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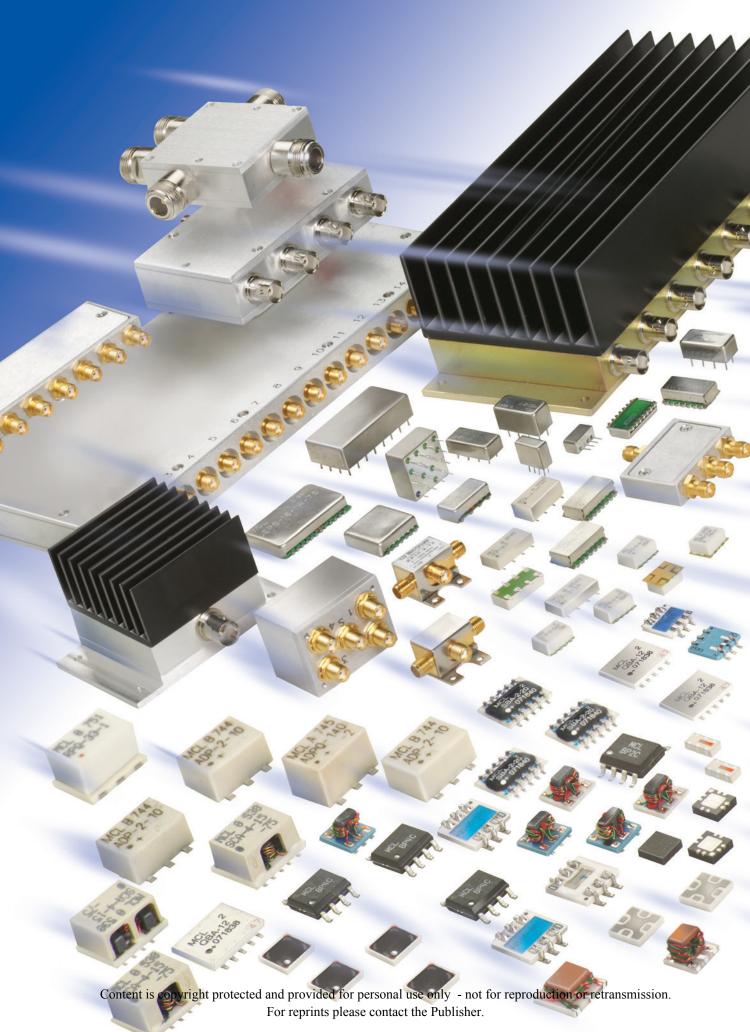
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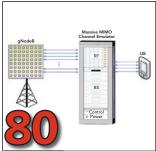


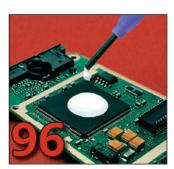












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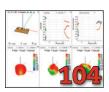
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EUROPEAN EDITORIAL OFFICE

16 Sussex Street, London SW1V 4RW, England Tel: Editorial: +44 207 596 8730 Sales: +44 207 596 8740 FAX: +44 207 596 8749

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Web Survey

Who invented British radar and oversaw the U.K.'s Chain Home radar during World War II?

Look for our multiple choice survey online at mwjournal.com

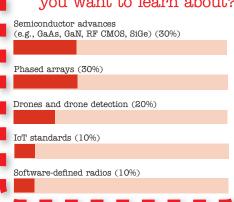
> **November Survey** What technology do you want to learn about?■



Alan Anderson, general manager of **Dow-Key Executive Interviews** Microwave, speaks of the company's 70-year heritage as the "oldest" RF/ microwave switch manufacturer and how the company continues to improve performance and reliability.

Kevin Beals, VP and GM of RF & Microwave Group at **Mercury Systems**, talks about the various aerospace and defense markets that Mercury Systems is addressing today, their unique technologies and centers of excellence within the company.





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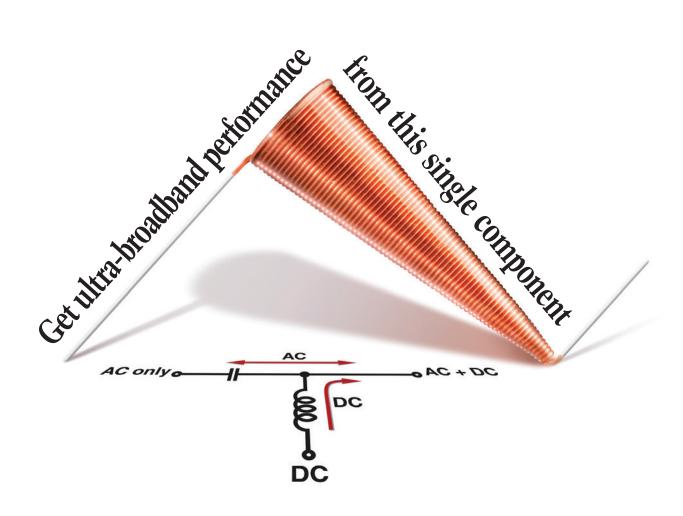
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The technical program for AUTOTESTCON 2018 will be determined by the interests of the participants submitting for presentation at the show. AUTOTESTCON is now accepting papers on key topics such as performance based logistics, health monitoring and diagnostics, embedded instrumentation, cyber security and test and support management. www.autotestcon.com

26-28

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Military Radar Summit 2018 brings together key stakeholders to learn, share and connect on radar resiliency, catch up to foreign developments, implement the newest scientific capabilities, overcome functional challenges and upgrade your existing resources.

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The theme of WAMICON 2018 is "mmWaves and IoT for Commercial and Defense." Submissions are welcomed on all aspects of mmWave and IoT related technologies including antennas, passive/active circuits, communication theory and system concepts.

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CON

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Deadline

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EuMW 2018 invites authors to submit their work on a range of topics, including passive/ active components, circuits and subsystems, field and circuit

analysis, simulation and characterization techniques, antennas and propagation and systems and applications.

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LOW LEAKAGE LEVEL LIMITERS

(Leakage Level as low as -10 dBm) 0.01 - 18 GHz





- . Maximum Input Power 1W CW, 100 W Peak
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MODEL	FREQ. RANGE (GHz)	NOMINAL ² LEAKAGE LEVEL (dBm)	TYPICAL ² LEAKAGE LEVEL (dBm)	TYPICAL ³ THRESHOLD LEVEL (dBm)
LL00110-1	0.01 – 1.0	-10	•	-11
LL00110-2		. 5		- 6
LL00110-3		0	1.0	- 1
LL00110-4		+5		+4
LL0120-1		-10		-11
LL0120-2	0.1 - 2.0	- 5		- 6
LL0120-3	0.1 - 2.0	0		-1
LL0120-4		+5		+4
LL2018-1	0.00		-10 TO -5	-10
LL2018-2	5.5		- 5 TO 0	- 5
LL2018-3			0 TO+5	0

Notes:

- 1. DC Supply required: +5V, 5mA Typ.
- 2. Typical and nominal leakage levels for input up to 1W CW.
- Threshold level is the input power level when output power is 1dB compressed.

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ComingEvents

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> PCB West 2018 February 8, 2018

WAMICON 2018 February 9, 2018

EuMW 2018 February 12, 2018

IEEE AUTOTESTCON 2018 February 16, 2018

Asia Pacific Microwave Conference 2018 February 28, 2018

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JANUARY

Radio and Wireless Week

January 14–17, 2018 ● Anaheim, Calif. www.radiowirelessweek.org

DesignCon

January 30-Feb. 1, 2018 • Santa Clara, Calif. www.designcon.com







FEBRUARY

EMV 2018

February 20-22, 2018 • Duesseldorf, Germany www.mesago.de/en/EMV/For_visitors/Welcome/index.htm

Military Radar Summit

February 26–28, 2018 • Washington, D.C. www.militaryradarsummit.com

Mobile World Congress 2018

February 26-March 1, 2018 • Barcelona, Spain www.mobileworldcongress.com











MARCH

IWCE 2018

March 5–9, 2018 • Orlando, Fla. www.iwceexpo.com/iwce18/Public/Enter.aspx

GOMACTech-18

March 12–15, 2018 ● Miami, Fla. www.gomactech.net

SATELLITE 2018

March 12–15, 2018 • Washington, D.C. http://2018.satshow.com/

EDI CON China 2018

March 20–22, 2018 • Beijing, China www.ediconchina.com

Microwave & RF 2018

March 21–22, 2018 ● Paris, France www.microwave-rf.com







APRIL

WAMICON 2018

April 9-10, 2018 • Sand Key, Fla. www.wamicon.org

ICMIM 2018

April 16–18, 2018 ● Munich, Germany https://icmim-ieee.org/

ExpoElectronica 2018

April 17–19, 2018

Moscow, Russia www.expoelectronica.ru

AUVSI Xponential 2018

April 30-May 3, 2018 • Denver, Colo. www.xponential.org/





MAY

CS MANTECH 2018

May 7-10, 2018 • Austin, Texas www.csmantech.org/

NIWeek 2018

May 21–24, 2018 ◆ Austin, Texas www.ni.com/niweek

Space Tech Expo USA 2018

May 22–24, 2018 ● Pasadena, Calif. www.spacetechexpo.com/







JUNE

EW Europe

June 5-7, 2018 • Lausanee, Switzerland www.eweurope.com

IEEE MTT-S IMS 2018

June 10-15, 2018 • Philadelphia, Pa. https://ims2018.org

Sensors Expo 2018

June 26–28, 2018 • San Jose, Calif. www.sensorsexpo.com



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Celebrating 60 Years



Carl Sheffres Microwave Journal *Publisher*

ixty years ago this month, the U.S. launched the Explorer 1 satellite on a Jupiter C rocket. It was the first satellite launched by the United States and successfully orbited Earth over 58,000 times before it re-entered the atmosphere a dozen years later. 1958 also brought the first successful demonstration of a working integrated circuit, leading to the invention of the microchip, by Jack Kilby of Texas Instruments and Robert Noyce of Fairchild Semiconductors. Another milestone that occurred, "under the radar" and with much less fanfare, was the debut of Microwave Journal in July of 1958. Since its inception, MWJ has covered the evolution of satellite technology, the semiconductor industry and all things wireless, while continuing to evolve itself, leveraging new technologies and platforms to accommodate your reading and learning preferences. This year, we celebrate the industry and our Diamond Anniversary with year-long features that you'll find in the magazine and on our website, including our special focus on

"diamond-based technologies" in the June issue.

This issue finds us looking ahead, with our cover story on "Antenna Technologies for the Future," authored by our editor Pat Hindle. Technical features include a look at the "Progress and Challenges of Test Technologies for 5G" and the "Evaluation of 77 to 79 GHz Automotive Radar Radome Emblems"subjects that were mere science fiction six decades ago. On our website, several companies share their predictions for 2018, along with our own Swami Hindle. Watch for this months' edition of Frequency Matters, which will examine the outlook for this year.

As always, our team will be canvassing all of the industry's events to report on the latest technical advances and new product launches. The events that we organize all find new homes this year. EDI CON China returns to Beijing on March 20-22 with an all-star list of keynote and guest speakers, along with an exhibition featuring leading Chinese and international companies. European Microwave Week

will take place in Madrid, Spain for the first time ever during the week of September 23, coming off of record-setting attendance last year. EDI CON USA moves to Santa Clara, Calif. and will take place October 17-19.

I would like to thank all of those who joined us in Boston this past September for EDI CON USA. Our goal is to deliver unique content related to both high frequency and high speed design solutions, and the feedback we received suggests that we are meeting that goal. Thanks also to all of the companies that supported this new event, led by Host Sponsor Analog Devices.

We will continue to provide a variety of webcasts from industry experts throughout the year and our bi-weekly Frequency Matters video series. Also watch for a series of eBooks beginning this month, in which we aggregate content on specific subjects for more efficient learning.

