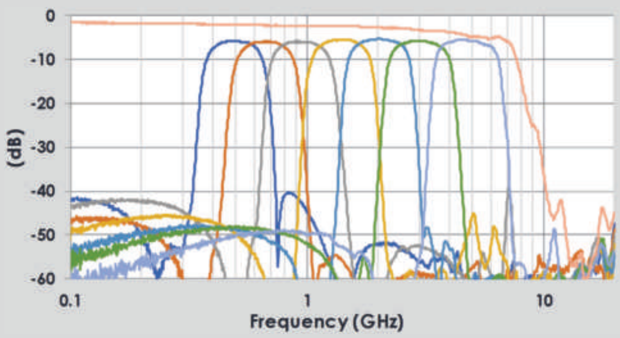
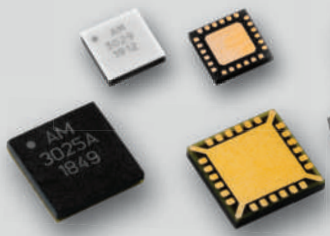
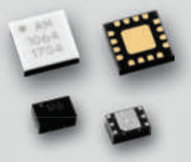




[redacted] Bank in a 9mm QFN

[redacted]w Also A[redacted] Connectorized Modules



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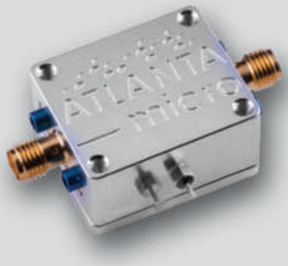

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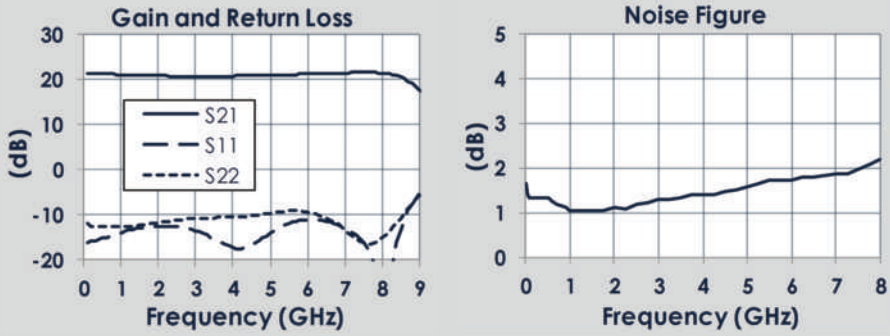

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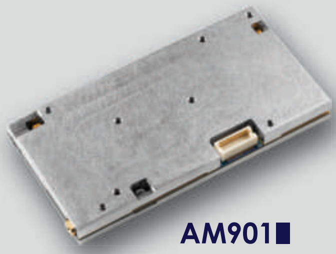

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Le Bourget. Airbus' defense facilities are in various locations around the country, including Toulouse and Élancourt, in the Île-de-France region.

Airbus' satellite business is based on another site near Toulouse, where the company develops, assembles and tests both standard-sized and miniature satellite systems for applications that include Earth observation, meteorology, mapping, reconnaissance and the monitoring of natural resources, as well as for scientific research.

Fig. 2 OneWeb Satellites inaugurated its pilot assembly line in Toulouse in 2017.

OneWeb Satellites is a joint venture between OneWeb and Airbus, and its 4,600 m^2 assembly facility in Toulouse was brought into service in June 2017 to begin the production of the communications satellites for OneWeb's low Earth orbit (LEO) satellite fleet (see ***Figure 2***). The Toulouse facility served to validate the large-scale production methods needed to manufacture 900 of these high performance satellites, and to establish the framework for the larger OneWeb Satellites factory near the Kennedy Space Center in Florida. The development of this facility was supported by Bpifrance within the framework of the French PIA program (Programme d'Investissements d'Avenir).

Callisto Space is one of the smaller companies in the Toulouse aerospace cluster. Callisto designs and manufactures high performance LNAs and provides consultancy, engineering design and services, principally for satellite ground stations. It operates independently as part of the Celestia Technologies Group. Callisto has carried out hardware and software product development for ground stations including a range of both narrowband and wideband cryogenic low noise amplifiers (LNA), room temperature LNAs and a measurement system for noise temperature.

Fig. 3 Callisto Space "Compact" range cryogenic dual-channel LNA for use in Earth Observation Ground Stations.

The use of cryogenically cooled LNAs can provide improved ground station G/T at a fraction of the cost of increasing antenna diameter. ***Figure 3*** shows one of the new generation "Compact" range of cryo LNAs, which has been developed for use in Earth Observation Ground Stations and applications where low power consumption, low maintenance, small size and low weight are of critical importance. This dual-channel cryo LNA is able to reach ~80°K physical temperature with a compact cryo cooler that can operate reliably for around 10 years without requiring maintenance.

TELECOMS

France's previously strong position in mobile communications has declined somewhat in recent years with the sale of Alcatel-Lucent to **Nokia** and the licensing of its handset products to Chinese manufacturer TCL. Nokia still retains a large R&D presence in France, with campuses at Paris-Saclay and Lannion in Brittany that house global competence centers for 5G, cybersecu-

rity and the IoT. France is also the second largest site for Nokia Bell Labs.

Orange, formerly France Télécom, is a French multinational company that employs 95,000 people in France. It is the tenth largest mobile network operator in the world, and the fourth largest in Europe, as well as running the landline and internet services formerly offered by France Télécom and Wanadoo before their rebranding to Orange in 2013. **Orange Labs** is its group of R&D centers, eight of which are in France, located at Issy-les-Moulineaux, Caen, Grenoble, Rennes, Lannion, Sophia Antipolis, La Turbie and Belfort. As would be expected, Orange Labs' current development projects include work on 5G infrastructure development, but also on new telecoms applications such as connected and autonomous vehicles (CAV), agritech and eHealth.

In April, Renault, Orange and Ericsson announced plans to work together on connected vehicles and 5G. This collaborative project aims to assess the potential for 5G to improve communications between vehicles and their environment in a hybrid vehicle-to-everything (V2X) architecture that will include 5G network slicing and Mobile Edge Computing technologies.

Huawei is also particularly active in France. It has recently opened an R&D center in Grenoble, which is its fifth R&D team in the country. Others are in Sophia Antipolis and in Paris, while two existing teams are based at Huawei's facility in Boulogne-Billancourt, and these are working on 5G standards and algorithms. In 2011, Huawei began a collaboration with the Paris Institute of Technology (ParisTech) to launch the "Seeds for the Future" program in France, later extended to other universities. More than 90 French students have already taken part in the program, which Huawei intends as a means for students to understand more about both China and the ICT industry.

AUTOMOTIVE

As CAVs are beginning to emerge as a new application area for microwave devices, it is interesting to note that France has a flourishing supply chain in the automotive sector. **Valeo** is an automotive supplier and partner to car OEMs worldwide. It is a technology-led company designing innovative solutions for smart mobility, with a focus on intuitive driving and reducing CO_2 emissions and is a notable potential customer for the semiconductor suppliers. France's indigenous automotive manufacturers, Renault and the PSA Group, which makes Peugeot and Citroen cars and, more recently, also Vauxhall and Opel, provide a ready home car OEM market, in addition to the possibility of exports.

SOUTH OF FRANCE

A number of microwave companies are located in the science and technology park of Sophia Antipolis, near Cannes, which is also the

home of the European Telecommunications Standards Institute (ETSI), which has over 850 member organizations drawn from over 60 countries and five continents.

As the recognized regional standards body dealing with telecommunications, broadcasting and other electronic communications networks and services, ETSI's role includes supporting European regulations and legislation and the development of European Standards (ENs), many of which are used not only in Europe but all over the world. It is also a partner in both the international Third Generation Partnership Project (3GPP), helping to develop 4G and 5G standards, and in the oneM2M partnership project to develop standards for machine-to-machine communications.

Other companies based at Sophia Antipolis that have activities related to RF and microwave include Broadcom; Cadence Design Systems; Qualcomm; Dassault Systèmes, parent company of SIMULIA; Huawei; Infineon; Maxim Integrated; NXP Semiconductors; Orange; ST Ericsson; and STMicroelectronics.

SEMICONDUCTORS

France has been successful in retaining a sovereign RF semiconductor manufacturing industry while fabs in other European countries have been diminishing in number since the 1990s. **OMMIC**, in Limeil-Brévannes near Paris, is a successful compound semiconductor fab, providing GaAs, InP and GaN MMICs and offering professional foundry services.

"The French microwave industry has many medium to small companies, whose size typically makes them agile and flexible," said Cédric Corrège, international sales manager of OMMIC. "This is certainly the case with OMMIC, and our strong innovation policy is the main reason that we are one of the few remaining III–V fabs in Europe. Our success is not confined to France, as 95 percent of our sales turnover comes from abroad."

Having previously focused on the space market with its low volume, high value mix, OMMIC has recently released a new 100 nm gate length GaN on Si process that offers new high volume opportunities. OMMIC has focused on developing a versatile process that is good both for RF power and for low noise and aimed at producing mmWave devices for 5G base station and 5G automotive applications as well as space and SATCOM. In 2017, it commissioned a new 800 m^2 production clean room

Fig. 4 A view of OMMIC's production clean room, which was extended in 2017 to provide additional capacity for high volume 5G chips.

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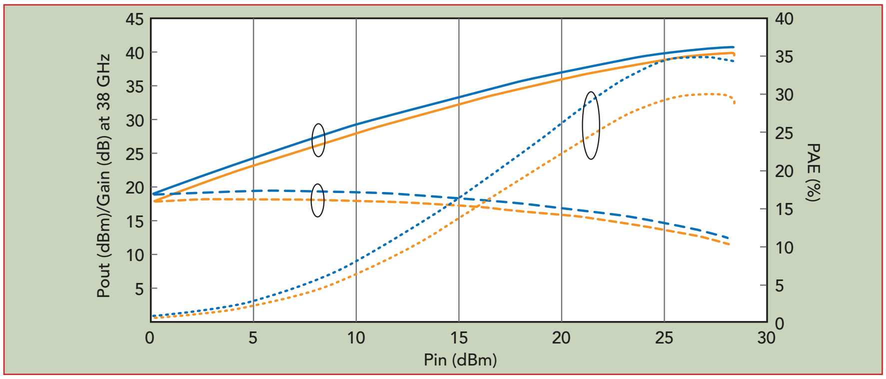

Fig. 5 Power output, gain and PAE vs. Pin for OMMIC CGY2651UH/C1 high-power GaN amplifier at 38 GHz.

(see ***Figure 4***), which doubled production capacity and is eventually planned to increase sevenfold to more than two million chips per year to address the high volume 5G market.

One of the latest GaN devices to be released is the CGY2651UH/C1 high-power amplifier (see ***Figure 5***) which gives 10 W output over 37 to 43 GHz, with 30 percent power added efficiency (PAE) at Psat and 40 GHz. OMMIC also continues to work on mmWave applications from E-Band up to THz frequencies and is finalizing a new process to go up to 300 GHz. In addition, the company is working on increasing the frequency for GaN power devices with the release of a 60 nm gate length process and is working towards a 40 nm process.

It has been 52 years since Motorola first opened a semiconductor manufacturing facility in Toulouse, which was its first outside the U.S. This site now belongs to **NXP**, since its merger four years ago with Motorola's semiconductor spinoff Freescale. NXP in Toulouse specializes in the design of RF semiconductors and sensors and is also involved in developing V2X communications to help enable CAVs and smart cities.

GaN and LDMOS RF PAs for 4G and 5G base stations and infrastructure are a major product line for NXP, which exhibited a suite of 5G base station PAs at IMS2019, including massive MIMO-based active antenna systems for sub-6 GHz and other products for 5G mmWave.

NXP has a second French semiconductor manufacturing site at Caen in Northern France making SiGe devices, which was formerly a Philips facility. The SiGe devices are being used to power highly integrated analog beamforming products at frequencies ranging from 24 to 40 GHz, for 5G mmWave infrastructure for both FWA and RAN applications.

STMicroelectronics in Grenoble is a leading player in the supply of RF GaN on Si ICs, through its col-

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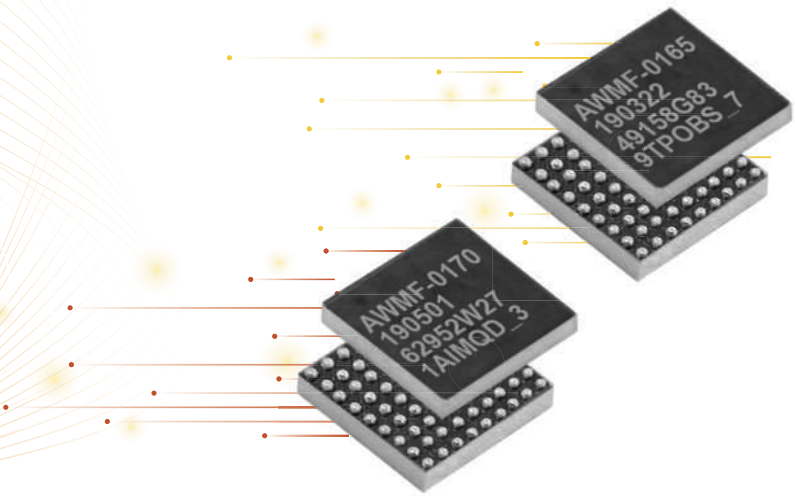

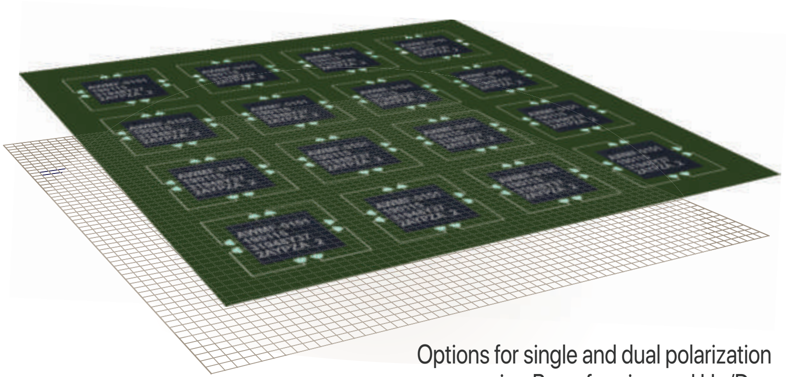

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laboration with MACOM. The company was created as SGS-Thomson Microelectronics in 1987, resulting from a merger of SGS Microelettronica of Italy and Thomson Semiconducteurs in France. Although now headquartered in Geneva, it still retains much of the character of a French company from its Thomson heritage.

Through the MACOM partnership, STMicroelectronics is targeting global 5G base station applications with an expansion of its production capacity of 150 mm GaN on Si and further scaling up to 200 mm wafers, has announced plans to extend this to handset applications.

United Monolithic Semiconductors (UMS) is a German-French Group with a site in Villebon, France that employs around 200 people, and a German site in Ulm. UMS was founded in 1996 as a joint venture between Thales and Airbus Defence and Space. Its core expertise is in the development and production of RF and mmWave GaAs, GaN and SiGe MMICs for telecoms, automotive, defense and space applications, offering a range of standard and custom products up to 100 GHz as well as a foundry service.

Like OMMIC, UMS also export many of their products since the big French space and defense OEMs export a high proportion of their systems. New opportunities are emerging however, with smaller entrants into the space market, such as those making CubeSats, and UMS also sees that the deployment of a new infrastructure networks for 5G will change the characteristics of their market. Automotive collision avoidance radar has provided a high volume market, which along with defense and space products, are delivered to both its parent companies Thales and Airbus plus other leading players around the world.

"Although UMS has recently introduced several high performance GaAs products, much of our current product development is focused on GaN, which is bringing new families of products such as HPAs for X-Band, wideband HPAs for defense applications and highly-integrated front-ends for 5G mmWave," said Eric Leclerc, field marketing manager of UMS. "We also are developing powerful and smart approaches for 5G sub-6 GHz requirements."

In April, UMS announced that it had been selected to develop, manufacture and qualify GaN power transistors for the realization of a SAR system for the seventh Earth Explorer Mission of ESA, Biomass, which is targeted at the global observation of above-ground forest biomass. Two packaged transistors at 15 and 80 W were developed for the driver and the power stage, respectively, of the SSPA the UMS space-evaluated 0.5 μm GaN process (GH50). They were assembled into hermetic metal-ceramic packages, and all qualification tests were successfully completed.

A recent product introduction is the CHA3656-FAA, a 5.8 to 16 GHz LNA designed on the UMS GaAs 0.25 μm process, which is evaluated for space communi-

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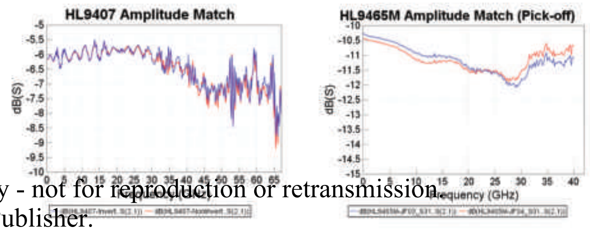

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cations by ESA EPPL, and is also suitable for radar, test instrumentation and similar hi-rel applications. It has a noise figure of 1.75 dB and a low power consumption of 70 mA at 3.3 V. It also features an OIP3 of 25 dBm and a gain of 20 dB, with a 1 dB compression point of 14.5 dBm. Three alternative biasing options provide additional flexibility, and the device is housed in a 6 mm × 6 mm hermetic package.

OTHER COMPONENTS AND INTERCONNECT

France has a long history of producing high quality passive components, cables and connectors at RF and microwave frequencies. Among the companies manufacturing passive and interconnect products in France are **Exxelia**, **Radiall**, **Axon' Cable**, **C&K Components**, **Esterline-Souriau** and **Draka Fileca**.

Although headquartered in New Zealand, crystal specialist **Rakon** has three manufacturing facilities in France, at Gennevilliers, Mougins and Pont-Sainte-Marie. The Gennevilliers team is focused on OCXO and SC-Crystal design and manufacture. Specialized low volume manufacturing is carried out on site, while high volume designs are transferred to the lower cost Indian facility. The Rakon team in Mougins and Pont-Sainte-Marie are designers and producers of high precision and high-reliability frequency solutions for space and defense applications, designed to operate in extremely demanding environmental conditions. The product portfolio includes space and defense qualified OCXOs, TCXOs, VCXOs, XOs, crystals, SAW oscillators and pulse compression sub-systems.

TEST & MEASUREMENT

Noise eXtended Technologies (Noise XT) develops cost-effective test & measurement products, specializing in phase noise analyzers and signal generators. Founded in 1992 as Europtest, the company was bought out by its employees in 2009 from its then parent company Aeroflex. Since 2017, Noise XT has been a subsidiary of Spherea Test and Services.

Its instruments find applications in space applications, where long-term frequency stability generation and analysis is required and there is a need for very low jitter signals for data transmission and conversion. Radar and defense applications need very low phase noise and a high spectral purity, and these also form an important part of the company's market.

"With 12 employees, we are a small but stable company with a strong record of innovation," said Guillaume de Giovanni, head of the business unit and founder of Noise XT. "Thousands of small companies like us have been able to thrive, thanks to the French culture of encouraging research and development and the strong links here fostered by industry with academia."

GOVERNMENT AND EU SUPPORT

The current French government, led by President Emmanuel


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Macron, has expressed a wish to revive France's declining manufacturing sector, and to stem the loss of hardware production to Asia and Eastern Europe, and keep key knowledge located both within the country and in Europe. A number of funding initiatives and tax incentives are available to support innovation, one of which is **France Brevets**, which supports businesses in monetization and protects French technological innovations by filing international patents. Created in 2011, with an initial commitment of €100 million and a further boost of €100 million in 2016, France Brevets is owned by the French State and the Caisse des Dépôts Group.

Recently, the French government collaborated with Germany, the U.K. and Italy to support the microelectronic industry with the launch of Nano 2022, the French component of a wide-ranging Important Project of Common European Interest (IPCEI). Launched in March at STMicroelectronics' facility in Crolles, Grenoble, Nano 2022 involves an investment of €5 billion over five years, including €1 billion of public funding. Along with STMicroelectronics, the other beneficiaries include UMS, Soitec and CEA-Leti. This strategic partnership with the French government and the private sector targets the research and development of innovative semiconductor technologies, with a special emphasis on making the move from prototypes to volume production. The French Ministry of Defense (DGA) is also providing strong support for semiconductor technologies that are strategic to military needs, notably GaN for high pulsed power generation.

"For Space, CNES is a very strong support, either directly through national programs or as the financing body of European Space Agency (ESA) programs such as ARTES or GSTP," said Jean-Louis Cazaux, innovation manager at Thales Alenia Space, who is also chairman of the Component and Technology Board (CTB) of the European Space Component Consortium (ESCC). "There is a tight coordination between CNES and DGA, especially on military space, but also on basic technologies such as GaN, MMIC, etc."

ANR is also participating on some programs. Industrial partners are expected to co-finance grants from CNES, DGA or ANR with their own R&D investment, typically at 50 percent or more, but the grants still provide a significant stimulus to innovation. At a European level, both the EU Horizon 2020 program and ESA are providing support for the industry and helping to stimulate the commercialization of European innovation.

SUMMARY

Overall the French industry landscape is characterized by strong defense and space sectors. This is coupled with a high level of academic expertise in microwave technology within universities and higher education, particularly in electronics and semiconductor physics, and this has supported an innovation culture in France. The French government is providing an especially nurturing culture for startups and SMEs, resulting in a very healthy microwave industry across all sectors of the supply chain, from wafers to large systems.■


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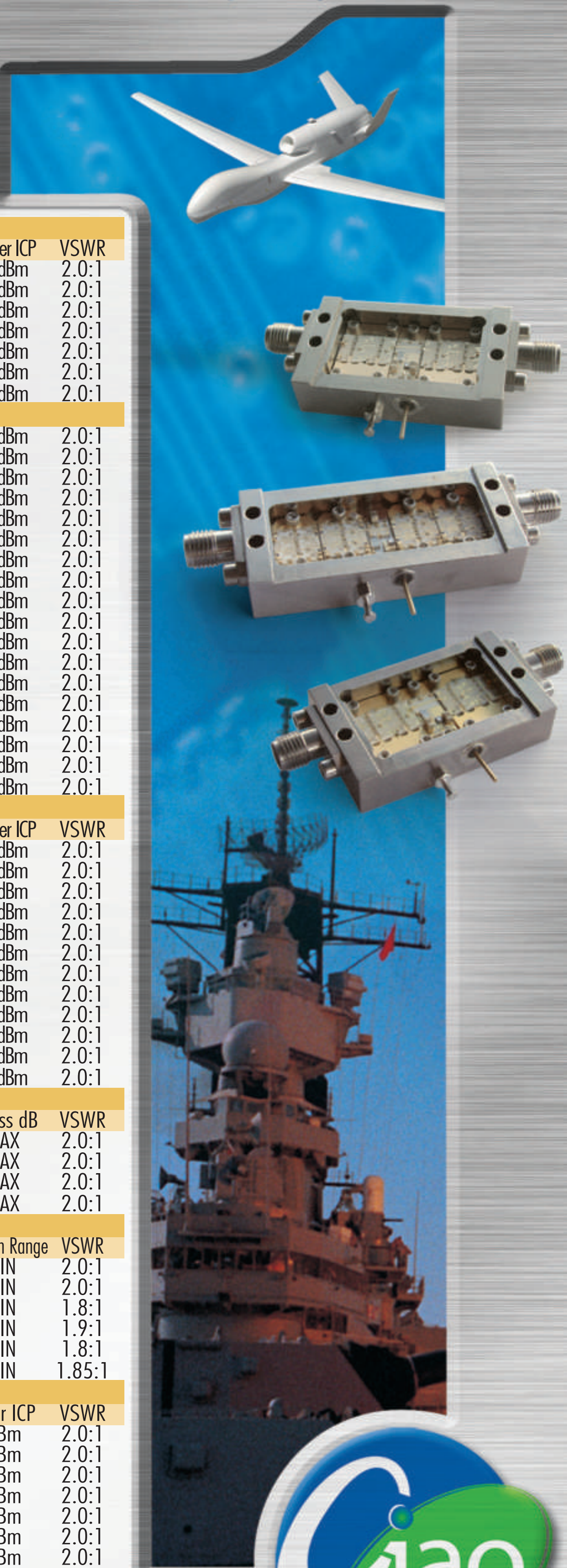

OCTAVE BAND LOW NOISE AMPLIFIERS

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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Cliff Drubin, Associate Technical Editor

Leonardo Unveils its Largest-Ever Drone

Building on the success of Leonardo's Falco family of tactical-class RPAS, the new drone features a payload capacity of 350 kg, more than 24 hours flight time and SATCOM capability for beyond-radio-line-of-sight operations, all within a 1.3 ton maximum take-off weight. Everything is designed in-house by Leonardo, from the aircraft itself to the sensor suite, mission system and ground control station (GCS), and the Falco Xplorer will be offered as both an integrated platform and as a fully managed information-superiority service.

It is undergoing certification for flight in non-segregated airspace, meaning Leonardo will be able to pitch it to civil customers such as coast guards and emergency responders as well as the military market. Because the Falco Xplorer system is entirely designed and manufactured in Europe, it is not subject to International Traffic in Arms Regulations (ITAR) restrictions and its technical characteristics place it within the Missile Technology Control Regime (MTCR) class II category. Together, these make the Falco Xplorer readily exportable around the world.

A series of trials will take place throughout the year, capped off by a flight campaign with the platform's fully integrated sensor suite on-board. The RPAS could then be delivered to its launch customer as early as 2020. The drone will be certified according to NATO STANAG4671, meaning that it will be readily approved to fly for NATO countries.

Leonardo believes that an unmanned capability goes beyond the aircraft, so the baseline "Block 10" equipment fit for the new RPAS takes advantage of Leonardo's in-house electronics portfolio to offer a comprehensive intelligence, surveillance and reconnaissance (ISR) capability over land and sea. The platform will come equipped with a Gabbiano T-80 surveillance radar, LEOSS electro-optical turret, SAGE electronic intelligence (ELINT) system and an automatic identification system (AIS) for maritime use. The sensors will be integrated through Leonardo's mission management system, which draws on the company's experience in both the manned and unmanned domains and includes protection from cyber-attacks as standard under the company's "secure by design" philosophy.

FALCO Xplorer (Source: Leonardo)

The Swiss Army Knife of Radars

A small object takes flight, picks up speed, turns and heads south—directly toward a U.S. military base. It could be anything from a guided rocket to an explosive-strapped quadcopter. Back at the post, a Ku-Band or KuRFS radar detects and tracks the object so soldiers can make the call: It is nothing to worry about. Just another bird. One of the radar's many important jobs is to know the difference.

"It's like a Swiss Army knife with all the components out and being used at once," said Don Williams, manager of Raytheon's Multifunction RF Systems product line. "The Army recognizes it as a true multi-mission radar because, unlike other radars, which can do multiple things but not at the same time, KuRFS does them all simultaneously."

Designed and built by Raytheon, KuRFS is an AESA radar that uses the Ku-Band frequency for precision tracking. One of its main missions is to provide non-stop surveillance of airborne objects, while another is to sense incoming threats such as rockets, artillery or mortars and warn soldiers so they can take cover.

The radar is being deployed as part of a counter-UAS for the battlefield. When paired with Raytheon's small, expendable Coyote® UAS, normally an intelligence and surveillance drone, KuRFS becomes a hit-to-kill kinetic interceptor that can take out small, consumer-sized drones.

The U.S. Army has taken the unique combination a step further, putting Coyote and KuRFS on an armored vehicle to create a mobile defense system. In addition, Raytheon has successfully integrated the radar into or tested it with a 50-caliber gun, the AI3 interceptor, land-based Phalanx® weapon system and more.

"Soldiers will now be able to take this defense against drones into the field with them, in addition to having it on their base," Williams said. "Drone threats are spiking and becoming more creative, and they're hard to see. That's one reason why this radar is so important."

"Before the laser system can destroy small drones from far away, it first needs to be able to know they

KuRFS (Raytheon Photo)

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

are there," said Dr. Ben Allison, product line director for Raytheon high-energy laser weapons systems. "KuRFS provides cue accuracy at long range. That level of precision, paired with the ability to simultaneously track multiple targets, makes high-energy lasers more lethal."

Precision Guided Munition Market

According to ASDReports market research, the precision guided munition market is projected to grow from $30 billion in 2019 to $47.5 billion by 2025, at a CAGR of 8 percent. Growing military modernization programs, the need to minimize collateral damage, the increasing use of satellite networks, navigation aids and drones to destroy high-value/long-range targets and the desire for miniaturized weapons are some of the key factors fueling demand and driving growth. Major manufacturers are Lockheed Martin (U.S.), BAE Systems (U.K.), Raytheon (U.S.), Northrop Grumman (U.S.), Elbit Systems (Israel), Saab AB (Sweden), General Dynamics (U.S.), Israel Aerospace Industries (Israel), Rheinmetall AG (Germany), LIG Nex1 (South Korea), NORINCO (China) and Bharat Dynamics (India), among others.

Based on product, the tactical missiles segment is estimated to lead the precision guided munition market in 2019 and is expected to continue its dominance till 2025. Tactical missiles are versatile weapons and can be fired in various modes, angles and platforms. They are equipped with advanced guidance technologies, which enable them to hit targets with high accuracy.

Based on technology, the GPS segment is expected to grow at the highest CAGR. GPS offers precision navigation capability with accurate velocity information. Hence, various vendors of precision guided munition focus on producing PGMs equipped with GPS technology.

Based on type, the autonomous segment of the market is projected to grow at a higher CAGR compared to the semi-autonomous segment. Autonomous precision guided munitions are equipped with high-resolution electro-optical and infrared cameras that help locate and guide the vehicle to the target. The increasing demand for multi-mission, multi-target precision-strike and air-to-ground precision weapons is estimated to propel this growth.

Based on region, the Asia-Pacific market is projected to grow at the highest CAGR. The growth of the market in this region can be attributed to a rising demand for precision guided munitions from defense forces of different countries. China, India, Japan and South Korea are investing heavily in the development of high strike precision weapons. OEMs and startups are fueling this growth along with some of the major regional manufacturers.


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Radar Sensors Market

According to MarketsandMarkets, the radar sensor market is projected to reach $20.64 billion by 2023, growing at a CAGR of 19.51 percent from 2017 to 2023. Radar systems are used in a wide range of end-user applications, including automotive, aerospace and military, as well as security & surveillance, traffic monitoring and management, environmental and weather monitoring.

In automotive, radar is used in adaptive cruise control and autonomous driving assistance systems (ADAS) for applications such as lane change support, collision avoidance and parking aid, as well as pedestrian and cyclist detection, and step-&-go functionality. A short-range sensor in automobiles helps in collision warning, lane change assistance, blind spot monitoring and as a parking aid, whereas a long-range radar helps in identifying blind spots in front of the vehicle and in determining the traffic situation ahead. Automotive is the largest segment of the radar sensor market and will continue to be dominant in the coming years.

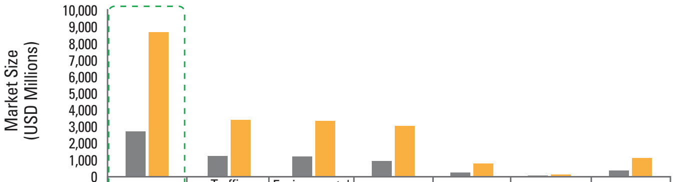
$20.64 billion in 2023 led by automotive.

In the military, radar systems are used in missile control, ground surveillance, navigation and military air traffic control, as well as to identify moving targets and assist in search and rescue operations. Increased military spending will lead to further growth. According to the Stockholm International Peace Research Institute (SIPRI), global military spending increased by 2.6 percent in 2018 compared with 2017 in the U.S., China, India, France and Saudi Arabia—top spenders that account for almost 60 percent of the global military outlay. Also, an increasing need for security and surveillance at borders has led to the requirement for advanced sensor network security systems.

Future Outlook

Growing development in self-driving/autonomous vehicles is likely to drive future adoption. Companies such as Ford, GM, Tesla and Volvo, are planning to release driverless cars by 2021. Ford is planning to deploy almost 1,000 driverless cars by 2021, Volvo is planning to offer 100 Swedish customers early access to their autonomous XC90 SUV by 2021 and Tesla is planning to release self-driving taxis (robotaxis) by 2020 in the U.S.

Developments have also been observed in integrated radar technologies. For example, in May, a team of researchers from the Fraunhofer Institute for Laser Technology (Germany); the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology (Germany); and the Institute of High Frequency Technology at RWTH Aachen University (Germany) developed a process by which radar sensors can be coated on vehicle headlights. In May, Libelium (Spain) introduced a smart parking device for cars with integrated radar technology. Also, continuing developments of military radar systems such as SPAR tiles from MACOM, Digital Array Row Transmitter (DART) from Lockheed Martin and the Artisan 3-D radar system from BAE Systems help to drive growth.



	Automotive	Traffic Monitoring & Management	Environmental & Weather Monitoring	Security & Surveillance	Industrial	Aerospace & Defense	Others
2017	2,790.6	1,253.4	1,245.9	989.6	296.6	93.2	416.8
2023	8,702.0	3,412.3	3,367.0	3,079.5	795.8	145.3	1,140.2
CAGR (2017-2023)	20.87%	18.17%	18.02%	20.83%	17.88%	7.67%	18.26%

"Radar Sensors Market" (Source: MarketsandMarkets)

Competitive Scenario

Robert Bosch Gmbh, Lockheed Martin, Infineon Technologies AG, Continental AG and HELLA GmbH & Co. KGaA are among the leading vendors in the market. Robert Bosch has gained popularity in the radar sensors market due to continuous investments in products related to automotive. For instance, in January, Bosch announced it will invest $1.1 billion to increase chip production owing to the rise in the adoption of sensors in cars. Apart from Robert Bosch, other vendors, such as Continental, HELLA and Infineon Technologies, dominate the market due to their strong foothold in automotive. Lockheed Martin's dominance is attributed to its strong foothold in aerospace and defense. Autoliv Inc., BAE Systems plc, NXP Semiconductors N.V., Saab AB and ZF Friedrichshafen AG are among other major vendors.

International Technology Vendors Address Urban Mobility, Sustainability & Resilience Challenges in South-East Asia

Cities across South-East Asia (SEA) face a diverse set of urbanization challenges, ranging from putting basic infrastructure in place to fuel the local economy in some of the poorest countries like Laos, Myanmar and Cambodia to making sure the economy does not come to a halt in the more developed and/or fast-growing economies like Thailand, Vietnam and Indonesia. These growing regions are facing increasing levels of congestion, pollution, waste management issues and pressures from tourism, prompting sustainability efforts and renewable energy

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generation. Common to all SEA countries are resilience efforts mitigating the impact of flooding, earthquakes and typhoons, concerns about rising traffic fatalities and growing inequality across urban-rural divides in terms of access to healthcare, education and employment, according to ABI Research.

"With limited local expertise and a lack of home-grown technology brands, SEA countries and cities are looking abroad for sourcing smart cities solutions, support and even financing," says Dominique Bonte, VP end markets, ABI Research. "Initiatives range from sharing best practices on an international level to partnerships with cities from Korea and Japan and commercial agreements with Asian, European and U.S. technology suppliers."

In April 2018, the 10 Association of Southeast Asian Nations (ASEAN) Member States (AMS), under the smart cities leadership of Singapore, established the ASEAN Smart Cities Network (ASCN) as a cooperative effort and framework to standardize, promote and share best practices. The ASCN is also tasked with exploring complementarities, facilitating cooperation with and funding by the private sector and financial institutions in 26 selected Pilot Member Cities, each of which was linked with an external ASEAN partner to work on smart city development.

Countries and cities across ASEAN are joining forces with cities in Japan, Korea and China. Cambodia partners with Japan on the development of smart cities and attracting more Japanese investment and the Smart City Consortium in Hong Kong. Amata City Chonburi in Thailand partnered with the Japanese city of Yokohama on feasibility studies and smart energy management through cooperation with the Yokohama Urban Solution Alliance. Additionally, partnerships are in place with the city of Incheon, Republic of Korea (development of a Korean Smart City Zone) and Hammarby/Saab Group (eco-friendly industrial area district).

"With limited local expertise and a lack of home-grown technology brands, SEA countries and cities are looking abroad..."

Commercial relationships with international technology suppliers include ABB (Ho Chi Minh City–Water Management Solution), Cisco (Hanoi–Telemedicine Technology), Alibaba (Kuala Lumpur–Malaysia City Brain powered by Alibaba Cloud), Dassault Systemes (Virtual Singapore 3D Model), Siemens (Bangkok–Rail-Bound Rapid Transit), Fujitsu (Jakarta Flood Information Platform (JAFIP)) and Singapore-based cryptocurrency and blockchain developer Pundi (smart city business district in Phnom Penh).

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MV336 10 MHz, +12V
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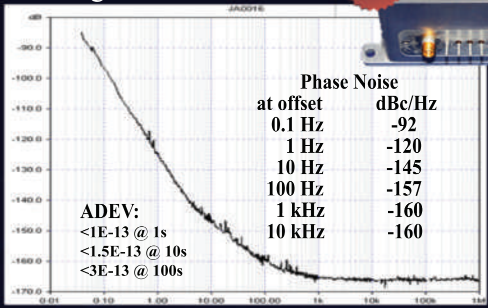
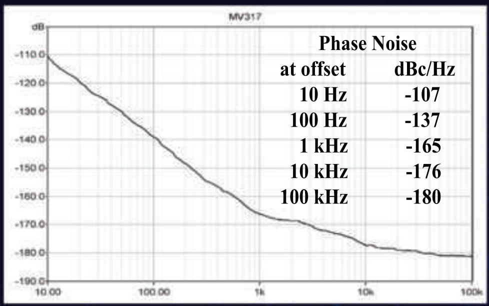


Phase Noise at offset	dBc/Hz
0.1 Hz	-92
1 Hz	-120
10 Hz	-145
100 Hz	-157
1 kHz	-160
10 kHz	-160

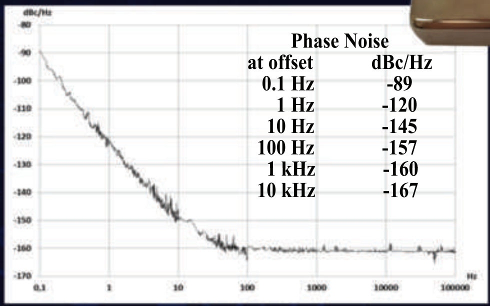
ADEV:
<1E-13 @ 1s
<1.5E-13 @ 10s
<3E-13 @ 100s

MV317 100 MHz, +5V/+12V
- Temperature Stability: 1E-8
- Aging: ±1E-7 per year
- Package: 25.8x25.8x10.3 mm



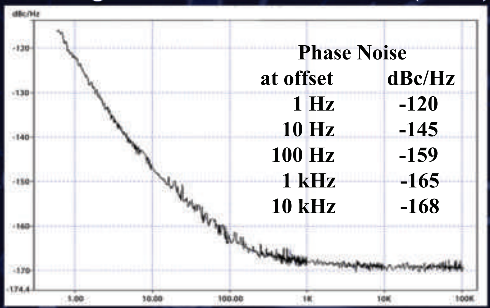
Phase Noise at offset	dBc/Hz
10 Hz	-107
100 Hz	-137
1 kHz	-165
10 kHz	-176
100 kHz	-180

MV341 10 MHz
- Temperature Stability: 1E-9
- Allan Deviation: <2E-13 per sec.
- Package: 50.8x50.8x12.7 mm



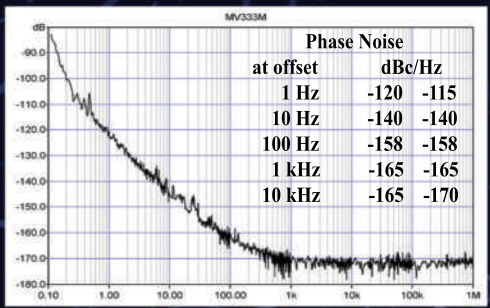
Phase Noise at offset	dBc/Hz
0.1 Hz	-89
1 Hz	-120
10 Hz	-145
100 Hz	-157
1 kHz	-160
10 kHz	-167

MV272M 10 MHz
- Temperature Stability: 1E-9
- Allan Deviation: <4E-13 per sec.
- Package: 41.0 x 30.0 x 17.0 mm (SMD)



Phase Noise at offset	dBc/Hz
1 Hz	-120
10 Hz	-145
100 Hz	-159
1 kHz	-165
10 kHz	-168

MV333M 10 MHz
- Temperature Stability: 3E-9
- Allan Deviation: <5E-13 per sec.
- Package: 25.8x25.8x12.7 or 36x27x16 mm



Phase Noise at offset	dBc/Hz	
1 Hz	-120	-115
10 Hz	-140	-140
100 Hz	-158	-158
1 kHz	-165	-165
10 kHz	-165	-170

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Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

DHI Telecom CEO Wallace Davis announced the acquisition of French-based startup **Travel WiFi**. The company was built from scratch starting in November 2013. Travel WiFi provides travelers to France, Europe and beyond with rentals of high-quality, pocket-sized Wi-Fi, with free pickup at Paris area airports and retail locations. Travel WiFi's widely available rental design has attracted over 200,000 customers. Trusted Shops online reviews awarded Travel WiFi Five Stars and the "Best Pocket Wi-Fi in Europe, 2019." DHI's Sapphire WiFi hotspots were initially designed for the military and DoD.