On behalf of all of us at *Microwave Journal*, we wish you a happy, healthy and successful year.



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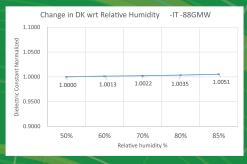
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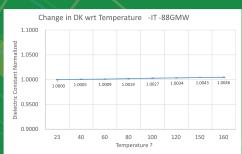
RF Material Solution



IT-88GMW

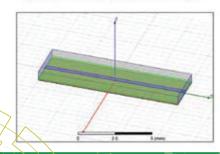
- Halogen Free
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- Low CTE from -40C to 120C
- ➤ Dk ~ 3.0
- Df ~ 0.0012 @ 10-100 GHz
- > Standard FR-4 PCB processes
- > Compatible with FR-4 for hybrids
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 77 GHz band (76-81 GHz)
- DAS (Distributed Antenna Systems)
- CPE (Customer Premises Equipment)
 Antennas
- 5G / mm wave applications



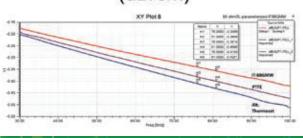


HFSS Microstrip Loss

HFSS Microstrip Model



Insertion Loss vs Frequency (dB/cm)



COME SEE

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RF Microwave

IT-8350G

Dk=3.50, Df=0.0025

IT-8338G

Dk=3.38, Df=0.0023

IT-8350G - Next Generation Halogen Free product for

Property

Glass Transition Temp (Tg)

Time to Delam (T300)

Dielectric Constant (Dk)

Solder Dip (PCT @1 hour and 121)

Thermal Decomposition Temp (5wt%) CTE: RT-150 CTE: a1

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- LNBs for Direct Broadcast systems
- Antenna applications - CPF antennas

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ELECTRICAL

PHYSICAL

Features

- Thermoset system with 200°C Tg Very low loss ~0.0025 at 10 GHz.

Data sheet - IT-83500

DSC

With Cu

@3GHz

@5GHz @10GHz

@2GHz

@3GHz @5GHz

- Excellent dimensional stability
- Very stable DK/Df with Temperature
 Ability to use very low profile Copper for reduced insertion loss.

min.

min.

ppm

lb/in

Qı

>60

268 3.80 504 (20 mils)

0.0025

0.0025

-	Highly suitable	for	Hybrids	

-	nigiliy	Suitable	IUI HYDIIUS
_	Ability	to make	high layer count heards

II-0330G - Next	Generation	nalogen
Free product for		

- 4 G LTE Base Stations, Power Amplifiers 24 GHz Automotive radar applications 77 GHz, SRR and MRR systems 5 G Base Stations & mm wave applications

- LNBs for Direct Broadcast systems
- plications
- **Features**
- Thermoset system with 200°C Tg Very low loss ~0.0023 at 10 GHz.
- Excellent dimensional stability
- Locenter unlessoned assuming
 Aphility to use very low profile Copper for reduced insertion loss.
 Highly suitable for Hybrids
 Ability to make high layer count boards

	- Antenna app
ı	- CPE antenna

	Data sheet - IT-8338G					
	Property		Units	IT-8338G		
` ,		Units	DK-3.38			
	Thickness		mm	0.504 (20 mils)		
		DMA		206		
	Glass Transition Temp (Tg)	DSC		195		
		TMA		185		
	Time to Delam (T300)	With Cu	min.	>60		
	Solder Float		min.	>60		
THERMAL	Solder Dip (PCT @1 hou	r and 121)	IIIII.	>60		
	Thermal Decomposition T	emp (5wt%)		425		
	CTE: RT-150	X-axis	ppm/	22.2		
	CTE: RT-150	Y-axis	ppm/	22.5		
	CTE: a1	Z-axis	ppm/	68		
	CTE: a2	Z-axis	ppm/	290		
	CTE	Z-axis	%	3.90		
	Thickness			0.504 (20 mils)		
	Dielectric Constant (Dk)	@2GHz		3.380		
		@3GHz		3.380		
		@5GHz		3.380		
ELECTRICAL		@10GHz		3,380		
	Dielectric Factor (Df)	@2GHz		0.0023		
		@3GHz		0.0023		
		@5GHz		0.0023		
		@10GHz		0.0023		
	Water Absorption	•	%	0.23		
PHYSICAL	Peel Strength	1 oz (HVLP)	lb/in	>4.0		
	Flammability		Second W/(mx°C)	VO		
	Thermal Conduc	Thermal Conductivity		0.46		
	Elastic modulus	X-axis	GPA	12.20		
		Y-axis	GPA	12.30		
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Antenna Technologies for the Future

Patrick Hindle
Microwave Journal Editor

raditional antenna technology has hit its limits in many demanding commercial and aerospace markets such as 5G, SATCOM, IoT and radar. But there are many companies developing new approaches and materials that could drastically improve antenna performance and enable new applications that were not previously envisioned because of these limitations. In this article, *Microwave Journal* looks at a sampling of these technologies that have come to our attention in the last couple of years.

3D PRINTED ANTENNAS

Recent advances in 3D printing or additive manufacturing have enabled complex RF structures to be realized. The characterization of the materials used in 3D printing processes has been shown to be critical in designing and accurately predicting the performance of these structures. Understanding the RF properties of the materials through characterization has led to the development of novel structures that could not ever be realized with traditional manufacturing techniques. 3D printing has also allowed manufacturers to produce traditional antenna shapes with less weight and at a lower cost.

SWISSto12 SA is an offshoot from the Swiss Federal Institute of Technology in Lausanne, Switzer-

land. The company has developed unique products using 3D printing that are based on polymer materials that are then metal plated or on metallic materials (such as aluminum or titanium) combined with advanced surface treatments and surface plating. Using these processes, SWISSto12 manufactures and tests aerospace qualified advanced RF products such as waveguides, filters, beamforming networks, antenna feed chains or array antennas.

Their use of 3D printing allows for increased flexibility in the manufacturing of complex product designs. This freedom can be used to produce higher complexity RF components, which often allows for better RF performance. Traditional machining technologies used to manufacture RF products are limited in their ability to produce products with complex shapes. To circumvent this limitation, complex products are often assembled out of a larger number of simpler subcomponents that are produced separately. SWISSto12's 3D printing technology does not have such constraints, allowing it to produce entire products in one single element that positively impact mass, cost, lead time, assembly quality and RF performance. The use of 3D printing also allows for optimized weight reduction. The technology has been demonstrated on waveguide, filter

and antenna components from C-to W-Band (4 to 110 GHz).

As this technology is rapidly gaining maturity and acceptance among the aerospace industry, SWISSto12 has already delivered a variety of prototypes to organizations in the space and SATCOM industries that have been qualified for use in airborne and space environments (the first commercial programs will be flying SWISSto12 products in 2018). More complex and integrated antenna or payload structures are in development, in particular Ku- and Ka-Band products. The company is also targeting emerging market opportunities such as high-altitude platforms, UAVs and Cubesat constellations. An example antenna product is a Ku-Band dual-reflector antenna comprising a conical chocked horn, a sub-reflector, a main reflector and metallic supports. This antenna system only weighs 145 g. The radiation properties of this antenna were found to be in an excellent agreement with simulation results over the design frequency range (see Figure 1). This antenna demonstrator was manufactured and tested in collaboration with the European Space Agency.

Optisys is another company that focuses on the design, fabrication and test of lightweight antennas using metal 3D printing. The specific method that Optisys uses for

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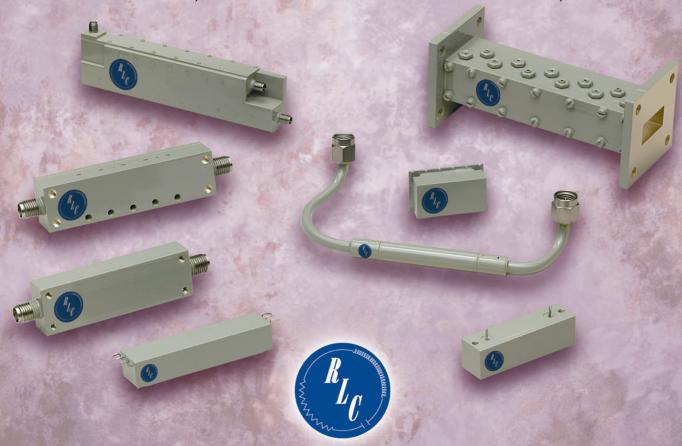
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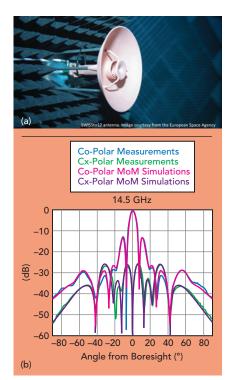
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▲ Fig. 1 Swissto12 Ku-Band dualreflector antenna (a) image courtesy of the ESA, and the radiation properties over the design frequency range (b).

fabrication is a powder bed fusion process, where thin layers of powder are welded into solid metal by a high-power laser. Through this welding process, a part is built one small layer at a time. This green manufacturing process allows for material to be added only where absolutely necessary to achieve a given mechanical or RF function.

As with any fabrication process, 3D printing has a set of design rules that determines what can and cannot be included in a design. Optisys is reimagining how waveguide is routed to achieve a desired RF function to take full advantage of the strengths of the printing process that allows, in some cases, for over an order-of-magnitude reduction in the size and weight of an antenna. Along with size and weight, part count reductions and absorbing tolerance stack-up can lead to simpler antenna assemblies with improved performance.

Optisys has designed a number of arrays using building blocks developed in-house that are rearranged and optimized for different functions and frequency bands. One of the key antenna designs is a Ka-Band 16-element tracking array shown in *Figure 2*. Signal pat-

terns show the sum and delta elevaperformance with measured and simulated performance overlaid. This part includes a 16-element array of horns that are circularly polarized, with a waveguide combiner network on both left- and right-hand circular polarizations. Additionally, the rightcombiner network feeds into a dual-axis monopulse comparator. All of this is implemented in a single part that weighs less than 2 oz and fits in the palm of the hand.

A second array design is the X64 antenna that takes the integration a step further, by including a waveguide dual-axis monopulse comparator on both polarizations and integrating an elevation rotation axis into the design. Fabricating this part in a traditional process would require well over 100 separate parts, compared to the single printed part. Signal patterns are shown for sum, delta elevation and delta azimuth on the right-hand circular polarization (see Figure 3). There are a total of eight simultaneous antenna beams generated in this antenna.

Another key area of innovation where Optisys has generated interest is in the design and building of lightweight feeds for parabolic reflectors, where the sub-reflector, feed horn and polarizer are printed as a single metal part without blockage or losses due to struts or a dielectric support. This design has been optimized to the key frequency bands of X-, Ku- and Ka-Band. The company refers to these antenna feeds as the integrated printed antenna family of feeds. The unit and 3D near-field scan pattern at a single frequency and a set of elevation patterns across the frequency band are shown in Figure 4.

16-element tracking arin *Figure 2*. Signal patissue of *Microwave Journal*, **The MI**Content is copyright protected and provided for personal use only - not for reproduction or retransmission.

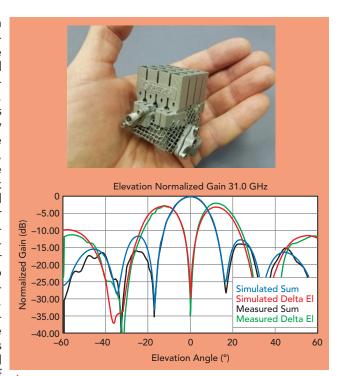


Fig. 2 Optisys Ka-Band 16-element tracking array with measured and simulated data.

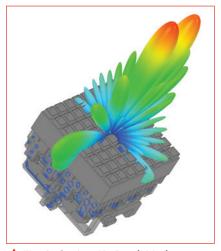
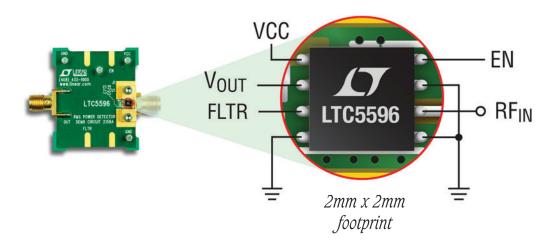


Fig. 3 Optisys Ka-Band 64-element tracking array with signal pattern.

TRE Corporation is investigating a new generation of 3D printing to realize the complex geometries of wideband phased array and metamaterial designs using commercial, low-cost, compact, desktop printers.¹ Samples of the 3D printed plastic and conductive ink printed at room temperature were characterized over frequency. The polylactic acid (PLA) dielectric constant and loss tangent are found to be stable up to 18 GHz. The PLA internal architecture was varied to achieve lower effective dissipation factors, which extends usefulness to high

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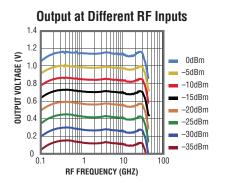
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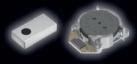






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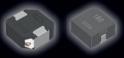
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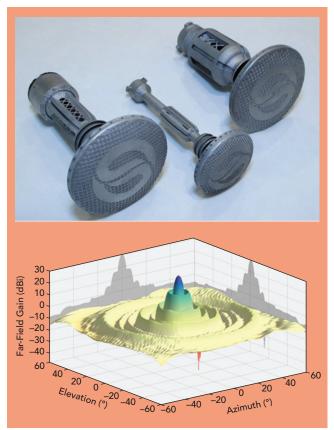
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▲ Fig. 4 Optisys Integrated Printed Antenna and signal pattern.

frequency applications. Microstrip line samples were fabricated with simulated and measured insertion loss data validating the high conductivity through mmWave frequencies. A 3D printed monopole Wi-Fi antenna was built and tested, showing good performance and agreement with simulations.

MITRE also has developed a wideband phased array concept that has a complex metamaterial design. It is based on a PCB design that was not physically realizable with traditional manufacturing. The design resembles an egg-crate construction with contiguous electrical connection (interdigitiated fingers) that is embedded within the orthogonal board interface, as illustrated in *Figure 5.*¹ Multi-material additive manufacturing is thought to be the only practical way to realize this design. They successfully printed a sample of the cross in the middle of the array, and a CT-scan showed the details of all of the fingers confirming the construction and working on full scale antenna structures.

METAMATERIAL BASED ANTENNAS

Metamaterials are made by arranging naturally occurring materials in a specific pattern that produces an electromagnetic response that is not found in nature. The periodic structures created are at scales that are smaller than the wavelengths of the phenomena they influence and can create materials with negative indexes that control electromagnetic energy in ways that cannot be done with natural materials. In traditional active electronically scanned arrays (AESA), phase shifters embedded in control circuitry steer the beam direction. Metamaterial-

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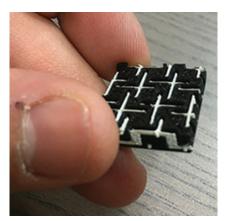
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 \triangle Fig. 5 A small test coupon of MITRE's biaxial metamaterial created with a Voxel8 multi-material 3D printer.

based AESAs can steer the beam without phase shifters, which reduces system complexity, eliminates a source of power loss and simplifies waste-heat dissipation. There are a couple of companies using unique metamaterial structures developed for this application.

Kymeta experimented these structures for many years and discovered that the metamaterials could be used to form holographic beams that could link to satellites and maintain the link while the antenna is in motion. Kymeta mTenna™ technology (see Figure 6) is manufactured using a completely different process and components than both traditional antennas and phased array antennas.² The "metamaterial" in mTenna technology is a metasurface in a glass structure. Their glass-on-glass structure is manufactured on the same production lines as LCD flat screen televisions, making it suited for low-cost, high volume manufacturing. They use the thin film transistor liquid crystal as a tunable dielectric. Instead of reflecting microwaves like a traditional dish antenna or creating thousands of separate signals like a phased array, Kymeta uses a thin structure with tunable metamaterial elements to create a holographic beam that can transmit and receive satellite signals.

They use software to steer the antenna, eliminating the need for mechanical gimbals to point the antenna toward a satellite. The antenna does not require active phase shifters or amplifiers. Key features of the approach:³

Feed Assembly Backshell Radome (Enclosure) Aperture Assembly Bezel Control

Fig. 6 Kymeta mTenna™ construction.



🖊 Fig. 7 Echodyne's radar vision unit next to an iPhone.

- 1. Transmit and receive via a single aperture
- 2. Wide angle scanning and excellent beam performance
- 3. Electronically controlled pointing and polarization
- 4. Extremely low power consump-
- 5. First electronically scanned antenna designed for mass production.

Traditional satellite dishes are heavy, large, expensive, consume a lot of power and have mechanical gimbals for steering, which have prevented or limited their adoption on most mobile platforms. Kyme-

ta's mTenna technology provides software-enabled, metamaterialsbased, electronic beamforming satellite solutions that are flat, lightweight, small and use software steer instead of mechanical parts.

This technology is being used to deliver internet connectivity to industries that have historically been inaccessible or difficult for the satellite industry to address, such as rail, bus and automotive. Also, the maritime and aviation markets have struggled to implement satellite technology broadly across smaller vessels and aircraft.

A second company, Echodyne, has developed metamaterial arrays for radar using similar antenna technology to Kymeta but optimized for radar applications. Echodyne's radar vision platform represents a unique sensor technology that combines the all-weather, long range and ground-truth measurements of radar with high resolution imaging capabilities (see Figure 7).4 Radar vision consists of high performance agile imaging radar hardware combined with computer vision-like software for classification, recognition and perception.

Their metamaterial based, electronically steered array radars operate in the same way as traditional

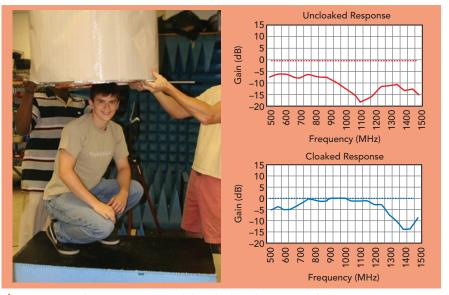
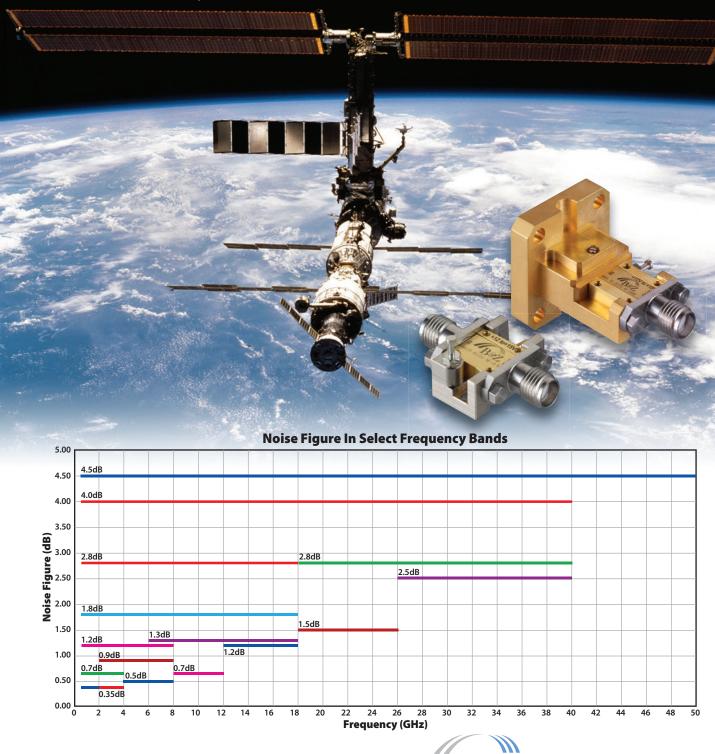


Fig. 8 Fractal Antenna's RF invisibility cloak and measured data. Content is copyright protected and provided for personal use only - not for reproduction or retransmission. MWJOURNAL.COM ■ JANUARY 2018 For reprints please contact the Publisher.

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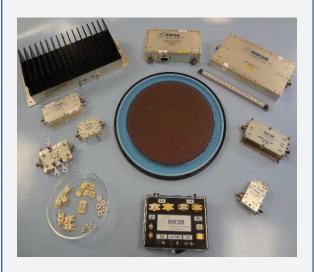
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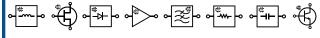


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designs, providing high resolution data at any time and in any weather. Like Kymeta's approach, they can be produced in high volume, at commercial price points and in small lightweight form factors. Their technology can switch in less than 1 µs, has beam shaping and multi-beam capabilities and can steer in both directions, providing near full hemisphere coverage. It operates at 24 GHz and has an operational range of 3.4 km with a field of view ≥120 degrees azimuth and 80 degrees elelvation with a range resolution of 3.25 m and velocity resolution 0.9 m/s.4

LiDAR and cameras have limited range and do not operate reliably in adverse weather, while traditional radar in this sector has inadequate resolution. Echodyne's radar vision platform represents a new category of sensor technology to enable many autonomous vehicles from drones to cars. Their high performance imaging radar is viable and affordable on commercial and small platforms, including all types of autonomous and unmanned vehicles and machines.

FRACTAL BASED ANTENNAS

A fractal is "self similar" complex pattern built from the repetition of a simple shape. A fractal element antenna is shaped using fractal geometry. The inherent properties of fractals can enable high performance antennas that can be 50 to 75 percent smaller than traditional antennas. Typical advantages are increased bandwidth, better multi-band performance and higher gain. Fractal antennas can be more reliable and lower cost than traditional antennas because antenna performance is attained through the geometry of the conductor, rather than with the accumulation of separate components or separate elements that can increase the complexity, potential points of failure and cost.

Fractal Antenna is a small company that produces fractal versions of many existing antenna types, including dipole, monopole, patch, conformal, biconical, discone, spiral and helical, as well as compact variants of each that is made possible through fractal technology. They were the first to demonstrate wideband RF invisibility cloaking and used fractal shaped metal patterns on a mylar sheet. In their demonstration, a signal from 750 to 1250 MHz was attenuated by only a fraction of a dB over the same 50 percent bandwidth that would normally be attenuated by 6 to 15 dB without the cloak (see **Figure 8**).^{5,6}

At EDI CON USA 2016, Dr. Nathan Cohen of Fractal Antenna gave a session and demonstration of their unique RF/microwave cloaking and deflection technology using fractal structures. Over a broad band, 2.5 to 3 GHz, he created a Waldo (window around a wall) that channeled the RF energy around a barrier (the "wall") using an array of closely packed fractal-shaped resonators that was wrapped around the barrier, creating a "window." The bandwidth is an impressive 500 percent for front scatter and 100 percent for backscatter with about 1 dB insertion loss.7

Fractus Antennas was featured in the October 2017 issue of Microwave Journal and has a new "antenna-less technology" that is based on replacing a complex and usually customized antenna design with

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off-the-shelf, standardized, miniature component called an antenna booster.⁸ Being a surfacemount, chip-like device, the antenna booster can be picked and placed like other surface-mount components onto a PCB for low cost assembly (see *Figure 9*). Aimed at mobile devices and IoT applications, it is made with metalized ceramic layers that use fractal shapes designed to meet different design requirements.