NEC Corp. and **Aviat Networks Inc.** announced an agreement under which the North American sales channel for NEC's microwave business changes hands from NEC Corp. of America to Aviat. Through this partnership, NEC will continue to provide its microwave products to customers in North America with services and customer support provided by Aviat. NEC Corp. is a leader in the integration of IT and network technologies that benefit businesses and people around the world. Aviat Networks Inc. is a leading expert in wireless transport solutions and works to provide dependable products, services and support to its customers.

COLLABORATIONS

ipoque GmbH, a **Rohde & Schwarz** company, announced a strategic partnership with **Martin Luther University (MLU) Halle-Wittenberg** to establish a joint research program. The R&S subsidiary provides market-leading network analytics solutions for more secure, reliable and efficient networks. The joint research with the Computer Science Institute of the MLU will focus on future technologies like big data analytics, machine learning or AI and how they can boost network analytics. The project is intended to run for four years. A fast and efficient identification of malicious software, encrypted malware and network attacks is the main prerequisite to keep the networks of the future safe and reliable.

The EMEA Satellite Operators Associations (ESOA) and the **Next Generation Mobile Networks (NGMN) Alliance** have joined forces to strengthen their relationship and to foster a closer co-operation in the area of integration of satellite solutions in the 5G ecosystem. This co-operation agreement brings together two widely recognized industry organisations in the field of 5G cellular and satellite networks, respectively. Conscious of the need to expand the benefits of connectivity to as many potential citizens as possible, NGMN and ESOA wish to explore synergies between satellite and terrestrial technologies. This will allow mobile and satellite operators to assess the benefits of new business models that will extend connectivity and potentially unleash new markets and growth for both sectors.

L3 Technologies announced that it has signed a joint venture agreement with **Saudi Arabian Military Industries (SAMI)** to collaborate on electro-optical and infrared (EO/IR) and special mission systems projects within the Kingdom of Saudi Arabia (KSA). The contract was signed on June 18 in the SAMI Chalet during the Paris Air Show. In February, L3 and SAMI announced the signing of a MoU relating to the joint venture.

Firefly Aerospace Inc. announced that it has signed an Intellectual Property and Engineering Support Agreement with **Israel Aerospace Industries (IAI)** for technology based on its Beresheet Lunar Lander. Firefly Aerospace is one of the nine companies selected by NASA to participate in the Commercial Lunar Payload Services (CLPS) program to deliver science payloads to the surface of the moon.

ACHIEVEMENTS

Pasternack, an Infinite Electronics brand, announced that it has received the Supplier Excellence Award from **Raytheon Integrated Defense Systems (IDS)** for superior supplier performance. Raytheon's IDS business instituted the annual Supplier Excellence Awards program to recognize suppliers who have provided outstanding service and partnership in exceeding customer requirements. Award candidates are judged on certain criteria, including overall quality and on-time delivery. Pasternack was one of 77 companies recognized for 4-Star honors.

Smiths Interconnect Inc. announced receipt of the James S. Cogswell Outstanding Industrial Security Achievement Award for 2019—the most prestigious honor the Defense Security Service (DSS) may bestow upon the top cleared facilities. The award was established in 1966 in honor of the late Air Force Col. James S. Cogswell, the first chief of industrial security within the DoD. Cogswell was responsible for developing the basic principles of the Industrial Security Program, which includes an emphasis on the partnership between industry and government to protect classified information.

CONTRACTS

General Dynamics Information Technology (GDIT) announced it has won a $2 billion contract to continue managing the **U.S. Department of State (DOS)** global technical security supply chain. The single-award contract with the Bureau of Diplomatic Security (DS), Countermeasures Directorate includes a base period of five years and a five-year award term. This award adds to the scope of the current supply chain management contract, which was awarded to GDIT in June 2012. Under the new contract, GDIT will provide DOS with a fully-integrated, turnkey solution consisting of technical se-

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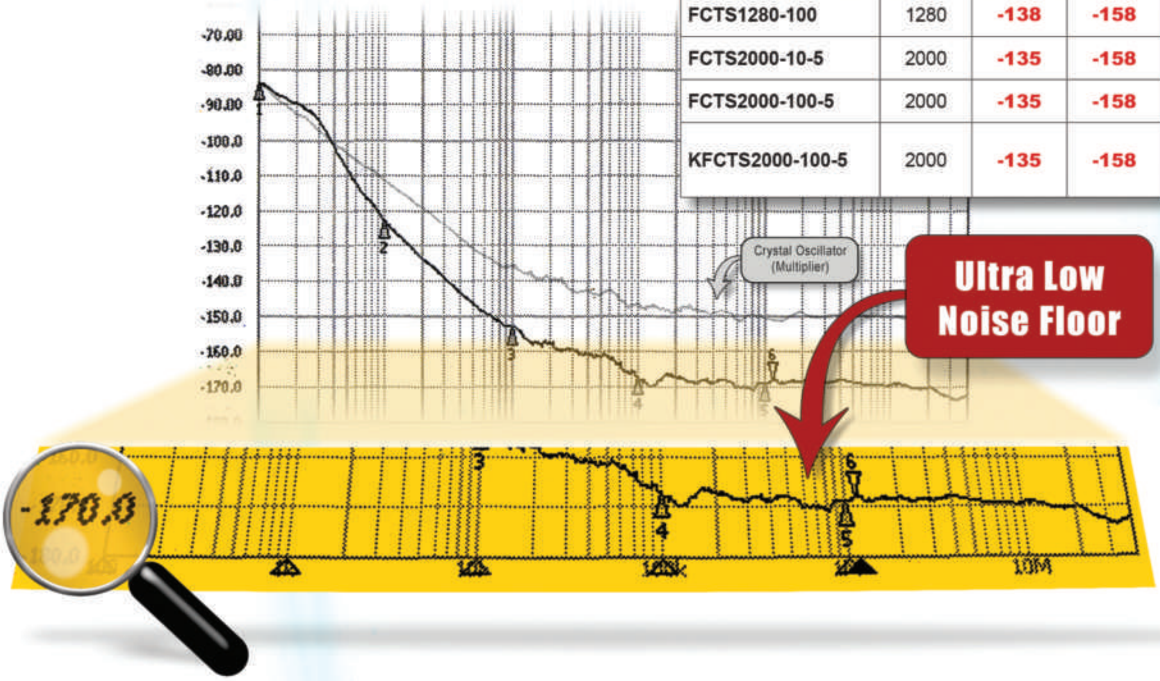
High Performance Frequency Converters
Base Station Applications
Agile LO Frequency Synthesis

Model	Frequency (MHz)	Phase Noise (dBc/Hz) [Typ.] @10 kHz	Phase Noise (dBc/Hz) [Typ.] @100 kHz	Package
VFCTS128-10	128	-155	-160	
FCTS800-10-5	800	-144	-158	
KFCTS800-10-5	800	-144	-158	
FSA1000-100	1000	-145	-160	
KFSA1000-100	1000	-145	-160	
FXLNS-1000	1000	-149	-154	
KFXLNS-1000	1000	-149	-154	
FCTS1000-10-5	1000	-141	-158	
KFCTS1000-10-5	1000	-141	-158	
FCTS1000-100-5	1000	-141	-158	
FCTS1000-100-5H	1000	-144	-160	
FCTS1040-10-5	1040	-140	-158	
FCTS1280-100	1280	-138	-158	
FCTS2000-10-5	2000	-135	-158	
FCTS2000-100-5	2000	-135	-158	
KFCTS2000-100-5	2000	-135	-158	



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U.S. Marine Corps has awarded **Northrop Grumman Corp. (NGC)** a $958 million contract for Lot 6 full-rate production of GaN AN/TPS-80 Ground/Air Task-Oriented Radar (G/ATOR) systems. G/ATOR is a crucial capability that protects warfighters and defends against today's threat environment and the threat environment of the future. G/ATOR replaces five legacy systems operated by the Marine Corps with a single system, providing significant improvements in performance when compared to the legacy radar families in each of its modes. This results in reduced training, logistics and maintenance costs.

CACI International Inc. announced it has secured an $880 million task order to provide information technology and engineering services to the **U.S. Army's Product Lead Reserve Component Automation System-Force Management System (PL RCAS-FMS)**. The Information Technology Enterprise Management Systems Solution (ITEMSS) task order, made under the U.S. General Services Administration's Alliant 2 contract vehicle, represents continuing work for CACI and expansion to support the Army's vision for Global Force Information Management. The government will rely upon CACI's Agile Solution Factory (ASF), already one of the largest and most modern Agile frameworks used by the federal government, to more quickly develop software for the Army's personnel and force management systems.

Harris Corp. has provided **Lockheed Martin (LM)** with the seventh of 10 advanced navigation payloads contracted for the U.S. Air Force's GPS III satellite program. The GPS III navigation payload features a Mission Data Unit (MDU) with a unique 70-percent digital design that links atomic clocks, radiation-hardened processors and powerful transmitters—enabling signals up to 3× more accurate than any GPS satellites currently in operation. The payload also boosts signal power, which increases jamming resistance by 8× and helps extend the satellite's lifespan. Harris is LM's navigation signal partner for GPS IIIF satellites, and in January received a $243 million award to provide the navigation signals for the first two GPS IIIF satellites, space vehicles 11 and 12.

Comtech Telecommunications has announced that during its third quarter of fiscal 2019, its Command & Control Technologies group, which is a part of Comtech's Government Solutions segment, received additional funding of $13.5 million to provide very small aperture terminals (VSAT) to support the **U.S. Army**. The Command & Control Technologies group is a provider of mission-critical, highly-mobile C4ISR solutions. Comtech designs, develops, produces and markets innovative products, systems and services for advanced communications solutions. The company sells products to a diverse customer base in the global commercial and government communications markets.

Around the **Circuit**

Orbit Communications Systems Ltd. announced that **Rafael Advanced Defense Systems** placed a $5.5 million order for Orbit's MPT 87 airborne SATCOM terminals and AL-4018 ground pedestals for integration with Israel Aerospace Industries' advanced Heron TP MALE UAV. Orbit's integrated solution of onboard Multi-Purpose Terminal (MPT 87) satcom terminals and AL-4018 high-speed ground pedestals will provide both line-of-sight (LOS) and beyond-LOS (BLOS) and connectivity and tracking for IAI's next-generation medium-altitude, long-endurance (MALE) UAVs. Delivery of the Orbit equipment is expected in 2019 and 2020.

PEOPLE

▲ *Dr. Niels Kramer*

Altum RF announced co-founder **Dr. Niels Kramer** as its managing director Europe and VP marketing. Kramer brings more than 25 years of semiconductor process and RF and microwave semiconductor industry experience to Altum RF. Kramer's industry background includes RF semiconductor process development, general management, project and product management and strategic marketing. Most recently with MACOM as senior director integrated solutions, Kramer had the responsibility of developing a portfolio of RF ICs for high performance applications. Prior to that, he served as department head of the MEMS & Micro Assembly Foundry at Philips, R&D and program manager for RF Products at NXP and RF device engineer at Philips Semiconductors.

▲ *Satish Dhanasekaran*

Keysight Technologies has announced that **Satish Dhanasekaran**, senior VP of Keysight and president of the company's Communications Solutions Group, has been appointed to the Technological Advisory Council (TAC) for the Federal Communications Commission (FCC). The FCC is an independent U.S. government agency that regulates communications within the U.S. and internationally. The TAC provides technical expertise to the FCC on a variety of topics including 5G, broadband networks, spectrum, AI and more. Dhanasekaran has been appointed to a two-year term on the council.

▲ *Jill Kale*

▲ *Shawn Black*

Jill Kale, president of **Cobham Advanced Electronic Solutions (CAES)**, a U.S. subsidiary of British firm Cobham plc, has retired as of July 1 and been replaced by current COO, **Shawn Black**. Black has years of leadership experience, from his role as a U.S. Marine Corps officer to a position as VP and general manager for win SEMICONDUCTORS | Compound Semiconductor Solutions from RF to Lightwave™

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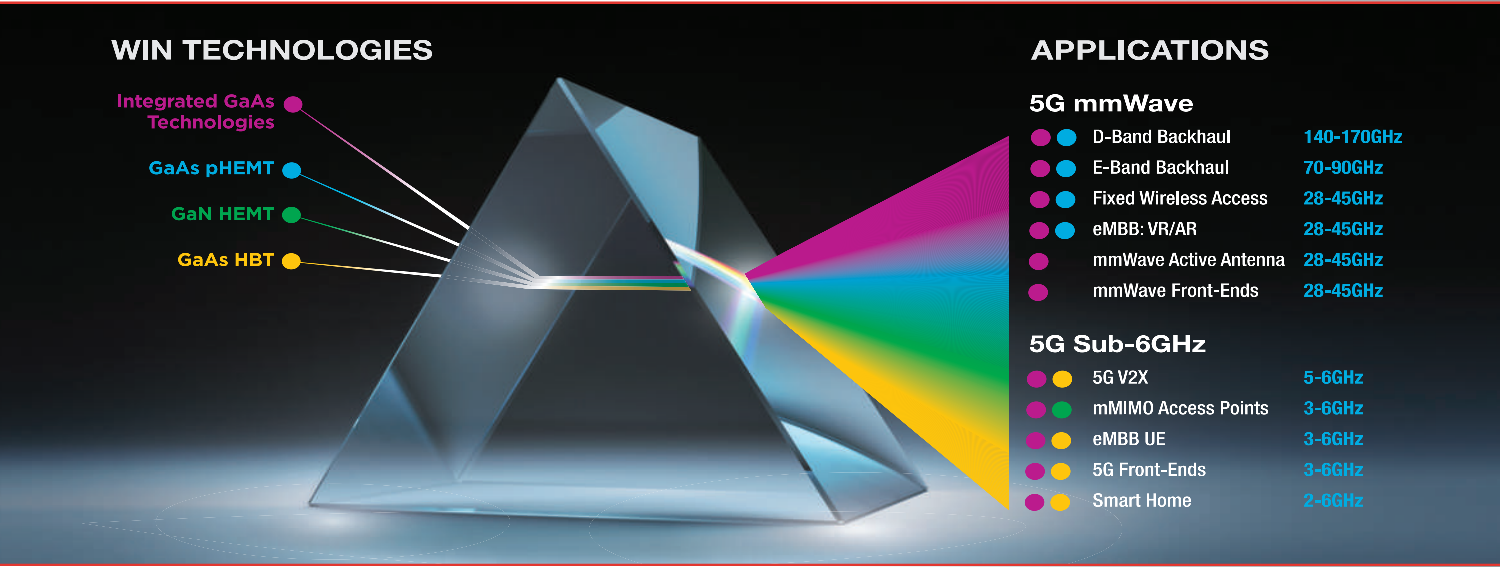

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- **Single Chip FEM:** PIH1-10 Integrated GaAs pHEMT with PIN
- **mm-Wave PA:** NP15 Power GaN HEMT
- **T/R Switch:** PIN3-00 Low loss PIN MMIC
- Bump or hot via assembly

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Leonardo DRS, which he held prior to joining CAES. In his new role, Black will report to the CAES board of directors. Kale became president of CAES in 2012.

▲ *Rhonda Turner*

Benchmark Electronics Inc. announced the appointment of **Rhonda Turner** as chief human resources officer (CHRO), effective immediately. In this role, Turner will lead all aspects of human resources, including talent acquisition and development, organizational design and effectiveness, compensation and benefits, diversity and inclusion and HR business operating systems. Turner brings over 20 years of experience to the role, and most recently served as senior VP of HR for Universal Technical Institute Inc. Prior to that, she held various HR leadership roles at leading companies such as ConocoPhillips, Circle K and Main Street Restaurant Group, a TGI Friday's franchisee.

REP APPOINTMENTS

Maury Microwave Corp. announced it has signed an agreement with **MRC Gigacomp** of Freising, Germany. MRC Gigacomp will be representing Maury in the German, Austrian and Swiss markets.

RFMW announced a distribution agreement with **Hirose Electric**, effective immediately. Under the agreement, RFMW will support Hirose's extensive product offering with a focus on their RF and microwave components portfolio including attenuators, terminators, dividers and directional couplers equipped with standard SMA/BNC/N coaxial connectors.

WEBSITE

EDI CON Online, a new interactive event to being held online September 10-12, 2019, has announced its lineup of technical session speakers. The interactive technical sessions will occur at no cost to attendees, and sponsors have the opportunity to present workshops and keynote sessions as part of the daily schedule. The sessions on September 10^{th} will focus on 5G and IoT, September 11^{th} on radar and antennas and September 12^{th} on signal integrity and power integrity. Attendees select the sessions for the online event in a single sign-on registration portal and can participate in as many sessions as they wish live (with question and answer sessions) or watch later on demand. Sessions are produced on a multimedia platform, including video, traditional webinar and screen sharing formats. EDI CON Online announced that Rohde & Schwarz, Mini-Circuits and Samtec will be the Platinum Sponsors of the event and will be producing each day's opening keynote, respectively. Visit ediconononline.com for further details.

Rogers' Laminates: Paving the way for tomorrow's Autonomous Vehicles

Autonomous "self-driving" vehicles are heading our way guided by a variety of sensors, such as short and long range radar, LIDAR, ultrasound and camera. Vehicles will be connected by vehicle-to-everything (V2X) technology. The electronic systems in autonomous vehicles will have high-performance RF antennas. Both radar and RF communication antennas will depend on performance possible with circuit materials from Rogers Corporation.

High-performance circuit laminates, such as RO3000® and RO4000® series materials, are already well established for radar antennas in automotive collision-avoidance radar systems at 24 and 77 GHz. To further enable autonomous driving, higher performance GPS/GNSS and V2X antennas will be needed, which can benefit from the cost-effective high performance of Kappa™ 438 and RO4000 series materials. These antennas and circuits will count on the consistent quality and high performance of circuit materials from Rogers.

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ANTENNA	
RO4000 Series Circuit Materials	Low loss, FR-4 processable and UL 94 V-0 rated materials
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To learn more visit:
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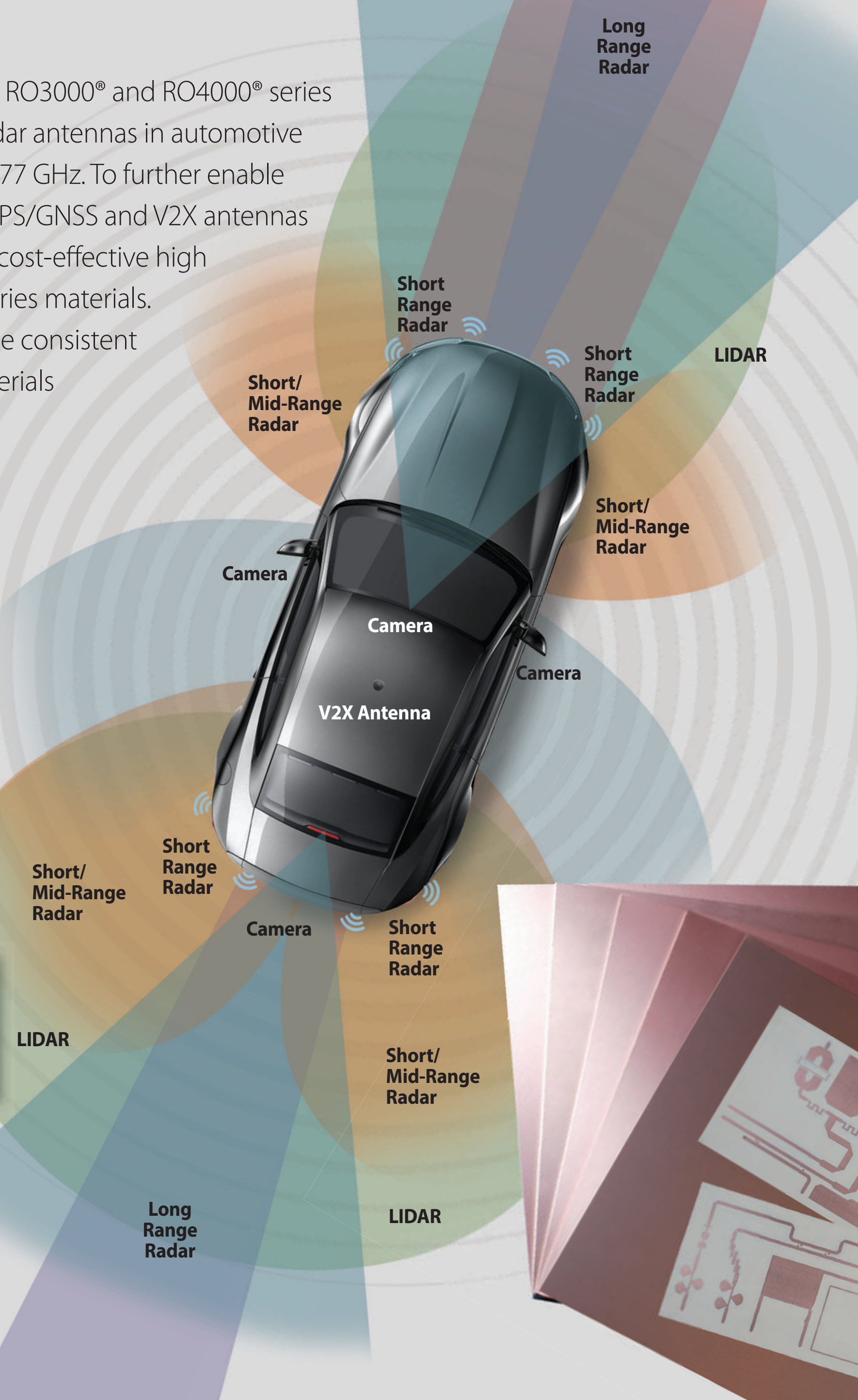

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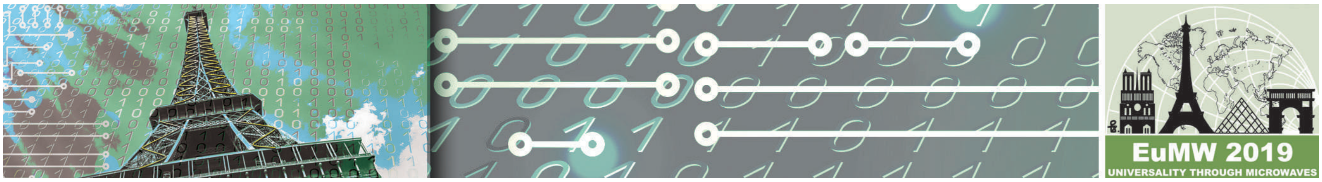


Welcome to the 22nd European Microwave Week

Denis Barataud and Christian Person
EuMW 2019 General Co-Chairs

For complete coverage of the EuMW 2019 conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show daily at mwjournal.com/eumw2019.

Welcome to France where the Declaration of the Rights was written in 1789 and welcome to Paris "La Ville Lumière"! It is our great pleasure to welcome you to the 22nd European Microwave Week (EuMW) to be held at the Paris Expo Porte de Versailles, Paris, from Sunday, 29 September to Friday, 4 October 2019.

"Universality through microwaves" is our motto this year to express how the microwave technologies are fundamental for all human beings who will have to face the challenge of integrating artificial intelligence (AI) into their modern way of communicating.

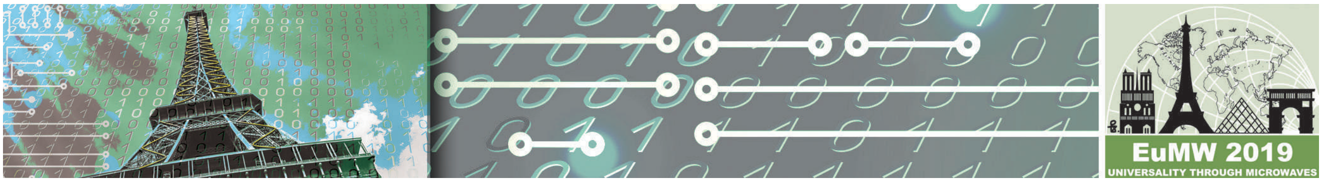
The EuMW was initiated by the European Microwave Association (EuMA) in 1998. EuMW 2019 continues the series of successful microwave events held in Amsterdam, London, Munich, Milan, Manchester, Nuremberg, Paris and Madrid. The week comprises:

- 49th European Microwave Conference (EuMC) to be held from 1–3 October.
- 14th European Microwave Integrated Circuits Conference (EuMIC) which will take place from 30 September–1 October.
- 16th European Radar Conference (EuRAD) which will run from 2–4 October.

Thanks to the excellent work of the 434 reviewers, the 110 members of the Technical Program Committee (TPC) were able to prepare 78 technical regular sessions representing 391 presentations. The programme is complemented by 24 workshops and five short courses covering the most relevant topics ranging from Antenna Booster Technology for IoT Applications to Multibeam Antennas, from Power Amplifiers to Automotive Radar and from Modern Advances in Computational Imaging at Microwave and mmWave Frequencies to High Data Rate Communications. Two other special sessions highlight the research activities in Latin America and in the Asia-Pacific Region.

This year's programme will boost and intensify the interaction between industry and academia thanks to 32 keynotes presented by internationally recognized industrial experts who will open selected sessions with presentations on challenges and state-of-the-art achievements in their field. Internationally renowned speakers will discuss the latest trends and developments in their keynotes at the conferences plenary sessions.

At the opening session of EuMW 2019, special talks will be dedicated to technical « souvenirs » of 50 years of EuMC from



London in 1969 to this year's edition. Then, Paolo Di Prisco, wireless transport product strategy leader from Nokia in Italy will give a presentation on "Beyond 100 GHz Transport Technology and Applications." The EuMIC opens with presentations by Prof. Dietmar Kissinger, from Ulm University, Germany, outlining the use of "BiCMOS Integrated Millimeter-Wave Circuits for Short-Range Wireless Communications and Sensing" and by Yves Mancuso, distinguished engineer in Thales Defence Mission Systems, France, on "Trends in Active Antennas and T/R Modules for Radar and Multi-Function Systems." Natanael Ayllon, head of the RF Equipment and Technologies Section at ESA-ESTEC, The Netherlands, has accepted the invitation to close the EuMIC with a presentation of the "Trends in Microwave Technologies for Space Applications."

During the EuRAD opening, which is held in conjunction with the DSS Forum, Florent Jangal, radar architect from the French Defence Procurement Agency (Direction Générale de l'Armement) will present some research and development activities supported by the Defence Innovation Agency. Then, Thomas Carpentier, Ground MFR product line manager, Thales Land & Air System, France, will present the new SF500 radar for the next-generation of FTI frigates for the French Navy. Dominic Walker, CEO at Aveillant Ltd., Great Britain, will describe the latest advances in holographic radar at the EuRAD closing session. The EuMW will close with a presentation about the "Soil Moisture and Ocean Salinity: A Microwave Instrument in Space" by François Deborgies, RF technology advisor at ESA-ESTEC, The Netherlands.

A selection of workshops and short courses presented by internationally recognized lecturers will be offered in addition to the three conferences. The Defence, Security and Space (DSS) Forum continues to be a major event. This year the Forum will focus on "New Radio Architectures and their Evolution for Satellite Constellations." The DSS Forum organisers have succeeded in attracting high-level speakers to discuss the need of new radio architectures using less power and having lower latency while still being low cost. Keynote speakers will consider the state-of-the-art of leading technologies and systems for satellite constellations, the estimated evolution of technologies and trends and consider expected functionalities to address future challenges.

For the first time, a new automotive forum is organised to provide an open platform for industrial experts to discuss technical aspects and market issues in the area of microwaves in automotive industry.

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Dynamic Range (BW=10Hz, dB, typ)	120	120	120	120	120	120	120	115	115	100	110	100	65
(BW=10Hz, dB, min)	110	110	110	110	110	110	110	100	105	80	100	80	45
Magnitude Stability (±dB)	0.15	0.15	0.15	0.15	0.15	0.25	0.25	0.3	0.3	0.5	0.5	0.8	0.5
Phase Stability (±deg)	2	2	2	2	2	4	4	6	6	8	8	10	6
Test Port Power (dBm)	10	13/6	13/6	11/6	6	9	-1	-2	-6	-10	-8	-25	-30

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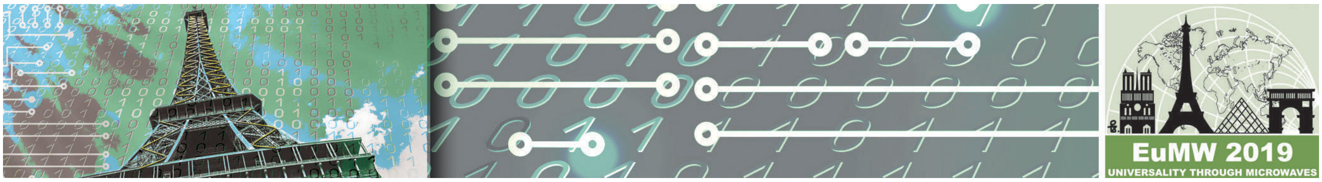


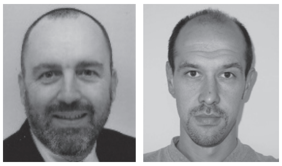
The forum will focus on hot topics such as system architectures for advanced radar, advanced methods for radar interference suppression, AI in radar signal processing and radar-based generation of digital maps.

Several events will occur in parallel with the conference sessions. The traditional Women in Microwave (WiM) Engineering event, co-sponsored by the IEEE MTT-S, will focus on the topic of instrumentation and metrology, and both women and men are welcome. Attendees will have the chance to follow in the footsteps of inventors of progress and explore a one-of-a-kind repository of scientific knowledge visiting the "Musée des Arts et Métiers–CNAM." For the third time, the WiM attendees will have the opportunity to interact with high school students who are invited to participate in this event. Early registration is encouraged, since the number of participants is limited.

For the younger generation, the EuMW 2019 will present a very stimulating Student Challenge, completed on site. Another event, the Student Design Competition will comprise three thrusts (PAs and filters) to be prepared in advance. Prototypes will be measured in front of an industrial panel. Two schools dedicated to sofware-defined radio (SDR), with hands-on activities, are proposed with a full day of high level lectures for master students and a half-day on the latest research topics for Ph.Ds. The Career Platform will continue to offer students opportunities for "speed dating" with industrial recruiters.

Another important event of EuMW is the exhibition, the largest traditional RF and microwave trade show in Europe. EuMW 2019 will see an estimated 5,000 visitors, with 1,700 to 2,000 conference delegates and in excess of 300 international exhibitors.

EuMW will offer several social events such as Monday's EuMIC Get-Together, Tuesday's Welcome Reception sponsored by Keysight Technologies and the EuRAD lunch on Friday. Enjoy Paris, the City of Lights, its rich and attractive cultural scene with shows and activities, festivals, expositions, new gallery openings, performing arts, art shops and its emblematic museums Le Louvre, Le Musée Rodin and more.■


Denis Barataud (left) and Christian Person (right), EuMW 2019 General Co-Chairs

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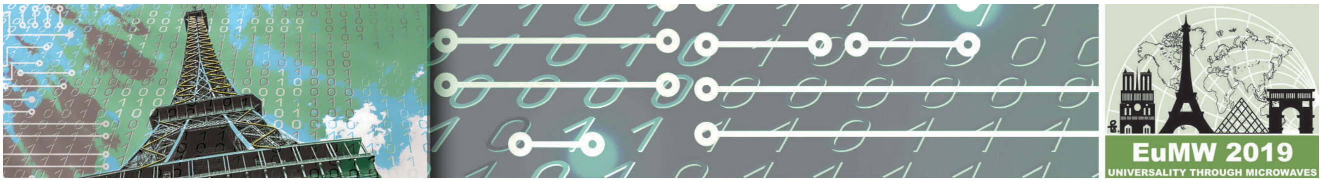


Attending European Microwave Week 2019

Complied by Pat Hindle
Microwave Journal *Editor*

European Microwave Week (EuMW) 2019 takes place at the heart of the ville lumière, Paris! Bringing industry and academia together, EuMW 2019 is a six day event, including three conferences and a major trade and technology exhibition featuring leading players from across the globe. EuMW 2019 provides access to the latest products, research and initiatives in the microwave industry. It also offers the opportunity for face-to-face interaction with those driving the future of microwave technology and a great place to network for future collaboration.

The 22nd European Microwave Week combines:

- Three major conferences
- Associated workshops
- Tailored courses and seminars for industrialists, academics and researchers
- Leading international trade show

In addition, exhibitor workshops and seminars will be provided by several top organizations with expertise in RF, microwave, wireless and radar.

Paris Convention Centre.

CONFERENCES

Choose from three separate but complementary conferences. Spanning the length of the week, starting from Sunday, 29 September, the conferences and workshops are scheduled as follows:

- European Microwave Integrated Circuits Conference (EuMIC), 30 September–1 October
- European Microwave Conference (EuMC), 1–3 October
- European Radar Conference (EuRAD), 2–4 October
- Workshops and short courses, 29 September–4 October
- Defence, Security and Space Forum, 2 October
- New Automotive Forum, 30 September

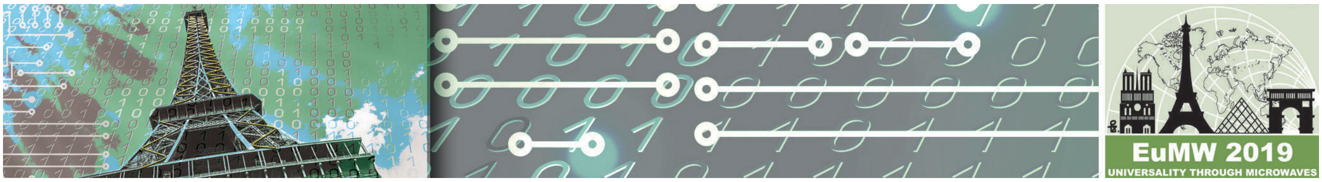
The conferences encompass a wide range of subject areas including:

- Microwave, mmWave and sub-mmWave systems
- Antennas and propagation
- Wireless technologies
- Telecommunication (RF, microwave and optical)
- ICs, semiconductor materials and packaging
- Radar architectures, systems and subsystems
- Sensors and remote systems
- Test & measurement

Conference rooms are located in Pavilion 7 as indicated by the signage. The conferences will be held in different rooms over the conference dates. Please refer to the conference program for a detailed overview and room assignments.

49th European Microwave Conference (EuMC)

This year is very special, as EuMC is celebrating 50 years of this flagship event of



the European Microwave Week. The conference welcomes delegates from around the world for the main annual European forum, which will allow the best researchers in the field of microwave, mmWave and THz systems and technologies to present the state-of-the-art technology and future trends. These topics related to high frequency electronics, from materials and technologies to circuits, systems and applications, will be addressed in all their aspects: theory, simulation, design and measurement. EuMC will also share several sessions with EuMIC, in the field of active devices, circuits and subsystems, and with EuRAD, in the areas of mmWaves, THz technologies and systems, antennas and propagation.

The EuMC opening session will take place on Tuesday, 1 October at 10:50 and the closing session on Thursday, 3 October at 13:50. These sessions are common to EuMC and EuMW, and will be presented during the welcome address of the EuMW General Chair. They will include presentations by distinguished speakers and award ceremonies, for the EuMC Microwave Award and the EuMC Young Engineer Awards.

The EuMC Technical Program Committee (TPC) received 469 submissions; and 54 percent of these contributions were selected to build a dense and high-quality conference program consisting of workshops, short courses to be held on Sunday, Monday and Wednesday, as well as special sessions that will be held in parallel with ordinary sessions from Tuesday to Thursday. Special oral sessions will be held to highlight invited speakers from two EuMC sister conferences: the Asia-Pacific Microwave Conference (APMC) and the Latin-America Microwave Conference (LAMC).

Each of the 37 regular oral sessions will allow five speakers to present their most recent results. During these sessions, 22 industrial keynotes (including eight shared with EuMIC and EuRAD) will allow industry leaders to expose market needs and trends. Interactive forums will be organized on Tuesday, Wednesday and Thursday in the exhibition area, allowing participants to listen, discuss and exchange ideas.

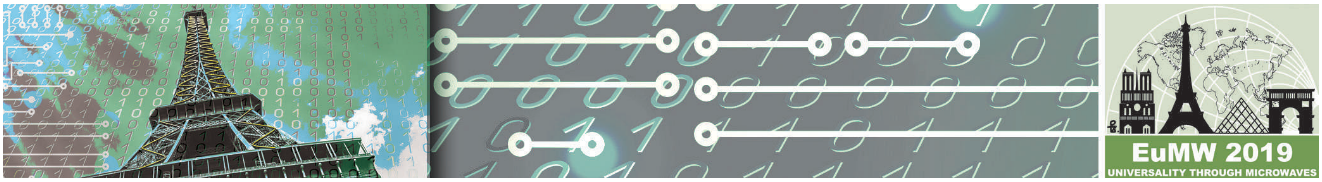
14th European Microwave Integrated Circuits Conference (EuMIC)

The EuMIC conference has been jointly organised by the GAAS® Association and European Microwave Association (Eu*MA*) since 2006. The scientific panel is composed of 10 regular EuMIC sessions and two EuMC/EuMIC joint sessions covering topics from device to system level. The intention is to stimulate the scientific discussion among experts from competing and complementary semiconductor technologies addressing the microwave to THz frequency regimes, encompassing all aspects from device technologies, modelling and characterization, to the application oriented design of integrated circuits.

The interactive poster session has been organised jointly with the EuMC and will be held on Tuesday, enjoying the lively atmosphere of the exhibition. Several high quality and topical workshops complement the EuMIC technical sessions and you are strongly encouraged to register for those of interest to you. EuMIC has included five relevant Industrial Keynotes thanks to the kind participation of prominent speakers from OMMIC, TTI Norte, EpiGaN and ENKRIS. Invited manufacturers will take the floor during the traditional foundry session hosted by the GAAS® Association.

The EuMIC opening and closing plenary sessions will feature three invited speakers, world-class in their fields. During the opening ceremony Prof. Dr.-Ing. habil. Dietmar Kissinger, Institute of Electronic Devices and Circuits, Ulm University, Germany will present on "BiCMOS Integrated Millimeter-Wave Circuits for Short-Range Wireless Communications and Sensing." In addition, Yves Mancuso, distinguished engineer


Where can we take you next?



in Thales Defence Mission Systems (TDMS), Microwave and AESA Technologies Design Authority, Elancourt Paris, will address the "Trends in Active Antennas and T/R Modules for Radar and Multi-Function Systems." During the closing session Natanael Ayllon, head of the RF Equipment and Technologies Section at European Space Agency, ESTEC, The Netherlands, will talk about the "Trends in Microwave Technologies for Space Applications."

16th European Radar Conference (EuRAD)

This year the EuRAD conference will reach its 16th edition, demonstrating the importance of such an event and also share state-of-the-art on numerous topics with the radar community. During the conference, top professionals will present their latest research and development, and discuss the present status and future trends in radar technology, system design and performance, radar components, radar propagation and target modelling, advanced signal processing techniques, as well as the most innovative radar architectures, concepts and applications.