Miniature chip antennas are not new, so what is unique here is the multiband capability with a single device. While conventional miniature chip antennas were based on high-permittivity ceramics and delivered good performance for narrowband, single frequency applications, these new boosters can deliver full mobile performance within a broad range of frequency bands (e.g., 698 to 2690 MHz) with a single device. The integration requires a

matching circuit that allows the device to operate at the desired bands of interest. Based on conventional low-cost materials and assembly processes, the boosters can be made in high volume at very low cost.

An example booster is 5 mm³ in size and operates from 824 to 960 MHz and 1710 to 2170 MHz simultaneously. With a matching network on the PCB, a VSWR ≤ 3:1 across the operating bands and an average total efficiency of 56.7 and 75.8 percent in the 824 to 960 MHz and 1710 to 2170 MHz frequency regions, respectively, is achieved (see Figure 10).8

OTHER UNIQUE TECHNOLOGIES

Plasma Antennas (PSiAn) offers a range of innovative plasma-silicon devices (PSiD) to form the compact RF core of future smart antennas. The PSiDs provide fast, electronic beamforming and beam selection functions. A PSiD can be regarded as a multi-port, wideband switch that replaces RF switches, phase shifters and attenuators with one compact, low loss device. Due to their silicon IC construction, PSiDs can be reproduced with high precision for the mass market at low cost. They have high power handling and, unlike RF MEMS, can be "hot" switched.

PSiAn uses either single or multiple PSiDs to perform azimuth



A Fig. 9 The CUBE mXTEND™ antenna booster from Fractus Antennas (5 mm³).

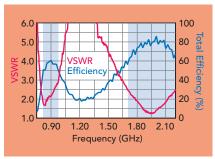


Fig. 10 VSWR and efficiency for 5 band mobile antenna from Fractus Antenna.



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and elevation beam steering. The PSiDs are mounted on RF PCBs and use transmission lines to link the device ports to traditional RF and antenna technologies, such as LNAs, PAs, printed feeds, lenses and reflectors to produce efficient smart antennas with steerable narrow beams. Potential applications of PSiAn plasma antennas include: small cell backhaul at V-Band (60 GHz), gigabit wireless LAN (e.g. WiGig), intelligent transport sys-

tems (ITS) at 63 GHz and vehicle radar (77 GHz).

The company recently introduced an antenna that reduces the cost of a 5G base station by up to 50 percent by eliminating phase shifters, reducing and consolidating amplification and reducing computation. The technology does not need calibration and can handle high-power, having been tested up to 40 W. The company has shown the technology in a variety of sce-

narios, including a 360 degree field of view, beamforming and steering, 28 GHz, 5 W, 16 dBi gain PSiAN, useful for pole mounted small cells, indoor small cells—also on a vehicle and a high-power, long range, low loss small cell base station antenna for standalone and MIMO 5G, fixed wireless access (FWA) and connected vehicle applications (see *Figure 11*).9 These devices can also be stacked to form and steer beams in two dimensions (azimuth and elevation) or to form multiple beams and MIMO applications.

announced They also their mmWave PSiAn for use in smartphones and other consumer electronics, delivering high throughput with low latency and utilizing directional beams that generate less interference and maximize energy efficiency.¹⁰ The introduction of mmWave connectivity for smartphones and other mobile devices faces significant problems as the signals are easily blocked by fingers, hands, heads and bodies. When used in combination with distributed radiating elements, PSiDs can be used as a switch and beam former to utilize only elements that are able to receive and transmit line-ofsight or reflected signals resolving this issue. Plasma Antennas recently modeled plasma silicon corner antennas as replacements for array modules for device manufacturers and silicon suppliers. This approach closely represented the publicly available solutions from Qualcomm and Samsung, for which there are many handling scenarios that would block the antennas. The array Plasma Antennas proposes now solves these problems and brings the intrinsic qualities of plasma silicon.

Gapwaves AB was founded in 2011 by Professor Per-Simon Kildal at Chalmers University of Technology in Gothenburg, Sweden, with the aim of enabling efficient wireless communication through the patented GAP waveguide technology. GAP waveguides provide a unique packaging technology for mmWave and terahertz circuits and components, with advantages compared to existing transmission line and waveguide technology. The technology is based on an artificial magnetic conductor that enables contactless propagation





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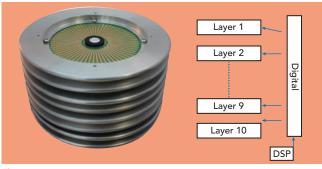


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▲ Fig. 11 Plasma Antenna 360° field of view beamforming and steering 28 GHz, 5 W, 16 dBi gain PSiAn.

of electromagnetic waves, significantly reducing transmission losses. The GAP waveguide is built up of two parts: a structured metal surface and a flat metal surface placed close one another, allowing for air gap between

the two parts (see Figure 12).11 The structured surface is characterized by pins forming a barrier, preventing the electromagnetic waves from propagating in undesired directions. In this way, the pins replace the walls in traditional rectangular waveguides without requiring perfect metallic contact. The waves are guided by ridges or grooves within the pin structure and propagate in air, resulting in low power losses. Antennas based on the GAP technology have more than 10x lower losses than micro strip lines, more than 3x lower losses than substrate integrated waveguide (SIW) and approximately the same losses as rectangular waveguides.¹¹

As no metallic contact is required between the layers, the assembly of multilayered, closely spaced waveguide structures is simplified. The antenna layers can be glued together with no screws, pressure or heat. Production of the antenna parts is accomplished using plastic injection molding in combination with metallization or using die-casting in metal, resulting in high volume capabilities and a cost-efficient manufacturing process. The low power losses enable broadband antenna arrays with gains up to 38 dBi to be achieved with above 80 percent efficiency. The design flexibility that comes from using multilayered waveguide structures enables tailoring of the radiation pattern, as demonstrated by a recently developed 38 dBi E-Band antenna that has achieved ETSI class 3 radiation pattern per-

The properties of GAP waveguides make it suitable for designing active antenna systems. A schematic view of an active antenna based on the GAP waveguide technology is shown in *Figure 13*. Due to its contactless nature, GAP waveguide based antennas can be more easily integrated with PCB, as RF interconnects between

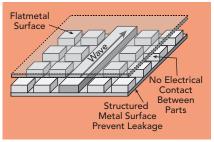


Fig. 12 GAP waveguide structure.

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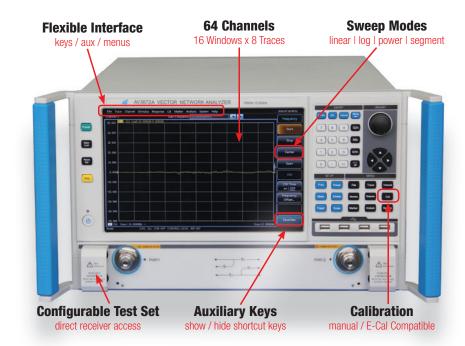
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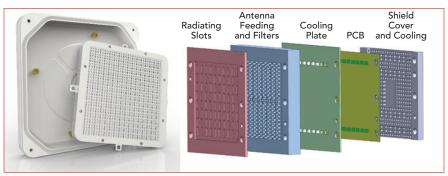


Fig. 13 Active antenna system construction using GAP waveguide technology.



the PCB and the antenna layers can be made without electrical contact. The pin structure also acts as a shield for the active components, protecting them from interference and preventing propagation within the substrate of the PCB. Removing the need for shielding walls and via holes frees up valuable circuit board space, which becomes available for the placement of active circuits and routing lines. The die-cast antenna layers also provide effective cooling for the active circuits from two sides. This is useful when integrating high-power amplifiers and CMOS based control circuits onto the same circuit board, which often require cooling from different sides.

SUMMARY

There are many exciting new technologies such as 3D printing, metamaterials and fractal antennas, that promise to revolutionize antenna technology in the next few years. They will solve many challenges that traditional antenna technology has not been able to overcome and enable new antenna shapes and applications that are not even possible with traditional antenna technology. The unique new approaches will address many of the challenges faced today in 5G, IoT, SATCOM and radar applications.

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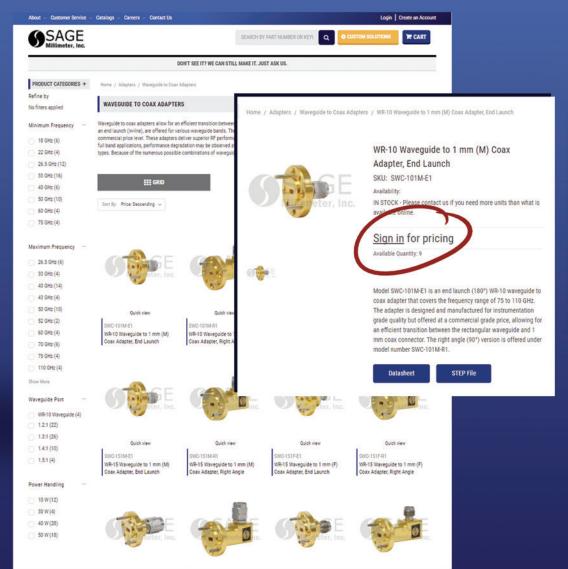
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Using 24 GHz Radar to Speed Commercial UAV Adoption

Abhishek Kapoor Analog Devices Inc., Norwood, Mass.

ver the last decade, unmanned aerial vehicles and systems (UAV and UAS)—also referred to as drones—have become widely popular and gained significant interest in commercial, consumer and government markets. What used to be a largely military application now has more than 400 companies, worldwide, developing drone technology and enabling use cases for the new era of commercial drones. The premise of a flying object performing mission and business critical tasks, without much human involvement, offers a pivotal moment in the realm of smart automation and productivity. Unfortunately, regulations by the U.S. Federal Aviation Administration (FAA) and other agencies, despite their positive intentions, limit the mass application of these drones. Additionally, growing competition is leading to commoditization before the market has even gained its footing. This article discusses how innovations in RF and microwave technology can provide a technical justification to ease the regulatory barriers and help drone manufacturers differentiate their solutions to better succeed in the marketplace.

The concept of UAV/UAS is not new and has been advocated in some shape or form since manned aircraft became widely used. Unfortunately, the limits of material science, propulsion, power and battery, sensor and software technologies have limited the use of drones to very specific industries and applications. Only large military forces could justify the cost to develop and use drones for intelli-

gence, reconnaissance and surveillance missions in environments too dangerous for humans. Even today, many of us relate drones to military missions that are commonly in the news.

Alternatively, low-cost, bare bones drones have been gaining popularity among enthusiasts and hobbyists for recreational purposes. Although drones have not been widely used for commercial applications, that is changing as the industry improves component technology and computing software. With the advent of industrial robots, autonomous driving,

and power efficient systems, the transition to UAVs is a natural evolution. An unmanned flying object that can be programmed to perform tasks that are too dangerous, time consuming or difficult for humans is a huge technological leap toward a more automated and productive world.

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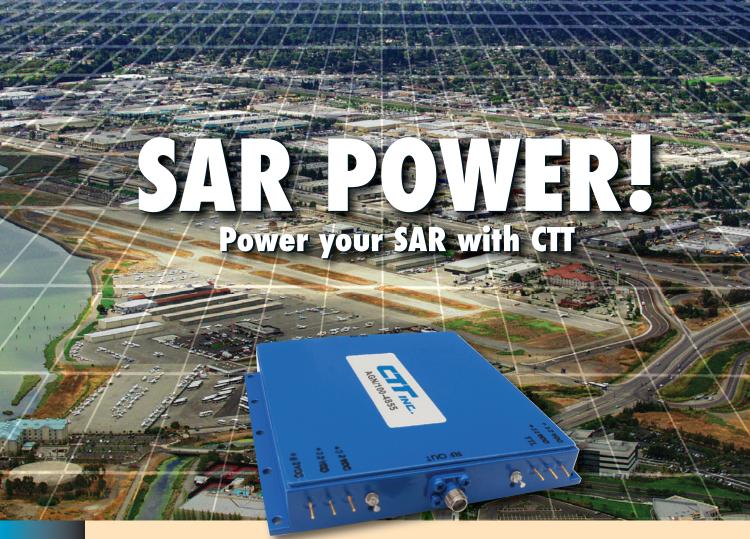
The drone market is expected to grow to about \$21 billion by 2022.1 Today, about 82 percent of the market is focused on military applications. Commercial drones are expected to account for about \$2.5 billion in revenue by 2021, representing a 19 percent yearover-year growth rate. The use cases in commercial and industrial markets range widely. Drones are being explored for applications such as precision agriculture (e.g., crop spraying), terrain and environmental monitoring, infrastructure monitoring (e.g., bridges and dams), public safety surveil-

lance, commercial freight, border control and oil and gas pipeline monitoring. Each month, dozens of new companies introduce products and services using drone technology to solve business problems. The prospects for commercial UAV applications are virtually limitless.

Unfortunately, even though the

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The confluence of advances in supporting technologies, such as processors and memories — as well as developments in UAVs — coupled with geopolitical demands for increased homeland security and greater intelligence gathering has pushed SAR (synthetic aperture radar) into the ISR (intelligence, surveillance and reconnaissance) spotlight.

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drone market is becoming widely popular, with multiple companies exploring many use cases (e.g., Amazon and Alphabet's Google), the industry faces challenges limiting its growth.

Heavily regulated and restricted—The FAA has strict rules that limit the use of drones in public air space. A 2015 ruling stipulates

drones weighing less than 55 pounds may only operate during the day and within the visual lineof-sight of the operator. These drones are not allowed to operate autonomously, reflecting the FAA's safety and security concerns.

From the government's standpoint, the risk posed by most drones, not equipped with reliable and accurate sensors, is too high to allow operation in open public spaces. While exceptions are granted (e.g., in large open agricultural areas), in the majority of cases, due to limited sensor technology and unproven sensor reliability, the FAA has taken a more conservative stance to ensure safety and security.

Competitive threats and commoditization—In addition to regulatory hurdles, the drone market is increasingly competitive, which creates pricing pressure. Drawn by UAVs' attractive growth potential and "cool" factor, more than 400 companies worldwide are already involved in drone-related development. The focus for most of these companies is differentiated hardware, rather than emphasizing the value-added services their drones may enable.

Limited RF and microwave expertise—To achieve widespread use, commercial and consumer drones must be equipped with navigational sensors that ensure safe and reliable autonomous operation. As in the automotive and industrial equipment markets, many of these wireless sensors use RF and microwave technology. Yet

most commercial companies developing drones are startups with limited expertise in RF and microwave design. Even well-established industrial equipment manufacturers with some RF experience are hard-pressed to quickly evaluate, design and manufacture radar sensor solutions for the fast changing UAV market.



The lack of RF expertise and readily available radar solutions creates a challenging cycle for the industry: the UAV market's inability to offer reliable sensors to help ensure safe and reliable autonomous operation prevents government agencies from relaxing the regulations that restrict autonomous drone operation.

RADAR TO THE RESCUE

At Analog Devices, we believe UAV manufacturers have an opportunity to influence regulatory policies governing drone operation by embracing the RF, microwave and mmWave technology that can enable the sensors needed to prove the safe, reliable navigation of drones. A 24 GHz radar, operating in the globally recognized industrial, scientific and medical (ISM) band, is one example of a basic

and versatile sensor for multiple use cases. An ISM band radar at 24 GHz can be used without regulation anywhere in the world for functions such as automatic collision avoidance and radio altimeters. In addition to measuring how high the drone is flying, the same radar can detect and track multiple objects—two of the most basic requirements

for safe drone operation.

By proving their solutions are technically capable operating autonomously, UAV manufacturers will be able to influence the existing regulations, rather than waiting for regula-

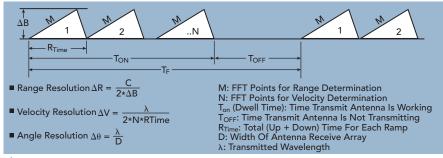
tors to define the way the industry should operate. To reach this point, UAV manufacturers need to take three steps:

- Develop a basic understanding of radar and its various modes
- Understand the components of the RF signal chain required for a complete radar solution
- Adopt radar solutions that provide a complete hardware setup with the software algorithms to allow them to get to market faster.

The following discussion provides an overview of these steps and a potential solution to help UAV manufacturers adopt 24 GHz radar for collision avoidance and radio altimeter applications.

BASICS OF RADAR

Radar sensors are commonly used in the automotive and industrial markets to detect, measure



▲ Fig. 1 FMCW radar operation.

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and track objects, e.g., blind spot detection and automotive driver assistance systems (ADAS). Compared to optical or ultrasonic sensors, radar can accurately detect and measure objects over a much longer range and wider field of view in very difficult environments, including dust, smoke, snow, fog and poor lighting. A typical radar has various modes, each best depending on what needs to be detected and tracked.

FMCW—Operating in the frequency modulated continuous wave (FMCW) mode, the radar measures the distance to stationary targets. By modulating the frequency, also referred to as an FMCW ramp or chirp, the radar measures the response of the reflected wave to derive range, velocity and the angle of the target. Figure 1 shows how the target's range, velocity and angle are derived in FMCW mode.

The range resolution depends on the transmitter's carrier sweep bandwidth; the higher the bandwidth, the higher the resolution of the radar sensor. The velocity resolution depends on dwell time and carrier frequency; the higher the carrier frequency or dwell time, the higher the resolution. Angular resolution depends on the carrier frequency; the higher the carrier frequency, the better the resolution.

Compared to laser detection, which measures a single spot, or

camera detection, which only captures a 2D image within the camera's field of view, FMCW radars provide a continuous, inherent average of the information from the target's reflection. This provides a wide, 3D field of view by measuring the distance, speed and angle, from as close as a few centimeters to several hundred meters between the sensor and the targets.

Range-Doppler—In range-Doppler mode, the range and speed of the target are analyzed. Range-Doppler is one of the most powerful modes because it processes multiple transmit ramps or chirps simultaneously using a 2D Fourier transform. The processed range-Doppler data is displayed in a 2D map that enables targets with different velocities to be separated, even if they are the same distance from the sensor. This is important to distinguish multiple targets moving at high speed in different directions, e.g., resolving complicated air traffic scenarios with targets traveling in opposite directions or during overtaking maneuvers.

DBF—With digital beamforming (DBF), the distance and the angle to the target are displayed. The receive signals from the four receive channels are used to estimate the angle of the target, and the data contains the spatial distribution of the targets in the xy-plane. In the DBF mode, the system is config-

ured the same as FMCW; however, the down-converted IF signals are processed differently. After calculating range, the angle information of the target is calculated by evaluating the phase differences between the four receive channels. The DBF mode requires a calibration of the radar front-end to eliminate deterministic phase variations between the receive channels.

24 GHz MULTI-CHANNEL RADAR

A 24 GHz radar is widely used in commercial and industrial applications, offering high accuracy, low power consumption and small size. These characteristics also make a 24 GHz radar a good fit for commercial and consumer UAV manufacturers, particularly considering the desire to reduce payload and power requirements. One such system developed by Analog Devices is shown in *Figure 2*.

A common misconception is the radar can operate at 77 GHz rather than 24 GHz. Current regulations dedicate the 77 GHz band to automotive vehicles and do not allow use with UAVs. While 77 GHz offers higher bandwidth for improved resolution, today's regulations prohibit a 77 GHz radar being used for UAV applications.

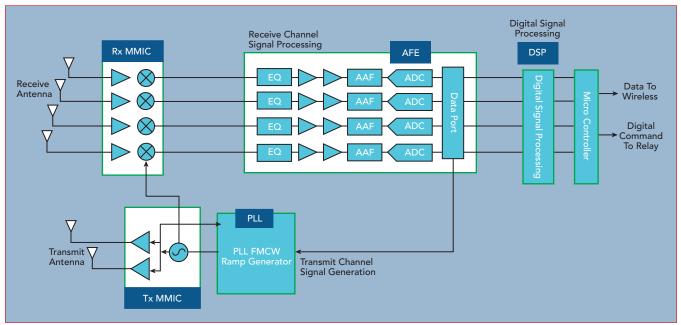
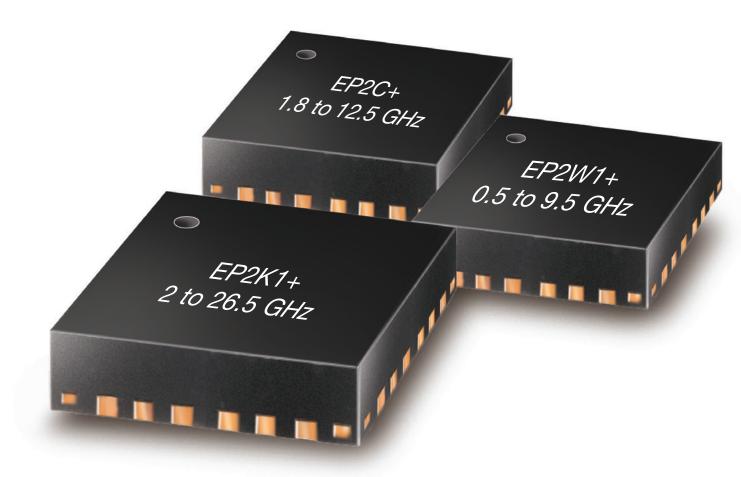


Fig. 2 Multi-channel radar sensor developed by Analog Devices.
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When building a radar sensor, every dB improvement in receiver sensitivity extends the detection range. Most sensors available today focus on cost reduction, trading off phase noise and the number of channels. This trade-off degrades the receiver signal-tonoise (SNR) ratio, which limits the detection of smaller targets in the presence of larger objects. In realworld radar applications, busy or cluttered target scenarios cumulatively increase system phase noise and desensitize the radar receiver. The higher system noise masks or hides small targets and prevents object detection—detecting a narrow tree branch masked by the facade of a building—which can compromise UAV safety. Most single-channel, single chip, lowcost sensors do not provide the needed performance to make this distinction.

Using a 24 GHz multi-channel platform with higher performance, UAV manufacturers can:

- Use the FMCW radar mode to detect the range and velocity of objects up to 200 m with a resolution of approximately 60 cm; the resolution can be improved to 15 cm using an antenna design developed for the specific appli-
- Achieve a field of view of approximately 120 degrees in azimuth and 15 degrees in elevation, depending on the antenna array design; using DBF, the field of view can be extended.
- Reduce power consumption while improving sensitivity 2x and extending the detection range 1.5x compared to traditional low-cost, single-channel radar sensors.

SUMMARY

The UAV/UAS market is growing quickly and offers tremendous potential for many new commercial applications. The landscape of sensor technologies is also changing rapidly, with newer sensor technologies such as light detection and ranging (LiDAR), time of flight (ToF) and ultrasonic being developed and adopted. UAV manufacturers should be aware of these newer options and incorporate the latest technologies as they mature.