On Wednesday, 2 October, in the opening session, we will enjoy the presence of two keynote speakers, one from the French defense procurement agency (DGA) and the second from Thales. The first speaker, Florent Jangal from the French MoD, will present the actual and future visions about electromagnetic detection and electronic warfare (EW) challenges. Then the second speaker, Thomas Carpentier from Thales Land & Air System, France, will present the new SF500 radar for the next-generation of FTI frigates for the French Navy, in which advanced concepts are included. For the closing session, keynote speaker Dominic Walker from Aveillant, Great Britain will describe the latest advances in holographic radar.

An attractive topical workshop program will be running alongside the conference program, some of which are shared with EuMC. Three workshops will be focused on radar topics, with one on advanced passive radar techniques and applications; the second will deal with the new radar concepts and processing for autonomous driving; while the third will address news concepts in integrated circuits and transceiver frontends for mmWave automotive radar. There will also be two workshops on wider topics, such as the interference risk between high frequency GHz radar devices or the test procedures and validation sensor functions for automotive radar and autonomous driving. One short course will address the modern advances in computational imaging.

Defence, Security and Space (DSS) Forum

The DSS Forum is jointly organized by the EuMA and *Microwave Journal* to complement EuMW's activity in the defense, security and space sector. Each year the DSS Forum focuses on a hot topic that is engaging industry, academia and organizations/agencies to develop, test and implement leading edge technology. For 2019 the topic is "New Radio Architectures: The Evolution for Satellite Constellations."

Keynote speakers will consider the state of the art of leading technologies and systems for satellite constellations, the estimated evolution of technologies and trends and consider expected capabilities and functionalities to address future challenges. The efforts made by the main players in the sector will be analysed and their views on new trends and technological developments will be offered.

The industry session will reflect the effort and investment that is being made to develop and test new radio architectures with improved size, weight and cost. Specific areas of activity include phased arrays, various types of beamforming, different RF partitioning, high-efficiency solid-state amplifiers, improved heat sinking materials, miniaturized radios and antennas, plus the test & measurement of those technologies.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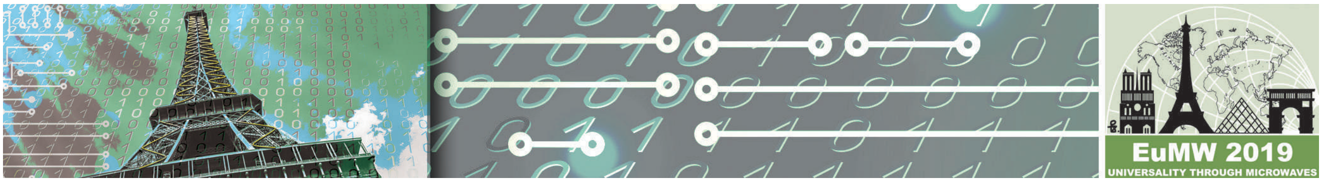


The executive forum will present the points of view of the different established and regulatory bodies that allow coexistence between the different aerial platforms and describe the activity of the different players already established and emerging in the field.

Automotive Forum

Following applications like keyless entry and tire pressure monitoring systems, mobile communications and recently automotive radar made microwave technologies a strong pillar inside the automotive world. The first 77 GHz automotive radar sensors entered the European market in 1999. For 2019—20 years later—the EuMA, for the first time, organises the Automotive Forum to provide an open platform for industrial experts to discuss technical aspects and market issues in the area of microwaves in automotive industry. The forum consists of a good mix of technical presentations, plenary and panel discussions as well as networking time. The forum mainly addresses technical experts from automotive industry throughout the whole supply chain. Keynote speakers will present their views on special technical solutions as well as regulatory or strategic issues. The event will close with a networking dinner.

INTERACTIVE SESSIONS

The interactive poster papers will be presented on electronic screens that are located in the exhibition on Tuesday, Wednesday and Thursday.

EXHIBITION HOURS

The exhibition area is located in Pavilion 7, Level 3. Registered delegates will have full access to the exhibition area.

The exhibition opening hours are:

- Tuesday, 1 October 9:30–18:00 (followed by the Welcome Reception)
- Wednesday, 2 October 9:30–17:30
- Thursday, 3 October 9:30–16:30

HOTELS AND TRAVEL

Horizon House Publications has teamed up with Connex Hotels and Events to offer the ability to book accommodations for EuMW at the most competitive rates available. It is very easy to make an immediate hotel booking. Simply visit their booking page www.connexhotelsandevents.com/eumw-2019-paris.html or email sally@connexhotelsandevents.com. You will find a wide range of accommodation to suit every budget. Alternatively, see the hotel booking pages within the program.

GETTING TO PARIS EXPO PORTE DE VERSAILLES

The convention center is located at 1 Place de la Porte de Versailles 75015 Paris. The city of Paris and convention center are well connected to the European motorway, rail and flight networks. Paris Expo Porte de Versailles can be accessed through a variety of transportation means.

Public Transport

Use the following public transportation to get to Paris Expo Porte de Versailles: **Metro:** Line 12, Porte de Versailles Station/Line 8, Balard Station **Tramway:** Lines T2 and T3a, Porte de Versailles–Parc des Expositions stop **Bus:** Line 80, Porte de Versailles–Parc des Expositions stop/Line 39, Desnouettes stop.

Flights

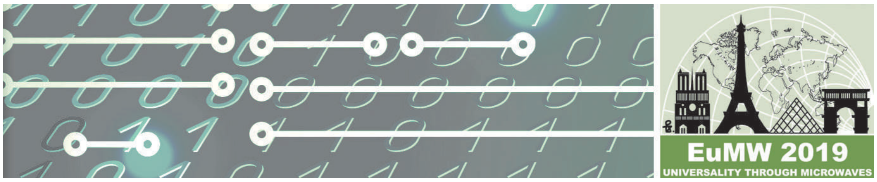
From Roissy-Charles de Gaulle Airport:

Take the RoissyBus to Paris–Opéra, then take Metro Line 8 (direction Balard) to Madeleine and change to Line 12 (direction Mairie d'Issy) to Porte de Versailles–Parc des Expositions Station.

Take the RER B (direction Saint-Rémy-lès-Chevreuse) to Cité Universitaire station, then take tramway T3 (direction Pont du Garigliano) to Porte de Versailles–Parc des Expositions stop.

From Orly Airport:

Take the Orlyval train to Antony, then the RER B to Cité Universitaire, change to the tramway T3 and get



off at the Porte de Versailles–Parc des Expositions stop.

Take the Orlybus to Denfert-Rochereau, then the RER B to Cité Universitaire, change to the tramway T3 and get off at the Porte de Versailles–Parc des Expositions stop.

SHOPPING & SIGHTSEEING

Paris, its special dynamism as a business centre goes hand in hand with its vitality, tourist appeal and fervent cultural and recreational life. Discover its sites, iconic museums and spectacular range of hotels and restaurants; and enjoy its endless nightlife and the flood of designs, fashion and trends you will find in the shop windows of one of Europe's leading capitals. A great city that boasts a rich treasure of art, culture and natural environments, set in a region packed with history and modernity. Visit https://en.parisinfo.com/ for information on top attractions and tips for your stay. Also see the "Social Events & Partner Programme" section of the EuMW Conference Program for tours and excursions before, during and after EuMW 2019.

SOCIAL EVENTS

EuMIC Get-Together

Date: Monday, 30 September
Time: 18:30 to 21:00
Location: Paris Expo Porte de Versailles
Cost: Free to EuMIC delegates.

Automotive Forum Networking Dinner

Date: Monday, 30 September
Time: 19:30 to 22:30
Location: Restaurant in Paris
Cost: Free and only available to the Automotive Forum registered delegates.

Welcome Reception

Date: Tuesday, 1 October
Time: 18:30 to 21:30
Location: Paris Expo Porte de Versailles
Cost: Free to conference delegates and invited exhibitors.

All registered conference delegates, as well as invited representatives from companies participating in the exhibition, are invited to the EuMW 2019 Welcome Reception, sponsored by Keysight Technologies, Horizon House Publications and EuMA. Delegates will need to bring their badge and exhibitors their invite along with them to gain entrance. The evening will begin with drinks at 18:30 followed by the General Chairs' handover from EuMW 2019, Paris to EuMW 2020, Utrecht, as well as an address from Platinum Sponsor Keysight Technologies. The open-buffet dinner will be served at 19:00.

EuRAD Lunch

Date: Friday, 4 October
Time: 12:30 to 13:50
Location: Paris Expo Porte de Versailles
Cost: Free to EuRAD delegates and Friday WS/SC delegates.

Defence, Security & Space Forum Cocktail Reception

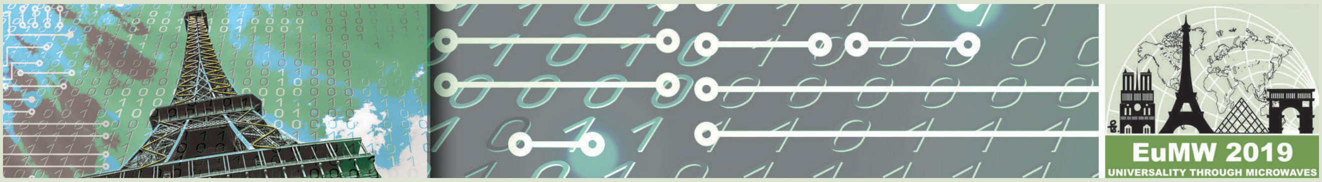
Date: Wednesday, 2 October
Time: 17:50 to 18:30
Location: Paris Expo Porte de Versailles
Cost: Free to DSS Forum registered delegates.

CONFERENCE REGISTRATION

Online Registration

All registrations prior to the event should be made online at www.eumweek.com. Those completed up to and including 30 August will be charged at the Advance Discounted Rate and those from 31 August will be charged at the Standard Rate. Online registration is available now and will remain available through the event. You can also register onsite starting from 16:00 on Saturday, 28 September, Sunday through Thursday from 08:00 to 17:00 and Friday until 10:00.

We hope to see everyone in Paris!■



EuMW PRODUCT SHOWCASE

For complete coverage of the EuMW 2019 conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show daily at mwjournal.com/eumw2019.

Maury Microwave — Stand 001

High-Power Pulsed SMUs

AMCAD's AM3100 high-power pulsed SMUs are the perfect pulsed-bias supply and acquisition instrumentation for pulsed load pull and general-purpose test & measurement applications. The AM3100 can operate up to 120 V and 30 A pulsed with pulse widths down to 1 us. It includes internal and external synchronization and triggering and can be controlled through direct SCPI commands via USB or Ethernet. The AM3100 includes multiple levels of protection circuitry including a fast short-circuit current breaker (e-fuse).

Active Load Pull for 5G & Wi-Fi

Maury's MT2000 mixed-signal active harmonic load pull system has been designed for 5G FR1 and FR2 device characterization up to 40 GHz. The MT2000 enables wideband impedance control over a bandwidth up to 1000 MHz for multi-channel 5G load pull measurements, and can accurately measure power, efficiency ACPR and EVM with its low noise floor and receiver sensitivity. The MT2000 offers the simplest configuration and ease-of-use based on a fully integrated and turnkey architecture.

www.maurymw.com

SPINNER GmbH — Stand 110

mmWave-to-Coaxial Adaptors

VENDORVIEW

The new SPINNER mmWave-to-coaxial adaptors for the V-, E- and W-Bands let you directly connect waveguide-based measurement network topologies to the coaxial ports of VNA or mmWave-range extender modules. In lab environments, you need to have the right interfaces handy: for waveguide-to-coaxial transitions and with male or female coaxial connectors, as required. These convenient solutions save time and let you focus on your testing work.

www.spinner-group.com

Spectrum Elektrotechnik GmbH — Stand 145

The 2019 Adapter Handbook

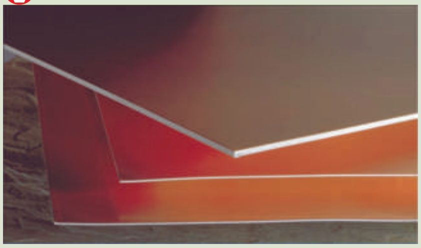
The new handbook shows, at over 500 pages, in detail 34 adapter categories, standard MIL- and DIN-products, as well as the Spectrum Elektrotechnik developments, In- and In-between Series. Waveguide, WR and WRD to coax adapters with a variety of connector types are shown in a special part. This most complete handbook is in each section headed by a reference table, indicating the contents of the section and referencing related products. Specification sheets show the electrical, mechanical and environmental performance of the series with interface dimensions.

www.spectrum-et.com

Rogers Corp. — Stand 200

TC350™ Plus Laminates

VENDORVIEW



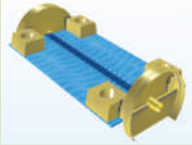
Rogers TC350™ Plus Laminates are ceramic filled PTFE-based woven glass reinforced composite materials providing a cost-effective, high performance, thermally enhanced material for the circuit designer. With a thermal conductivity of 1.24 W/m·K, this next-generation PTFE-based laminate is ideally suited for higher power microwave and industrial heating applications requiring higher maximum operating temperatures, low circuit losses and excellent thermal dissipation within the circuit board.

www.rogerscorp.com

Stand numbers are complete at the time of going to press.

COMSOL AB — Stand 235

RF Modeling Software for 5G, IoT & More



The COMSOL Multiphysics® software can be used to analyze and optimize designs involving multiphysics phenomena. The latest version of the RF Module, an add-on product to COMSOL Multiphysics®, provides tools for RF and microwave designers to model different PCB materials and study how they affect the performance of microwave and mmWave circuits. The Application Library introduces several design examples that work as a starting point for modeling 5G, IoT, automotive radar and SATCOM.

www.comsol.com/rf-module

Cicor Group — Stand 275

Thin Film Substrates

As part of the Cicor Group, the Ulm and Wangs sites are specialized in the production of sophisticated rigid and flexible substrates in thin film technology and has extensive manufacturing expertise in this field. The sites produce thin film substrates on Al2O3, AlN, LCP, polyimide, glass, ferrite and quartz in prototype and serial production.

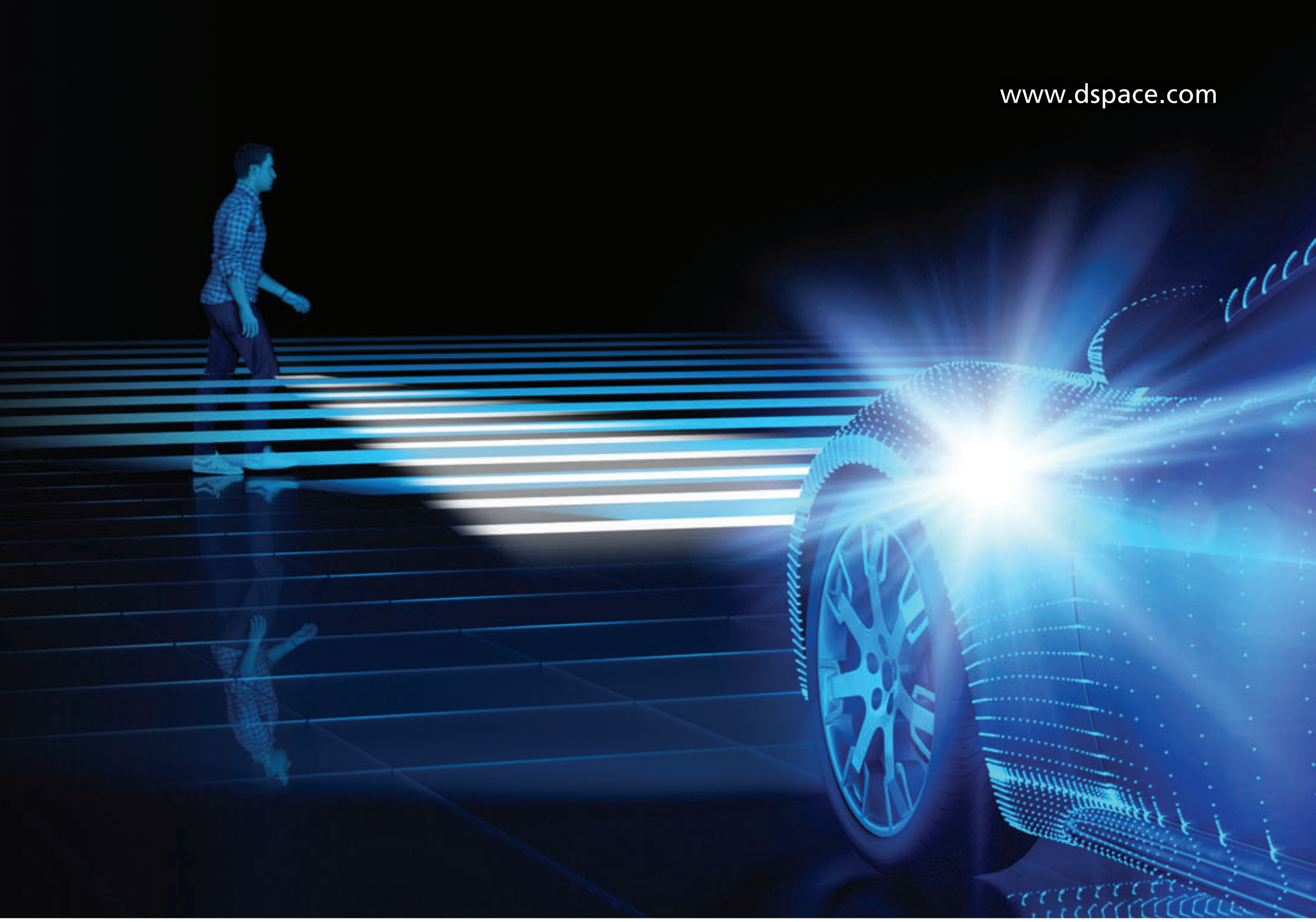
www.cicor.com

Holzworth — Stand 280

40 GHz Multi-Channel RF Signal Source

VENDORVIEW

Holzworth's high performance HSX Series now offers options that extend the frequency range to 40 GHz. The broadband design (10 MHz to 40 GHz) offers superior spectral purity performance and unrivaled channel-to-channel phase coherency, which translates to optimal channel-channel stability. The HSX Series 1U chassis allows for up to 2× 40 GHz, phase coherent channels.



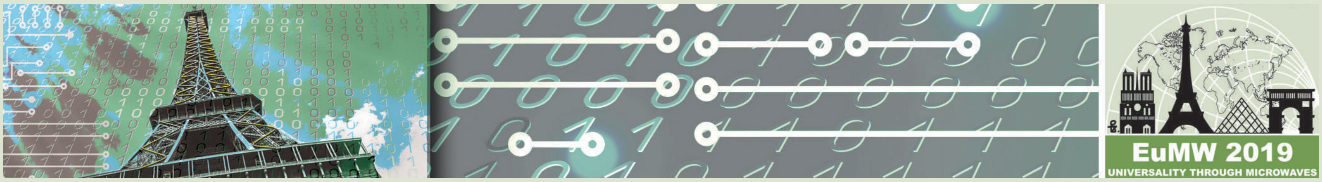
Testing Radar Sensors Over the Air

[redacted]

How can you test radar sensors quickly, reliably and thoroughly? The answer is over-the-air simulation with the new dSPACE Automotive Radar Test Systems – DARTS. Simply place the small, easy-to-use, stand-alone test device in front of a radar sensor. DARTS receive a signal from a radar sensor, generate an echo, and return it to the sensor – as if used in a real environment. Manipulate the echo as you like, to test what you want. For example, simulate reflections at 60 cm to 1,000 meters with small, precise steps. That's DARTS. And it does the job for chip testing, R&D, end-of-line tests, type approval – You name it.

Visit us at the European
Microwave Week in Paris:
Booth B350 | Pavilion 7.3

Embedded Success dSPACE



Visit Holzworth at EuMW to test drive Holzworth's latest RF synthesis and phase noise analysis products.
www.Holzworth.com

National Instruments (AWR) Stand 310

Design Software Solutions

VENDORVIEW

Stop by National Instruments' stand to see the latest release of NI AWR Design Environment software, which provides new capabilities in design automation and customization for 5G, IoT and radar applications with enhancements to the software's API, PCB import wizard, load-pull technology and more. In addition, the latest release of AntSyn™ antenna design, synthesis and optimization software offers twice the number of antennas in the template library, ability to specify waveguide feeds and new advanced library search.
www.awr.com

Times Microwave Systems Stand 345

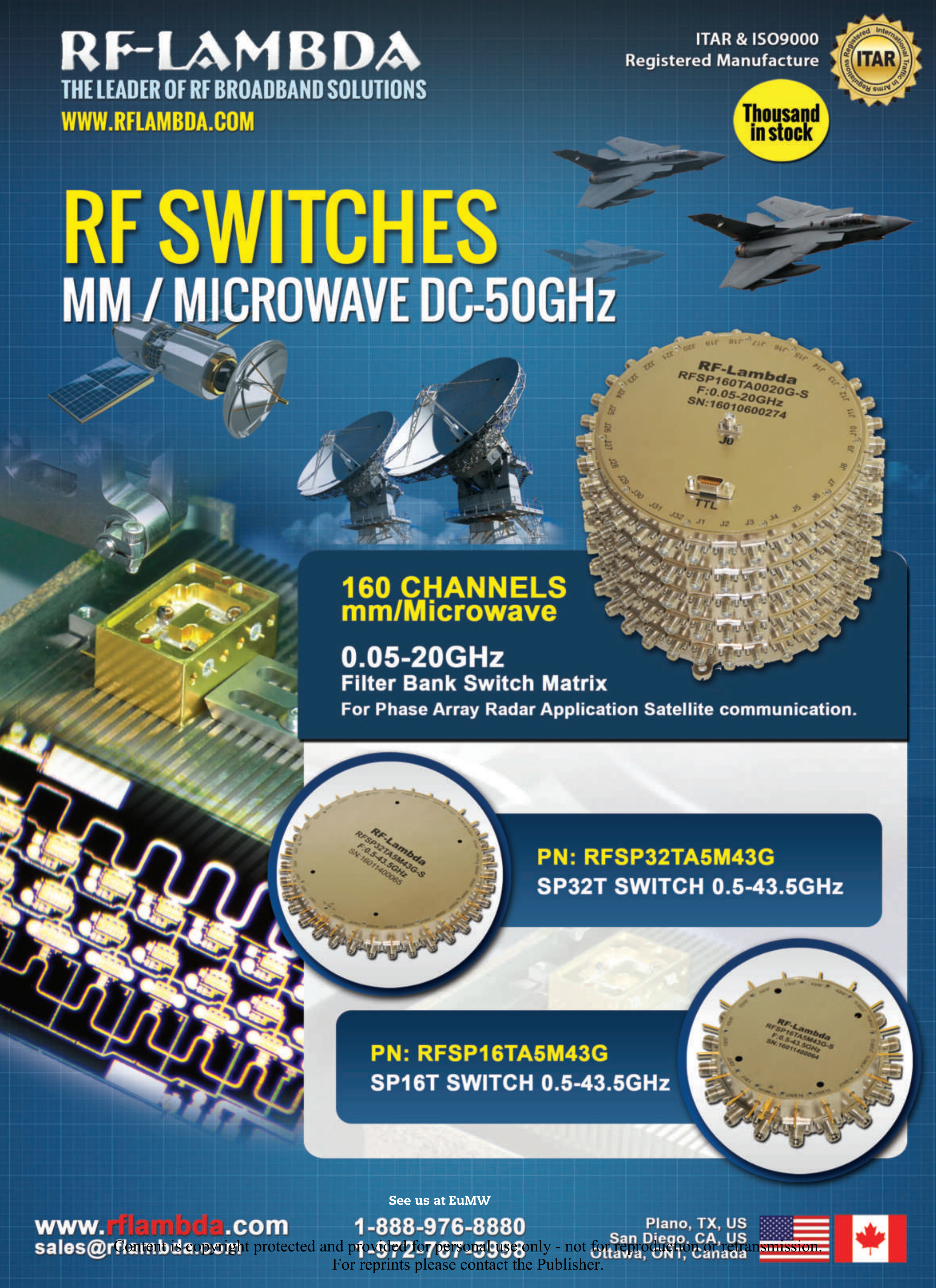
Clarity™ Series 40 GHz Test Cables

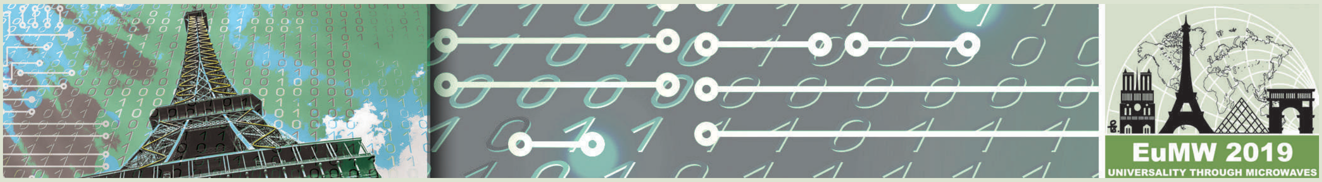
Times Microwave introduces its new Clarity Series of 18, 26.5 and 40 GHz coax test cables. Clarity boasts steel torque, crush and overbend protection with abrasion resistance yet does not compromise flexibility. The cable is ultra-stable through 40 GHz with exceptionally low attenuation. An industry first includes an ergonomically designed, injection molded strain relief and Times' new SureGrip™ coupling nut to significantly improve the user's everyday experience. Clarity is appropriate for use as an VNA test port extension, R&D lab, production test and even system interconnect cables.
www.timesmicrowave.com

dSpace Stand 350

Over-the-Air Simulation of Echoes

dSPACE Automotive Radar Test Systems (DARTS) form a product family for testing radar sensors for civilian use in vehicles. With DARTS, radar sensors can be tested in the laboratory in clearly definable, reproducible scenarios. DARTS simulate object reflections that occur in road traffic at different distances, speeds and sizes in real-time. DARTS play a decisive role in the validation of radar-based driver assistance systems and autonomous vehicles throughout the entire value chain.
www.dspace.com/go/darts


RF-LAMBDA
THE LEADER OF RF BROADBAND SOLUTIONS
WWW.RFLAMBDA.COM
ITAR & ISO9000
Registered Manufacture
ITAR
Thousand in stock
RF SWITCHES
MM / MICROWAVE DC-50GHz
RF-Lambda
RFSP160TA0020G-S
F:0.05-20GHz
SN:16010600274
160 CHANNELS
mm/Microwave
0.05-20GHz
Filter Bank Switch Matrix
For Phase Array Radar Application Satellite communication.
PN: RFSP32TA5M43G
SP32T SWITCH 0.5-43.5GHz
PN: RFSP16TA5M43G
SP16T SWITCH 0.5-43.5GHz
See us at EuMW
www.rflambda.com
1-888-976-8880
Plano, TX, US
San Diego, CA, US
Ottawa, ONT, Canada



EuMW PRODUCT SHOWCASE

Altum RF — Stand 360

ARF1306C5

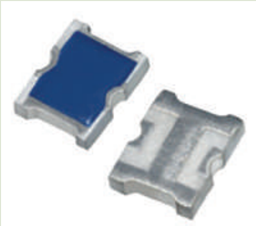
Altum RF's ARF1306C5 is a packaged, GaN distributed amplifier for 2 to 20 GHz applications. The amplifier provides 17 dB small-signal gain, 3 W saturated output power with 14 dB of power gain and 22 percent power added efficiency. The ARF1306C5 features a robust, lead-free and RoHS-compliant 5 × 5 mm ceramic QFN package with excellent thermal and electrical properties. The ARF1306C5 is suitable for higher performance commercial and defense applications, such as test & measurement equipment, EW and commercial or defense radar systems.

www.altumrf.com

RFMW — Stand 375

Wideband SMT Attenuators Push Performance Boundaries

VENDORVIEW



Smiths Interconnect TT9 Series fixed attenuators offer DC to 20 GHz performance for broadband, surface-mount applications demanding higher power handling of up to 500 mW CW. Available in 1 dB Increments from 0 to 10 dB, the 0.07 × 0.06 in. package is ideal when space is premium. Footprint compatible temperature variable options (TVA Series) are available.

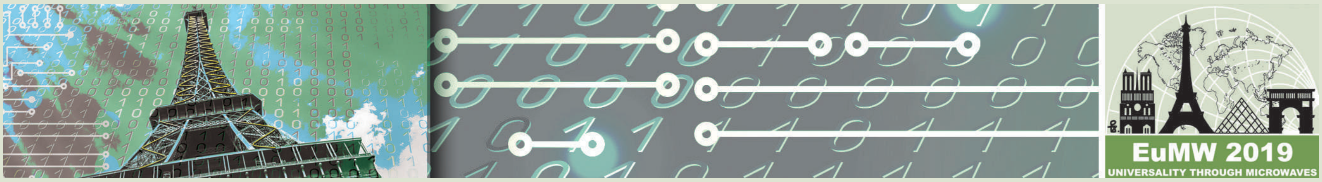
www.rfmw.com

AR Europe Ltd. — Stand 380

Control Your Amplifier Remotely

As technology evolves, electronic devices continue to take on a more mobile and virtual nature. While RF and microwave amplifiers themselves may never become truly "mobile," the way we control them can be. AR's new ampwebwARe gives you the capability to monitor and control your amplifier remotely without needing any software of your own. The software allows for remote communication to AR amplifiers through any device connected to the same network as the amplifier via an embedded webpage.

www.arworld.us/html/appNote-request.asp?appnote=84



RF-LAMBDA USA LLC — Stand 435

Hermetically Sealed Ka-Band Power Amplifier

RF-Lambda offers a 15 W hermetically sealed Ka-Band power amplifier to cover 26.2 to 34 GHz with a high gain of up to 52 dB. The hermetically sealed design features a laser sealed housing for superior environmental protection and outstanding performance in harsh and dynamic environments. Featuring D-sub connectors that are designed for top-level performance ideal for aerospace/military, wireless infrastructure and test & measurement applications.

www.rflambda.com

Huber+Suhner — Stand 460

Microwave Cable Assembly

VENDORVIEW

HUBER+SUHNER has launched its high performing 50 GHz SUCOFLEX®550S microwave cable assembly—a customizable solution providing the longest life-time currently available on the market. Unlike other similar solutions, the SUCOFLEX 550S is available in tailored lengths with immediate availability for stock assemblies and a quick manufacturing turnaround on customized configurations. It has a life-time of more than 100,000 flex cycles.

www.hubersuhner.com

Planar Monolithics Industries Inc. — Stand 515

Absorptive Switch

VENDORVIEW

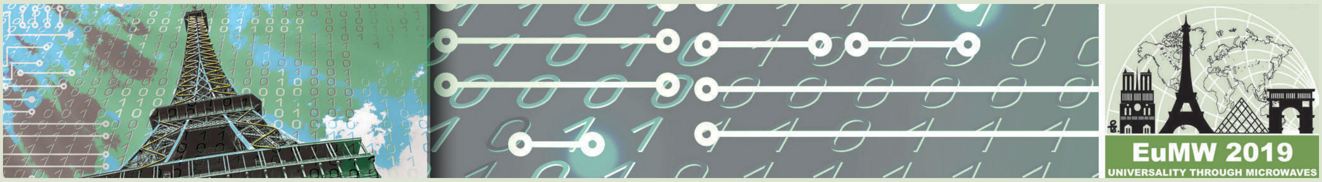
PMI Model Number: P16T-100M52G-100-T-DEC is a 0.1 to 52 GHz, SP16T absorptive switch. This model offers a typical insertion loss of 16 dB while maintaining a typical isolation of 70 dB. Other specifications include 100 ns switching speed; VSWR in/out: 2.5:1 at 18 GHz and 3.5:1 at 52 GHz; input power, 20 dBm CW max; control signal, TTL logic; and operates using +5 V at 1100 mA max and –12 V at 720 mA max. Unit is 8 × 3 × 0.65 in. and uses 2.92 mm connectors.

www.pmi-rf.com/product-details/p16t-100m52g-100-t-dec

Southwest Microwave — Stand 545

Board-Mounted Vertical Launch Connectors

Providing excellent signal integrity for microstrip and grounded coplanar waveguide designs, Southwest Microwave vertical launch connectors are reusable and can be



installed without soldering. The newest edition is the industry's first 1 mm board-mounted vertical launch connector, achieving low insertion loss and VSWR to 110 GHz. The connectors are also available in 1.85 and 2.92 mm configurations, covering DC to 67 and DC to 40 GHz, respectively.
www.southwestmicrowave.com/interconnect

Rohde & Schwarz GmbH Stand 580

Analog Microwave Signal Generator

VENDORVIEW

The analog microwave signal generator R&S SMA100B now covers frequency ranges of up to 31.8, 40, 50 and 67 GHz—with industry-leading RF performance. In overrange operation, it even

provides signals up to 72 GHz. The R&S SMA100B generates signals with lowest single sideband phase noise and highest output power with extremely low harmonics at the same time. It is a future proof investment for all microwave applications and an ideal instrument for the characterization of microwave components, devices and systems.
www.rohde-schwarz.com

Analog Devices Stand 585

Integrated 24 to 44 GHz Up-/Down-Converter ICs

VENDORVIEW

The highly integrated ADMV1013 up-converter and ADMV1014 down-converter chipset forms the essential core for high performance mmWave radios. With > 1 GHz bandwidth capability, superb linearity and dynamic range, these devices support the demanding requirements of mmWave 5G, radar, test equipment and defense applications. Each IC contains an LO buffer, x4 multiplier, programmable filters and amplifiers and I/Q phase and amplitude correction to achieve unmatched sideband and carrier suppression, small size and ease of use.
www.analog.com

AnaPico Stand 1070

Multi-Channel Analog Signal Generators

AnaPico's APMS series multi-channel analog signal generators cover a frequency range 300 kHz to 6, 12, 20, 33, 40 GHz. Enclosed in a 19 in. rack-mountable module (1 HU), all the channels are independently adjustable


Are you pushing the limits?
We can help.
4N9
3
A 30+ year legacy of space qualified RF/Microwave components and subsystems, connectors and cable assemblies.
A heritage of innovative solutions for the most demanding applications.
As your global partner for **innovative connectivity solutions** we can provide you with a competitive advantage when tackling the challenges of higher power, higher data rates, wider bandwidth, and greater connectivity **all within a smaller footprint**.
smiths interconnect
bringing technology to life
more > smithsinterconnect.com
See us at EuMW

in power, frequency, phase and modulation. Other features are excellent phase coherence, phase-coherent switching, very low phase noise, flexible external references, fast switching (25 us), very high frequency synchronization between the modules, USB/LAN/GPIB communication ports, etc. They are widely used in quantum computing, radar, antenna array testing and experimental systems.
www.anapico.com

K&L Microwave Inc. — Stand 2005

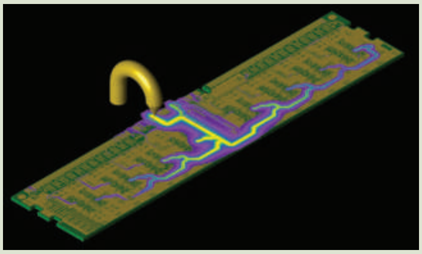
Custom Integrated Microwave Assemblies

K&L Microwave is releasing new custom integrated microwave assemblies all the time. This 10 to 18 GHz balanced amplifier module was recently developed as part of an EW IMA. It has a typical gain of 23 dB, 3 dB noise figure and +18 dBm P1dB with positive gain slope and integrated limiter. Internal design competencies in filter, amplifier, switching and integration technologies enables K&L to offer more functionality and better performance for filter-based IMAs in a small form factor.
www.klmicrowave.com

Remcom Inc. — Stand 2050

Electrostatic Discharge Testing in XFdtd

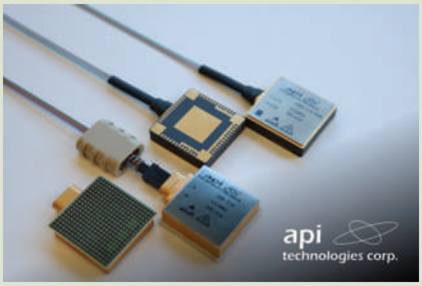
VENDORVIEW



Predict locations at risk of suffering dielectric breakdown with XFdtd® Electromagnetic Simulation Software. XF simulates electrostatic discharge (ESD) testing, enabling engineers to identify potential locations of dielectric breakdown and components at risk of damage in their device designs. For less obvious damage this pre-prototype insight is especially valuable, as it minimizes the chance of undetected weaknesses and reveals areas of concern prior to hardware testing.
www.remcom.com

API Technologies Corp. — Stand 2110

OPTO-FIRE™ Micro-Optical Transceiver



The new OPTO-FIRE™ micro-optical transceiver from API Technologies enables the improvement of critical data communication systems in airborne, naval and renewable energy applications. With a range of high speed data rates (20 Mbs to 25 Gbs), multiple-channels and protocol agnostic architecture, the OPTO-FIRE™ micro-optical transceivers are specifi-

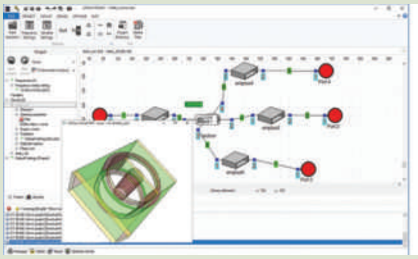

Spectrum
Elektrotechnik GmbH
Adapters, In-Series and Between-Series
1.85 mm
2.4 mm
2.92 mm
3.5 mm
7 mm
7/16
13/30
BMA
BNC
C
HN
N
SBX
SBY
SC
SCC
SMA
SMP
SMPM
SPM
TNC
TNX
Largest Series of Adapters:
• High Precision
• High Power
• Pressurized
• Hermetically Sealed
• DC to 71.0 GHz
80905 Munich, Germany P.O.Box 450533
Telephone: +49-89-3548-040 Fax: +49-89-3548-0490
www.spectrum-et.com Email: Sales@spectrum-et.com
See us at EuMW

cally designed for harsh environment applications. OPTO-FIRE™ is a major change in optical core technology which enables significant size and weight reductions. Available in customized rugged packaging styles to withstand harsh –58°F to +212°F operating temperature requirements.

www.apitech.com

MICIAN GmbH — Stand 2160

μWave Wizard EDA Software



Mician's μWave Wizard EDA software products are powerful tools for synthesis, analysis and optimization of microwave assemblies. The hybrid EM solver guarantees fast and accurate simulation of passive components, feed networks and antennas. Typical applications include horn and reflector antennas, feed clusters, OMTs, polarizers, circulators, waveguide and combline filters, multiplexers, couplers and more. Mician will show the latest release of the software and there will also be a preview of some of the new features of the upcoming release.

www.mician.com

Milexia France — Stand 2240

Thermopad©

Smiths Interconnect's Thermopad® (Patent #5,332,981) is a totally passive, surface mountable temperature variable attenuator. It requires no bias or control voltages and does not generate distortion. The Thermopad® can be used in place of a standard chip attenuator to combine level setting or buffering and temperature compensation in a single chip design. This reduces component count, increases reliability and lowers costs. Applications include power amplifiers, mixers, MMIC amplifiers, directional couplers and diode detectors.

www.milexia.fr
www.milexia.com

For complete coverage of the EuMW 2019 conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show daily at mwjournal.com/eumw2019.

Planar Monolithics Industries, Inc.

30 MHz to 40 GHz - Broadband Low Noise, Limiting & Test Bench Amplifiers

PMI offers a full line of RF, Microwave, and mmWave Amplifiers that range from 30 MHz up to 40 GHz. Many types are available including Low Noise, Limiting, Variable Gain, Low Cost, and Test Bench Amplifiers. Custom designs can be supplied using any of our catalog or customer driven specifications. For a full list of available configurations go to: https://www.pmi-rf.com/categories/amplifiers

- Amplifiers – Solid State
- Attenuators – Variable/ Programmable
- Couplers (Quadrature, 180° & Directional)
- Detectors – RF/Microwave
- DLVAs, ERDLVAs & SDLVAs
- DTOs, VCOs, PLO, DROs, & Frequency Synthesizers
- Filters & Switched Filter Banks
- Form, Fit, Functional Products & Services
- Frequency Discriminators & IFMs
- Integrated MIC/MMIC Assemblies (IMAs)
- IQ Vector Modulators
- Limiters – RF/Microwave
- Log Amplifiers
- Millimeter Wave Components (Up to 50 GHz)
- Miscellaneous Products
- Multifunction Integrated Assemblies (MIAs)
- Phase Shifters & Bi-Phase Modulators
- Power Dividers/Combiners (Passive & Active)
- Pulse Modulators (SPST)
- Rack & Chassis Mount Products
- Receiver Front Ends & Transceivers
- SDLVAs, ERDLVAs & DLVAs
- Single Side Band Modulators
- SMT & QFN Products
- Switch Matrices
- Switched Filter Banks
- Switches – Solid State
- Systems - Radar Sense & Avoid
- Systems – Fly Eye Radars
- Threshold Detectors
- USB Products


PUB-14-30M20G-14-LCA


PEC-30-0R2520R0-5R0-22-12-SFF


PEC3-40-30M26R5G-6R0-12-12-SFF


PEC-42-500M40G-20-12-292FF

Broadband Low Noise Amplifiers

PMI Model No.	Frequency Range (GHz)	Gain (dB Typ)	Gain Flatness (dB Typ)	Noise Figure (dB Typ)	OP1dB (dBm Typ)	Configuration Size (Inches) Connectors
PUB-14-30M20G-14-LCA https://www.pmi-rf.com/product-details/pub-14-30m20g-14-lca	0.03 - 20	14	±1.5	2.5	+14	1.08" x 0.71" x 0.29" SMA (F)
PEC-30-0R2520R0-5R0-22-12-SFF https://www.pmi-rf.com/product-details/pec-30-0r2520r0-5r0-22-12-sff	0.25 - 20	26.5	±0.7	3.0	+22	1.08" x 0.71" x 0.32" SMA (F)
PEC3-40-30M26R5G-6R0-12-12-SFF https://www.pmi-rf.com/product-details/pec3-40-30m26r5g-6r0-12-12-sff	0.03 - 26.5	45	±2.5	4.5	+12	1.92" x 0.78" x 0.36" Super SMA (F)
PEC-42-500M40G-20-12-292FF https://www.pmi-rf.com/product-details/pec-42-500m40g-20-12-292ff	0.5 - 40	42	±2.5	3.85	+19: (1-18) +17 (18-40)	1.37" x 1.0" x 0.6" 2.92mm (F)


PEC2-1G18G-60-9DBM-LM-SFF


PEC2-2G18G-2DBM-LM-SFF


PEC2-2G18G-21DBM-LM-SFF

Broadband Limiting Amplifiers

PMI Model No.	Frequency Range (GHz)	Spurious Rejection (dBc Typ)	Harmonic Rejection (dBc Typ)	Noise Figure (dB Typ)	Output Power (dBm)	Size (Inches) Connectors
PEC2-1G18G-60-9DBM-LM-SFF https://www.pmi-rf.com/product-details/pec2-1g18g-60-9dbm-lm-sff	1 - 18	-60	-10	3.5	+7 to +11	2.98" x 0.78" x 0.36" SMA (F)
PEC2-2G18G-2DBM-LM-SFF https://www.pmi-rf.com/product-details/pec2-2g18g-2dbm-lm-sff	2 - 18	-60	-15	7.0	+4 to 0	2.98" x 0.78" x 0.36" SMA (F)
PEC2-2G18G-21DBM-LM-SFF https://www.pmi-rf.com/product-details/pec2-2g18g-21dbm-lm-sff	2 - 18	-60	-13	3.0	+21 to +25	2.98" x 0.78" x 0.36" SMA (F)


PLNA-35-100M18G-P1dB24-120VAC


PEC-50-0R118-6R5-18-120VAC-1U-SFF


PTB-42-1G40G-12-292FF-DC12-100VAC

Broadband Test Bench Amplifiers

PMI Model No.	Frequency Range (GHz)	Gain (dB Typ)	Gain Flatness (dB Typ)	Noise Figure (dB Typ)	OP1dB (dBm Typ)	Size (Inches) Connectors
PLNA-35-100M18G-P1dB24-120VAC https://www.pmi-rf.com/product-details/plna-35-100m18g-p1db24-120vac	0.1 - 18	40	±2.0	3.0	+27	1.92" x 0.78" x 0.36" SMA (F)
PEC-50-0R118-6R5-18-120VAC-1U-SFF https://www.pmi-rf.com/product-details/pec-50-0r118-6r5-18-120vac-1u-sff	0.1 - 18	50	±2.0	4.0	+14	11U Height, 10" Depth SMA (F)
PTB-42-1G40G-12-292FF-DC12-100VAC https://www.pmi-rf.com/product-details/ptb-42-1g40g-12-292ff-dc12-100vac	1 - 40	40	±2.5	4.0	+22 (1-18) +18 (18-40)	4.92" x4.92" x 2.1" 2.92mm (F)

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INVITED PAPER

Computer-Controlled K-Band Frequency Synthesizer Using Self-Injection Locked Phase-Locked Optoelectronic Oscillator: Part 1

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A two-part article is presented describing a highly stable computer-controlled K-Band frequency synthesizer using a tunable optoelectronics oscillator (OEO). The first part describes LabVIEW control of a rack-mountable frequency synthesizer covering 16 to 24 GHz. A narrowband computer-controlled filter is realized using a broadband YIG filter combined with a narrowband, optically-tuned transversal filter. A forced self-injection locked phase-locked loop (SILPLL) technique is employed to suppress side-modes generated in OEOs because of long fiber delay lines, which reduces the oscillator phase noise to an estimated 12 fs timing jitter. Computer control of this SILPLL OEO is demonstrated with linear chirp (FMCW) and pseudo-random frequency hopping. Future generations of the forced SILPLL OEO will use integrated optoelectronics. In Part 2 of the article, compact OEO solutions based on designs compatible with Si photonics are described.

High frequency oscillators are important for high speed data transmission. Forced oscillation is a technique where the oscillation frequency can be stabilized using the concept of injection locking (IL)[1-2] and phase-locked loops (PLL).[3-5] Distribution of a highly stable, low phase noise external frequency reference is employed to force the oscillator to lock to the clean phase noise characteristics of the reference. The indirect optical injection locking[6-7] has been applied to distributed microwave[8] and mmWave oscillators[9-14] for optical control of large phased-array antennas for radar and communications.[15-18] The analytical modeling of injection locked oscillators has been developed based on parametric oscillation[19-24] to achieve low phase noise from various frequency references. The combination of both injection locking with a phase-locked loop is proposed as an injection locked, phase-locked loop (ILPLL) forced stabilization process, and its superior performance is experimentally demonstrated. A number of oscillator topologies[25-28] are used for efficient front-end operation of a low phase noise, high frequency stability[28] low free-running phase noise oscillator, combined with mixing conversion gain with high dynamic range.

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Prime power and space saving are also achieved.[26-27] It is feasible to combine mixing with oscillation and phase shifting[17] as a very elegant solution for electronically scanned phased-array antennas for communication and remote sensing.

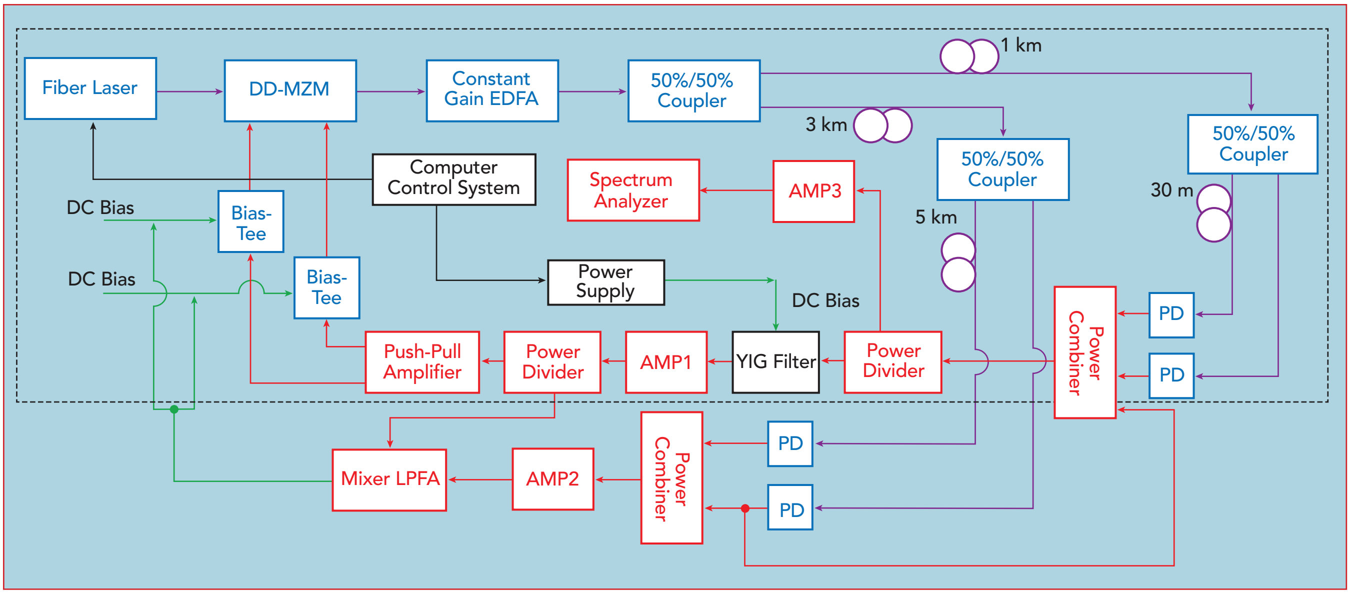
The category of oscillators based on long optical delay lines to provide high frequency stability[29] is known as OEO.[30] This structure has been widely employed for implementing high frequency RF oscillators because of its high spectral purity,[31] and it has been extended to operate to 50 GHz.[32] One of the challenges encountered with the OEO is the temperature sensitivity of the long fiber-optic delay lines.[33] Performance can be improved by employing passive temperature compensation using special hollow-core photonic crystal fibers (HC-PhC),[34] improving both short-term and long-term frequency stability.[35] The broadband behavior of fiber-optic delay lines provides frequency tuning of the OEO with a large number of potential oscillation frequencies. Narrowband filters are the core part of an OEO, determining the oscillation frequency by employing extremely narrowband fixed frequency filters.[33] To achieve broadband frequency tuning, YIG filter structures[36] are integrated in the optical delay line,[37] as reported with FET-based tunable oscillators.[38] Even though the OEO can have a higher quality factor with longer fiber delay lines, multiple side-modes exist around the oscillation frequency; 5 km of fiber will have side-mode oscillations every 40 kHz. Removing them is not feasible, even using narrowband electronic filters. Coarse tuning of a wideband YIG filter[36] combined with fine tuning a narrowband wavelength-tuned optical transversal filter[39-43] using short delay lines or a chirped fiber Bragg grating[44] provides high resolution frequency selectivity. Nonetheless, a number of side-modes persist, although forced oscillation techniques can reduce the oscillation side-modes.[44]

The benefits of ILPLL[25] in electronic systems[45] are from improvements in close-in phase noise, pull-in time and the locking and tracking ranges, compared to the standard IL or PLL, and reduced prime power and space compared to a multiplier chain. These benefits can also be achieved in oscillators without an external frequency reference, using the concepts of self-IL (SIL)[46-49] or self-PLL (SPLL).[50-52] They improve phase noise both close-in and far from the carrier, while oscillation side-modes are suppressed using multiple loops with harmonic delays. SIL and SPLL can be combined as SILPLL,[53] demonstrating improvement in close-in phase noise of dielectric resonator oscillators[54] and significant side-mode suppression, yielding low timing jitter.[55]

This article focuses on the development of a self-forced OEO and is presented in two parts. Part 1 discusses the design and testing of a 19 in. rack-mountable, computer-controlled K-Band synthesizer with high frequency resolution. The SILPLL OEO design uses a Mach-Zehnder modulator (MZM) and YIG filter combined with an optical transversal filter to achieve extremely narrowband frequency operation. The synthesizer employs a dual-drive modulator (DD-MZM)[56] with a bias voltage dependence of either the quadrature point ($V_{\pi}/2$) or pinch-off voltage (V_{π}). The operating point close to $V_{\pi}/2$ has higher gain, while operation at Vπ results in lower gain with second-order harmonic generation. Low phase noise is achieved over 16 to 24 GHz, with a frequency resolution of 20 kHz/pm of optical wavelength control at 1550 nm. Computer control generates both FMCW and frequency hopped operation of the synthesizer, enabling it to be used for remote sensing and secure communications applications. In Part 2 of the article, additional design innovations are described which lead to a compact OEO.[57-60]

SYNTHESIZER DESIGN

The block diagram of the OEO synthesizer is shown in ***Figure 1***. A fiber laser with low relative intensity noise, the TWL-C-HP-M, is used to provide a tunable wavelength laser signal. The laser signal transmits



▲ Fig. 1 Detailed block diagram of the OEO system.

through optical fiber delay lines and is received by high speed photodetectors (Discovery Semiconductors DSC50S) to generate an electrical signal which passes through a narrowband filter. This narrowband filter is the core of the OEO, used to select the oscillation frequency. A high Q metallic filter is the classic approach to realize a fixed frequency OEO, where mechanical adjustment of the cavity length tunes the frequency. As this approach is not suitable for computer control, a YIG filter[36] is used for this synthesizer design. The YIG filter is attractive because it has a broad tuning range and can be computer-controlled. To compensate for the poorer frequency selectivity of wide-tuning YIG filters, a narrowband optical transversal filter[42] is added, realized with a 30 m fiber. The YIG filter provides coarse tuning of the synthesizer, i.e., 50 MHz/mA. The highest resolution for the power supply (Keysight E3631A) in constant current mode is 1 mA, so smaller frequency steps will be provided by the transversal filter.

An optical transversal filter[42] can provide narrowband filtering of microwave signals; a first-order transversal filter is shown in ***Figure 2***. An optical signal is divided into two paths, with one path the reference, the other creating the delay. This is represented by the following filter transfer function, in terms of RF frequency

$$H(\omega) = \frac{\left|1 + \cos\left[\omega\left(\tau_d + \tau_D\right)\right]\right|}{2} \tag{1}$$

where τ_d is the fiber delay at the fiber laser wavelength. The delay is related to the difference in length, ΔL, between the reference and delayed paths. $n(\lambda_0)$ is the index of refraction at the wavelength λ_0.

$$\tau_d = \Delta L n(\lambda o) / c \tag{2}$$

τ_D is a term reflecting fiber dispersion, expressed as


PERFORMANCE
OVER TIME

$$\tau_D = D\Delta L(\Delta\lambda) \qquad (3)$$

In Equation 3, D is the dispersion parameter in units of ps/nm/km, while Δλ is the difference between the optical source wavelength and original wavelength. The null-to-null bandwidth is around 4.5 MHz at 1550 nm. The tuning sensitivity achieved using the picometer resolution of the fiber laser is 20 kHz/pm. Using computer control, after setting the desired frequency, the frequency setting process terminates when the difference between the desired frequency and the detected frequency is smaller than half the fine tuning resolution, approximately 10 kHz; the final output is then shown on the LabVIEW display.

In addition to the optical frequency selectivity, SIL,[49] SPLL[52] and the combination SILPLL[53-54] is used to reduce the synthesizer's phase noise, both close-in and far from the carrier frequency. The block diagram outside the dotted area of Figure 1 depicts the single delay loop SIL[49] and dual optical delayed DSPLL.[52] There are two paths for the modulated signal after the MZM: one is used as the main loop of the OEO, with the other loop further split into two paths of 3 and 8 km, which are used as dual phase-locking signals. The combined phase-locking signal drives a PCB board containing the "Mixer LPFA" block shown in Figure 1. A double balanced mixer is integrated on the same board with a lowpass filter amplifier, realized with op-amp circuits, which serves as the phase detector and lowpass filter portion of the PLL. The phase error of the OEO main loop is compared with the dual delay lines of the PLL, and the phase error signal is fed back to the bias port of the MZM. The self-injection locking signal takes advantage of the PLL path and shares the same fiber used in the SPLL path. The 3 km SIL signal is split from one PLL signal and directly injected into the output of the metallic cavity. The injected power level is given by $\rho = \sqrt{(P_i/P_O)}$, where P_i is the injected signal power and P_O the OEO power level. A higher value of ρ results in better suppression of the phase noise far away from the carrier.

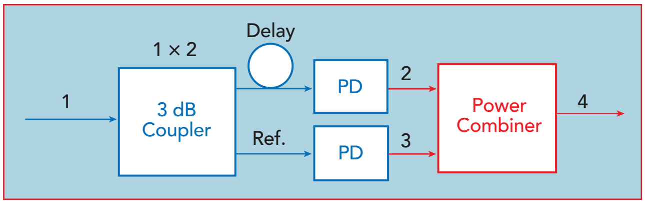


Fig. 2 First-order optical transversal filter using a 3 dB splitter and combiner with an optical delay in one path.

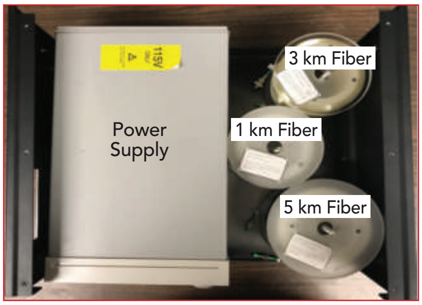


Fig. 3 View of the custom fiber mandrels adjacent to the computer-controlled DC power supply.

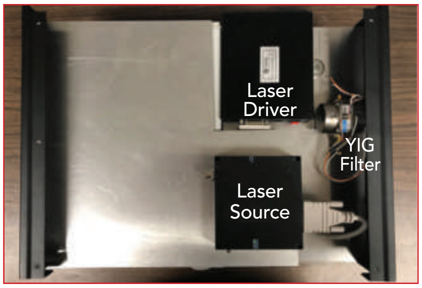


Fig. 4 View of the fiber laser source, driver and commercial YIG filter.

After successfully demonstrating the synthesizer on a lab table, it was integrated into a 19 in. rack for practical use. The assembly detail is shown in the following views, where the step-by-step assembly of the system reflects the block diagram shown in Figure 1. The first floor of the synthesizer box (see ***Figure 3***) comprises three fiber mandrels and the DC power supply. The topside of the cover over the mandrels and power supply contains the laser driver, laser and YIG filter (see ***Figure 4***), commercial products from Optilab and Teledyne. A third-level assembly integrates the remaining RF and fiber-optic components, mounted on a sheet metal cover and connected using coaxial cables or optical fibers (see ***Figure 5***); this

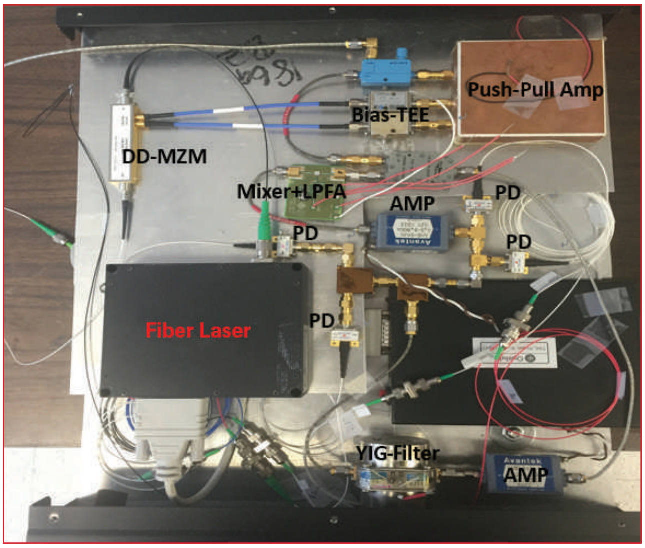


Fig. 5 View of the RF and fiber-optic components on the third level of the synthesizer housing.

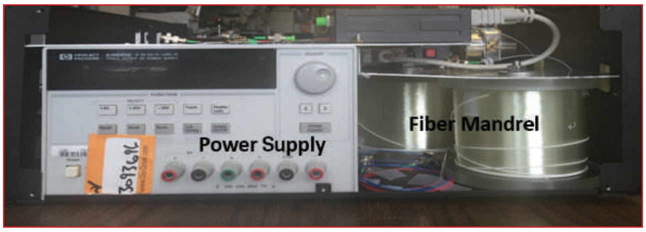


Fig. 6 Front view of the OEO synthesizer, showing the power supply (left), 1 and 5 km fiber mandrels, laser driver and other components.

sheet is placed on top of the second level. ***Figure 6*** shows a front view of the three levels, with all the circuits packaged within the overall height of the enclosed box, covered with metal on the front, top and back sides, with venting to help dissipate the heat of the power supply. A commercial Er doped fiber amplifier (EDFA) is mounted on top of the OEO box and shares the screws with the OEO box for stabilization and to maintain good connection between the EDFA and OEO unit (see ***Figure 7***).

Fig. 7 Complete SILPLL OEO system.

The synthesizer has DB9 and RS232 interface ports for computer control of the laser source and DC power supply. The program for computer control, developed using LabVIEW 2018, controls the output wavelength of the fiber laser and the current bias of the YIG filter to realize the narrowband frequency selection (see ***Figure 8***). To set the operating frequency, users type the desired value into the graphical interface shown in the figure. Using a look-up table, the program iteratively changes the current bias of the YIG filter and wavelength of the fiber laser, corresponding to coarse and fine tuning, respectively. The desired frequency is achieved in under 15 seconds. The time for frequency acquisition reflects

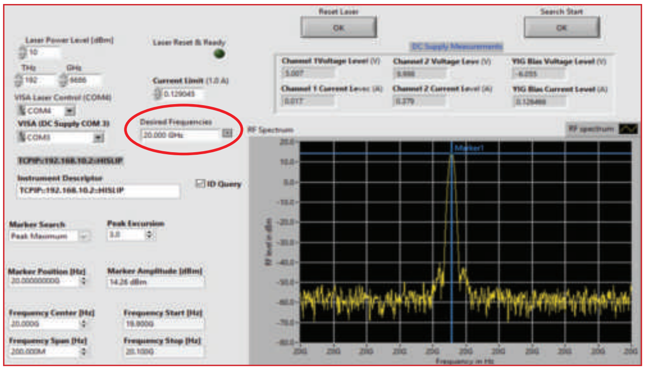


Fig. 8 LabVIEW control interface for the synthesizer.

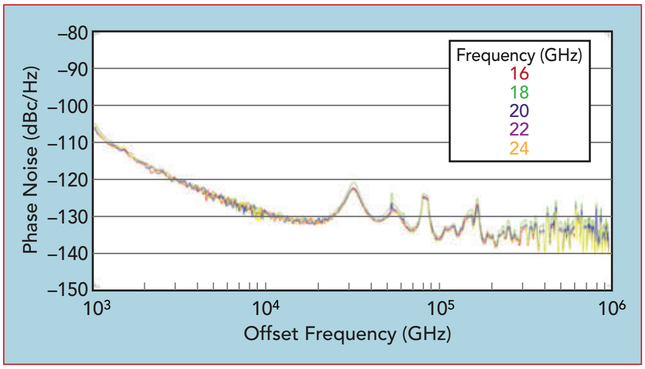


Fig. 9 Measured phase noise of the K-Band OEO system with 16 to 24 GHz carriers.

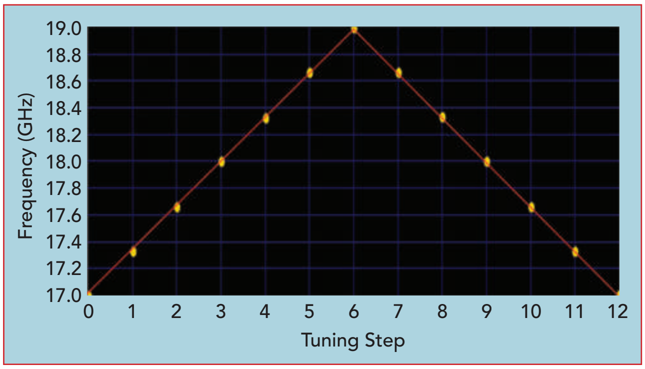


Fig. 10 Linear frequency sweep using the LabView control program.

the iterative process to attain the proper YIG filter bias current and fiber laser wavelength, given the extremely narrowband bandpass characteristics of the cascaded YIG and optical transversal filters. This settling time can be reduced using a custom power supply and controllers.

The measured phase noise of the OEO system is shown in ***Figure 9***. The synthesizer outputs are measured at steps of 2 GHz from 16 to 24 GHz, demonstrating operation across all of K-Band. The measured phase noise is −105 dBc/Hz at 1 kHz offset from the carrier and −130 dBc/Hz at 10 kHz offset. The long-term stability of the 19 in. unit was evaluated, recording a 4.5 kHz frequency shift over 1 hour. The estimated rms timing jitter of the synthesizer is under 10 fs, which can be reduced using SILTPLL.[54-55] A contributor to the phase noise is the 1/f noise of the amplifier; this can be improved using a SiGe HBT amplifier rather than GaAs

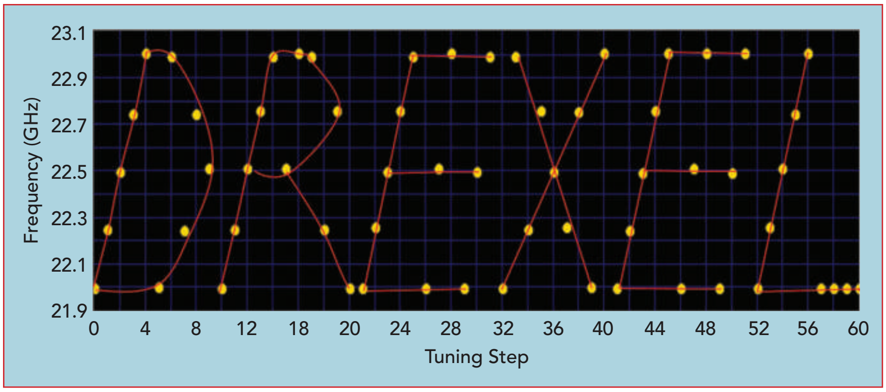


Fig. 11 Frequency sequence spelling DREXEL, demonstrating the broadband frequency hopping capability of the OEO synthesizer.

PHEMT,[61-62] and with proper selection of the operating conditions of the transistors.[63]

Computer control of the K-Band synthesizer was demonstrated by generating a sequence of frequencies for several applications. ***Figure 10*** shows the LabVIEW routine for linear frequency modulation, representing a practical FMCW radar application. The program steps the frequency from 17 to 19 GHz with six linear steps, then steps back at the same rate to 17 GHz. ***Figure 11*** shows a pseudo-random frequency hopped pattern representing a frequency hopped communication system; the pattern was designed to spell DREXEL after 61 steps. These examples demonstrate the frequency synthesizer's tuning capability, low close-in phase noise and computer-controlled frequency selection.

CONCLUSION

This article discussed the realization of a LabVIEW-based, computer-controlled K-Band synthesizer using an MZM OEO system. Suppression of the inter-modal oscillation of long fiber-optic delay lines reduces the close-in phase noise.[55] The measured phase noise is around −130 dBc/Hz at 10 kHz offset over all of K-Band, from 16 to 24 GHz. The design of a reduced cost and smaller OEO synthesizer using a PhC-PM device, Sagnac loop PM-IM convertor[64-65] and a multi-mode, multi-section semiconductor laser[58] will be presented in Part 2 of this article.[66] ■

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INVITED PAPER

Digital Code Modulation MIMO Radar Improves Automotive Safety

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Uhnder, Austin, Texas

Automobiles are technologically sophisticated and connected. Newer vehicles include advanced sensor technologies to improve safety, and manufacturers continue to incorporate more sensors to provide real-time data from the external environment to the driver and the car's control systems. These sensors enable many safety features: early warning, corrective steering and braking systems encompassing lane departure, adaptive cruise control, autonomous emergency braking and blind-spot detection.

Nevertheless, new solutions are needed to increase safety and achieve truly autonomous driving—at level 5 of the Society of Automotive Engineers capability scale. Recent research and investment have targeted sensor technologies such as LiDAR and enhanced passive imaging, i.e., cameras. Some industry pundits have posted that autonomous driving vehicles will include a very rich portfolio of these optical sensors on the path to levels 4 and 5. Perhaps counterintuitively, radar, which has been a mainstay in vehicles for some years, has not achieved the same fanfare as LiDAR, since radar already offers a stable, all weather, cost-effective sensor to help enable the current levels of autonomy and safety. On the other hand, compared to optical technologies, one radar weakness is angular resolution, defined as the minimum angle the radar can distinguish and separate two equally large targets at the same range.

This article discusses the application of new technology and advanced signal processing that will enable radar to do much more. First, basic concepts about angular resolution and antenna patterns in radar will be described. Then, Uhnder's development of digital code modulation (DCM) radar with coherent MIMO technology will be discussed, outlining its advantages compared to state-of-the-art radar technology.

ANGULAR RESOLUTION

A radar's angular resolution is directly proportional to the effective area of its antenna array, typically referred to as the antenna aperture. As shown in ***Figure 1***, when defining angular resolution, the main lobe half-power points (−3 dB) of an antenna's radiation pattern are normally specified as the limits of the antenna's beamwidth. Two identical targets at the same distance are resolved in angle if they are separated by more than the −3 dB beamwidth. In the common driving scenario shown in Figure 1, to distinguish two identical cars at a slant range, R, from the sensor and spaced at distance, d, from

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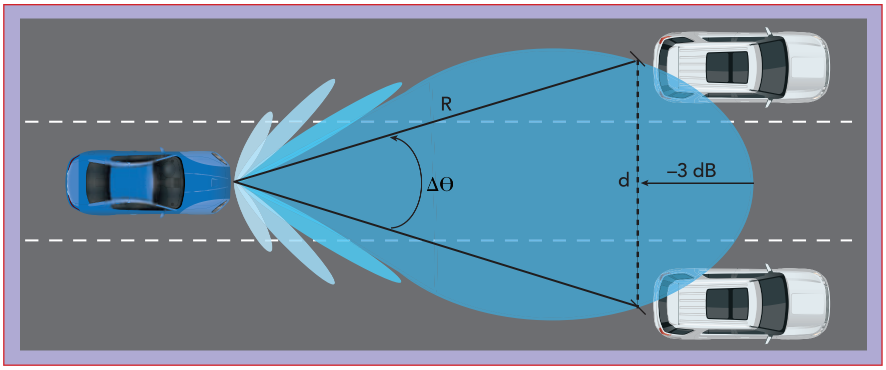
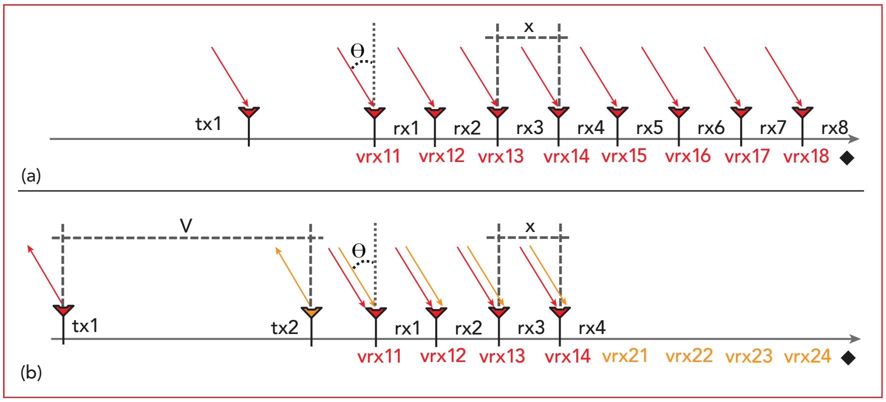


▲ **Fig. 1** **The angular resolution of a radar is determined by the −3 dB beamwidth of the main lobe.**



▲ **Fig. 2** **Standard (a) and MIMO (b) antenna arrays to achieve eight virtual receivers.**

each other, the required angular resolution is defined by the following expression:

$$\Delta\theta = \sin^{-1}\left(\frac{d}{R}\right) \quad (1)$$

For example, if d = 4 m and R = 125 m, an antenna beamwidth of 1.8 degrees is required to achieve this angular resolution. This case exemplifies the scenario where the vehicle needs to decide whether the lane between the two cars is occupied. It is a challenging requirement for currently deployed automotive radars, which achieve a few degrees of angular resolution at the expense of having a very narrow field of view (FOV) and ambiguity in angles (i.e., allowing targets from multiple angles to fold onto each other). Fortunately, that issue can be solved with a coherent MIMO radar.

MIMO RADAR

To understand the MIMO radar, refer to ***Figure 2a***, which shows the physical antenna configuration for a quasi-monostatic radar. A single transmit (Tx) and eight receive (Rx) antennas provide closely located channels, forming a single-input-multiple-output (SIMO) radar. The distance x between the Rx antennas is chosen to achieve the desired unambiguous FOV:

$$\pm\theta_{FOV} = \pm\sin^{-1}\left(\frac{\lambda}{2x}\right) \quad (2)$$

where λ is the wavelength. This unambiguous FOV defines the angular region within which the target directions are uniquely identified, assuming all targets are within this region. Targets beyond this region will appear to fold into it and cannot be distinguished from the targets within the region. The FOV will be maximum (±90 degrees) when x = λ/2. That is the preferred choice to avoid ambiguities when estimating target directions. When Tx1 sends a waveform, the eight Rx antennas will receive an attenuated copy of the signal, shifted in phase by a constant Φ between each of the eight Rx antennas. The phase shift is computed from:

$$\phi = \frac{2x \cdot \pi \cdot \sin^{-1}(\theta)}{\lambda} = \pi \cdot \sin^{-1}(\theta) \text{ if } x = \frac{\lambda}{2} \quad (3)$$

where θ is the angle of arrival or the target's direction. From the receiving antenna Rx1 to Rx8, the total phase shift will be 7Φ.

A completely equivalent result can be achieved with a thin MIMO array, shown in ***Figure 2b***, which is formed with two Tx antennas separated by 2λ and four Rx antennas separated by λ/2. In this case, each Rx antenna will receive a pair of waveforms, Tx1 and Tx2. For the Rx channels to separate the signals coming from the two Tx antennas, the transmitters need to generate orthogonal waveforms. After matched filtering of the two Tx waveforms, to separate the received signals from the two transmitters at each receive antenna, eight virtual receivers (VRx) are created (i.e., 2 × 4 = 8), which have equivalent phase shifts as the configuration of Figure 2a.

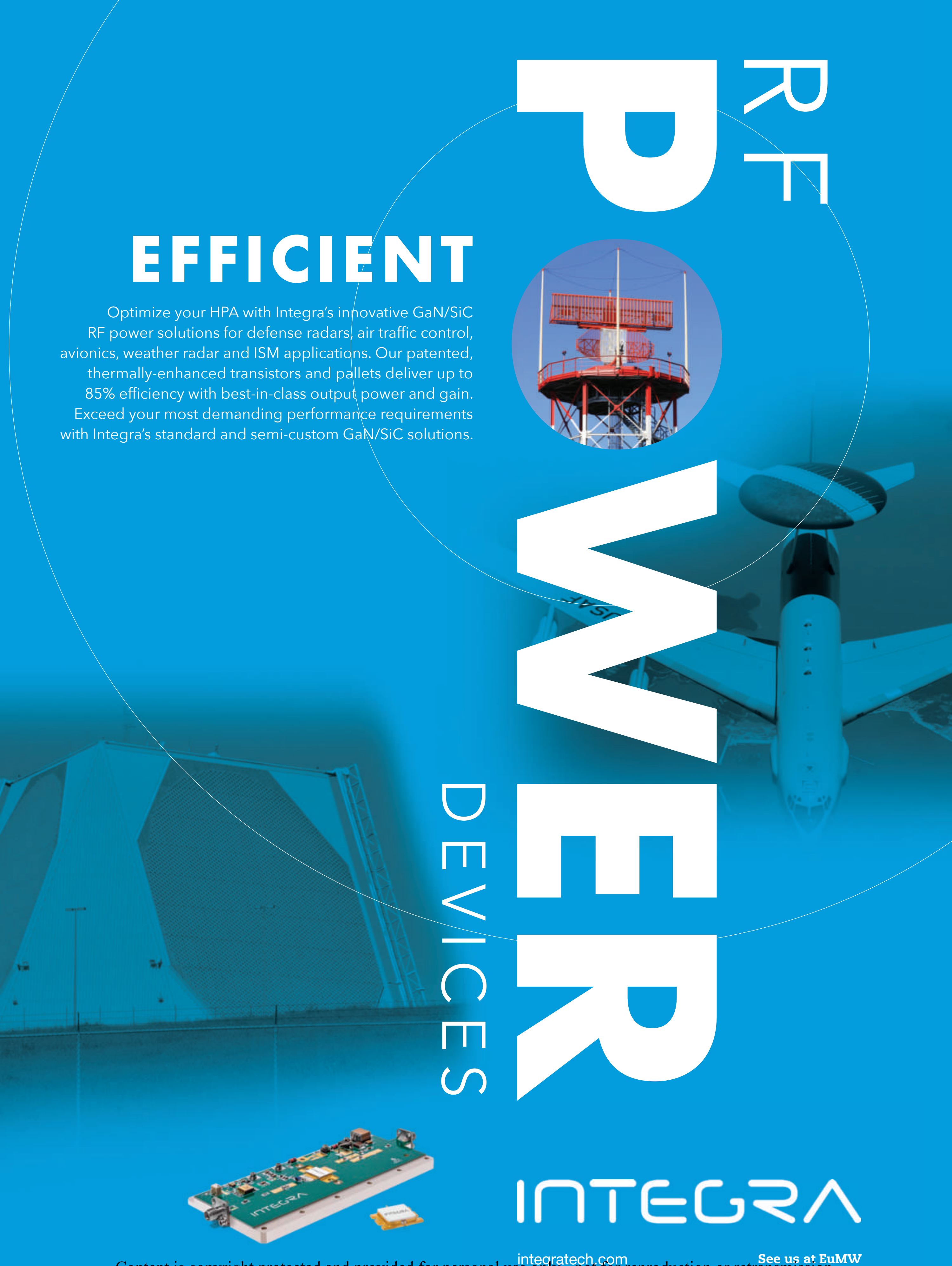
The single and dual Tx configurations provide equivalent angular resolution. However, the MIMO architecture uses only six antennas, compared to nine with the SIMO design. The reduction in hardware with the MIMO version is a significant advantage.

This same principle, on an entirely different scale, was used in space research to create the first direct images of a black hole. Astronomers created a "virtual telescope," a planet-scale array comprising eight radio telescopes, to increase the antenna aperture and improve angular resolution down to 20 µarcseconds—3 million times sharper than 20/20 vision.[1]

An antenna array, like those in Figure 2, will have a beamwidth given by:

$$\Delta\theta = \frac{\lambda}{N_{Tx} \cdot N_{Rx} \cdot x \cdot \cos\theta} = \frac{2}{N_{Tx} \cdot N_{Rx} \cdot \cos\theta} \text{ if } x = \frac{\lambda}{2} \quad (4)$$

where N_{Tx} and N_{Rx} are the number of Tx and Rx antennas, respectively. Both arrays have an angular resolution of approximately 14 degrees. For comparison, ***Figure 3*** shows the achievable angular resolution at boresight (θ = 0) versus the number of Rx and Tx antennas. From the figure, an angular resolution of 1.8 degrees can be achieved with a configuration combining eight Rx and eight Tx antennas.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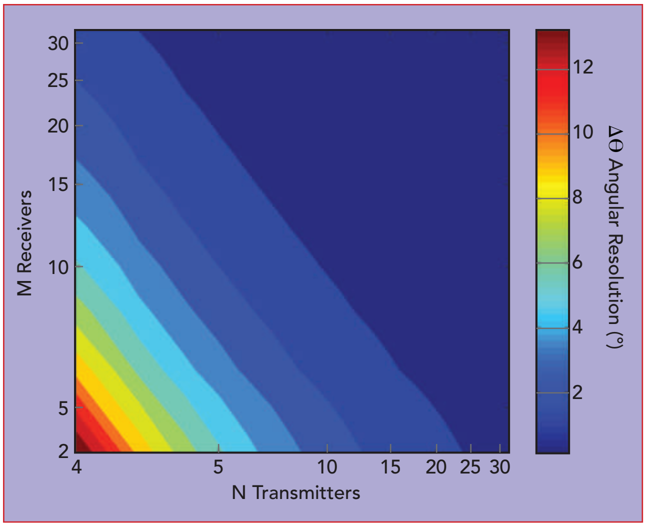


Fig. 3 Angular resolution for a MIMO radar vs. number of Rx and Tx channels.