However, radar remains the most compelling sensor technology, offering performance and versatility. To help the widespread commercial adoption of UAVs, UAV manufacturers need to lead the industry by embracing RF, microwave and mmWave radar, considering more than just the cost of the hardware, to demonstrate that UAVs can be safely operated autonomously.■

Reference

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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	MOISE AND	3.0 MAX, 2.5 TYP MEDIUM POV	+10 MIN	+20 dBm	2.0:1	
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 CA23-3116	2.2 - 2.4 2.7 - 2.9	30 29	0.6 MAX, 0.45 TYP 0.7 MAX, 0.5 TYP	+10 MIN +10 MIN	+20 dBm +20 dBm	2.0:1	
CA23-3110 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 +20 dBm	2.0:1	
CA1315-3110 CA12-3114	13.75 - 15.4 1.35 - 1.85	25 30	1.6 MAX, 1.4 TYP 4.0 MAX, 3.0 TYP	+10 MIN +33 MIN	+20 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 CA1213-7110	8.0 - 12.0 12.2 - 13.25	30 28	5.0 MAX, 4.0 TYP 6.0 MAX, 5.5 TYP	+33 MIN +33 MIN	+41 dBm +42 dBm	2.0:1	
CA12157110	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	
	ADBAND &	MULTI-OC	TAVE BAND AN		0 10 1 100	VICILIE	
Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB) 1.6 Max, 1.2 TYP	Power-out@P1-dB +10 MIN		VSWR 2.0:1	
CA0102-3111 CA0106-3111	0.1-2.0 0.1-6.0	28 28	1.9 Max, 1.5 TYP	+10 MIN +10 MIN	+20 dBm +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 CA26-3110	0.5-2.0 2.0-6.0	36 26	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm +20 dBm	2.0:1	
CA26-4114	2.0-6.0	20	2.0 MAX, 1.5 TYP	+10 MIN +30 MIN	+20 dBm	2.0.1	
CA618-4112	6.0-18.0	25	5.0 MAX, 3.5 TYP 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 30	3.5 MAX, 2.8 TYP	+30 MIN +10 MIN +20 MIN	+20 dBm	2.0:1 2.0:1	
CA218-4110 CA218-4112	2.0-18.0 2.0-18.0	29	5.0 MAX, 3.5 TYP 5.0 MAX, 3.5 TYP	+20 MIN +24 MIN	+30 dBm +34 dBm	2.0.1	
LIMITING A			3.0 MAN, 0.3 TT	1217/111	TO T GDIT		
Model No.		nput Dynamic Ro	ange Output Power		er Flatness dB	VSWR	
CLA24-4001 CLA26-8001	2.0 - 4.0 2.0 - 6.0	-28 to +10 dB	m +7 to +1 m +14 to +1		/- 1.5 MAX /- 1.5 MAX	2.0:1 2.0:1	
CLA712-5001	7.0 - 12.4	-50 to +20 dB -21 to +10 dB -50 to +20 dB	m +14 to +1	9 dRm +	/- 1.5 MAX	2.0.1	
CLA618-1201	6.0 - 18.0			9 dBm +	/- 1.5 MAX	2.0:1	
AMPLIFIERS \			TTENUATION	·		VCMD	
Model No. CA001-2511A	Freq (GHz) 0.025-0.150	Gain (dB) MIN 21 5	Noise Figure (dB) Pow	v <mark>er-out@P1-dB Gain</mark> +12 MIN	Attenuation Range 30 dB MIN	2.0:1	
CA05-3110A	0.023-0.130	23 2			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		15 dB MIN	1.9:1	
CA1315-4110A CA1518-4110A	13.75-15.4 15.0-18.0				20 dB MIN 20 dB MIN	1.8:1 1.85:1	
LOW FREQUE			.U MMA, Z.U III	I I O IVIIIV	LO UD MIIN	1.03.1	
Model No.	Freq (GHz) (Gain (dB) MIN			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 CA001-2215	0.04-0.15 0.04-0.15	24 23	3.3 MAX, 2.2 I Υ P 4 Ω MΔΥ 2 2 TYP	+13 MIN +23 MIN	+23 dBm +33 dBm	2.0:1 2.0:1	
CA001-2213	0.01-1.0	28	3.5 MAX, 2.2 TYP 4.0 MAX, 2.2 TYP 4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1	
CA002-3114	0.01-2.0	2/	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 +25 dBm	2.0:1	
CA004-3112	0.01-4.0		4.0 MAX, 2.8 TYP	+15 MIN		2.0:1	
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DefenseNews Cliff Drubin, Associate Technical Editor



US Navy Accepts 5th MUOS Satellite for Secure Global Military Cellular Network

he U.S. Navy's Communications Satellite Program Office and Lockheed Martin recently handed over full operational control of the fifth Mobile User Objective System (MUOS) satellite to the Naval Satellite Operations Center (NAVSOC).

This followed the successful completion of the MUOS-5 satellite's on-orbit testing and delivery of all operational products needed to "fly" the satellite. In April, the Navy, working with Army Forces Strategic Command (ARSTRAT), configured one of MUOS-5's two communications payloads—its legacy Ultra High Frequency (UHF) payload—for testing.

The handover of this satellite to NAVSOC clears the final hurdle allowing for ARSTRAT to provide the payload's final configurations to support the Navy's legacy UHF satellite communications mission.

"Today, every Combatant Command in aircraft, ships, submarines, ground vehicles, as well as by troops in the field and special operations, rely upon secure, beyond-line-of-sight UHF satellite communications provided by the Navy," said Mark Woempner, Lockheed Martin's director for Narrowband Communications. "ARSTRAT's final configuration of MUOS-5's UHF legacy payload allows the satellite to fully support our military forces in these Combatant Commands."

Eventually, legacy narrowband UHF communications will transition to next generation Wideband Code Division Multiple Access (WCDMA) capabilities. To facilitate that transition, all five on-orbit MUOS satellites were intentionally designed with two communications payloads to support both Legacy UHF and WCDMA.

Early combatant commander testing of the on-orbit WCDMA payloads began in July 2016. The new MUOS capabilities will revolutionize communications for mobile forces with simultaneous, crystal-clear voice, video and mission data over a secure high speed Internet Protocol-based system. Users with new MUOS terminals will be able to seamlessly connect beyond line-of-sight around the world and into the Global Information Grid, as well as into the Defense Switched Network, as part of the Navy's worldwide cellular network.

Once fully operational, the MUOS network of five onorbit satellites and four relay ground stations will provide more than 10x the communications capacity of the legacy UHF satellite system. MUOS' network already provides near-global coverage, including communications into polar regions. MUOS also has demonstrated successful communication of Integrated Broadcast Service (IBS) messages.

"Similar to a civilian cellular phone service, upgrades to this new secure global military cellular network are ground-based and designed in an AGILE software

development environment. We continue to make upgrades to the system based on user needs and look forward to bringing its full capabilities to our warfighters," Woempner said.

Today there are more than 55,000 radio terminals currently fielded that can be upgraded to be MUOS-compatible, with many of them requiring just a software upgrade.

Advanced Electromagnetic Maneuver Warfare Capabilities Showcased at AOC

orthrop Grumman Corp. recently showcased two milestones in the development of advanced electromagnetic maneuver warfare capabilities during the 54th Annual Association of Old Crows (AOC) International Symposium and Convention. The symposium, themed "Innovation and Change in Electromagnetic Warfare," took place in Washington, D.C., November 28-30.

At the symposium, Northrop Grumman showcased its Multifunction Transceiver (MFXTM) and direct RF technology. MFXTM and RF offer unique approaches through sampling and synthesis that enable a variety of RF-enabled mission solutions. These mission enablers form part of the technological foundation of forthcoming advanced integrated mission systems.

MFX™ is an advanced programmable receiver, exciter, signal processor and waveform generator that enables multifunction applications through scalable choices of operating frequencies, bandwidths and channels. Its inclusion in the RF chain allows for integrated capabilities in domains such as electronic warfare (EW), communications, signals intelligence (SIGINT) and radar. Northrop Grumman recently demonstrated these unique capabilities at the U.S. Pacific Command's 2017 Northern Edge Combat Exercise. The MFX™ enabled electronic attack/electronic support measure (EA/ESM) subsystem is just one of ten next-generation air warfare capabilities Northrop Grumman successfully demonstrated during the exercise. Attendees at AOC had the opportunity to see MFX™ and its concept for utilization in advanced mission systems.

Complementing the capabilities of MFXTM, Northrop Grumman's development of novel analog-to-digital and digital-to-analog converters enables direct RF sampling and synthesis. RF sampling and synthesis plays an important role in eliminating the need for bulky analog front-end components and substantially reducing the size, weight and power of future mission payloads while simultaneously improving system level performance.

These direct digital conversion components were recently integrated and tested on an advanced prototype multifunction system, demonstrating the ability to sup-

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port disparate mission needs including EW, communications, SIGINT and radar—proving the feasibility and operational benefits of this integrated electromagnetic maneuver warfare system approach.

MWJ's technical editor, Gary Lerude, recently attended the AOC event. For a full recap and his impressions, visit www.mwjournal.com/aoc2017

LM, Indra to Provide AESA Radar to Worldwide Anti-Air Warfare Platforms

orthrop Indra and Lockheed Martin recently signed a Heads of Agreement that extends their exclusive relationship in the development of a state-of-the-art S-Band active electronically scanned array (AESA) radar for the Spanish Navy's F-110 program and establishes a framework for the commercialization of this solid state radar for other anti-air warfare opportunities worldwide. Navies from other countries will benefit from the ongoing work performed for the F-110, a vessel with an Aegis Combat System adapted to respond to conventional and asymmetric threats in coastline operations. This AESA radar will be an option

for any frigate with similar requirements to the F-110. Under this agreement, both companies will work together to fulfill customer needs. The F-110 frigate is the Spanish Navy's future multi-mission surface vessel, due to see operations in the next decade. With production expected to begin in 2018, the first F-110 frigate would be commissioned in 2023 equipped with the first Aegis Weapon System integrating the new solid state S-Band radar.

LM and Indra have been collaborating since 2009 to develop a state-of-the-art S-Band solid state radar for Spain's F-110 Frigate Program, and their cooperation in S-Band naval radars dates to 1997 when Indra began supplying components for the SPY-1D radar. Over those 20 years, Indra has delivered components to every Aegis Combat system for the U.S. Navy and all five international Aegis partner navies. Under this new radar partnership, nearly a decade of joint funding and technical collaboration has been invested to combine and mature the best of LM and Indra S-Band solid state radar technologies.

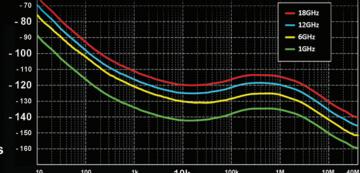
The Spanish Navy operates five Aegis-equipped Álvaro de Bazán-class (F-100) frigates equipped with the LM-developed Aegis Combat System and SPY-1 radar. F-110 will aim to evolve the strong partnerships between U.S. and Spanish industry established during the development and fielding of the first four ships of the F-100 program and expanded for F-105.

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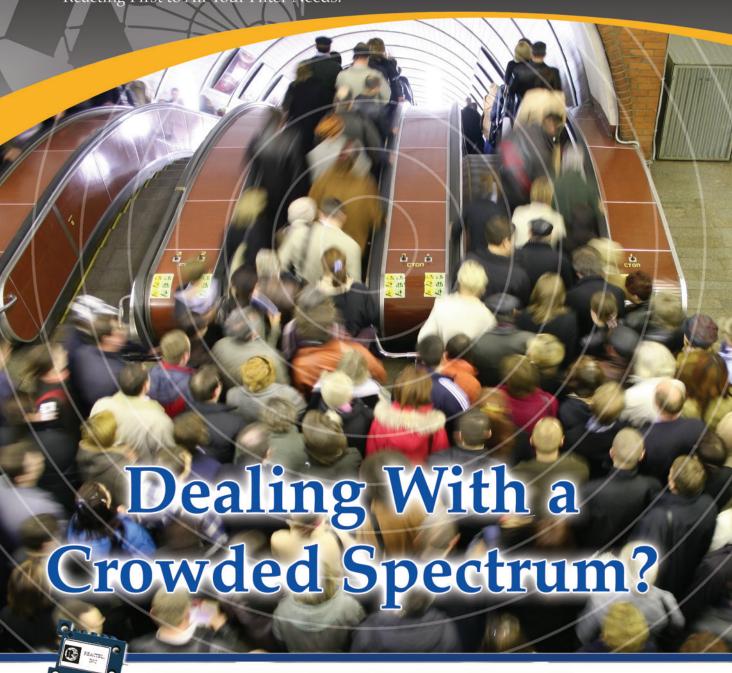




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Richard Mumford, International Editor

Leti Announces FED4SAE Project to Accelerate European CPS Solutions

eti, a coordinator of the pan-European Federated CPS Digital Innovation Hubs for the Smart Anything Everywhere (FED4SAE) consortium, announced that the 14 project partners have launched a three-year European Commission program to facilitate the acceleration of European cyber-physical-system (CPS) solutions to market. This project will boost digitization of European industry by strengthening companies' competitiveness in the CPS market.