MIMO + WAVEFORMS

As mentioned, Tx orthogonality is key to the Rx channels distinguishing the Tx signals. While there are multiple ways to achieve orthogonality, almost all have costly engineering trade-offs. The choice ultimately depends on the application and the radar waveform.

Frequency modulated continuous wave (FMCW) radars are by far the most popular for automotive. Numerous FMCW MIMO implementations have been reported, with the most common using a time-division multiplexing (TDM) approach. This is not true MIMO, although it can be a good approximation, as the signals are not a snapshot of the same environment, given the time delay. ***Figure 4*** shows how FMCW works with a three Tx radar sharing the same frequency modulated band. The radar frame is divided into three time slots, each devoted to one transmitter. The received signals are distinguished and processed based on this time division. One disadvantage of this option: since the transmitters are not operating at the same time, the maximum Tx output power is limited to the output from a single Tx. Consequently, while the FMCW TDM radar gains angular resolution, it trades maximum achievable range.

An alternative is where the transmitters share both frequency and time and are differentiated with orthogonal phase-coded waveforms (see ***Figure 5***). Each transmitter radiates a uniquely coded signal which is "matched" by the receiver. Transmitting on all Tx channels simultaneously provides a link budget gain of $10\log_{10}(N_{Tx})$. This can be used to increase the maximum range, without affecting other radar parameters, or to reduce the area of the silicon used for functional blocks like the power amplifiers.

Conceptually, DCM radars modulate the phase of the transmitted signal during a given time period, called the chip period or chip duration, where each phase is one of a finite number of possible phases. For simplicity, assume the modulation is binary phase shift keying (BPSK). The phase modulated signal is spread using a predefined code consisting of a sequence of chips and is mapped onto a sequence of phases to create the transmitted signal. The signal is of the form

$$s(t) = \sqrt{2P}\cos\left(2\pi f_c t + \phi(t)\right) \qquad (5)$$

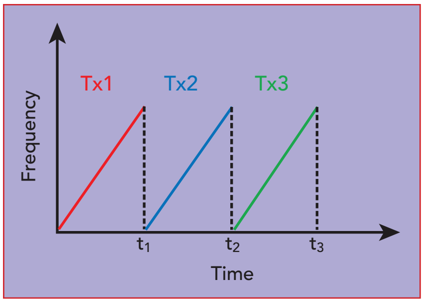


Fig. 4 Frequency vs. time for an FMCW radar.

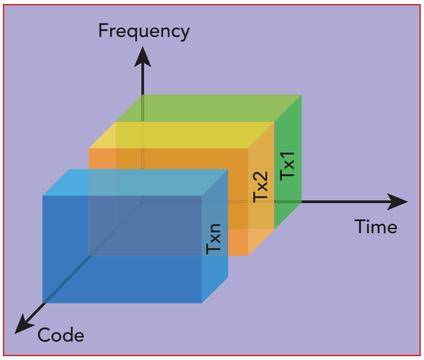
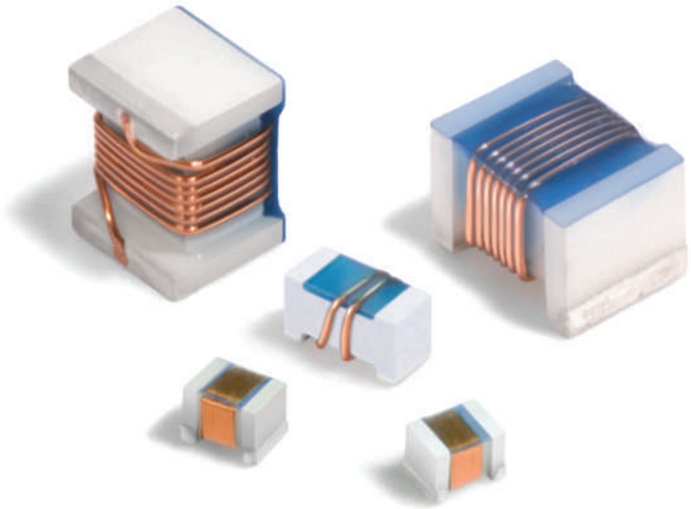


Fig. 5 Code domain MIMO.

Blue Chip Performers



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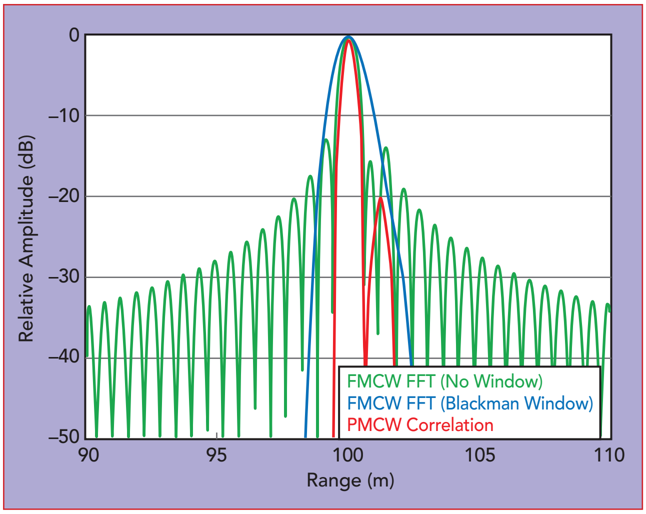

Fig. 6 **Correlation of two targets with large differences in radar cross section.**

where P is the power, f_c is the carrier frequency and $\Phi(t)$ is the phase of the transmitted signal. While the phase can vary continuously to minimize bandwidth, the phase function is a sequence of phases held constant for T_c seconds, where T_c is the chip duration. That is,

$$\phi(t) = \phi_l \text{ for } l\,T_c < t \le (l+1)T_c,\, l = 0,1,\ldots \quad (6)$$

where a(t) is either +1 or −1, corresponding to $\Phi(t)$ = 0 or π, respectively.

The sequence of values of the binary modulation signal are called chips. The sequence of chips causes the spectrum of the signal to spread the energy over a bandwidth proportional to $1/T_c$.

The baseband spreading waveform, a(t), that modulates the oscillator to generate the transmitted phase modulated CW signal, s(t), is given by

$$s(t) = \sqrt{2P}a(t)\cos(2\pi f_c t) \quad (7)$$

where a(t) is either +1 or -1, corresponding to $\phi(t)$ = 0 or π, respectively.

The transmitted signal from a single antenna is reflected off the targets in the environment, and the reflected signals at the receiving antenna are processed. A simple model for the received signal is

$$r(t) = \sum_{l=1}^{L} \alpha_l s(t - \tau_l) \quad (8)$$

assuming L targets that reflect the transmitted signals. The transmitted signal, s(t), reflected by a target is attenuated by the factor α_l and delayed by τ_l between the transmitter, target and the receiver. The delay between the transmitted signal and the received signal is related to the distance by $d_l = c\,\tau_l/2$, where c is the speed of light and the factor 2 reflects the roundtrip time from the transmitter to the receiver.

The digital signal processing includes a matched filter to determine the correlations of the received signal with various delays of the transmitted signal. In a DCM system, multiple periods of the spreading code are transmitted, and the matched filter produces an output at time t that corresponds to the correlation of the input from time t−T, where T is the duration of the matched filter's impulse response. The red curve in ***Figure 6*** shows the correlation between phase modulated signals that are reflected by two close targets, about 100 m distance and approximately 20 dB difference in radar cross section. The targets are easily distinguished, showing the capability of DCM systems to discriminate targets in challenging high contrast resolution scenarios. For comparison, the target discrimination of an FMCW radar are also plotted (see the green and blue curves), showing the FMCW returns limited somewhat by the windowing of the fast Fourier transform (FFT).

FIRST DIGITAL AUTO RoC

Uhnder has developed a radar sensor IC that incorporates advanced digital signal processing techniques, such as MIMO, to create a new generation of automotive radar sensors. This fully integrated radar on a chip (RoC) was designed for flexibility, a versatile platform to support diverse applications while minimizing cost.

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This RoC architecture is based on DCM with phase modulation and MIMO, capable of processing up to 192 virtual receive channels without external RF PCB circuitry. The RoC (see ***Figure 7***) integrates a 77 to 79 GHz transceiver with 12 Tx and 16 Rx channels that can be time-multiplexed to two sets of antennas, covering both azimuth and elevation profiles. The RoC uses a 15.2 to 16 GHz local oscillator (LO) generated by an external phase-locked loop, with differential LO inputs converted to quadrature using a polyphase filter.

The transmitter uses a Gaussian minimum shift keying (GMSK) digital modulator feeding a zero IF quadrature up-converter to mmWave. At baseband, a programmable pseudo-random noise (PRN) code is generated, digitally GMSK modulated and fed into current-steering 2, 4 and 8 GSPS digital-to-analog converters, whose current outputs are amplified and filtered by reconstruction filters.

Compared to BPSK implementations, this transmitter achieves higher spectral efficiency due to the absence of the large adjacent frequency sidelobes. The quadrature GMSK up-converter generates a constant envelope phase modulated signal, so it can use a fully saturated

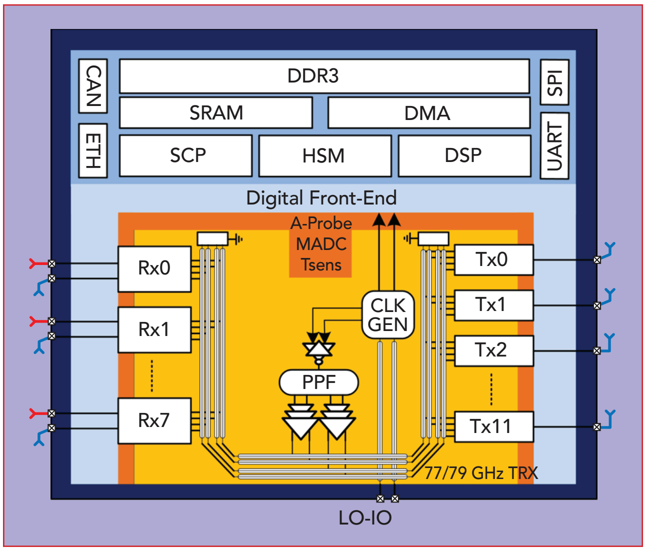

Fig. 7 Radar SoC, including 77 to 79 GHz MIMO transceiver with 12 Tx and 8 x 2 Rx, DSP, memory and interfaces.

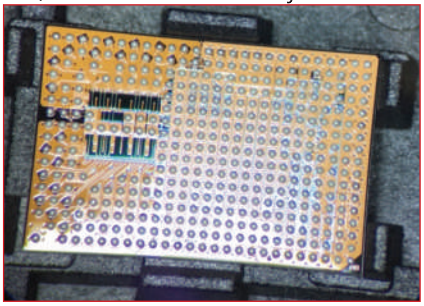

Fig. 8 SoC in a fan-out wafer-level package.

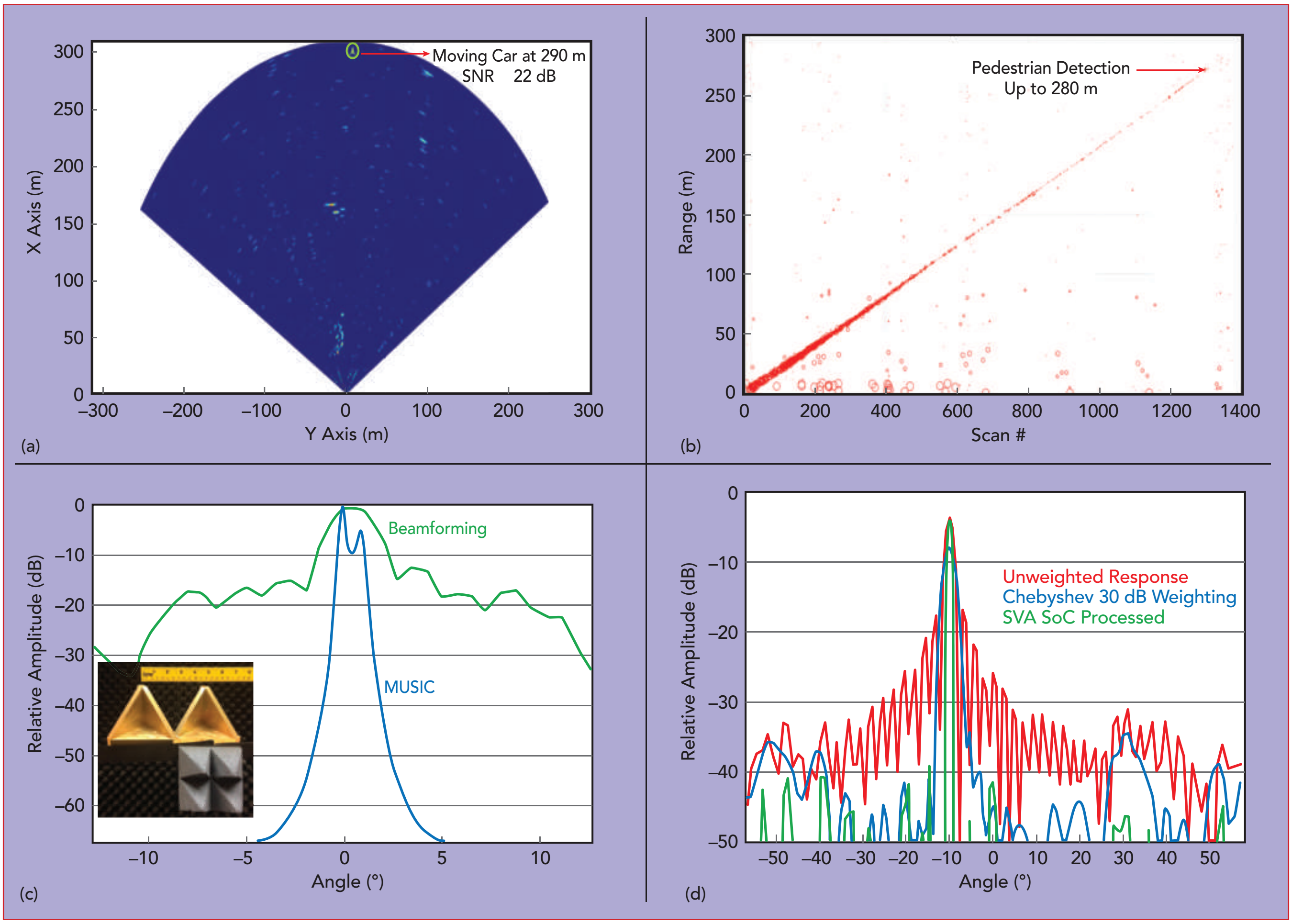

Fig. 9 Radar measurements: 25 mph moving car MIMO detection at 290 m with 22 dB SNR (a), beamforming pedestrian detection to 280 m (b), −108 dBsm corner reflectors in anechoic chamber after beamforming (green) and MUSIC (blue) (c) and angle sidelobe performance after digital beamforming (red), using a Chebyshev window (blue), applying SVA in hardware (d).

power amplifier to maximize efficiency while meeting the challenging link budget—a big challenge for all mmWave systems. Using DCM technology and MIMO enables the Uhnder design to place more power on target by simultaneously using multiple Tx channels with different codes. Transmit phased array is an available mode of operation that allows the user to trade field of view for higher effective isotropic radiated power. For a given link budget, designing smaller power amplifiers becomes a desirable and viable option.

At the receiver, the received signal is amplified with a low noise amplifier (LNA), mixed down to baseband using the same oscillator as used for the transmitter. Converted from analog to digital, the signal is digitally processed to estimate the range, frequency, Doppler and angles of the targets in the environment.

With Uhnder's implementation, the spreading code can be a PRN sequence with a very large period, so it appears to be a nearly random sequence. The resulting signal has a bandwidth that is proportional to the rate at which the phases change (i.e., the chip rate), which is the inverse of the chip duration. By comparing the return signal with the transmitted signal, the receiver can determine the range and the velocity of reflected targets.

The Rx front-end addresses the modulated self-interference artifact from the radar's internal transmitters, which can saturate the receiver and increase the correlation noise floor. This challenge is more significant in MIMO radars, where multiple Tx active channels may constructively sum up at specific Rx inputs. To address the self-interference artifact, the RoC cancels self-interference using a pattern generator unit combined with separate analog and digital interference cancellation units (A-ICU and D-ICU, respectively). The A-ICU runs a background channel estimation algorithm, continuously calculating the impulse response, including the signal path delays, and then applies corrections to the up-converted mmWave feedback signal, where the resulting sig-

nal is then power-combined into the transformer feeding the LNA.

The D-ICU estimates the complex sum of the wideband self-interferer presented at each receiver input and removes the residual interferer before the correlators. The radar data control unit processes up to 1024 range bins for a single radar scan. The Winograd FFT engine manages up to 800 million points per second Doppler throughput. The beamforming engine throughput is 1.6 billion beams per second and implements a covariance matrix singular value decomposition engine, which supports direction-of-arrival algorithms such as MUltiple SIgnal Classification (MUSIC), estimation of signal parameters via rotational invariance techniques (ESPRIT) and Capon's algorithm, to further improve the angular resolution.

Compared to FMCW radars—or the newer variant fast chirp modulation (FCM)—the Uhnder architecture shifts the modulation complexity and precision to the high speed data converters and the DSP, where performance scales with the CMOS process node.

CMOS IMPLEMENTATION

The RoC was implemented in 28 nm high performance computing (HPC) CMOS technology and packaged in a fan-out wafer-level package (see ***Figure 8***). Digital signal and other radar computational processing is supported on chip with two floating point CPUs and two DSP engines. The overall software-defined hardware pipeline is capable of over 20 TOPS baseband processing.

At the package output reference plane, with 12 Tx active, the combined output power is approximately +19.6 dBm at 80 GHz and 125°C. The Rx noise figure measured at the analog-to-digital converter output is approximately 16 dB at 80 GHz and 125°C. Using an external PLL, the 77.5 GHz Tx phase noise at 1 MHz offset is −110 dBc/Hz. Power consumption varies with the application; typically, the RoC consumes 15 W and is biased with 0.9, 1.3 and 1.8 V supplies.

Figure 9 shows the capability of the RoC. Using the MIMO mode, Figure 9a shows a car on boresight moving at 25 mph, instantaneously detected at 290 m with 22 dB SNR. In Figure 9b, the radar, operating in phased array mode, tracks a person on boresight moving out to 280 m. Figure 9c shows the difference in angular resolution with beamforming (green line) and MUSIC processing (blue line). The targets were two −10 dBsm corner reflectors in an anechoic chamber, spaced within about ±1 degree. Figure 9d shows the improvement in the unweighted digital beamforming sidelobe performance using windowing and spatially variant apodization implemented in the hardware.

SUMMARY

The Uhnder RoC is a software-defined radar, impervious to light and weather conditions and tremendously software configurable, enabling the user to choose the optimal spreading code depending on the objective of the radar system and the desired performance. By using a large number of virtual receivers, the RoC achieves best-in-class angular resolution. The results presented in this article represent just one implementation.

This RoC is the most integrated CMOS radar sensing platform to be reported.[2] It represents a significant advancement in automotive radar technology and offers a path for evolution. Combining standard CMOS semiconductor technology with advanced DSP concepts from the commercial communications industry, Uhnder has introduced a new capability for automotive sensors, based on an architecture that is software-defined and customizable, to address the most demanding sensor requirements. The approach is cost-effective, scalable and open to future innovation.■

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INVITED PAPER

A Traceable K Connector for 43.5 GHz Measurements

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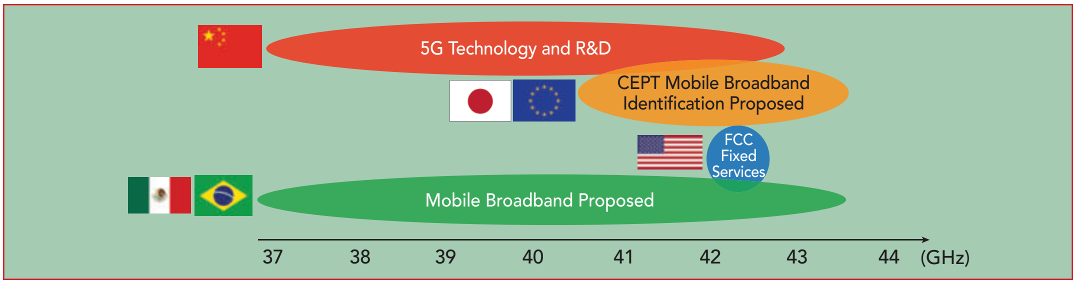
The 5G mobile communications standard is a big leap forward from its predecessor, 4G. The focus is no longer just sub-6 GHz for communications, rather on multiple frequency bands that accommodate different purposes in the communications chain. While most of the legacy frequency bands already in use fall into standard test equipment frequency bands, i.e., 10, 20 and 40 GHz, the 5G spectrum from 37 to 43.5 GHz has created a new requirement. Test & measurement (T&M) equipment manufacturers have responded to the need for broader frequency coverage by releasing equipment that measures to 43.5 GHz. However, a measurement is only as good as the components that exchange signals with the test equipment, and these components are only as good as their connectors. Accurate measurements to 43.5 GHz require precision components that leverage the 2.92 mm (K) connector currently used to 40 GHz, while providing mode-free performance to 43.5 GHz and a clear path of traceability.

WHY 43.5 GHz?

While many of the initial 5G deployments are using sub-6 GHz spectrum, the mmWave range (i.e., 24 GHz and above) has the advantage of providing immense bandwidth. Many countries are allocating spectrum in the 37 to 43.5 GHz range (see ***Figure 1***). In June 2018, the U.S. FCC proposed using 42 to 42.5 GHz for broadband or fixed wireless service, while Brazil and Mexico have similar proposals for mobile broadband within the 37 to 43.5 GHz range. Japan and the European Union have proposed 40.5 to 43.5 GHz for similar mobile broadband functionality. China may be the biggest driver for adoption of the frequencies up to 43.5 GHz. China's Ministry of Industry and Information Technology has been at the forefront of 5G for R&D testing.[1] In addition to proposing spectrum for 5G, China has held R&D trials leading to product trials, which began in late 2018.

This extension of frequencies has been quietly incorporated by many T&M companies over the last few years, adding this frequency option to existing and new products. One of the many aspects of providing 43.5 GHz coverage is the connector interface, i.e., the link between the user and the test equipment. Currently, there are two approaches to getting a user to 43.5 GHz:

2.4 mm connectors on the test equipment—This option has a dual purpose. Foremost, it supports performance to 50 GHz on the connector and establishes traceability. However, one issue with this approach is



▲ Fig. 1 5G mmWave spectrum by country and application.[1]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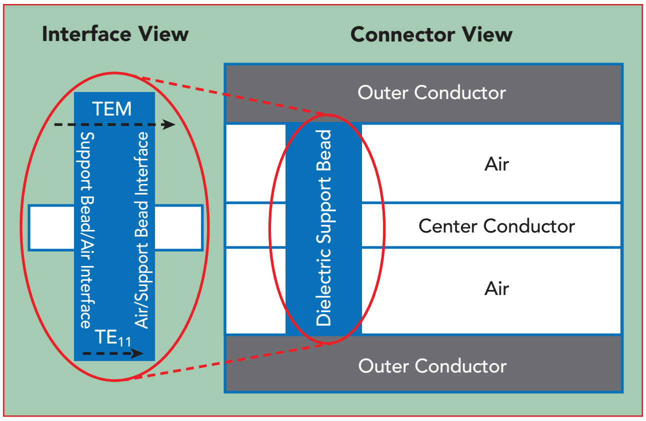
that the user must replace all cabling, adapters, calibration kits and other components to those with 2.4 mm connectors. This is costly, as 2.4 mm components are usually more expensive than 2.92 mm solutions. Another issue is that many devices being tested have the 2.92 mm K connectors, meaning users must add an adapter to convert from the 2.4 mm connectors on the test equipment to 2.92 mm connectors on the device being tested. While most manufacturers with 2.4 mm connectors offer adapters to 2.92 mm, unless the adapter is rated or specified to 43.5 GHz on the 2.92 mm side, the performance may not extend to 43.5 GHz, limited by over-moding, the creation of modes on the connector. This will be discussed below.



▲ Fig. 2 Over-moding at the dielectric support bead.

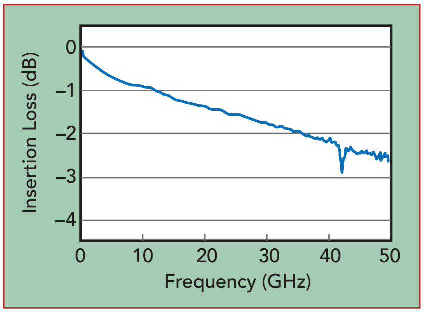
2.92 mm connectors on the test equipment—The second approach uses 2.92 mm connectors on the instrument, with the caveat that traceability is not available from 40 to 43.5 GHz, and the specified performance is "measured." The drawback with this approach is the connectors are most likely not tested individually and are part of a "catch all" approach to defining the instrument's specifications.

OVER-MODING

Two of the most important aspects of the connector's electrical performance are its frequency scalability and whether it supports the required performance to 43.5 GHz. To achieve optimal performance, mode propagation in the connector should be prevented. For the K connector, with 2.92 mm dimensions, only the desired transverse electromagnetic (TEM) mode can theoretically propagate up to about 46 GHz. Practically, the cutoff frequency is lower: dielectric support beads are required to make the connector mechanically stable, and because the wavelength shrinks in the dielectric, compared to air, additional modes can propagate below 46 GHz. This is why K connectors are typically specified to 40 GHz.

Above the cutoff frequency, an additional mode—TE11, which is not transverse—can propagate, with other modes propagating at higher frequencies.[2] This is a problem, as energy from the input signal can transform between the modes, launched by small imperfections on the bead surface (see ***Figure 2***). Since the modes have different impedances and phase velocities, this leads to a resonance in transmission or reflection. Over-moding within the connectors will reveal itself during measurements, clearly visible in a transmission measurement of the connector, seen as a large attenuation spike within a small bandwidth (see ***Figure 3***). Once the frequency of the resonance is passed—the coupling of energy between modes is not as efficient—the trace will return back to the original transmission path.

Over-moding can be avoided by reducing the dielectric bead circumference, optimizing the bead impedance and reducing the chance of energy coupling into the mode, by tightening other tolerances, for example. Assuming a manufacturer overcomes all the obstacles and designs a 2.92 mm connector that will not over-mode to beyond 43.5 GHz, will that provide sufficient confidence in the measurements? The answer varies from application to application, based on how stringent the test specifications. This information can be shown in datasheets, where the performance is qualified as a hard or measured specification.



▲ Fig. 3 Generic over-moded transmission response at 42 GHz.[3]

WHY TRACEABILITY IS IMPORTANT

A term used with the electrical specifications in the 40 to 43.5 GHz region of a test instrument is "measured." A measured or characteristic specification refers to measurements that provide a set of data that can be quantified with some level of confidence and used to represent all units. While this is not an uncommon approach to setting electrical specifications and is becoming more prevalent, the difference between the specifications below 40 GHz and the approach using measured data to define the specifications above 40 GHz is traceability. Below 40 GHz, the uncertainty budget is clearly defined through an unbroken chain of traceability; measurements between 40 to 43.5 GHz generally do not have the same confidence. For manufacturers, the uncertainty may be important, as the measurement of a product will establish whether it passes or fails a test specification.

While traceability is the path to establishing a solid uncertainty budget, it is much more: a quality assurance system tied to a recognized national metrology institute, like NIST or METAS. Not all connectors can be traceable, such as the SubMiniature version A (SMA) connector. Although used extensively, the SMA is not usually considered traceable because of its dielectric interface, lack of standardization and low repeatability. This is why SMA connectors do not yield precision measurements.

Fortunately, the K connector's basic characteristics can support traceability and, with careful design, can achieve reasonable and documentable uncertainties to 43.5 GHz. The most fundamental aspect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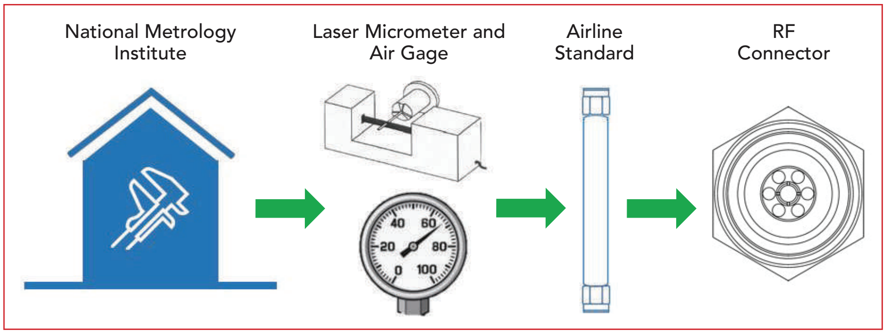

Fig. 4 Traceability path for RF connectors.

of traceability for the connector is impedance, which depends on the dimensional assessment and control in airlines used to measure the connectors. Dimensional measurements are performed with traceable tools such as laser micrometers, coordinate measuring devices and air gages. Once these measurements have been made, the next step is to link airline performance through calibration kits and other components to an individual connector (see ***Figure 4***). Some of the measurement quantities used to assess the connectors are outlined in the IEEE P287 Standard for Coaxial Connectors.[4]

TRACEABLE K CONNECTOR

To address the challenges designing a 43.5 GHz connector with traceability, Anritsu created a new connector functionality known as Extended-K™. Extended-K components with 2.92 mm connectors do not over-mode, provide traceable specifications to 43.5 GHz and avoid the costly investment to move a measurement system to 2.4 mm connectors. Anritsu offers a complete K connector system for 43.5 GHz measurements, including test port cables, adapters for 2.4 mm connectors, a portable thru-open-short-load calibration kit in both male and female gender and Anritsu's ShockLine™ vector network analyzers with Extended-K functionality. Anritsu's adapters are traceable and enable the user to quantify the uncertainty budget.■

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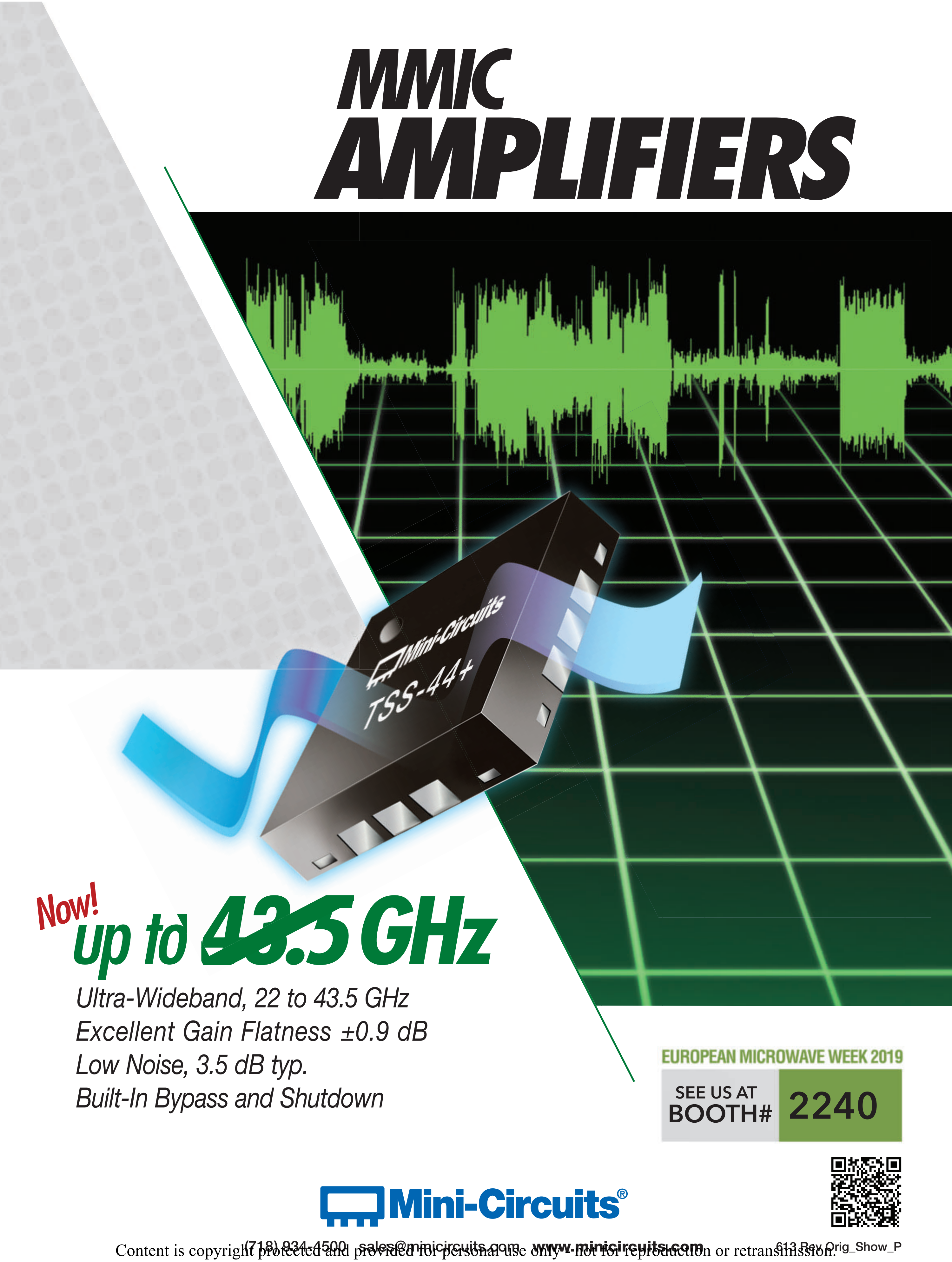
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INVITED PAPER

Using CDF to Assess 5G Antenna Directionality

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Three of the goals for 5G mobile communications networks are to increase data capacity, decrease latency and connect many more devices. mmWave frequencies with large channel bandwidths are being used to help meet these needs. Indeed, release 15 of the 3GPP 5G specification includes frequencies in the 28 and 38 GHz bands. Drawbacks of these higher frequencies are increased path loss in clear air, in air with precipitation and in environments with higher reflectivity—especially with larger cells outside of dense urban environments.[1]

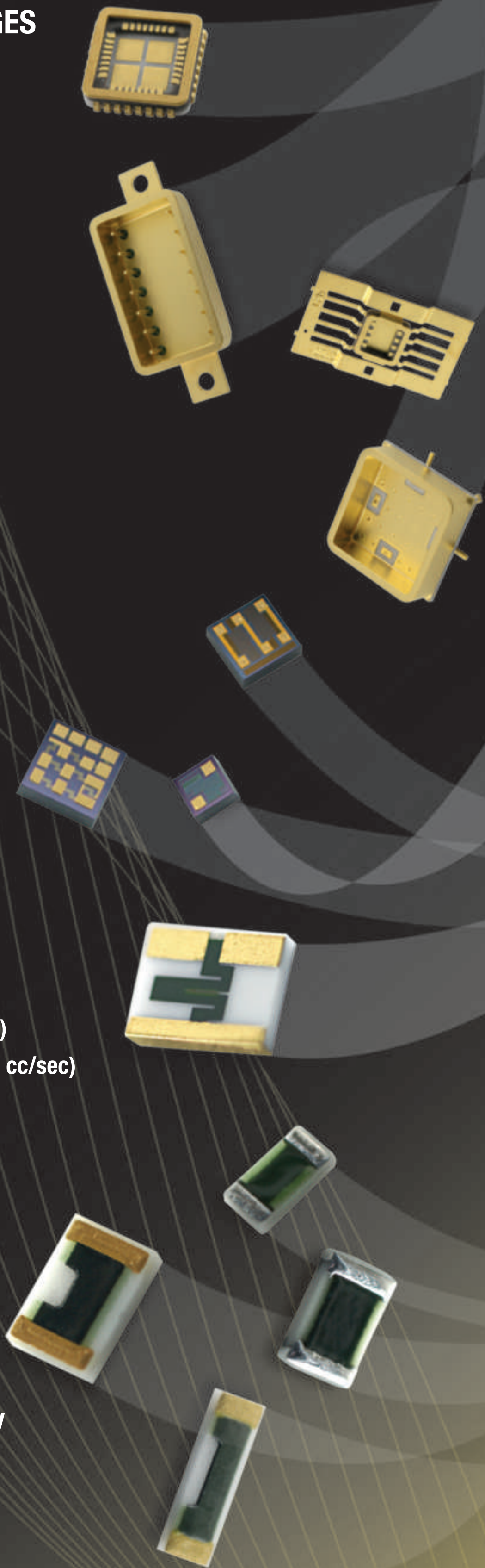
Fortunately, the shorter mmWave wavelengths enable more directional antennas in both the base station and user equipment (UE) than is practical at lower frequencies. Antenna arrays for which the radiation pattern can be steered are particularly interesting because higher gain in the desired direction makes up for some of the added path loss, and the narrower beamwidth can reduce same-cell interference. At mmWave, arrays become more practical, even for a mobile phone.[2]

A significant metric for the performance of a mobile phone antenna is the gain in the direction of the base station. Since the orientation of a phone and direction toward the tower can vary greatly, the phone should to be able to point its maximum gain in any direction. Hence, characterizing the ability of an antenna system to accomplish this is an important metric; one way to do this is predicting or measuring the effective or equivalent isotropic radiated power (EIRP) over all possible directions.

EIRP AND CDF

EIRP, which is a function of direction, is the gain of a transmitting antenna in that direction multiplied by the power delivered to the antenna from the transmitter.[3] EIRP can be thought of as the equivalent power required to be delivered to an isotropic antenna to produce the same signal level. For example, if an antenna is driven by 2 mW (3 dBm) from the transmitter and the antenna has 5 dB gain in a given direction, the EIRP in that direction is 8 dBm; the signal in that direction would be the same as if the antenna were isotropic and driven with an 8 dBm signal.

Antenna gain, G, and EIRP, E, are usually expressed as a function of direction, i.e., $G(\theta,\varphi)$ and $E(\theta,\varphi)$. For practical antennas, gain and EIRP are typically continuous func-



tions with minimum and maximum values:

$$0 < G_{min} < G_{max} < \infty \text{ and } 0 < E_{min} < E_{max} < \infty \quad (1)$$

In dB,

$$-\infty < G_{min} < G_{max} < \infty \text{ and } -\infty < E_{min} < E_{max} < \infty \quad (2)$$

For an ideal isotropic antenna, $G_{min} = G_{max}$ and $E_{min} = E_{max}$.

We can define a probability density function, f (E(θ,φ)), over all directions ($0 \leq \theta \leq \pi$, $0 \leq \varphi < 2\pi$) as

$$\int_{-\infty}^{\infty} f(E)dE = \int_{E_{min}}^{E_{max}} f(E)dE = 1 \quad (3)$$

The probability over all directions of the EIRP being between any two values E_1 and E_2 (inclusive) is

$$P = \int_{E_1}^{E_2} f(E)dE \quad (4)$$

In a typical polar 3D gain or EIRP plot, the magnitude at each θ and φ is plotted as a radius from the origin. For this type of plot, the EIRP of an antenna system will be contained in the closed region between a sphere of radius E_{min} centered on the origin and an equal or larger sphere centered on the origin of radius E_{max}.

A cumulative distribution function (CDF) or, simply, the distribution function of the probability density function f (x) is

$$F(x_1) = \int_{-\infty}^{x_1} f(x)dx \quad (5)$$

and gives the probability that $x \leq x_1$.[4]

For the EIRP probability density function f (E), the corresponding CDF, $F_E(x)$, gives the probability that the EIRP will be ≤ x:

$$F_E(x < E_{min}) = 0 \text{ and } F_E(x \geq E_{max}) = 1 \quad (6)$$

For $E_{min} \leq x \leq E_{max}$, $F_E(x)$ gives the fraction of all possible directions (i.e., fraction of 4π steradians) for which $E \leq x$ and $(1 - F_E)$ gives the fraction for which $E > x$, i.e., the fraction of a polar plot of E which is "poking out" of a sphere of radius x. For example, ***Figure 1*** shows a sphere representing the realized gain of the 3λ/2 resonance of a 76 mm printed circuit dipole, showing a magnitude of 2 dBi. Approximately 10 percent of the directions have gain more than 2 dBi; in this case, F(2 dBi) ≅ 0.9, so about 90 percent of the gain pattern is contained within the sphere.

When the EIRP over the sphere is sampled at a finite number of directions, such as in a measurement or simulation, the CDF can be approximated by

$$F_E(x) \cong \frac{\#\text{Directions with } E \leq x}{\text{Total \# of Directions}} \quad (7)$$

PATCH ARRAY

To illustrate, the CDF of the EIRP will be calculated for a 64 element patch array antenna at 28 GHz.[5] All simulations and processing are performed using XFdtd®.[6] The geometry is an 8×8 element patch array on a 52.5 mm × 52.5 mm × 0.254 mm substrate with a ground

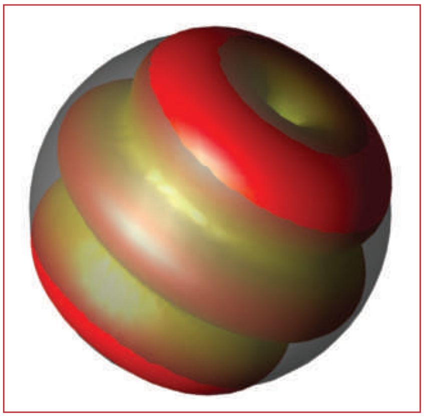


Fig. 1 Realized gain CDF at the 3 λ/2 resonance of a 76 mm printed circuit dipole.

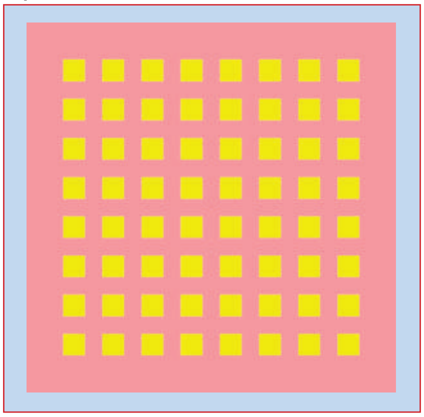
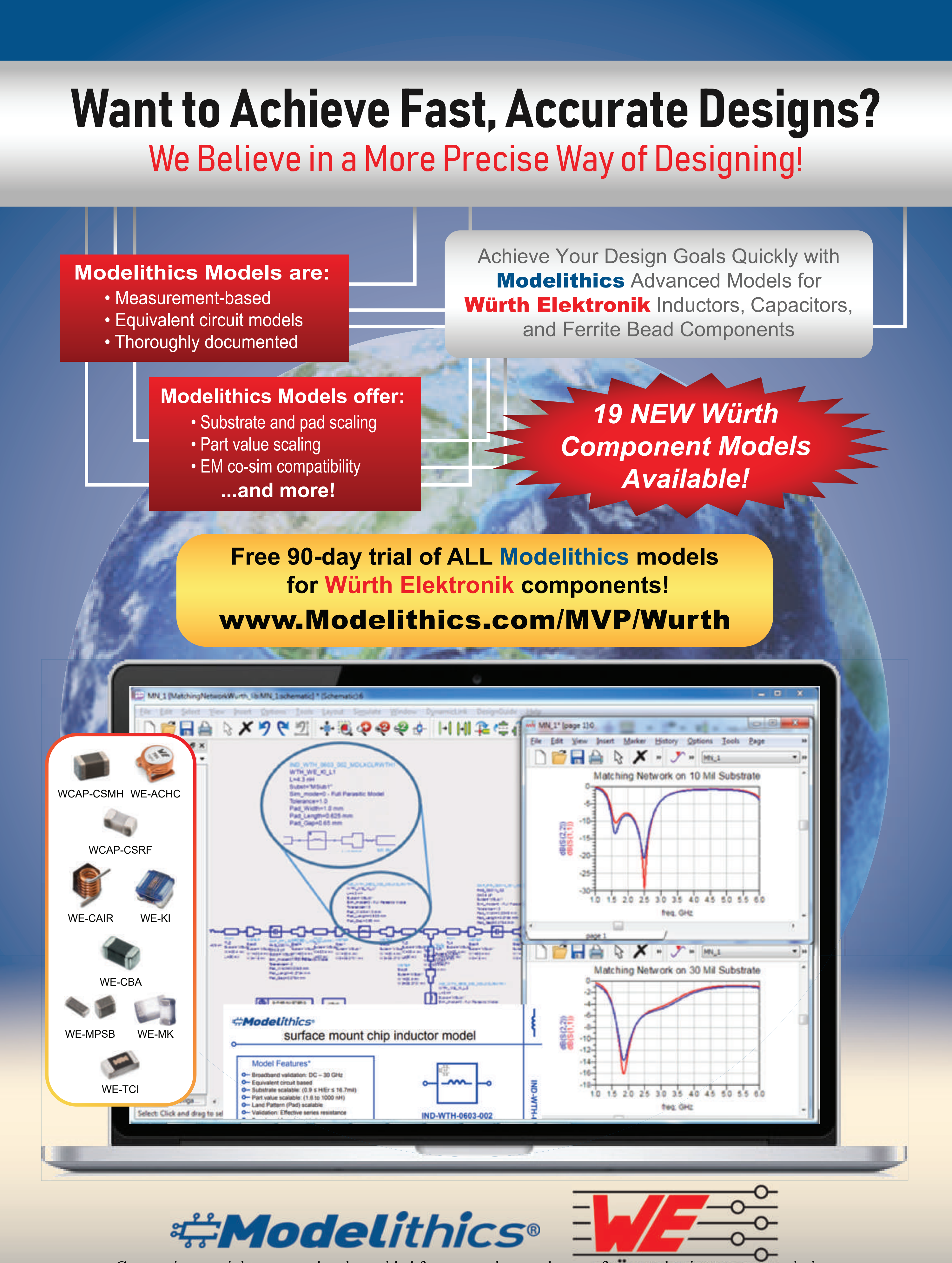


Fig. 2 8 × 8 patch antenna array on a 52.5 mm x 52.5 mm substrate.



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plane (see ***Figure 2***). The electrical parameters of the substrate are ε_r = 2.2 and loss tangent = 0.0009. This example is restricted to the antenna array structure to illustrate the method. In practice, the antenna would be evaluated by itself in the initial stages of the design, then simulated in a more complex environment, including the complete mobile phone geometry and, possibly, other arrays added for better diversity of coverage and polarization.

The realized gain patterns for maximum signal in two directions are shown in ***Figures 3*** and ***4***. Figure 3 shows the radiation pattern of the array with all elements fed in phase, so the principal lobe is perpendicular to the plane of the antenna, i.e., θ = 90 degrees. The maximum gain is 24.2 dBi. Figure 4 shows the radiation pattern of the array with all elements fed with a phase taper across the 2D array, so the principle lobe is along the direction θ = 37 degrees and θ = 90 degrees. The maximum realized gain in this case is 23 dBi. A single element of this array will have reduced gain toward the back (i.e., the ground plane side), so the array will not have gain as high in that hemisphere. Also, integrating the array into a phone will yield additional effects on the radiation pattern.

Determining how well the array performs in every direction is useful. What is the distribution of EIRP over the sphere? Since this is a simulation, it is straightforward to characterize the maximum gain in many directions. However, to capture the many variations we expect on the gain pattern due to the geometry, the number of sample directions needs to be large. The CDF of EIRP provides a useful, one-dimensional function to characterize the array's performance over all possible directions.

The far zone radiation due to each element in the array is computed for the full geometry. These patterns can be combined in post processing to compute the gain and EIRP for any combination of elements, enabling the power and phase delivered to each element to be set independently. To compute the CDF, the phase of each element in the array is adjusted to provide maximum EIRP in each of a suitably large number of sample directions representing the sphere of all possible directions. The CDF of EIRP function can then be computed from Equation 7.

A CDF of the EIRP for the full 8×8 element array and several subarray combinations is shown in ***Figure 5***. For all cases, the transmitter is assumed to have a power of 23 dBm, which is typical for a mobile phone. For the 8×8 element case, the EIRP is about 37 dBm at a fractional area of 0.5, which means that half of the directions have an EIRP larger than 37 dBm. For the 4×4 subarray, elements from one quarter of the array are used to determine the CDF of EIRP. This CDF curve has a similar shape but shifted down in EIRP, as expected for an array with one quarter as many elements. Elements from

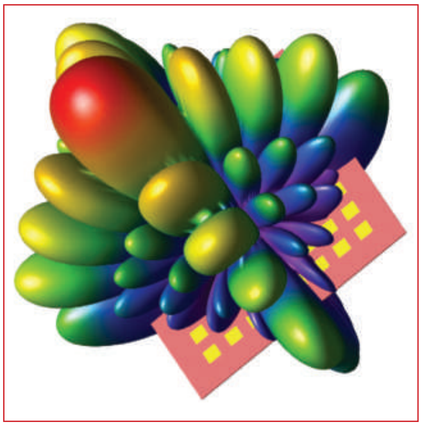

Fig. 3 Realized gain of the 8 × 8 patch, fed for maximum gain normal to the plane of the patches.

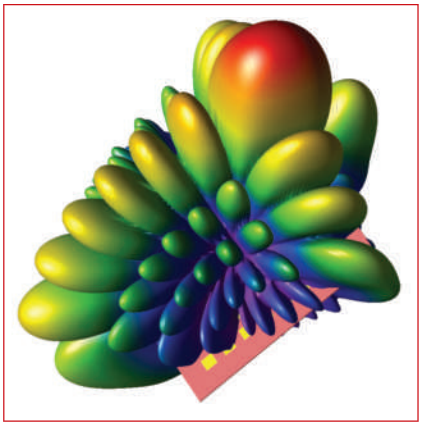

Fig. 4 Realized gain of the 8 × 8 patch, fed for maximum gain at θ = 37 degrees and φ = 90 degrees.

one corner of the array are used in the CDF for the 2×2 subarray, and the CDF has a similar drop in EIRP compared to the 4×4 case. Finally, a 1×8 arrangement of elements from one side of the array shows the EIRP lies between the 2×2 and 4×4 element subarrays, again as expected. This type of array might be used in a mobile phone, with arrays on two sides to provide more complete coverage.

As seen from these curves, about half of the possible directions have significantly lower EIRP due to the ground plane, which emulates the placement of the array in a phone. One way to provide broader coverage is to place multiple antenna arrays in the device, such as on either edge of the mobile phone, as mentioned. By properly combining the distributions, the CDF of the EIRP can be used to estimate the ability of multiple arrays or subarrays to work in combination to provide higher EIRP in all directions and reduce blind spots. This measure can also be evaluated using multiple antennas for diversity and coverage in all polarizations.

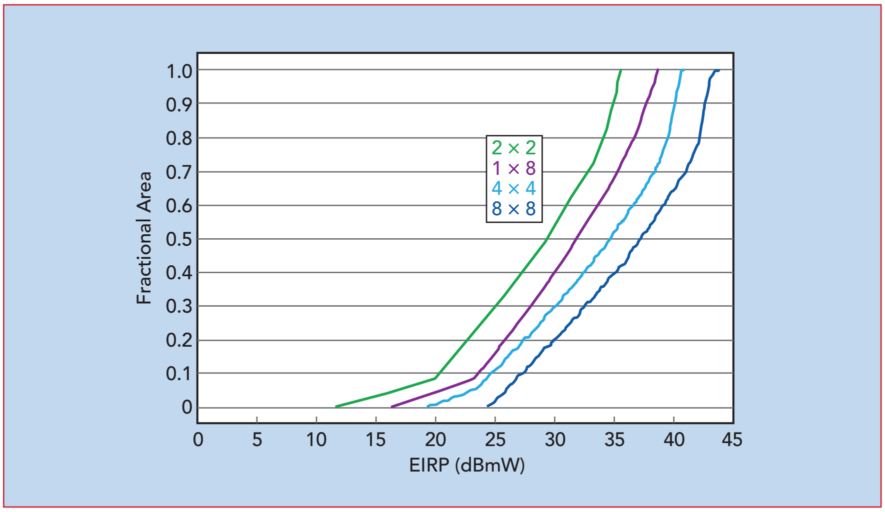

Fig. 5 EIRP CDFs for the full 8 × 8 element patch array and several subarrays.

CONCLUSION

Steerable array antennas are of significant interest to help meet the goals of 5G mobile communications. At mmWave frequencies, such as 28 and 38 GHz, fairly large and directional arrays become practical for relatively small devices such as mobile phones; however, these frequencies have higher path loss than at microwave frequencies which have been used in previous generations. For a given power level, the ability of antenna arrays to control the direction of maximum radiation will allow for much better EIRP in the direction of communications.

The CDF of EIRP, computed from a suitably large number of sample directions, may be used to assess the directionality and effective coverage of an antenna array. The article used a simple example of an 8×8 patch antenna array to demonstrate the usefulness of the CDF of EIRP to characterize the ability of an array to provide good EIRP in all directions.■

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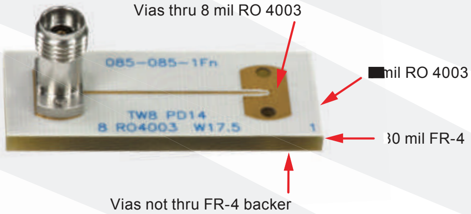

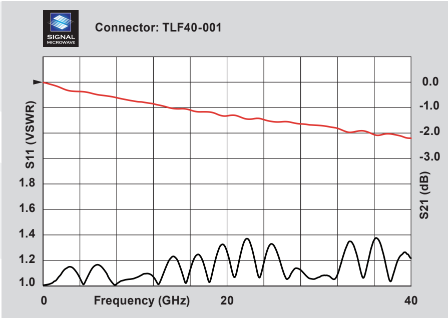

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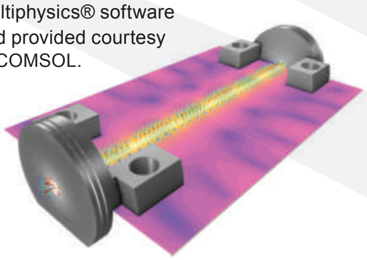

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Gain-Enhanced Antenna with Metamaterial Structure and Pin Array Reflector for WiMAX and WLAN Applications

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East China Normal University, Shanghai, China

An antenna for WiMAX at 3.7 GHz and WLAN at 5.8 GHz consists of an asymmetric triangular metamaterial structure fed by coplanar waveguide (CPW). The characteristics of the structure are studied using parametric retrieval and eigenmode analysis. Measured performance is in good agreement with simulation. Owing to its single layer 50 Ω CPW design, this antenna is easily integrated with other RF circuits.

Use of WiMAX and WLAN is now widespread, and antenna technologies are emerging for these applications. WiMAX, also known as IEEE 802.16e, is a broadband wireless access standard generally operating in the frequency range from 2 to 6 GHz, that provides both high speed data services and user mobility. In December 2010, the International Telecommunication Union officially included WiMAX in the 4G standard. Compared with LTE, WiMAX has lower network installation costs and is popular in many regions. Multiband antennas have been explored for WiMAX and WLAN applications[1-3] using traditional methods with stacked layers,[4] slotted microstrip patches[5] or Yagi arrays with different length elements.[6] These structures, however, are complicated and therefore difficult to fabricate and, for this reason, are generally unsuitable for most commercial applications. The design of a practical compact multiband antenna remains the subject of ongoing research. Multiband antennas that utilize metamaterials,[7] including open complementary split ring resonators used in printed monopole antennas[8-9] and a tri-band metamaterial structure,[10] either have low gain or low radiation efficiency.[11-14]

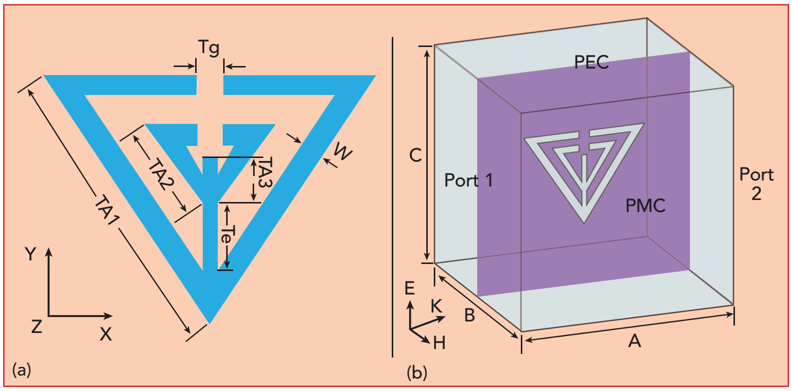

Fig. 1 **Asymmetric triangular electromagnetic resonator: element configuration (a) and as modeled in HFSS (b).**

The asymmetric triangular electromagnetic resonator (ATER) is a new kind of multi-resonant metamaterial structure that supports both electric and magnetic resonances. An ATER has negative permittivity or negative permeability when excited by an

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TABLE 1 GEOMETRIC PARAMETERS OF THE ATER STRUCTURE (mm)					
TA1	TA2	TA3	Tg	Te	Dg
26	19	13.5	4	3.5	0.35
mw	rhole	W	A	B	C
1.8	1.4	1.1	40	10	40

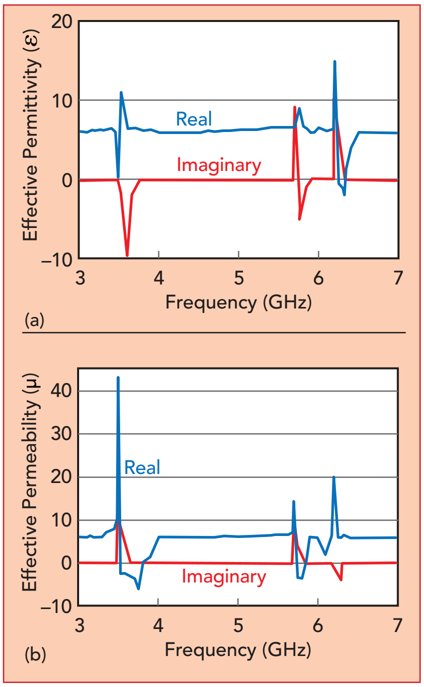

Fig. 2 Retrieved effective permittivity (a) and effective permeability (b).

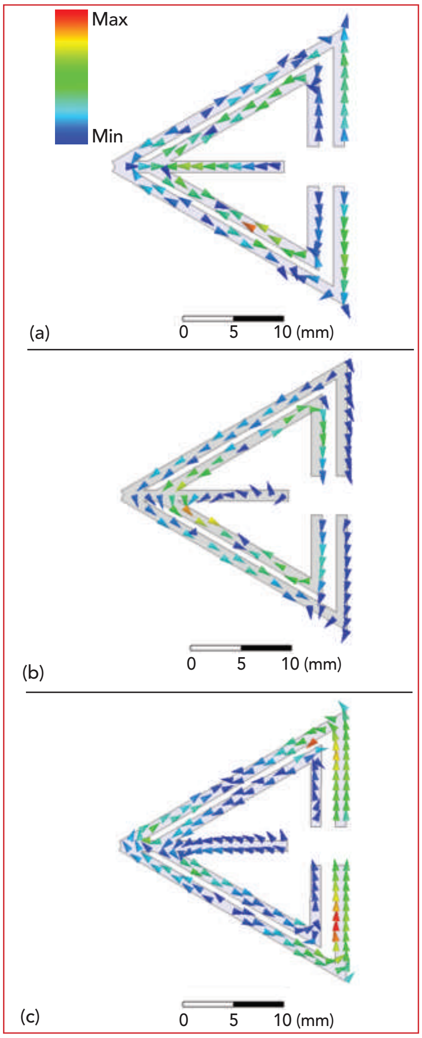

Fig. 3 Eigenmode current distributions at 3.5 (a), 5.7 (b) and 6.2 GHz (c).

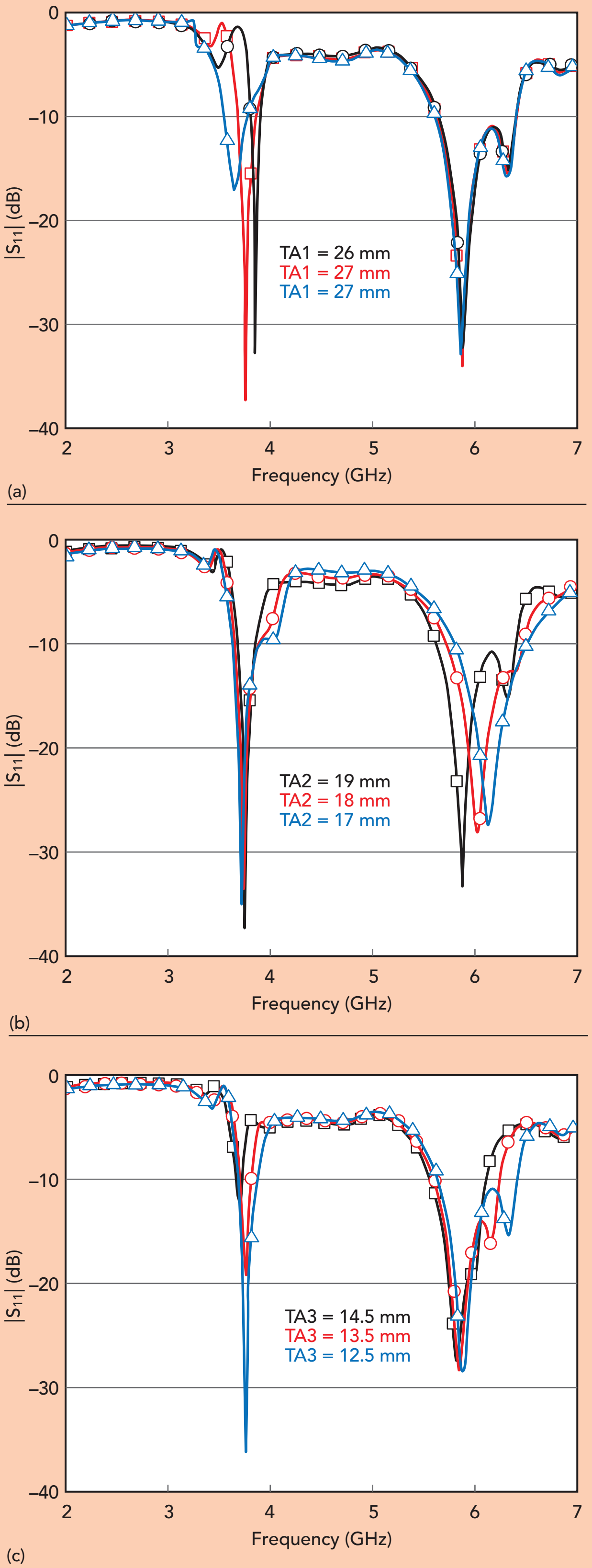

Fig. 4 Simulated $|S_{11}|$ vs. TA1 (a), TA2 (b) and TA3 (c).

electric or magnetic field.[10] In this work, a folded ATER is used to design a multiband, compact antenna suitable for WiMAX at 3.7 GHz and WLAN at 5.8 GHz. Due to its asymmetry, the ATER has two magnetic resonances and one electric resonance. The gain of the antenna is enhanced in one plane with a pin array reflector.

ANALYSIS OF METAMATERIAL STRUCTURE

Parametric Retrieval Analysis

The folded ATER, shown in ***Figure 1***, is composed of two equilateral triangles with open slots connected at their apexes opposite the slots. It is designed on a Rogers 6006 substrate with a thickness of 1.27 mm, relative dielectric constant (ε_r) of 6.15 and loss tangent (tanσ) of 0.0027, measured at 10 GHz. The remainder of the volume is air. Two kinds of boundary conditions, perfect electrical conductor (PEC) and perfect magnetic conductor (PMC), are modeled as shown in Figure 1b; the top and bottom faces of the box are PEC and the front and back faces are PMC. The structure was simulated with Ansoft HFSS using the finite element method. The geometric parameters are listed in ***Table 1***, where Dg and mw are the gap width and width of the CPW, respectively, and rhole is the hole diameter of the pin array reflector.

Using the parametric retrieval method,[15] the effective permittivity and effective permeability are calculated (see ***Figure 2***). Figure 2a shows an electric resonance at around 6.2 GHz, where the value of the real part of the effective permittivity changes from positive to negative. Similarly, in Figure 2b, two magnetic resonances occur at around 3.5 and 5.7 GHz, with the strongest magnetic resonance occurring at 3.5 GHz. Both the second mag-

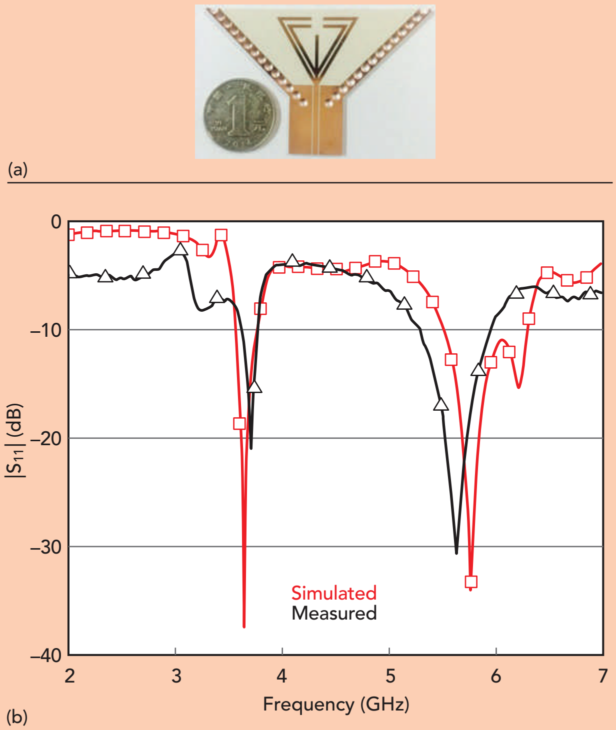

Fig. 5 Fabricated antenna (a) and simulated vs. measured $|S_{11}|$ (b).

netic resonant frequency and electrical resonant frequency occur in the WLAN band. The lower band at 3.7 GHz is suitable for WiMAX.

Eigenmode Analysis

To characterize the intrinsic electromagnetic properties of the folded ATER, the HFSS eigenmode solver is set to a convergence precision of 0.1 percent with three eigenmodes. The eigenmode frequencies are 3.5, 5.7 and 6.2 GHz. Their current distributions are shown in ***Figure 3***.

At the eigenfrequencies of 3.5 GHz and 5.7 GHz, the surface current is concentrated in the outside and inside triangular arms, respectively, as shown in Figures 3a and b. The main current forms a circle due to magnetic coupling, resulting in a negative permeability. At the eigenfrequency of 6.2 GHz, surface current is in three arms (see Figure 3c). The outside and inside triangular arms also display coupling with the magnetic field, but due to the asymmetrical structure, the surface currents from the outside and inside arm cancel on the middle arm. Therefore, the surface current in the

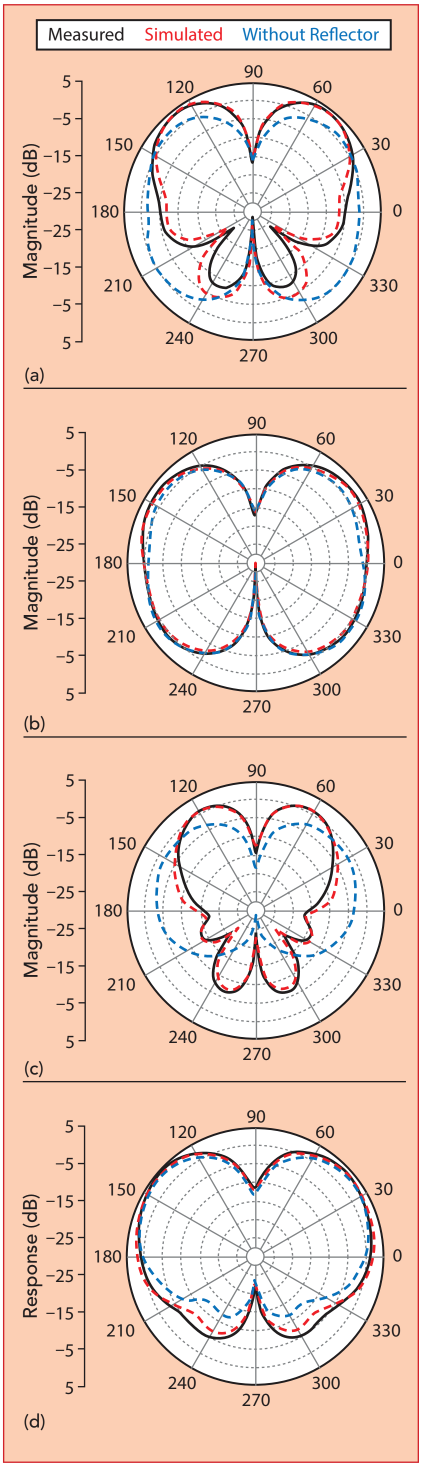

Fig. 6 Simulated vs. measured radiation patterns in the WiMAX and WLAN bands: xoy plane at 3.7 GHz (a), yoz plane at 3.7 GHz (b), xoy plane at 5.8 GHz (c) and yoz plane at 5.8 GHz (d).

middle arm is caused by coupling to the electric field, resulting in a negative permittivity; the electric resonance at 6.2 GHz, however, is weak.

ANTENNA DESIGN AND PARAMETER ANALYSIS

Varying one parameter and fixing the others, influences on the resonant frequencies were investigated in HFSS. ***Figure 4*** shows three resonant frequencies, from low to high, corresponding to two magnetic couplings and one electric coupling. These are determined, independently, by the lengths of TA1, TA2 and TA3. As their lengths increase, the corresponding resonant frequencies decrease; the electrical resonance is sensitive to the length of the middle arm, as well.

In accordance with the current distribution of the ATER metamaterial structure, an equivalent circuit model can be obtained. It consists of a parallel equivalent capacitor, C, and equivalent inductor, L, where C is induced by coupling between the arms and L is produced by the arms, themselves. The values of C and L are different for the three resonances since the electrical arm lengths are unequal. Once these values are determined, the operating frequencies of the antenna are simply derived from

$$\omega_o = \frac{1}{2\pi\sqrt{L * C}}$$

This formula provides an approximate working frequency since coupling between the ATER and pin array reflector is neglected. As noted, both the second magnetic resonant frequency and electrical resonant frequency occur in the WLAN band, and the lower operating band at 3.7 GHz is suitable for WiMAX.

EXPERIMENTAL RESULTS

A photograph of the antenna is shown in ***Figure 5a***, fabricated on Rogers 6006 and fed by 50 Ω CPW. The metal pin array reflector, arranged linearly on both sides, enhances the gain in one plane. Coupling between the reflector and the outer triangular arm can be disregarded when the distance between them is larger than 3× the arm width. The measured and simulated $|S_{11}|$ are shown in ***Figure 5b***. A small frequency difference between measured and simulated is observed, especially at higher frequencies. This is caused by antenna fabrication tolerances; however, the antenna is still operational in the WiMAX and WLAN bands.

The xoy plane and yoz plane radiation patterns at 3.7 GHz and 5.8 GHz are shown in ***Figure 6***. In each sub-graph, the results of measured, simulated and simulated without pin array reflector are marked. Measured results agree well with simulation. The radiation pattern in the yoz plane is in the shape of a figure eight. The measured antenna gain is 3.8 dBi at 3.7 GHz and 5.5 dBi at 5.8 GHz using the gain comparison method. By adding the pin array reflector, the antenna gain is enhanced by approximately 2.15 dB at 3.7 GHz and 2.2 dB at 5.8 GHz in the xoy plane. In the yoz plane, the pin array reflector has a weak influence on the radiation pattern. A comparison with recently published antenna designs for WiMAX and WLAN applications is shown in ***Table 2***.

CONCLUSION

A dual-band antenna for WiMAX at 3.7 GHz and WLAN at 5.8 GHz is excited by magnetic and electric resonances generated by a metamaterial structure. Antenna operation was analyzed using parametric retrieval analysis and eigenmode simulation. The operating bands can be tuned independently by changing the length of the triangular arms and center section. A metal pin array reflector improves the gain by more than 2 dB for each band in one plane. The 50 Ω CPW feed and single layer construction has the advantages of ease of fabrication and integration with RF circuits.■

TABLE 2

GAIN AND ANTENNA EFFICIENCY COMPARISON

Reference	WiMAX (3.7 GHz)		WLAN (5.8 GHz)	
	Gain (dB)	Efficiency	Gain (dB)	Efficiency
1	2.5	*	3.5	*
3	2	*	0.75	*
11	*	*	2.92	0.955
12	–2.5	0.9	1.5	0.92
13	–2.1	0.74	–1.0	0.87
14	3.22	0.74	2.8	0.76
Proposed Antenna	3.8	0.93	5.5	0.95
Without Reflector	1.65	0.93	3.3	0.95

*The reference antenna does not operate in this band, or the band is not mentioned.

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Dual-Band Resistive Third Harmonic Continuous Inverse Class F Mode Power Amplifier

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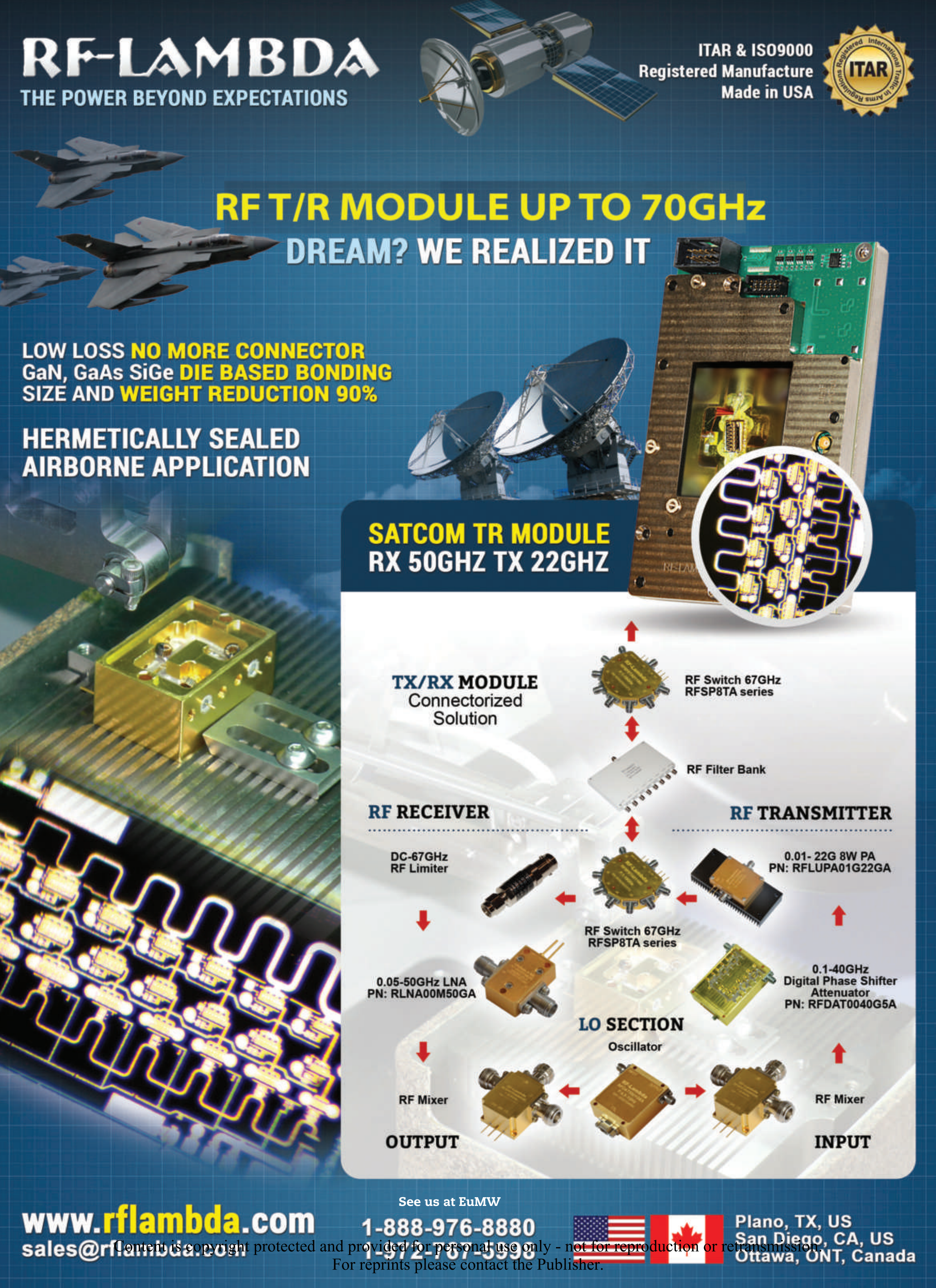
A dual-band continuous inverse class F mode power amplifier (PA) operates efficiently with a resistive third harmonic termination. Analysis predicts the effect of the resistive termination on drain efficiency and output power. Measurements demonstrate 10 W output power with 75 and 71 percent power-added efficiency (PAE) and greater than 13 dB gain at 0.8 and 2.4 GHz, respectively.

The rapid development of wireless communication technologies is driving the need for increased system bandwidth.[1] The PA, a key transmitter component, is now expected to operate efficiently over broader frequency ranges. It is feasible to realize high efficiency and wideband performance with continuous modes;[2] however, a multiband continuous mode PA is a better solution for high efficiency when frequencies extend beyond one octave. Harmonically tuned PAs, such as the continuous class F mode and continuous inverse class F mode, are used to achieve high efficiency. Unlike class A or B operation, harmonically tuned PAs require precise harmonic impedance control, as well as a proper fundamental impedance match. The continuous class F mode, for example, requires an infinite third harmonic termination, while the continuous inverse class F PA requires a short at the third harmonic.

Recent research in this area employed mixed class F and class F^{-1} modes to design a concurrent dual-band PA at 0.8 and 1.25 GHz.[3] In another design, a dual-band harmonic control network was used to realize accurate harmonic terminations for high efficiency dual-band PA operation.[4] Both obtained superior efficiency and output power at two operating frequencies; however, reactive third harmonic impedances are required, which inevitably results in a frequency conflict with a dual-band PA, when two operating frequencies f_1 and f_2 meet the condition $3f_1 = f_2$. In this case, the third harmonic load for operating frequency f_1 must be reactive while the fundamental component for the frequency f_2 must simultaneously be resistive. To resolve this conflict, this article proposes using a resistive third harmonic continuous inverse class F mode design for a dual-band PA.

TRADITIONAL CONTINUOUS INVERSE CLASS F MODE

The classic inverse class F mode PA requires the drain voltage waveform to be a half sinusoid and the drain current waveform to be a square wave at the transistor's intrinsic plane. A Fourier series expansion shows a half-sinusoidal drain voltage waveform contains even harmonics of the fundamental, while a square current waveform con-



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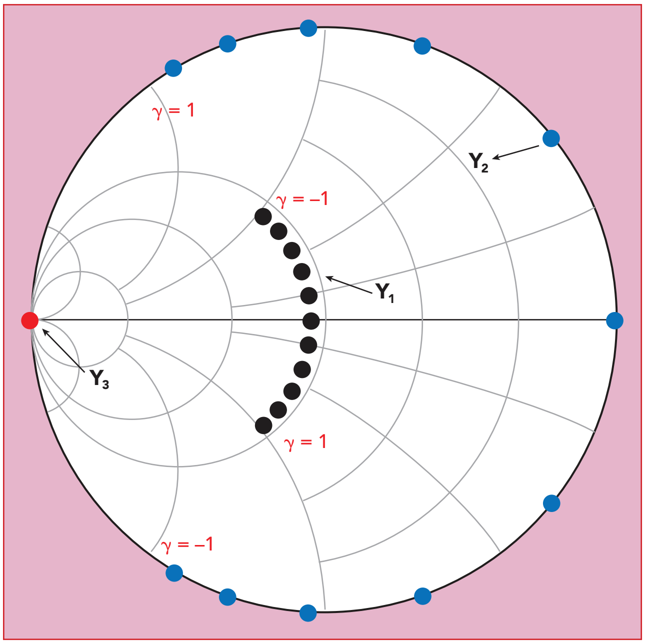
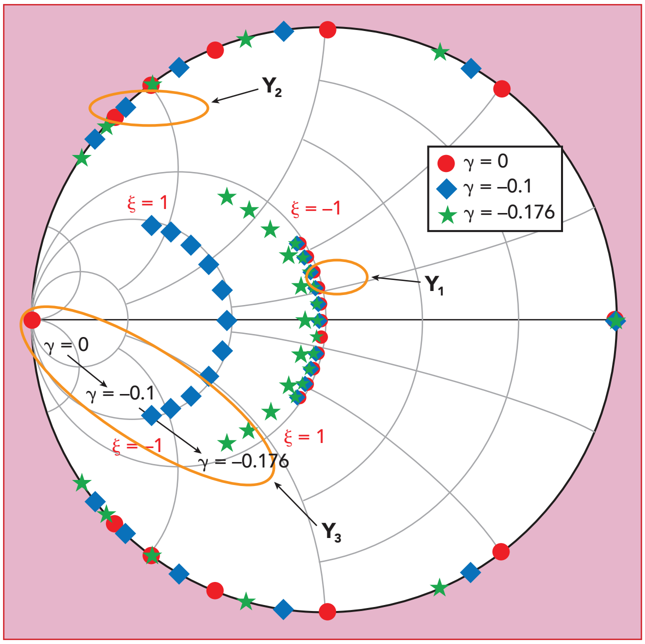


▲ Fig. 1 Design space of the continuous inverse class F mode.