CPS link the physical world with the virtual world of information processing. They are comprised of diverse constituent parts that function together to create some global behaviour. These constituents may include software systems, communications technology and sensors/actuators that interact with the real world, often including embedded technologies.

The FED4SAE project will create a pan-European network of Digital Innovation Hubs (DIH) by leveraging existing regional tech or businesses ecosystems across complete value chains and multiple competencies. The network of DIHs will enable startups, SMEs and midcap companies in all sectors to build and create new digital products, smart applications and services.

This pan-European network will enable companies to use CPS platforms combined with expertise and knowhow from the R&D advanced platforms. The ultimate goal of each industrial project within FED4SAE is to develop a complete solution that can get to market and scale. This includes combining hardware and software components and deploying them in a range of testbeds prior to deployment into the targeted market, as well as support in business modelling and market insights through guidance from conceptual design through market launch. Application experiments will be funded for developing innovative CPS products that will increase the competitiveness of European innovative companies.

imec Demos Ring Oscillator Development

t the 2017 International Electron Devices Meeting (IEDM) in December, imec reported on multiple key process optimizations for vertically stacked gate-all-around (GAA) silicon nanowire transistors. The optimized CMOS process flow was then used to integrate, for the first time, the GAA nanowire transistors in a functional ring oscillator.

GAA MOSFETs based on vertically stacked horizontal nanowires or nanosheets are promising candidates to succeed FinFETs in sub-5 nm technology nodes, thus extending today's CMOS technology beyond its scaling limits. This innovative transistor architecture offers

a more aggressive gate pitch scaling than FinFETs because it achieves a better electrostatic control. Moreover, in very scaled standard cells where only one fin device is allowed, nanosheets provide more current per footprint than fins, and thus can drive higher capacitive loads. Finally, integrating nanosheet devices with variable widths in a single platform enables power/performance optimization with high granularity.

At IEDM, a team of researchers from imec and Applied Materials demonstrated multiple optimizations for the fabrication of stacked silicon nanowire and nanosheet FETs. The first process optimization is the implementation of SiN Shallow Trench Isolation (STI) liners, which suppresses oxidation-induced fin deformation and improves the shape control of the nanowire or nanosheet. Secondly, SelectraTM etch was used to enable nanowire/nanosheet release and inner spacer cavity formation with high selectivity and without causing silicon reflow. Finally, for the first time, ring oscillator circuits were reported based on stacked silicon nanowire FETs, including dual work function metal gates for threshold voltage control.

KDDI Selects Gilat's Backhaul Solution for LTE Network in Japan

DDI has chosen Gilat Satellite Networks Limited's satellite based LTE cellular backhaul solution to extend reach and resilience with high speed data and high quality voice over LTE (VoLTE) throughout Japan. The cellular backhaul solution provides voice, data and video services at true LTE speeds and high voice quality.

Gilat's VSATs will be installed in fixed sites as well as on deployable vehicles for emergency response—Cellular on Wheels (COW). The solution leverages the company's patented LTE backhaul solution and leading mobility features to support continuous service for public safety, in addition to the outstanding performance provided in fixed LTE cellular sites.

"We are very pleased to select Gilat's LTE cellular backhaul over satellite solution to play a key part in KDDI's Mobile Services mission to deliver superior customer experience in Japan, including in islands and the metro-edge and for tourists visiting national parks and mountainous areas. Gilat's technology will be used to extend our network reach as well as a basis for our disaster recovery capabilities," said Nobuyuki Kawai, general manager, Global Network Engineering and Operations Centre at KDDI.

"We are honoured to have been selected by KDDI to support their vision of revolutionizing the lives of Japanese people and visitors to Japan, by providing superior connectivity with data and VoLTE anytime and everywhere," said Abhay Kumar, RVP Asia at Gilat.

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Huawei, NTT DOCOMO Reach 5G Milestone

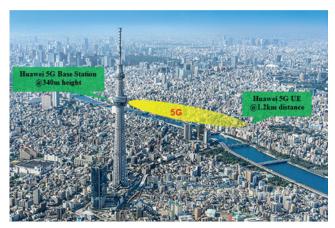
uawei and NTT DOCOMO, INC. reached a milestone in their joint 5G trials by succeeding in high speed data transmission over a distance of 1.2 km on the 28 GHz mmWave spectrum.

The field trial, which took place at Tokyo Skytree in downtown Tokyo, was conducted in an environment where a base station working over 28 GHz was located at Tokyo Skytree's viewing deck at a height of 340 m above the ground, while user equipment was placed on the roof of a shopping facility at Asakusa Station. Under adverse conditions of a -10 dBm penetration loss which came from the window glass of the viewing deck, the partners achieved more than a 4.52 Gbps downlink throughput and a 1.55 Gbps uplink throughput with a coverage range of 1.2 km.

Huawei's 5G base station, which supports Massive MIMO and beamforming technologies, is being utilised in these trials to support successful long distance data transmission over 28 GHz. In addition, the 5G core network and 5G mmWave test user equipment (TUE) was provided by Huawei to enable an end-to-end 5G network. Visitors to this open field trial experienced next generation video communication using a Microsoft HoloLens over the end-to-end 5G network.

An immersive experience was created during the livedemo, with clear voice calls and smooth video footage free of freezing being displayed.

Gan Bin, vice president of Huawei 5G Product Line said, "This successful long distance live-demo on a 5G mmWave is a groundbreaking achievement in our joint effort with NTT DOCOMO to build a fundamental 5G commercial environment. It makes us more confident in realizing the goal of commercializing 5G by 2020."



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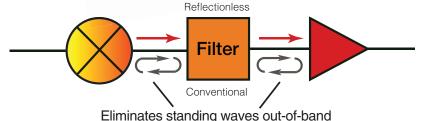


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Commercial Market Cliff Drubin, Associate Technical Editor

Telecoms Industry mmWave Obsessed, But 3.5 GHz Will be the Killer 5G Band

he industry has had to tap into a wide range of radio spectrum frequencies from sub-1 to 100 GHz including licensed, unlicensed and shared spectrum to address the potential of 5G. According to new findings from ABI Research, while the use of mmWave is one of the most distinguishing features of 5G, in the near term C-Band is emerging with the most global consensus for the timely launch of a commercial 5G network in 2019. Many of the lab and field 5G trials conducted by industry participants have focused on higher frequencies, but based on the recent regulatory announcements by about 20 countries, C-Band is the most common spectrum range identified

for 5G.

"Will 5G mmWave technology be up to speed for 5G mobile broadband in 2019-2020?" "In the long-term the whole breadth of the sub-1 to 100 GHz spectrum range will be critical to address the various use cases and meet enhanced speeds, latency, reliability and other 5G metrics in different usage scenarios. In the

near-term, however, use mmWave for 5G services in 2019-2020 is limited due to technology challenges and global spectrum availability," explains Prayerna Raina, senior analyst at ABI Research.

Since current cellular communication takes place below 6 GHz, the use of higher frequency ranges for mobile broadband is unfamiliar territory for mobile operators. Similarly, key 5G antenna and base station technologies such as MIMO are currently deployed in the sub-6 GHz range on a low order of four to 16 antenna elements in most cases. At higher mmWave frequencies, massive MIMO antennas are likely to feature hundreds of antenna elements, which brings its own set of challenges.

The use of higher frequencies such as 26 and 28 GHz for fixed mobile broadband service on 5G networks is certain, but it is C-Band with its global harmonization that is creating opportunities for large scale deployment.

"Ultimately 5G must make good business sense for operators who continue to battle stagnating ARPUs, rising network traffic and the need to cost-effectively optimize network management and operations," says Raina. "C-Band, with the support of new technologies, including uplink decoupling, will likely be the dominant 5G spectrum band, since it allows operators to deploy 5G on an existing network grid, rather than spend significantly on new cell cites," Raina concludes.

Smart Integration Brings Opportunity, Complexity for Car Manufacturers

he importance of the growing smart home market is drawing in car manufacturers and their development strategies. Mercedes, BMW, Ford and others are all bringing Amazon Alexa and other smart home voice control platforms into their connected cars. But, voice control is just the start. According to ABI Research, by 2022, more than 500 million connected cars will have shipped and the ability to tie those vehicles into the platforms controlling more than 300 million smart homes around the world is driving investment and partnerships amid the vendors and technology suppliers across both markets.

"Extending smart home voice control into the connected vehicle is part of an ongoing integration that will pull together home and vehicle personalization. It marks a weakening of Original Equipment Manufacturers' (OEM) total control over the technologies embedded into their vehicles," says Jonathan Collins, research director at ABI Research. "That means OEMs will have to select partnerships and technology suppliers that can best support the widest integrations."

Starting with smart home voice control, vehicle integration with smart home management will increasingly draw other functions into the connected vehicle. Navigation, insurance, health, energy management, AI, media management and other applications and sup-

"Partnerships between OEMs and technology suppliers offer new capabilities, but weaken OEM control."

porting industries will integrate with connected vehicles and often directly through smart home interaction.

However, the smart home market remains a wildwest style market with a variety of vendors, including Amazon, Apple, Google and others building fiefdoms with industry-wide standards remaining minimal. This leaves vehicle OEM manufacturers faced with conflicting options for technologies and smart home partnerships to maximize the appeal of their connected car strategies.

"With the looming potential of autonomous vehicles, OEMs are faced with an array of potential partners to help support that generation of vehicles that increasingly threaten the OEMs sole role in controlling the functionality and appeal of their vehicles," says Collins.

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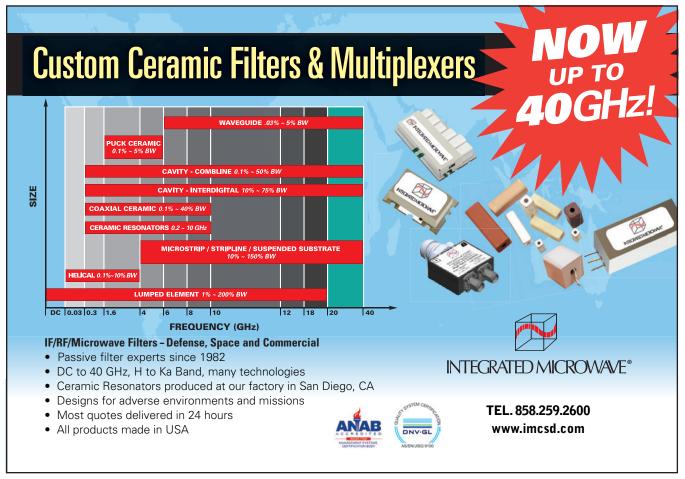
Computer Vision Will Help 650 Million Mobile Devices See, Do More Than Ever

e are entering an era where devices can see rather than simply respond to touch. Recent smartphone launches from Apple (iPhone X), Huawei (Mate 10) and Google (Pixel 2 and Google Clips) are starting to shift the focus from what we see and do with our devices, to what the devices see and do for us. Major features such as security (e.g. Apple Face ID), social networking (Apple animojis) and content (Google Clips) are early examples of this confluence of computer vision, Al and machine learning.

These devices also highlight a trend where both computer vision and AI are moving to the end device instead of relying on the cloud, engendering additional market opportunity for chip suppliers to bring to market more robust SoCs and GPUs and solutions like accelerators and VPUs. ABI Research forecasts that by 2022, over 650 million mobile devices will support more advanced vision applications on the device. Our phones will move from retouching our photos in the cloud to using vision to recognize when we are upset and perhaps starting some music to ease our troubled minds.