▲ Fig. 2 Fundamental and harmonic impedances vs. γ.

tains odd harmonics. Therefore, to achieve 100 percent drain efficiency, the ideal inverse class F amplifier requires all odd harmonics to be shorted and even harmonics to be open circuited.

The normalized drain voltage and current waveforms for the inverse class F mode can be expressed as

$$V_{ds\_IF}(\theta) = 1 + \sqrt{2}\cos\theta + 0.5\cos 2\theta \quad (1)$$

$$i_{ds\_IF}(\theta) = i_{DC} - i_1\cos\theta + i_3\cos 3\theta \quad (2)$$

where i_{DC} = 0.37, i_1 = 0.43 and i_3 = 0.06.

To realize the inverse class F mode precisely, short- or open-circuit transmission lines with high Q-factors are often used, typically limiting the bandwidth of the inverse class F mode to less than 10 percent. To address the bandwidth limitation, the performance of the continuous inverse class F mode amplifier is explored by attaching a factor, ξ, to the drain current waveform. The drain current waveform is then expressed as

$$i_{ds\_CIF}(\theta) = \left(i_{DC} - i_1\cos\theta + i_3\cos 3\theta\right) * (1 - \xi\sin\theta), -1 < \xi < 1 \quad (3)$$

According to Equations 1 and 3, the fundamental and harmonic admittances in the continuous inverse class F mode can be expressed by the relationship

$$Y_n = -i_{ds,n} / V_{ds,n} \quad (4)$$

so that

$$Y_{1,CIF} = \sqrt{2}G_{opt}(i_1 + ji_{DC}\xi) \quad (5)$$

$$Y_{2,CIF} = -j2G_{opt}(i_1 + i_3)\xi \quad (6)$$

$$Y_{3,CIF} = \infty \quad (7)$$

Figure 1 shows the admittance distribution on the Smith chart. Compared with the traditional inverse class F mode amplifier, introduction of the parameter ξ extends the design space. By simultaneously varying the fundamental and second harmonic admittances on a circle of constant susceptance, this mode can deliver the same output power and drain efficiency as the standard inverse class F amplifier.[5] Although the second harmonic admittance, Y_2, is no longer restricted to an open circuit on the Smith chart, a short-circuited third harmonic termination is still maintained.

RESISTIVE THIRD HARMONIC CONTINUOUS INVERSE CLASS F MODE

In the above discussion, the multiplication factor 1 − ξ sinθ was introduced in the expression for the drain current of the standard inverse class F PA. Similarly, the drain current waveform for a resistive third harmonic continuous inverse class F mode PA is defined as

$$i_{ds}(\theta) = \left(i_{DC} - i_1\cos\theta + i_3, \cos 3\theta\right) * (1 - \xi\sin 2\theta), -1 < \xi < 1 \quad (8)$$

The voltage waveform is obtained by adding the multiplication factor 1 + γcos3θ to the voltage expression of the standard inverse class F mode amplifier:

$$V_{ds} = \left(1 + \sqrt{2}\cos\theta + 0.5\cos 2\theta\right) * (1 + \gamma\cos 3\theta) \quad (9)$$

Combining Equations 8 and 9, the fundamental, second and third harmonic admittances are derived:

$$Y_1 = \frac{2}{\sqrt{2} + 0.25\gamma} \times \left(i_1 + \frac{1}{2}j(i_1 + i_3)\xi\right)G_{opt} \quad (10)$$

$$Y_2 = -j\frac{4i_{DC}\xi}{1 + \sqrt{2}\gamma}G_{opt} \quad (11)$$

$$Y_3 = \frac{(-2i_3 + ji_1\xi)}{\gamma}G_{opt} \quad (12)$$

where G_{opt} represents the optimal admittance of the class B PA. A resistive third harmonic impedance is

enabled with the introduction of the parameter γ. To prevent fundamental and third harmonic impedances from going beyond the Smith chart, γ must be restricted to be within −1 and 0.

Figure 2 shows the theoretical fundamental, second and third harmonic admittances of the resistive third harmonic continuous inverse class F mode PA on the Smith chart. With γ decreasing, the third harmonic impedance gradually moves away from the short-circuit point; when γ decreases to −0.176, the third harmonic impedance approaches close to the fundamental impedance, and the fundamental impedance remains nearly constant.

Based on Equations 8 and 9, the drain efficiency (DE) and normalized output power (P_{out}) are calculated by

$$DE = 0.581 * \left(\sqrt{2} + 0.25\gamma\right) \qquad (13)$$

$$P_{out} = 0.215 * \left(\sqrt{2} + 0.25\gamma\right) \qquad (14)$$

Output power degeneration is the difference between the output power of a traditional continuous inverse class F mode PA and the resistive third harmonic continuous inverse class F mode PA. ***Figure 3*** shows the variation in DE and output power degeneration as γ varies from −0.5 to 0. With decreasing γ, DE decreases correspondingly, and efficiency greater than 78.5 percent is maintained with γ greater than −0.176. The output power remains nearly unchanged, as there is little variation of the fundamental impedance.

TABLE 1

THEORETICAL IMPEDANCES γ = −0.176 AND ξ = 0

	Frequency (GHz)		
	0.8	1.6	2.4
Impedance (Ω)	48	∞	44

SIMULATION

A dual-band PA operating at 0.8 and 2.4 GHz was designed to verify this analysis. To obtain the optimum impedances, an iterative load-pull simulation was employed from the low to high frequency. First, the optimal impedance was determined at 0.8 GHz by fundamental load-pull simulation with a proper harmonic impedance. Then, the optimal second harmonic impedance was obtained with harmonic load-pull simulation using the optimal fundamental impedance. In a similar manner, this process was repeated at 2.4, 4.8 and 7.2 GHz. Finally, γ was selected to be −0.176 with ξ = 0. ***Table 1*** shows the theoretical impedances in this case.

Having determined the optimal impedances, the output matching network for the dual-band PA was designed. ***Figure 4*** shows the design topology. For harmonic control at 1.6 GHz, a $\lambda_1/4$ short-circuited transmission line, TL7, was used, where λ_1 is the wavelength at 0.8 GHz. TL7 presents an infinite impedance at 0.8 and 2.4 GHz, so it does not affect the impedance match at either fundamental frequency. First, a $\lambda_2/4$ short-circuit transmission line, TL2, and $\lambda_2/12$ open-circuit transmission line, TL3, were used to present a short-circuit load at 4.8 and 7.2 GHz, respectively, where λ_2 is the wavelength at 2.4 GHz. Then, TL1 with the proper characteristic impedance and electrical length was added to realize the harmonic impedances required. Finally, the fundamental impedance matches for 0.8 and 2.4 GHz were obtained with a three-section impedance transformer (TL4, TL5 and TL6), with the parameters calculated.

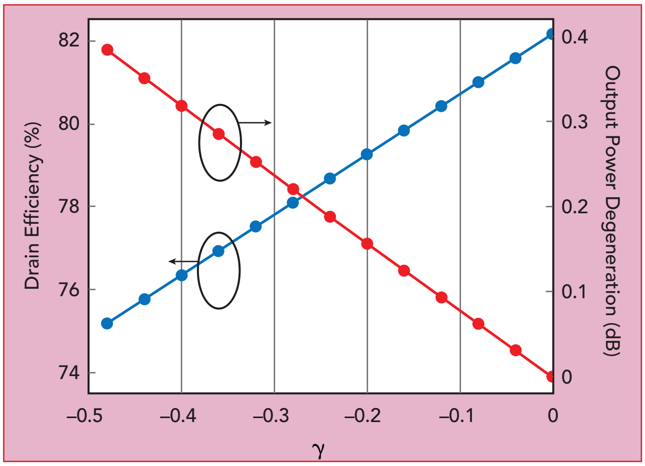


Fig. 3 Drain efficiency and output power degeneration vs. γ.

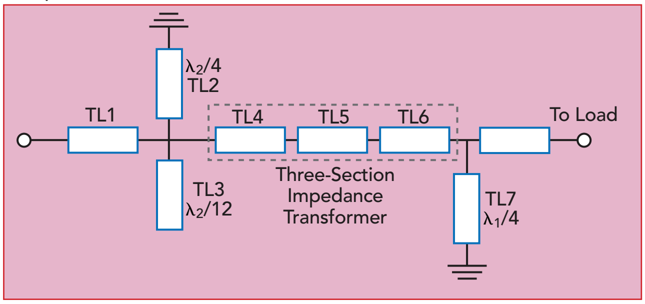


Fig. 4 Topology of the output matching network.

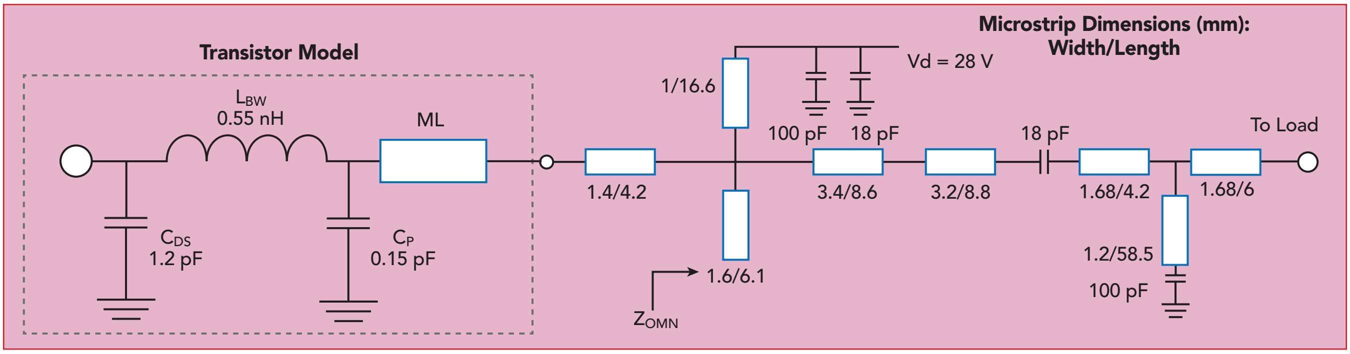


Fig. 5 Output matching network with transistor parasitic model.

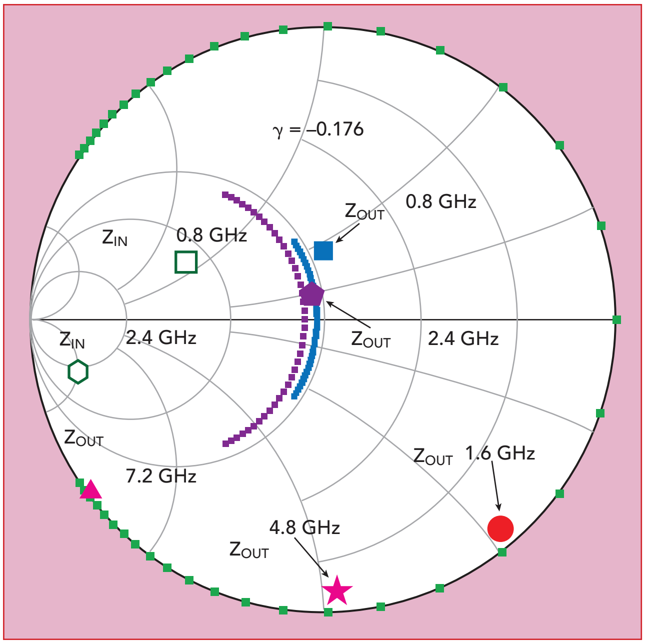


Fig. 6 PA input and output impedances vs. frequency, with γ = –0.176.

Fig. 7 Assembled dual-band PA.

Figure 5 shows the final output matching network using a Wolfspeed CGH40010F transistor.[6] The achieved impedance and targeted design space when γ equals –0.176 at the current generation plane are shown in ***Figure 6***. These impedances are all located in the design space and close to the theoretical impedances in Table 1.

EXPERIMENTAL RESULTS

The Wolfspeed CGH40010F transistor was mounted on a 30 mil RF35 substrate with relative permittivity of 3.5 (see ***Figure 7***). It was biased with –2.36 V at the gate and 28 V at the drain. A single tone continuous wave signal was applied, sweeping the input power from 18 to 30 dBm at each frequency (see ***Figure 8***). With 28 dBm input power, the PA achieved a PAE of 75 percent at 41 dBm output power and 71 percent PAE with 41.4 dBm output power at 0.8 and 2.4 GHz, respectively. In both cases, the gain exceeded 13 dB. ***Figure 9*** compares the simulated and measured PAE, gain and output power with 28 dBm input power over the two operating bands. ***Table 2*** summarizes this performance, comparing it with similar published results.

CONCLUSION

For a dual-band PA, a resistive third harmonic continuous inverse class F mode design provides a resistive third harmonic component to the complex fundamental impedance, solving the conflict when

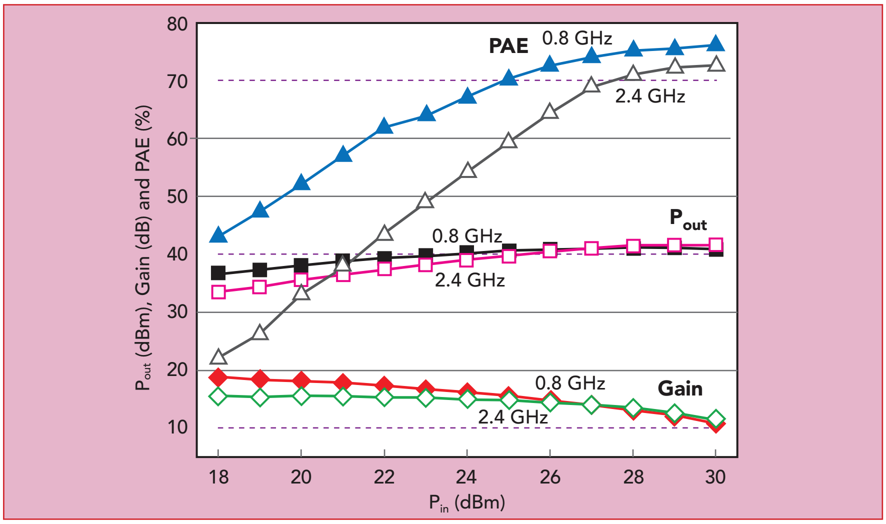


Fig. 8 Measured P_{out}, PAE and gain vs. P_{in} at 0.8 and 2.4 GHz.

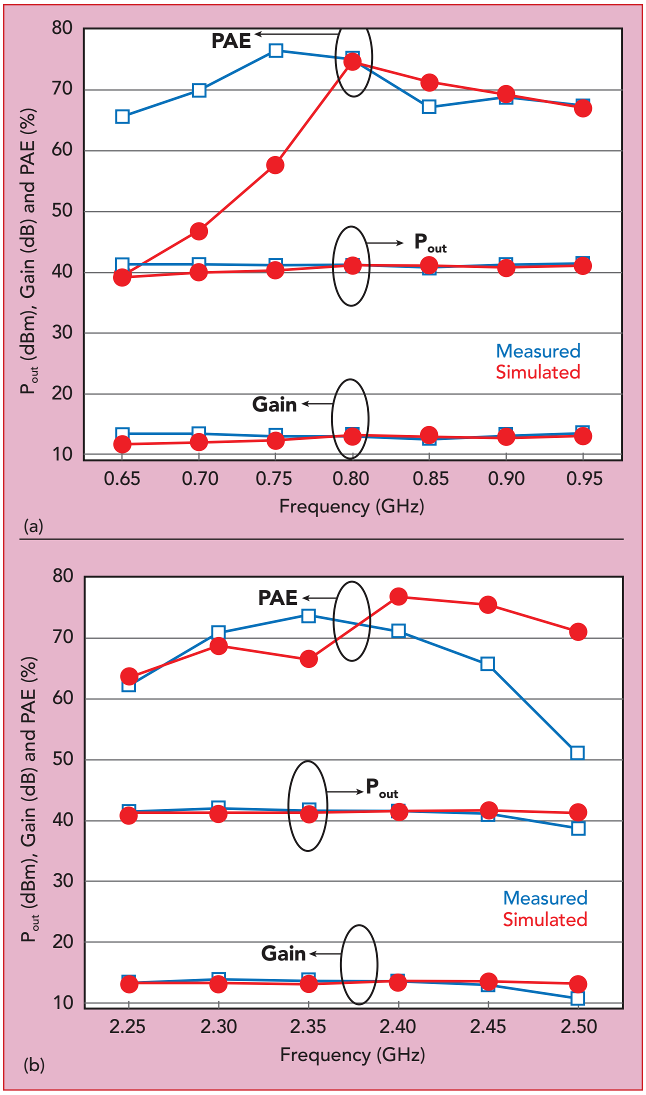


Fig. 9 Measured vs. simulated P_{out}, PAE and gain vs. frequency in the lower (a) and upper (b) bands.

TABLE 2

COMPARISON WITH PREVIOUS WORK

Reference	Frequency (GHz)	P_{out} (dBm)	Gain (dB)	PAE (%)
2	0.8, 1.25	40.6, 41.8	N/A	81.7, 80
3	1.9, 2.6	41.1, 40.8	10, 10	72, 66
6	1.8, 2.4	43, 43	10, 9	64, 54
This Work	0.8, 2.4	41, 41.4	13, 13.4	75, 71

two operating frequencies f_1 and f_2 meet the condition $3f_1 = f_2$. An efficient dual-band PA was simulated, built and measured, demonstrating the validity of this approach.■

ACKNOWLEDGMENTS

This work was supported by China Scholarship Council, the National Natural Science Foundation of China (61001012) and Teaching Research Project of Huazhong University of Science and Technology (15027).

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

10:10 – 10:40 **Coffee Break**

10:40 – 13:00 **Challenges in Satellite Constellations and Impact on Communications Technologies**

13:00 – 14:00 **Strategy Analytics Lunch & Learn Session**
Global Satellite Market Outlook
Asif Anwar, Strategy Analytics, UK

14:10 – 15:50 ***Microwave Journal* Industry Session**
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- New Generation of GaN MMICs for SATCOM and Electronic Warfare from X- to Ka-Band Cédric Corrége, **OMMIC**

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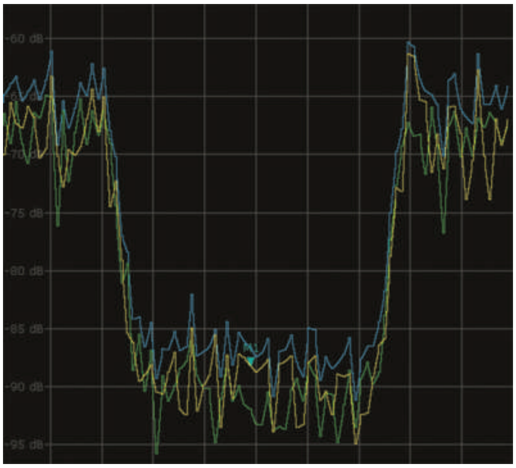

Easy Measurement of Radar Pulse Stability

Rohde & Schwarz
Munich, Germany

Radars not only receive echoes from the targets they detect, they receive echoes from surrounding objects such as trees, buildings and ocean waves. These incidental echoes, known as clutter, are of no interest and can impair radar performance. Signal processing in advanced radar systems detects and suppresses these unwanted reflections, by comparing the phases and amplitudes of successive echoes and displaying only moving targets, for example. The greater the phase and amplitude stability of the transmitted pulses, the better the results from signal processing. With high quality radar signals, any phase and amplitude variation can be assumed to be from the target, not from any instabilities in the transmitter. Thus, knowing the phase and amplitude stability of the transmitted pulses is crucial to assessing the sensitivity of a radar system to detect targets with a very small radar cross section, such as micro aerial vehicles. Power amplifiers (PA), in particular, can degrade stability, making precise measurement of the PA necessary to determine overall system sensitivity.

Fig. 1 The R&S FSWP phase noise analyzer feeds a pulsed signal to an amplifier, then analyzes the amplifier's output.

COMPLEX MEASUREMENT, SIMPLE SETUP

Historically, high sensitivity measurements of the phase and amplitude stability of pulses required a complicated test setup with multiple instruments. A new option for the Rohde & Schwarz FSWP phase noise analyzer and VCO tester makes these measurements easy and straightforward. The R&S FSWP-K6P option is an enhancement to the R&S FSWP-K6 pulse measurement option, specifically intended to characterize pulse stability. The R&S FSWP-K6P option uses the FSWP hardware, which was designed with very low phase noise, capable of measuring phase and amplitude stability with higher sensitivity than a spectrum analyzer.

The R&S FSWP can generate pulses like a radar system, which feed the amplifier or other device being tested. The amplifier output is connected back to the R&S FSWP, which analyzes the signal. For this complex and highly sensitive measurement, the test setup could not be any simpler, as seen in ***Figure 1***.

THEORY

Since the phase noise of the local oscillator in the R&S FSWP and the generated pulses are identical or correlated, the phase noise can be suppressed, leaving only the phase change caused by the device being tested. This residual measurement has a sensitivity of less than −80 dB for pulse-to-pulse phase and amplitude stability. If the source in the R&S FSWP is not adequate for the application, the R&S FSWP offers users the flexibility to insert an external source as a local oscillator for the measurement.

The dB values for phase stability are calculated from the equation:

$$\text{Phase Stability} = 10\log\left[\frac{1}{N-1}\sum_{i=1}^{N-1}\left(\theta_{i+1}-\theta_i\right)^2\right]$$

where θ_i is the phase at the sampling point of the ith of N pulses. An average pulse-to-pulse phase deviation on the order of 0.1 mrad corresponds to –80 dB. A similar calculation applies to amplitude stability.

Typical radar applications do not use simple pulses; they employ bursts or complex pulse sequences (see ***Figure 2***). Consequently, burst signals are required to accurately test radar components, since components will heat up during the "on" portion of the burst signal, and this has a strong effect on the phase and amplitude stability. The R&S FSWP can generate pulse sequences and bursts, so the results reflect the performance of the device being tested under actual radar operation.

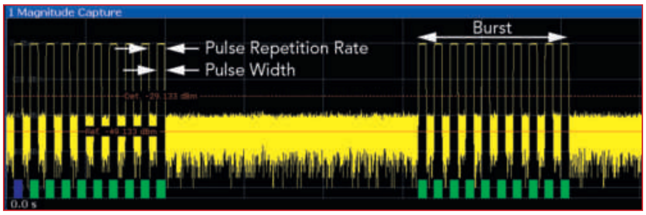

Fig. 2 **The burst signal consists of 10 pulses followed by a pause.**

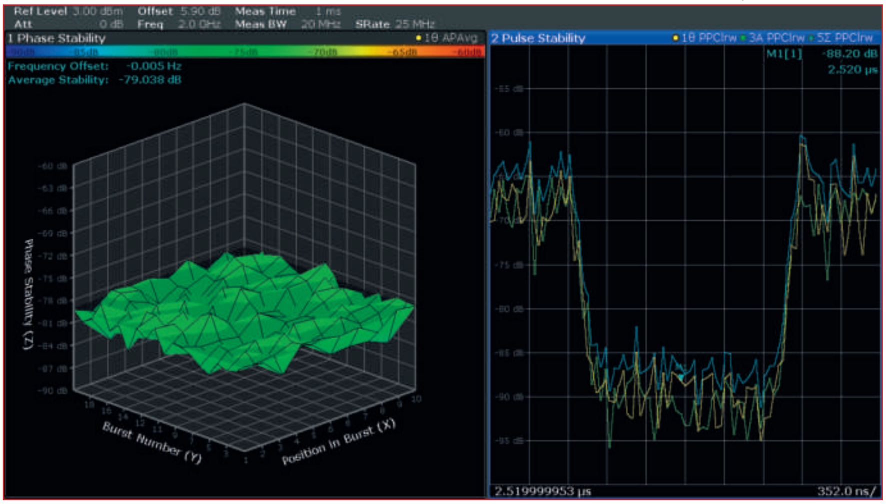

Fig. 3 **Phase deviation from the average of each pulse for all recorded bursts (left). Pulse-to-pulse phase stability (yellow), amplitude stability (green) and sum of the two (blue) averaged over all pulses (right).**

OUTPUT PRESENTATION

With the R&S FSWP-K6P option, users choose whether to make measurements using the broadband spectrum analyzer or the more sensitive phase noise tester. With the latter, users can either measure the pulsed signal directly or employ the residual test mode using internally generated pulses to stimulate the device being tested.

Phase and amplitude stability can be displayed for each individual pulse, with the deviation from the average at each sampling point in a pulse calculated and displayed. The R&S FSWP can average the values over an entire burst or calculate the difference between pulses, delivering pulse-to-pulse phase and amplitude stability. Both of these averaging techniques produce smoother, more instructive traces (see ***Figure 3***).

The better the amplitude and phase stability within a radar pulse, the more information a radar system can extract from the received signal. Making stability measurements with the required level of sensitivity used to be complex and costly. With the new option for the R&S FSWP phase noise analyzer and VCO tester, these measurements become easy and straightforward.

VENDORVIEW

Rohde & Schwarz
Munich, Germany
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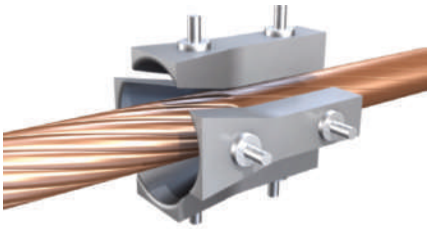

Rotary Swaging Combines Low Loss with High Flexibility

HUBER+SUHNER AG
Herisau, Switzerland

Most coaxial cables on the market have either a solid or stranded inner conductor, making the selection of a cable assembly a trade-off between lower loss (choosing the solid wire) or flexibility and phase stability (choosing the stranded wire).

A stranded wire cable assembly has higher attenuation compared to solid wire. Well known as the skin effect, the signal only flows in the outermost few microns of the inner conductor, so the signal path in the stranded conductor is longer than in the solid wire. This behavior is more pronounced with microwave signals than at low frequency. Also, the greater contact resistances between the individual strands contribute to higher loss.

On the other hand, microwave cables with solid wire have greater phase deflection with bending than cables with stranded wires, particularly for cable types with a dielectric diameter greater than 2 mm. This effect is caused by interaction among the various elements of the cable. The cable length is reduced slightly when bent, which deforms the inner conductor and results in a phase shift. To plastically deform the individual wires of a strand, a stronger bending movement is required. Alternatively, the same bending of the two cable types yields smaller changes in length and a more stable phase in the stranded microwave cable.

TWO-IN-ONE

To resolve this either/or trade-off, HUBER+SUHNER has combined the advantages of the solid and stranded wire assemblies into one product, a two-in-one cable assembly with a flexible inner conductor that is low loss and phase stable. HUBER+SUHNER has achieved this with a unique and patented rotary swaging technology, combining the advantages of solid and stranded wires in the SUCOFLEX 500 family. The latest addition to the family is the SUCOFLEX 550S, which has excellent performance to 50 GHz.

Rotary swaging is a process of mechanical deformation, guaranteeing a near-perfect round and smooth surface (see ***Figure 1***). It is achieved through repeated blows to a conventional strand, using automated "hammers" to smooth the surface of the stranded wire. The smooth surface prevents possible discontinuities in the microwave cable, reducing return loss peaks. Conventional stranded wire has a structure susceptible to return loss peaks, caused by variations in diameter that change the impedance of the cable and reflect a portion of the microwave signal. Discontinuities occurring at a regular interval will cause a strong reflection or return loss peak at a certain frequency. The rotary swaged stranded wire eliminates this possibility, mimicking the signal path of the solid wire and improving the return loss (see

Fig. 1 **Inner conductor before and after swaging.**

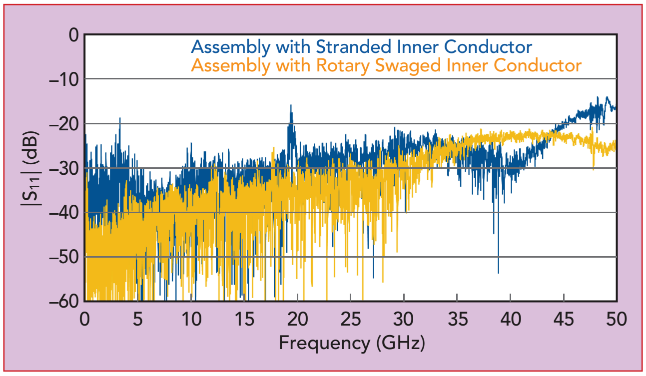

Fig. 2 **$|S_{11}|$ comparison between cable assemblies with a stranded inner conductor and a rotary swaged inner conductor.**

Figure 2). Also, the contact resistance is lower compared to a conventional, true concentric stranded wire, which reduces insertion loss.

Developed in Switzerland, the rotary swaging technology provides the longest assembly/cable lifetime currently available on the market at an excellent price-performance ratio. Typically, cables with solid wire will break after 10,000 to 20,000 flex cycles, but all SUCOFLEX 500 assemblies will withstand more than 100,000 flexures without degrading performance. They are designed to withstand abrasion, pressure and moisture.

The SUCOFLEX 550S is well-suited for test & measurement applications, including benchtop, high throughput production testing and vector network analyzer measurements to 50 GHz (see ***Figure 3***). For test & measurement applications, the SUCOFLEX 500 assemblies deliver the best phase and amplitude stability versus flexure, movement, temperature and tensile stress—with outstanding return loss and insertion loss to 50 GHz.

Fig. 3 **The SUCOFLEX 550S is well-suited for vector network analyzer measurements to 50 GHz.**

The SUCOFLEX 550 family supports customers who need affordable, customized assemblies with short delivery times. HUBER+SUHNER supplies all standard-length products within five working days and customized lengths within 10 working days, worldwide.

Other products in the HUBER+SUHNER portfolio use swaging technology, including the SUCOFLEX 100 series, flexible microwave cable assemblies with superior electrical and mechanical performance for static and dynamic applications, and the Spuma RS FR, the most flexible cable in the Spuma family, featuring a new TPU jacket material which is flame retardant without compromising flexibility.

Cable selection is no longer a trade-off. Unique in the market, the patented rotary swaging technology reflects HUBER+SUHNER's innovative leadership in the industry.

VENDOR**VIEW**

HUBER+SUHNER AG
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Bits to Beams: Chipset for 5G mmWave Radio

Analog Devices Inc.
Norwood, Mass.

The 5G market is undergoing a rapid transformation as networks and commercial services are deployed. mmWave spectrum will be indispensable, given the large swaths of contiguous bandwidth to support high capacity, with low latency and dense spatial re-use. Trials have culminated in the first commercial offerings, and regulatory agencies are adding even more spectrum from 24 to above 40 GHz.

Active antenna arrays and beamforming underpin the mmWave 5G architecture, enabling spatial re-use and helping overcome the high path loss at mmWave frequencies. This technology provides flexibility with the system design, to address urban and suburban use cases such as small cells, fixed wireless access and macro base stations, each requiring different equivalent isotropically radiated power (EIRP), mobility, interference tolerance and beam steering range. One common aspect for all use cases is that active antenna arrays require many antenna elements, from 16 to 1024 elements depending on the deployment scenario. They can be split into vertical and horizontal polarizations to transmit different sets of data to different users or to improve the link margin when serving a single user. Integrating more channels into a beamforming system is necessary to reduce the cost, power and board area of these systems, particularly as volumes grow.

As with each generational shift in mobile networks, operators are demanding the optimal cost/performance trade-off. In this environment, semiconductor suppliers capable of offering a cost-effective, end-to-end solution will play a crucial role in commercial, high volume 5G deployment and achieving the implementation cost, board area, system power and time-to-market goals. A complete system offering eases system-level optimization and calibration, freeing equipment manufacturers to focus on system performance, rather than having to optimize a multi-vendor lineup at the component level. A complete solution simplifies the radio manufacturer's supply chain.

For hybrid beamforming architectures, as shown in ***Figure 1***, Analog Devices' "bits to beams" mmWave lineup provides a system-level offering encompassing the entire

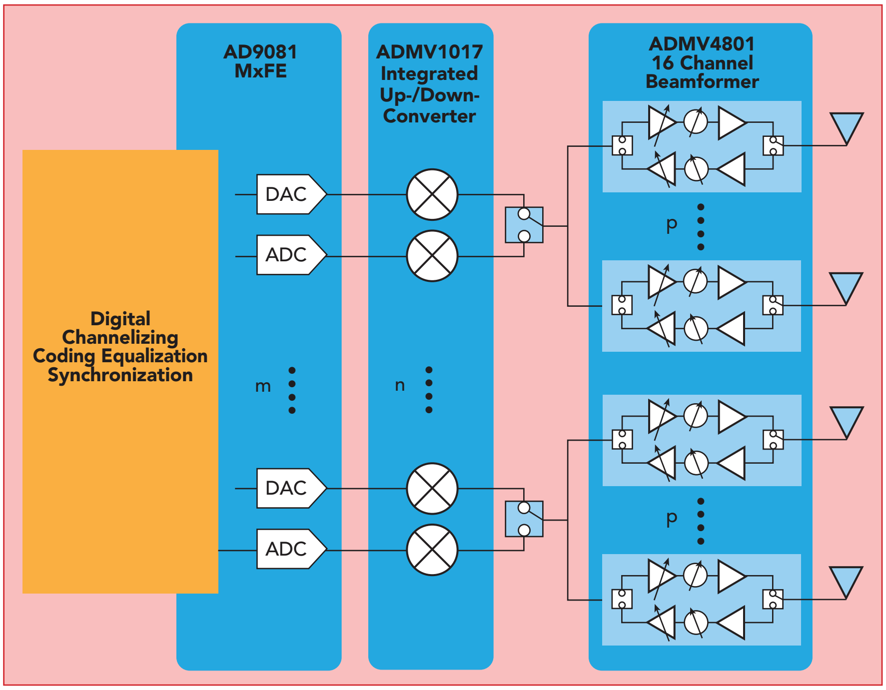

Fig. 1 Hybrid beamforming signal chain.

chain of digital, mixed-signal, IF and mmWave functionality—ending at the antenna array. Covering 24 to 30 GHz, ADI's chipset comprises a 16-channel dual/single polarization beamformer IC (ADMV4821), 16-channel single polarization beamformer IC (ADMV4801), mmWave up-/down-converter (ADMV1017) and the MxFE™ RF data converter platform (AD9081 and AD9082). This chipset offers the highest integration, supporting the n257, n258 and n261 bands with a single footprint for each function.

For maximum flexibility in the field, where dynamic adjustment to beam shape is critical, the beamformers feature a fast switching mode and beam storage. The MxFE, up-/down-converter and beamformer chipset is 3GPP compliant, providing best-in-class EIRP and error vector magnitude, tested using 5G New Radio (NR) waveforms with 64- to 256-QAM modulation. The closely coupled designs of the up-/down-converter and beamformers enable array calibration to optimize the beam profile to meet stringent use cases in the field. The dual-polarization beamformers address an emerging customer requirement for a single small, power efficient and low-cost active antenna system, rather than using two, single polarization arrays.

The up-/down-converter provides a range of IF options, i.e., either zero IF or one between 3 and 10 GHz. The MxFE data converters have high dynamic range and instantaneous channel bandwidths to 1.2 GHz to support multi-band architectures. Time-division duplex duty cycle modes enable the sharing of the receive path between traffic data and antenna array calibration steps, while maintaining phase coherency. Multi-chip synchronization ensures data timing alignment across multiple antenna arrays.

Integrating 16 channels simplifies the complexity of the mmWave radio design, leaving room for other components on the back of the antenna array. It reduces chip-to-chip variation for a given array size, reducing the component count from 2 to 4× compared to four or eight channel RFICs. As ADI demonstrated at the 2019 International Microwave Symposium (IMS), random amplitude variations up to ±1 dB and random phase variations up to ±10 degrees do not appreciably degrade the sidelobe level or beam gain at boresight and, therefore, the array does not need calibration (see ***Figures 2*** and ***3***).

Larger array sizes, such as 256 elements, are being designed to transmit a single beam using all the elements or four simultane-

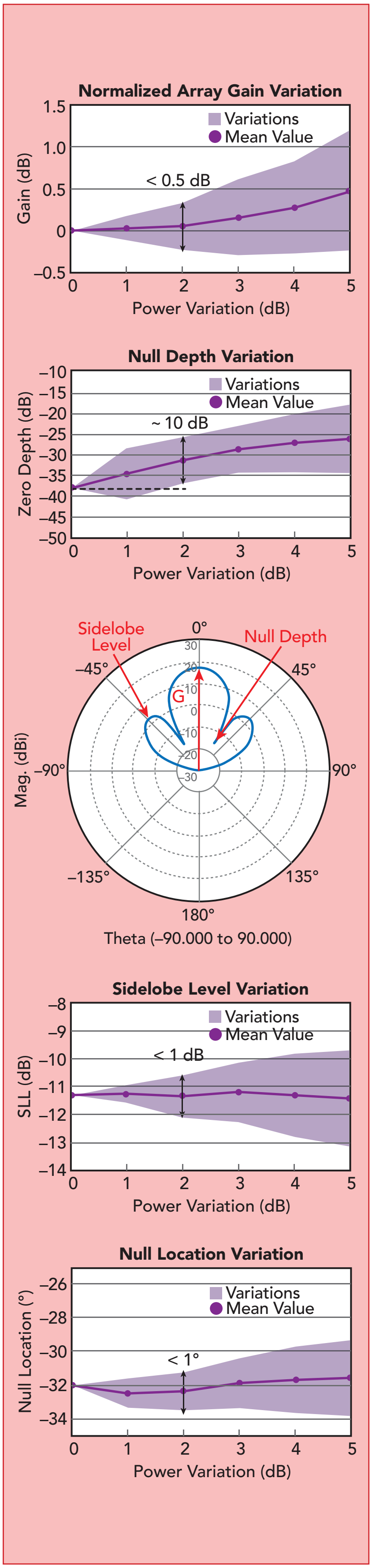

Fig. 2 Effect of random element gain variation on beam shape.

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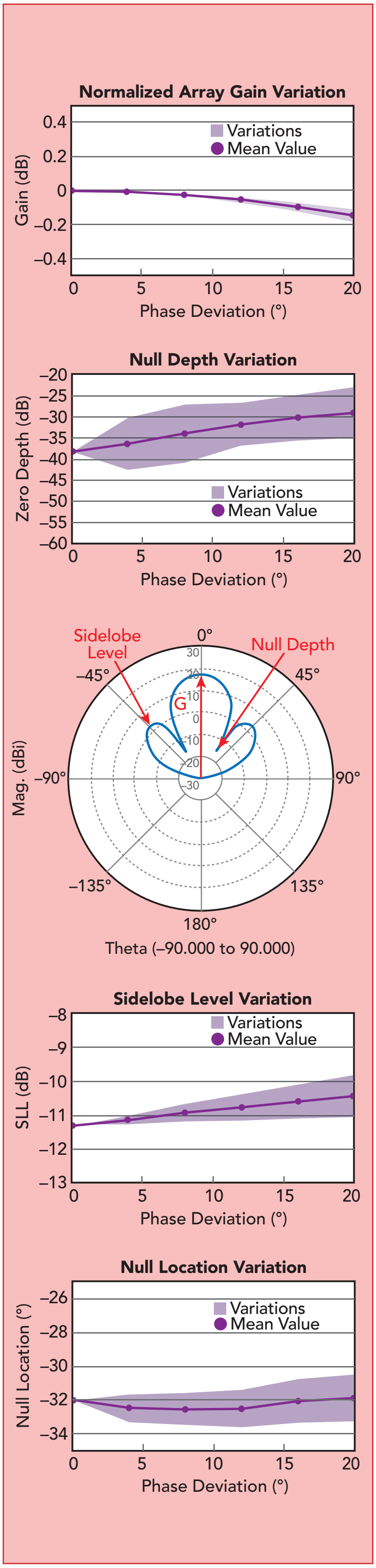

Fig. 3 Effect of random element phase variation on beam shape.

ous beams, each with 64 elements. When the subarrays are combined to serve a single user, phase variation among the subarrays greater than 5 degrees will require the subarrays be calibrated. ***Figure 4*** shows an example where a ±20 degree phase differences among the subarrays degrades the antenna gain

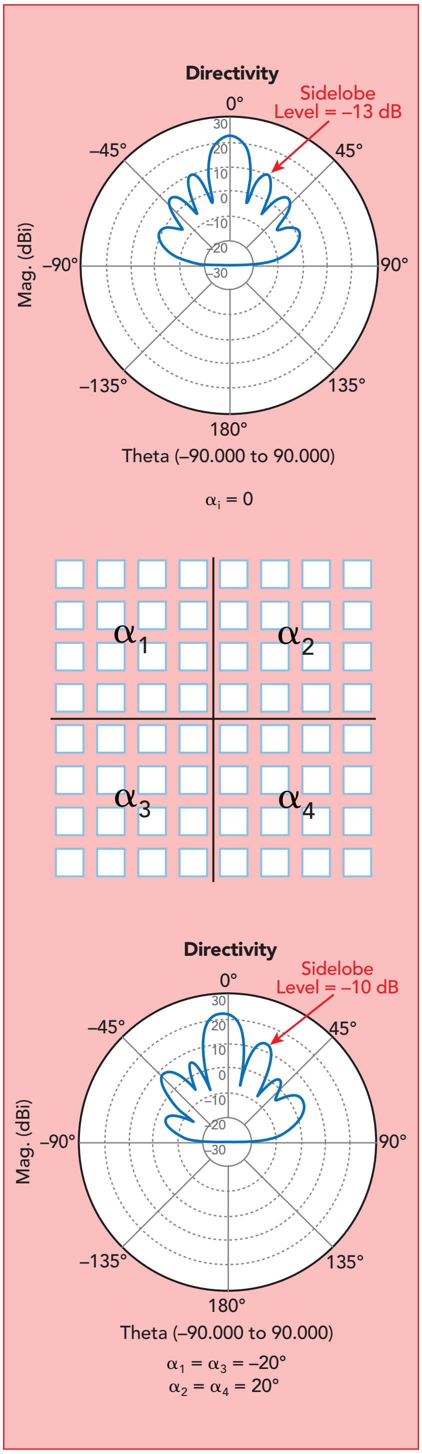

Fig. 4 Phase variation among subarrays will degrade gain and sidelobes.

by 0.5 dB and the sidelobe level by 3 dB. This is a practical concern, which has been identified with 256 element arrays currently deployed. Higher sidelobe levels increase the probability of interference, which will reduce the maximum cell density in a network. Decreased gain reduces a radio's range, which will increase the cost to cover a given area.

HIGHEST INTEGRATION

Given mmWave IC design challenges, the industry has generally not developed beamformers with more than four or eight channels. However, lower density beamformers shift design complexity to the customer: added high frequency routing, supply and control signaling and operational inefficiencies related to a more complex supply chain. ADI's heritage in mmWave technology offers world-class system design expertise and applications support, helping customers optimize the system RF, thermal, power and signal routing.

The adoption of mmWave for 5G active antenna arrays with stringent high volume cost requirements will accelerate as early commercial deployments ramp into production and 5G becomes integral to the consumer's life. This technology will be foundational to provide ubiquitous, secure, high capacity connectivity at a low cost-per-bit. Continuing innovations will enable advanced signal processing functions to be integrated into the chipset. ADI recently demonstrated an antenna-in-package design incorporating the entire mmWave front-end in a single 20 mm × 20 mm surface-mount IC. This broadband, high density packaging IP is compatible with all relevant silicon process technologies, supporting the integration of digital processing such as crest factor reduction, digital predistortion and array calibration.

VENDORVIEW

Analog Devices Inc.
Norwood, Mass.
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- European Radar Conference (EuRAD) 2nd - 4th October 2019
- Plus Workshops and Short Courses (From 29th September 2019)
- In addition, EuMW 2019 will include, for the 10th year, the Defence, Security and Space Forum on 2nd October 2019 and for the first time the Automotive Forum on 30th September 2019.

The three conferences specifically target ground breaking innovation in microwave research. The presentations cover the latest trends in the field, driven by industry roadmaps. The result is three superb conferences created from the very best papers submitted. For the full conference programme including a detailed description of the conferences, workshops and short Courses, please visit **www.eumweek.com**. There you will also find details of our Partner Programme and other Social Events during the week.

FAST TRACK BADGE RETRIEVAL

Register online and print out your badge in seconds onsite at the Fast Track Check In Desk

CONFERENCE PRICES

There are TWO different rates available for the EuMW conferences:

- **ADVANCE DISCOUNTED RATE** – for all registrations up to and including 30th August 2019
- **STANDARD RATE** – for all registrations made after 30th August 2019

Please see the Conference Registration Rates table on the back page for complete pricing information. All payments must be in Euro – cards will be debited in Euro.

Online registration is open now, up to and during the event until 4th October 2019

DELEGATES

Registering for the Conference

- Register online at **www.eumweek.com**
- Receive an email receipt with barcode
- Bring your email, barcode and photo ID with you to the event
- Go to the Fast Track Check In Desk and print out your delegate badge
- Alternatively, you can register onsite at the self service terminals during the registration opening times below:

  - Saturday 28th September (16:00 - 19:00)
  - Sunday 29th September - Thursday 3rd October (08:00 - 17:00)
  - Friday 4th October (08:00 - 10.00)

Once you have collected your badge, you can collect the conference proceedings on USB stick and delegate bag for the conferences from the specified delegate bag area by scanning your badge.

CONFERENCE REGISTRATION INFORMATION

EUROPEAN MICROWAVE WEEK 2019, 29th September - 4th October, Paris, France

Register Online at www.eumweek.com

ALL FEES ARE INCLUSIVE OF FRENCH VAT @ 20%

ONLINE registration is open from 28th May 2019 up to and during the event until 4th October 2019.

ONSITE registration is open from 16:00 on 28th September 2019.

ADVANCE DISCOUNTED RATE (up to and including 30th August) STANDARD RATE (from 31st August & Onsite).

Reduced rates are offered if you have society membership to any of the following*: Eu*MA*, GAAS, IET or IEEE.

Eu*MA* membership fees: Professional € 25/year, Student € 15/year.

If you register for membership through the EuMW registration system, you will automatically be entitled to discounted member rates.

Reduced Rates for the conferences are also offered if you are a Student/Senior (Full-time students 30 years or younger and Seniors 65 or older as of 4th October 2019). The fees shown below are invoiced in the name and on behalf of the European Microwave Association. Eu*MA*'s supplies of attendance fees in respect of the European Microwave Week 2019 are inclusive of French VAT.

ADVANCE REGISTRATION CONFERENCE FEES (UP TO AND INCLUDING 30TH AUG.)

CONFERENCE FEES	ADVANCE DISCOUNTED RATE			
	Society Member (*any of above)		Non Member	
1 Conference	Standard	Student/Sr.	Standard	Student/Sr.
EuMC	€ 470	€ 130	€ 660	€ 190
EuMIC	€ 360	€ 120	€ 510	€ 170
EuRAD	€ 320	€ 110	€ 450	€ 160
2 Conferences				
EuMC + EuMIC	€ 670	€ 250	€ 940	€ 360
EuMC + EuRAD	€ 640	€ 240	€ 890	€ 350
EuMIC + EuRAD	€ 550	€ 230	€ 770	€ 330
3 Conferences				
EuMC + EuMIC + EuRAD	€ 810	€ 360	€ 1140	€ 520

STANDARD REGISTRATION CONFERENCE FEES (FROM 31ST AUG. AND ONSITE)

CONFERENCE FEES	STANDARD RATE			
	Society Member (*any of above)		Non Member	
1 Conference	Standard	Student/Sr.	Standard	Student/Sr.
EuMC	€ 660	€ 190	€ 930	€ 270
EuMIC	€ 510	€ 170	€ 720	€ 240
EuRAD	€ 450	€ 160	€ 630	€ 230
2 Conferences				
EuMC + EuMIC	€ 940	€ 360	€ 1320	€ 510
EuMC + EuRAD	€ 890	€ 350	€ 1250	€ 500
EuMIC + EuRAD	€ 770	€ 330	€ 1080	€ 470
3 Conferences				
EuMC + EuMIC + EuRAD	€ 1140	€ 520	€ 1600	€ 740

WORKSHOP AND SHORT COURSE FEES (ONE STANDARD RATE THROUGHOUT)

FEES	STANDARD RATE			
	Society Member (*any of above)		Non Member	
	Standard	Student/Sr.	Standard	Student/Sr.
Half day WITH Conference registration	€ 100	€ 80	€ 130	€ 100
Half day WITHOUT Conference registration	€ 130	€ 100	€ 170	€ 130
Full day WITH Conference registration	€ 140	€ 110	€ 180	€ 130
Full day WITHOUT Conference registration	€ 180	€ 140	€ 240	€ 170

SPECIAL FORUM FEES

	ADVANCED RATE (UP TO & INCL 30TH AUG)	
Automotive Forum Monday 30th September	€ 260 For Delegates (those registered for EuMC, EuMIC or EuRAD)	€ 360 For All Others (those not registered for a conference)
	STANDARD RATE (FROM 31ST AUG & ONSITE)	
	€ 320 For Delegates (those registered for EuMC, EuMIC or EuRAD)	€ 420 For All Others (those not registered for a conference)
	ONE STANDARD RATE THROUGHOUT	
Defence, Security and Space Forum Wednesday 2nd October	€ 20 For Delegates (those registered for EuMC, EuMIC or EuRAD)	€ 60 For All Others (those not registered for a conference)

EUROPEAN MICROWAVE WEEK WORKSHOPS & SHORT COURSES

SUNDAY 29th September		
Full Day	WS-01	EuMC/EuMiC
Full Day	WS-02	EuMC/EuMiC
Full Day	WS-03	EuMC
Full Day	WS-04	EuMC
Full Day	WS-05	EuMC
Half Day AM	WS-06	EuMC
Half Day PM	WS-07	EuMC
Full Day	WS-08	EuMC/EuMiC
Full Day	WS-09	EuMC
Full Day	SS-01	EuMC
Half Day AM	SS-02	EuMC/EuMiC

THURSDAY 3rd October		
Half Day AM	WTh-01	EuRAD
Full Day	WTh-02	EuMC/EuRAD

MONDAY 30th September		
Half Day AM	WM-01	EuMC/EuMiC
Half Day PM	WM-02	EuMC
Full Day	WM-03	EuMC
Full Day	WM-04	EuMC/EuMiC
Full Day	WM-05	EuMC
Full Day	WM-06	EuMC
Half Day AM	WM-07	EuMC
Half Day PM	WM-08	EuMC
Half Day AM	WM-09	EuMC/EuMiC
Half Day PM	SM-01	EuMC

TUESDAY 1st October		
Half Day AM	STu-01	EuMC

WEDNESDAY 2nd October		
Full Day	WW-01	EuRAD
Full Day	WM-02	EuRAD

FRIDAY 4th October		
Half Day AM	WF-01	EuRAD
Full Day	WF-02	EuMC
Half Day AM	SF-01	EuRAD

OTHER ITEMS

Proceedings on USB Stick

All papers published for presentation at each conference will be on a USB stick, given out FREE with the delegate bags to those attending conferences. The cost for an additional USB stick is € 50.

Partner Programme and Social Events

Full details and contacts for the Partner Programme and other Social Events can be obtained via the EuMW website www.eumweek.com.

SPECIAL SESSIONS

Date	Time	Title	Location	No. of Days	Fee
Tuesday 1st October and Wednesday 2nd October	08:30 - 17:50	European Microwave Student School	Room 746 - Tuesday Booth by Reg. Desk - Wednesday	1 full day & 2 half-days	€ 40
Tuesday 1st October and Wednesday 2nd October	13:50 - 17:50 Tuesday 09:00 - 17:50 Wednesday	European Microwave Doctoral School	Room 741BC - Tuesday Booth by Reg. Desk - Wednesday	1 half-day & 2 half-days	€ 80

100 kHz to 18 GHz Programmable Integer Frequency Divider

For test & measurement applications, Guzik Technical Enterprises offers a broadband, programmable frequency divider, the G1182. The divider has an input frequency range from 100 kHz to 18 GHz, with an output frequency equal to the input divided by an integer between 1 and 65,536. The wide range is achieved by cascading two 256 dividers, which are set from the front panel of the rack-mountable or desktop housing or via a USB interface on the back of the unit. A 5-segment LED display on the front panel shows the division ratio. Because the two 256 dividers are cascaded, not all values in the 65,536 range are possible—for example, ratios divisible by a prime number greater than 256. In such cases, the microcontroller skips these values.

The divider achieves low jitter and phase noise: the phase noise at 1 kHz offset from an input 13.3 GHz carrier divided by 14 typically measures −131 dBc/Hz. The spurious-free dynamic range is better than 75 dBc compared to the output.

The G1182 provides four SMA outputs configured as two "differential" pairs (i.e., channel 1 ± and channel 2 ±). Each output provides 0.5 V peak-to-peak into a 50 Ω load with a 50 percent duty cycle for any division ratio. The input is similarly configured as a "differential" pair with two SMA connectors, accepting a signal from −6 to +10 dBm. Any unused inputs and outputs should be terminated with 50 Ω loads for best performance.

The divider uses an external 12 V power supply, which is supplied with a 2 m connecting cable. Power consumption is typically 9 W. The G1182 is designed to operate from 0°C to 50°C. The size of the unit is 8.3 in. wide, 4.6 in. deep and 1.66 in. high.

Guzik Technical Enterprises
Mountain View, Calif.
www.guzik.com

1 MHz to 18 GHz SMT Balun with Tight Matching

HYPERLABS has developed a surface-mount, ultra-broadband balun covering 1 MHz to 18 GHz with exceptional phase and amplitude matching. The inverting and non-inverting outputs of the model HL9491 are amplitude matched within ±0.25 dB over the full operating band and phase matched within ±5 degrees of 180 degrees at 10 GHz. This performance makes the HL9491 the leader among broadband surface-mount baluns.

This new balun is compact, designed to fit within a board footprint of 1.1 in × 0.2 in. × 0.2 in. The HL9491 has an operating temperature range of −40°C to +85°C and will withstand an input power of +30 dBm.

Similar to other baluns in HYPERLABS' ultra-broadband coaxial portfolio, the HL9491 design uses high frequency lossy transmission lines and lower band ferrite beads to provide flat frequency response. The proprietary launch design has a bandwidth well over 25 GHz—measured—which enables the coaxial balun to be implemented as a surface-mount component. The HL9491 is available on an evaluation board with a calibration standard, enabling the user to de-embed the PCB.

The balun is well-suited to drive a wide array of high frequency analog-to-digital converters (ADC). The small, narrow footprint supports multi-channel ADCs or other multi-lane systems that require differential drive.

Founded in 1992 and privately owned, HYPERLABS develops ultra-broadband components, including power splitters, matched pickoff tees and samplers, including harmonic mixers. The company was the first to develop and offer time-domain reflectometry (TDR) instruments, controlled impedance analyzers and signal path analyzers using USB for control and power.

HYPERLABS Inc.
Beaverton, Ore.
www.hyperlabsinc.com

Full Band Waveguide Power Amplifiers

With the launch of 5G mmWave technologies and the start of 6G research activities, there is a growing need for frequency generation at the higher mmWave and lower THz frequencies. Adding to that growth is the commercialization of space creating more demand for high frequency sensing and communication systems. In order to meet these needs, Virginia Diodes (VDI) has released full band waveguide power amplifiers for WR12 (60 to 90 GHz) to WR4.3 (170 to 260 GHz). All amplifiers have high gain and saturated output power with single voltage bias.

VDI Model WR12AMP covers 60 to 90 GHz with typical gain of 21 dB, typical saturated output power of 21 dBm and output P1dB of 17 dBm. Typical input and output return loss is 10 dB with bias voltage of 9 ± 1 V and typical current of 150 mA.

VDI Model WR10AMP covers 75 to 110 GHz with typical gain of 21 dB, typical saturated output power of 20 dBm and output P1dB of 17 dBm. Typical input and output return loss is 10 dB with bias voltage of 9 ± 1 V and typical current of 150 mA.

VDI Model WR6.5AMP covers 110 to 170 GHz with typical gain of 22 dB, typical saturated output power of 18 dBm and output P1dB of 10 dBm. Typical input and output return loss is 10 dB with bias voltage of 9 ± 1 V and typical current of 200 mA.

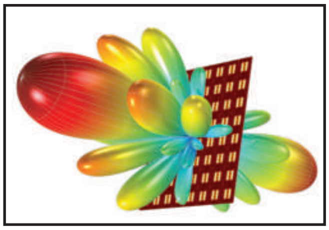
VDI Model WR4.3AMP covers 170 to 260 GHz with typical gain of 25 dB, typical saturated output power of 16 dBm and output P1dB of 10 dBm. Typical input return loss is 10 dB and output return loss 3 dB with bias voltage of 5 ± 0.5 V and typical current of 550 mA.

VDI is also developing a WR15 (50 to 75 GHz) power waveguide amplifier that will be available soon.

Virginia Diodes
Charlottesville, Va.
www.vadiodes.com

Software and Mobile Apps

COMSOL Multiphysics®



The RF Module, an add-on product to the COMSOL Multiphysics® simulation software, enables engineers to analyze RF, microwave, mmWave and THz designs in multiphysics scenarios. The COMSOL® software includes Application Libraries featuring a variety of antenna examples. The RF Module allows for the computation of antenna impedance matching, far-field radiation pattern, gain and directivity; and can be extended to include other physics phenomena, such as structural deformation induced by temperature change.

COMSOL Inc.
www.comsol.com/rf-module

On-Line Filter Synthesis Tool

K&L Microwave's Filter Wizard® filter synthesis and selection tool streamlines identification of filter products meeting customer specifications across a large portion of K&L's standard product offerings. Filter Wizard® accelerates user progress from specification to RFQ for RF and microwave filters spanning an ever-increasing range of response types, bandwidths and unloaded Q values. Provide the application with your desired specifications, and the software will return a list of products that match, placing response graphs, outline drawings and downloadable S-parameters at your fingertips. Visit their website to get started today.

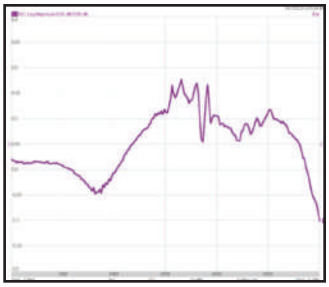
K&L Microwave
www.klfilterwizard.com

SPIKE Spectrum Analyzer Software

IoT is accelerating the need for connectivity to a wide range of applications. WLAN and Bluetooth are positioned to capture large portions of this market. WLAN standards are being expanded to address higher data rates, transmit range and battery efficiency. Signal Hound's SPIKE spectrum analyzer software now includes specialized WLAN modulation analysis features. This capability is designed for making physical layer measurements on WLAN transmitting devices, providing RF metrics to accurately evaluate your signal performance and quality.

Signal Hound
www.signalhound.com/WLAN

CMT VNA Software



Copper Mountain Technologies' VNA software is available for Linux OS, specifically Ubuntu and Mint. The CMT VNA software for Linux includes all the same features as the company's VNA software for Windows. Any CMT VNA can now operate in a Linux environment, whether it is controlled manually or its operation is automated using SCPI commands via TCP/IP sockets. HiSlip interface uses the same SCPI command set and further allows for instrument discovery and automation through the Visa library of your choice.

Copper Mountain Technologies (CMT)
https://coppermountaintech.com

MCL Microwave Calculator App

VENDORVIEW

The MCL Microwave Calculator, developed by Mini-Circuits, performs 21 calculations commonly needed by RF and microwave system designers in a wide range of applications. Quickly compute the effect of VSWR or return loss on transmitted power; cascaded gain and noise figure for up to five amplifier stages; and power-to-voltage conversion. It is the perfect tool to help you solve problems and save time, whether you are working in the lab or in the field.

Mini-Circuits
www.minicircuits.com/applications/microwave_calculator.html

Designing RF Cables Easily Online

Do you want to assemble RF cables with coaxial connectors individually and add cable cover, labelling and cable length according to your requirements? Then the COAX configurator developed by Telegärtner is just what you need. It is available 24 hours a day, allowing you to compile complex configurations with just a few clicks, and provides you with exactly the information you need to create your individual product. Visit the company's website to find out more.

Telegärtner
www.telegaertner.com/en/service/tools/coax-configurator

NEW PRODUCTS

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FEATURING VENDORVIEW STOREFRONTS

Anokiwave

24/26 GHz Portfolio of Silicon ICs for 5G Networks

VENDORVIEW

The 24/26 GHz 5G band is here. Anokiwave's newest IC family in this band features full RF signal chain functionality that improves performance, reduces cost and provides digital functionality that simplifies the active antenna array design. The AWMF-0165 Tx/Rx Beamformer IC supports dual polarization architectures while adding new and enhanced features to make 3GPP compliant cutting-edge performance even easier while the AWMF-0170 up-/down-converter IC provides frequency conversion functionality and a x4 LO multiplier all integrated into a single IC.

www.anokiwave.com

COMTECH PST

Ultra-Wideband High-Power Solid-State RF Module

COMTECH PST introduces its ultra-wideband high-power solid-state RF module. Comtech's latest development continues to expand on its proven innovative integrated RF GaN power amplifier designs by further increasing the bandwidth and power density. Consistent with its planned technology development roadmap, Comtech introduces the latest GaN-based 4 to 18 GHz RF amplifier. This design is ideal for use in communication, EW and radar transmitter systems where space, cooling and power are limited. It is ideal for UAV/airborne, ground mobile, surface and shipboard applications.

www.comtechpst.com

Ducommun

Manual Coaxial Switches SPDT

Ducommun offers two types of single-pole-double-throw (SPDT) manual coaxial switches for all applications. Current options range from DC to 3 GHz up to 50 W (CW) of power. For additional information regarding Ducommun's manual coaxial switches, please contact a sales representative.

www.ducommun.com

Exceed Microwave

High-Power Coaxial Filters

VENDORVIEW

Exceed Microwave offers custom designed high-power coaxial filters with very low insertion loss and high frequency selectivity. Their filter model BPF-C-00101 has 0.15 dB insertion loss and handles 5 kW peak power. Exceed Microwave designs and manufactures custom, high performance passive waveguide and coaxial components for defense, space and commercial applications. The company's engineers work directly with customers to provide immediate response and the optimum solution.

www.exceedmicrowave.com

Fairview Microwave

Ultra-High Frequency Waveguide Antennas

VENDORVIEW

Fairview Microwave Inc., an Infinite Electronics brand, has unveiled a new line of waveguide antennas designed to address wireless communication applications covering 40 to 220 GHz bands including test & measurement, R&D, military/aerospace and experimental radar.

www.fairviewmicrowave.com

Integra Technologies

Fully-Matched X-Band GaN/SiC RF Power Transistors

Integra Technologies Inc. announces new X-Band power solutions addressing the increasingly challenging needs of the X-Band radar market for higher sensitivity, improved resolution, superior detection and smaller form factor. The IGT1112M90 operates instantaneously over a frequency range of 10.8 to 11.8 GHz, delivers a minimum peak output power of 90 W at 50 V drain bias voltage and 11 dB of gain, achieving 43 percent efficiency.

www.integratech.com

Kaelus

iPA Series Portable PIM Analyzer

VENDORVIEW

The iPA is the first battery-powered PIM Analyzer versatile enough to support multiple test scenarios, such as testing at the top of the tower, base of tower, rooftop and in-building for DAS systems. The iPA possesses an intuitive user interface that increases carrier efficiency while saving time and provides extensive reporting capabilities and fully configurable frequencies, powers and IM products while delivering one of the most rugged devices available withstanding rough field usage.

www.kaelus.com

Kratos General Microwave

X- & Ku-Band Solid-State Power Amplifiers

Kratos General Microwave's cutting-edge, field proven SSPAs are designed and built for the harshest environment conditions, including hostile temperatures, shock, vibration, moisture, altitudes and G-forces. The custom and off-the-shelf SSPAs in X- and Ku-Bands, utilize the latest GaN and GaAs technologies and provide high-power density in a compact footprint to meet critical space and weight requirements in high frequencies. All of their SSPAs can be supplied to meet the most stringent environmental requirements.

www.kratosmed.com

NewProducts

MECA Electronics Inc.

Right Angle SMA Inner DC Block

VENDORVIEW

MECA has expanded its family of RoHS compliant, DC Blocks to include Right Angle SMA model covering wireless band applications from 0.4 to 3 GHz. Typical VSWR 1.35:1 and 0.3 dB max insertion loss. Models also available in 7/16 DIN, SMA, N, BNC & TNC configurations with RF power ratings to 500 W (2.5 kW peak) and breakdown voltages to 2.5 kV making them ideal for eliminating unwanted DC voltages or surges to tower top amplifiers. Made in U.S. with 36-month warranty.

www.e-meca.com

Micro Lambda Wireless

MLBF-Series Bench Test Filters

The MLBF-Series Bench test filters are ideal for production test sets, laboratory tests and test equipment racks where filtering of microwave signals is essential. These benchtop filter assemblies provide either bandpass or band reject (notch) filter types depending on application. Frequency coverage is dependent on which production filter type is chosen. Frequency coverage for bandpass models range from 500 MHz to 50 GHz while the band reject models cover 350 MHz to 20 GHz.

www.microlambdawireless.com

MilesTek

High-Temp Teflon Cable Assemblies

VENDORVIEW

MilesTek's Teflon-jacketed cables can be used in applications where extreme external or internal heat sources exist that would melt or damage other cable jacket types. Cable conductors are often the most vulnerable components when it comes to heat related failures and Teflon jackets provide the protection they need. MilesTek now offers 50 Ω Triaxial cables with Teflon jackets that boast an operating temperature range of –55°C to +200°C. These robust assemblies are offered off-the-shelf with multiple connector combinations including TRB jacks, TRB plugs and blunt ends.

www.milestek.com

Mini-Circuits

Ultra-Wideband Coaxial 2-Way 0° Splitter/Combiner

VENDORVIEW

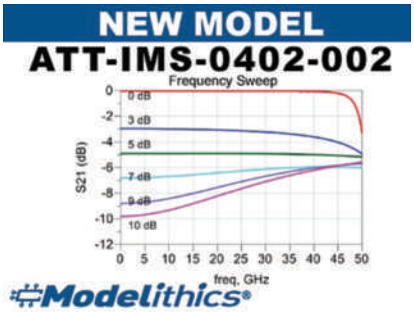
Mini-Circuits' ZN2PD-E653+ is an ultra-wideband coaxial 2-way 0° splitter/combiner providing coverage from 10 to 65 GHz, supporting a wide range of applications including 5G, Ku-, K- and Ka-Band SATCOM, microwave point-to-point backhaul, instrumentation and more. This model provides 10 W power handling as a splitter with 1.2 dB insertion loss, 22 dB isolation, 0.1 dB amplitude unbalance, 1° phase unbalance and DC passing up to 440 mA. The splitter/combiner comes housed in a rugged, aluminum alloy case measuring 3.5 × 2 × 0.5 in. with 1.85 mm-F connectors.

www.minicircuits.com

MiniRF
1.2 GHz Balun with DC Bias Tap
VENDORVIEW

MiniRFs new high performance micro-size balun saves biasing components, board space and minimizes DC issues in a package 65 percent smaller than the competition. With 400 mA DC current capability, 23 dB return loss and excellent phase/amplitude match, the 5713 is a key component that will enhance the output of any DOCSIS push-pull driver.
www.minirf.com

Modelithics Inc.
Microwave Global Model™



Modelithics has introduced a new equivalent circuit-based scalable Microwave Global Model for International Manufacturing Services (IMS) IMS2652 thin-film surface mount attenuator family. The model is validated up to 50 GHz and features substrate, pad and part value scaling over the full range of the attenuator series, 0 to 10 dB. IMS is a Sponsoring MVP and is sponsoring free 90-day trials of all available Modelithics models for IMS parts by request and with approval.
www.Modelithics.com/MVP/IMS

Pasternack
Tunnel Diode Detectors
VENDORVIEW

Pasternack, an Infinite Electronics brand, has introduced a new product line of coaxial packaged tunnel diode detectors that are in-stock and available with no MOQ required. These detectors are ideal for prototype and proof-of-concept applications used in aerospace and defense, military and commercial radar, test & measurement, SATCOM applications and more. Pasternack's comprehensive offering includes 26 models of tunnel diode detectors.
www.pasternack.com

RLC Electronics
High Frequency Surface Mount Cavity Filters

RLC Electronics manufactures high frequency surface mount cavity filters for low profile system integration. High Q performance is available up to 30 GHz with profile height < 200 mm. The design is suitable for reflow attachment, providing savings on size, cost and weight. This type of design achieves rejection of 60 dBc up to 3× fo, while also maintaining low loss (< 1 dB) and good VSWR (14 dB min).
www.rlcelectronics.com

NewProducts

Richardson RFPD

Silicon Carbide Module

Richardson RFPD Inc. announced the availability and full design support capabilities for a new SiC module from Wolfspeed, a Cree Company. Wolfspeed developed the XM3 power module platform to maximize the benefits of SiC, while keeping the module and system design robust, simple and cost-effective. With half the weight and volume of a standard 62 mm module, Wolfspeed's maximizes power density while minimizing loop inductance and enabling simple power bussing.

www.richardsonrfpd.com

Skyworks

Ultra-High Linearity Antenna Aperture Tuner

VENDORVIEW

Skyworks is pleased to introduce the SKY5™–9269-702LF, their new MIPI® ultra-high linearity antenna aperture tuner and latest solution from their Sky5™ portfolio for 5G applications. The wideband 16-state device is extremely compact and designed to deliver best-in-class efficiency and enhanced bandwidth coverage—from 600 MHz to 6 GHz for LTE Advanced Pro to emerging 5G standards—across a wide range of mobile platforms. This solution may be used in aperture tuning applications to optimize radiated power in 5G, LTE or GSM bands.

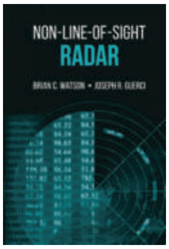
www.skyworksinc.com

Synergy Microwave Corp.

DC to 1 GHz Wideband Double Balanced Mixer

The CLK-7B5S is a wideband double balanced mixer. The RF/LO operating BW is 5 to 2000 MHz with a given operating LO of +7 dBm nominal. The DC coupled IF port operates from DC to 1000 MHz. The low conversion loss is 7 to 9 dB typical over the full band. High inter-port isolation ranges from 32 to 65 dB typical, s for superior overall performance. In addition to the above performance, the IP3 is +13 dBm and the 1 dB compression is +7 dBm typical. This model is well balanced for use in many up-/down-conversion applications. The mixer is packaged in a small connectorized housing terminated in SMA female connectors. The operating temperature is −55°C to +85°C.

www.synergymwave.com



Non-Line-of-Sight Radar

Brian Watson and Joseph R. Guerci

SAVE ON PRESENTER JOSEPH GUERCI'S NEWEST RELEASE!

Non-Line-of-Sight Radar is the first book on the new and exciting area of detecting and tracking targets via radar multipath without direct-line-of-sight (DLOS). This revolutionary capability is finding new applications in the tracking of objects in non-line-of-sight (NLOS) urban environments including detection and tracking of UAVs. This book brings together for the first time all the essential underpinnings and techniques required to develop and field a viable NLOS radar. It presents many examples, including electromagnetic (EM) radiation propagation in urban NLOS environments, extracting building location and morphology from readily available terrain databases, predictive ray-tracing techniques and multi-target NLOS tracking.

Readers will learn how to apply radar to urban tracking that was previously deemed impossible. The book shows how real-time physics calculations can be incorporated into the radar processor, and how existing radar hardware can be adopted for NLOS radar use without major upgrades. Including results from both high fidelity, physics-based simulations and actual flight test data, this book establishes the efficacy of NLOS radar in practical applications.

To order this book, contact:

Artech House
www.artechhouse.com
Email: artech@artechhouse.com
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UK +44 (0)20 70596 8750

ISBN: 978-1-63081-531-8
225 pages

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IEEE COMCAS 2019

International Conference on Microwaves, Communications, Antennas & Electronic Systems

4-6 November ▪ David Intercontinental Hotel ▪ Tel Aviv, Israel

IEEE COMCAS 2019, The international conference on Microwaves, Communications, Antennas, & Electronic systems is one of the world leading IEEE conferences.

As in previous years, we expect to welcome more than 1500 Scientists, Engineers, Managers, and Researchers (academic and industry) from all over the world.

IEEE COMCAS continues the tradition of providing an international, multidisciplinary forum for the exchange of ideas, research results, and industry experience in the areas of microwave/RF/mm-wave engineering, communications, antennas, solid state circuits, electronic devices, biomedical engineering, radar, sonar, signal processing and electronic systems.

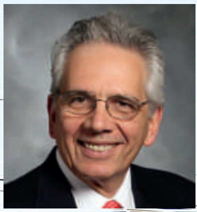
Looking forward to see you in Tel Aviv,

Shmuel Auster, Conference Chair
Amir Boag, Technical Program Committee Chair

REGISTER NOW

Keynote Speakers

Dr. Avram Bar-Cohen
Raytheon – Space & Airborne Systems



Prof. Richard D. Gitlin
University of South Florida

Prof. Theodore (Ted) S. Rappaport
NYU Tandon

Dr. Hava Siegelmann
DARPA

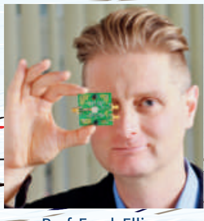
Invited Speakers (partial list)

Prof. Constantine A. Balanis
Arizona State University

Prof. Andrea Bevilacqua
University of Padova

Dr. Charles F. Campbell
Qorvo

Prof. Larry Dunleavy
University of South Florida



Prof. Frank Ellinger
Technische Universität Dresden

Prof. Caleb Fulton
The University of Oklahoma

Dr. Amelie Hagelauer
University of Erlangen

Prof. Ingmar Kallfass
University of Stuttgart

Prof. Allen Katz
College of New Jersey

Prof. Andrea Massa
ELEDIA Research Center

Dr. Kumar Vijay Mishra
US Army Research Laboratory

Prof. Giacomo Oliveri
University of Trento

Prof. Zoya Popovic
University of Colorado

Prof. Sembiam R. Rengarajan
California State University

Prof. Shlomo Shamai
Technion

Prof. Jeffrey H. Shapiro
MIT

Prof. Almudena Suárez
University of Cantabria

Dr. Horst Theuss
Infineon Technologies

For the full list of Invited Speakers, please visit COMCAS website: www.comacs.org

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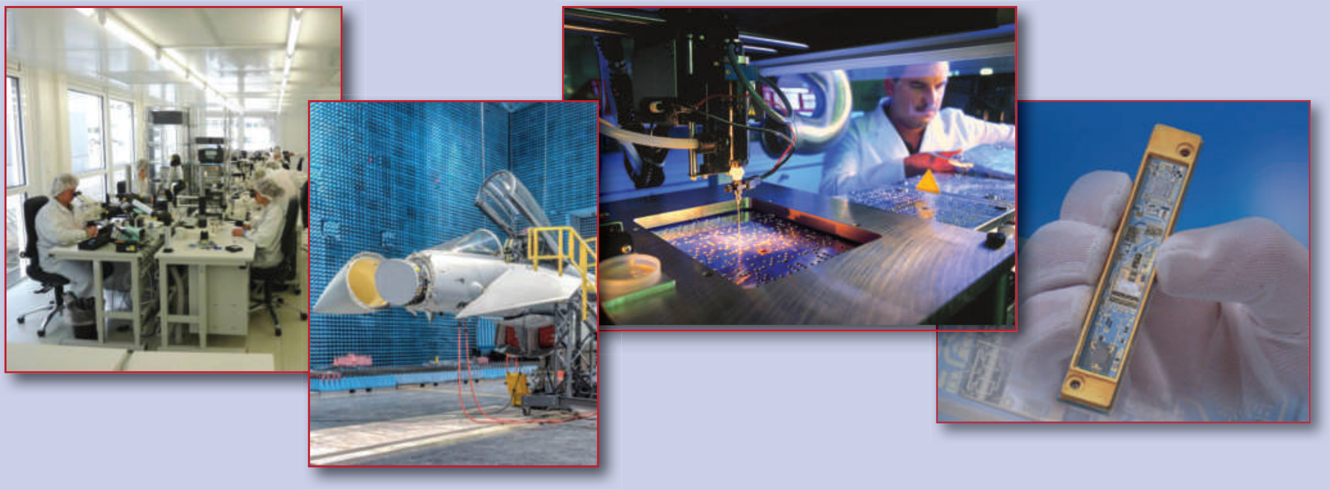
FABS and LABS

HENSOLDT—Sensor Solutions That Detect and Protect



While HENSOLDT is a new name in the defence industry, the name is not new, reflecting the legacy of Moritz Carl Hensoldt, born in Germany in 1821 and remembered as a pioneer in optics and precision mechanics. The company named in his honor was spun out of Airbus' defence electronics segment in early 2017, with a mission to provide sensor systems for radar, electronic warfare (EW), avionics and optoelectronics. HENSOLDT, based in Munich, generates more than €1 billion in revenue, 47 percent from Germany, 25 percent from the rest of Europe and the remaining 28 percent from the rest of the world. The firm employs some 4,500, a staff described as highly skilled and fascinated by high-end technology.

HENSOLDT's technology is found in many European defence systems: flying on the Eurofighter, Gripen and Rafale fighters, sailing on the German F125 frigate and riding in the Puma and Leopard armored vehicles. HENSOLDT is building the new Captor-E phased array radar for the Eurofighter. After delivering two production-ready active antennas during 2018, the first series production deliveries begin this year. The firm is also applying phased array technology to IFF systems for warships and a collision avoidance radar that will help commercial and military pilots detect and avoid UAVs. The company's heritage in space extends for nearly 60 years, leading to space-qualified products on the recent TanDEM-X earth observation and EDRS-A data relay satellites.

To support the development and production of these advanced radar, EW and avionics systems, HENSOLDT maintains a strong RF/microwave technology portfolio, from design through manufacturing. While the company currently sources semiconductor devices such as GaAs MMICs and GaN transistors from external foundries, it integrates them with other components internally, to fabricate complex, multi-function modules. The RF/microwave operation comprises a staff of some 100, with 2,000 m^2 of class 10,000 clean room—one of the largest clean room facilities in Europe.

HENSOLDT's assembly capabilities include eutectic and conductive epoxy die attach and the full range of bonding processes: ball, wedge, ribbon, gap welding and conventional soldering. For defence systems, the modules must be hermetically sealed, which is accomplished with seam or laser welding or special solder processes. HENSOLDT's comprehensive RF/microwave test capabilities handle all the specialized test flows dictated by the various programs and are supplemented with chambers for the normal environmental tests, such as temperature, vibration and shock.

For the development and production of phased array systems, HENSOLDT's manufacturing capacity will produce around 25,000 T/R modules per year, which can be doubled to meet additional program demands. For more complex, highly integrated modules, such as those used in broadband EW systems, the facility can assemble and test approximately 600 modules per year.

Today, Herr Hensoldt would likely be amazed by the widespread use of RF/microwave technology for surveillance and reconnaissance, compared to the optical telescopes and binoculars he developed in the mid-1800s to accomplish the same mission. Yet his relentless drive for innovation still inspires the company that bears his name, as this generation applies the newest technology to detect and protect.

www.hensoldt.net