"The combination of AI, machine learning and computer vision will help us use and interact with our devices in new and more profound ways—we will move from one-to-one connections between devices and the Web and remote services to an increasingly connected ecosystem of components that work together," says Michael Inouye, principal analyst at ABI Research. "While some of the markets supporting embedded vision like VR and AR may appear to be new, they are in fact much older than the recent product launches—they are simply spreading because the technology has reached a critical level where science fiction and imagination are starting to become reality."

Mobile devices will remain the largest market opportunity by volume of devices for computer vision. Even the expansion of markets like AR and VR will fall short of mobile devices; further, many of these AR/VR applications will leverage or rely on smartphones. Computer vision will in some ways be bounded by what the camera can see. Google Clips offers a new take on cameras which attempts to automatically look for and capture great moments. Smartphone cameras intelligence may be most limited by their field of view. They will be blind when they are in our pockets; a 180-degree front-facing camera may have immensely more useful intelligence compared to approximately 100 degrees of many devices today.





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MERGERS & ACQUISITIONS

Würth Elektronik announced the acquisition of U.K.-based IQD Frequency Products. U.K.-based IQD Frequency Products Ltd. and U.S.-based IQD Frequency Products Inc., have now become the latest members of the Würth Elektronik eiSos Group. IQD is among the leading manufacturers of frequency control devices in Europe with customers in over 80 countries. IQD develops, manufactures and markets quartz crystals, oscillators, VCXOs, TCXOs, OCXOs, GPS-synchronized OCXOs and rubidium oscillators. The company also offers product solutions built to customer specifications.

HBD Industries announced the expansion of its Precision Components platform through the acquisition of True Position Technologies LLC. Based in Valencia, Calif., True Position is a provider of complex machined components for flight control applications. True Position specializes in manufacturing high specification components that require multiple machining, testing and finishing processes all within extremely tight tolerances. Allen Sumian will continue to lead True Position and has been appointed president of HBD's Precision Components Group, which also includes California Drop Forge and Precision Metal Products. Both companies are leading high alloy near net forge component providers for aerospace, defense and medical industries.

Broadcom offered to buy out all outstanding shares of **Qualcomm** for \$60 in cash and \$10 in Broadcom Stock. Qualcomm branded this as an unsolicited offer and suggested that Qualcomm stock is worth much more. However, Broadcom is not giving up. They continue to receive positive feedback from customers and, having had initial meetings with certain relevant antitrust authorities, remain confident that any regulatory requirements necessary to complete a combination will be met in a timely manner. They would prefer to engage in a constructive dialogue with Qualcomm. They have repeatedly attempted to engage with Qualcomm, and despite stockholder and customer support for the transaction, Qualcomm has ignored those opportunities.

Eclipse Microwave, located in San Jose, Calif. has acquired the ownership of the Wafer fabrication equipment to support the manufacturing of Tunnel Diodes from MACOM.

COLLABORATIONS

Raytheon Co. and Pivotal Software Inc. announced that Raytheon has joined the Pivotal Ready Partner Program to assist the Department of Defense (DoD) to develop software capabilities to more rapidly bring new technology to the military. The agreement establishes an important relationship that will help the DoD

migrate legacy applications to the cloud and accelerate software development and delivery timelines. Pivotal Cloud Foundry brings a software-led digital transformation to its customers. Through its cloud-native platform, Pivotal has helped hundreds of commercial customers, and recently the DoD, modernize their legacy systems, significantly improving delivery time and generating millions in cost savings.

ZTE Corp. is providing its 5G base stations and core network equipment to **SoftBank** for experimenting in the 4.5 GHz band. SoftBank obtained its obtained its experimental license for this band on November 20, 2017. The experiment will be conducted in the Shiba-Daimon area of Tokyo. ZTE has established close relationships with SoftBank while experimenting with massive MIMO, which is one of the important elemental technologies adopted for 5G starting in 2015, and by supplying massive MIMO equipment in SoftBank's commercial networks since 2016.

NEW STARTS

TMD Technologies LLC has recently upgraded its company website to further support its growing customer base in North America. TMD U.S.'s new website is at www.tmdus.com. The improved website allows customers to download technical data sheets and provides downloadable product-specific capability brochures. Also, the latest developments in TMD's evolving product line-up of microwave power modules (MPM), travelling wave tubes (TWT), high voltage supplies and commercial amplifiers will be posted to keep customers informed of the company's expanding technical road maps. The new TMD U.S. website will be updated regularly to announce company information, new product releases and relevant technical information.

ACHIEVEMENTS

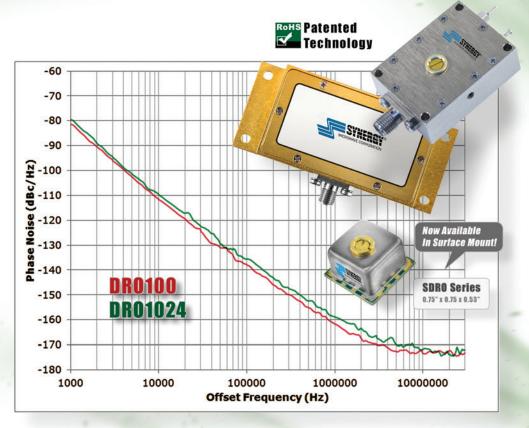
Quintech Electronics & Communications Inc. announced that it was awarded a patent for the XTREME 256 matrix switch modular design that allows its switch chassis to be configured with either a symmetric or asymmetric number of inputs and outputs. Unlike traditional RF switch matrices that require multiple chassis in order to scale and meet both symmetric and asymmetric input/output port requirements, Quintech's patented modular asymmetric feature lets customers "customize" matrix sizes in a standard chassis. Quintech offers customers a distinct advantage in that a single XTREME 256 chassis can be used where competing matrices would require multiple chassis.

United Monolithic Semiconductors announced that its GH25-10 MMIC GaN HEMT technology has been successfully space evaluated and is now part of the European Preferred Part list (EPPL), supported by the European Space Agency (ESA). The reliability study and ESCC evaluation of the technology were supported by ESA, CNES and French MoD (DGA). The GaN 0.25 μm HEMT process is optimized for high-power applications

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Around the Circuit

up to 20 GHz. It also provides a good HEMT noise performance, as well as enabling LNA design. The MMIC process includes precision TaN resistors, high value Ti-WSi resistors, MIM capacitors, inductors, air-bridges, via-holes through the substrate and two metal layers for interconnection.

Rohde & Schwarz announced that its R&S QPS200 mmWave technology has achieved TSA Advanced Imaging Technology (AIT) detection certification. TSA certification validates that the R&S QPS200 meets TSA's stringent aviation security detection requirements. The R&S QPS200 security scanner uses safe mmWave radio frequency technology to screen passengers automatically for concealed threats while protecting passengers' privacy. The R&S QPS200 is the first Rohde & Schwarz AIT system to achieve TSA detection certification and has achieved certification by the European Civil Aviation Conference (ECAC) and is in use at airports across Europe.

Guerrilla RF Inc. announced an update to a previous milestone achievement. Guerrilla RF is proud to announce the organization has progressed from recommended status to final confirmation that they have been awarded ISO9001:2015 certification status by TUV Rheinland of North America, a 3rd party registrar. As part of the ISO certification process, Guerrilla RF underwent a rigorous audit of its business and management processes, including the design, operations and sales processes. This achievement is another step and further confirms Guerrilla RF as a major supplier in the design and sale of high performance RFICs and MMICs for consumer, commercial and military wireless product applications.

CONTRACTS

BAE Systems has received a \$139.8 million contract from the U.S. Navy to modernize the dock landing ship USS Tortuga (LSD 46). The Tortuga will undergo 16 months of restorative work at the company's shipyard in Norfolk, Va., the ship's homeport. The contract includes options that, if exercised, would bring the cumulative value to \$183.7 million. BAE Systems will begin working aboard the 610-foot-long Whidbey Island-class ship in January 2018 and will perform a combination of maintenance, modernization and repair. The availability is expected to be completed in May 2019, with the reactivation of the ship for operational service.

Kaman Corp. announced that its aerospace segment has received an order with an expected value of approximately \$85 million for the procurement of Joint Programmable Fuzes (JPF) for the U.S. Air Force (USAF) and 18 foreign militaries. The award is the first order under Option 13 of Kaman's JPF contract, with the USAF, with deliveries anticipated to occur in 2018 and 2019. Kaman has been the sole provider of the JPF to the USAF since 2002. In addition to the USAF, Kaman provides the JPF to 26 other nations.

Harris Corp. has awarded Cobham with a series of orders worth approximately \$39 million for RF microelectronics that support a leading edge electronic warfare (EW) program. The order will be managed by the Cobham Advanced Electronics Solutions division of Cobham. The order will be developed at the San Jose and San Diego locations of Cobham Microelectronic Solutions. Cobham's technology and manufacturing strategies allow for high levels of technical performance in demanding environments while meeting the affordability objectives of customers and end markets. Harris' EW program provides self-protection capability against surface-to-air and air-to-air radar guided threats by detecting, identifying and managing electronic countermeasure responses to radar threats.

NCI Inc., a provider of advanced information technology (IT) solutions and professional services to U.S. Federal Government agencies, announced that it was awarded a three-year task order valued at \$21 million under the Total Engineering and Integration Services (TEIS) III contract for IT services. The contract is in support of NCI's long-standing customer, the U.S. Army Information Systems Engineering Command (USAISEC), Fort Detrick, Md., Engineering Directorate (ISEC-FDED). Under the award, the company is providing services related to the expansion, upgrade and replacement of wired and wireless local area networks at U.S. Army medical treatment facilities, and associated outlying or remote facilities worldwide.

Comtech Telecommunications Corp. announced that during its first quarter of fiscal 2018, its Command & Control Technologies group, which is part of Comtech's Government Solutions segment, has received a contract from a major U.S. space contractor to source and test space components in support of a critical NASA Program. This contract is valued in excess of \$8 million and was initially funded in excess of \$4 million. The Command & Control Technologies group is a leading provider of mission-critical, highly-mobile C4ISR solutions from the desktop to the edge of the network, for land, maritime and airborne applications.

Anaren Microwave Inc., a subsidiary of Anaren Inc., announced it has received a \$5 million order from a leading defense prime contractor for hardware support of an airborne electronic warfare application. The order was booked at the end of last quarter and is expected to ship over the next several quarters.

The U.S. Air Force's Space and Missile Systems Center (SMC) has selected Ball Aerospace to deliver a next-generation environmental satellite system, Weather System Follow-on–Microwave (WSF-M). As the prime contractor, Ball will be responsible for developing and integrating the entire microwave system, which includes the microwave instruments, spacecraft and system software. WSF-M is a predominantly fixed price contract that will provide for system design and risk reduction of a Low Earth Orbit (LEO) satellite with a passive mi-





Around the Circuit

crowave imaging radiometer instrument and hosted Government furnished energetic charged particle (ECP) sensor.

PEOPLE



▲ Mark Popovich

3D Glass Solutions Inc., manufacturer of glass-based system-in-chip (SiP) and integrated passive devices (IPD) for RF and IoT applications announced the appointment of **Mark Popovich** as its chief executive officer. Jeb Flemming, company founder, will continue to serve as chief technology officer and a director of the company. Popovich brings more than 25 years

of senior management and high-volume manufacturing experience in the electronic components and packaging industry.



▲ Emmanuel Sabonnadiere

Leti, a technology research institute of CEA Tech, has named **Emmanuel Sabonnadiere** as the institute's new CEO. He will lead one of Europe's largest micro- and nanotechnologies research institutes, which employs approximately 1,900 scientists and engineers, has a portfolio of 2,700 patents and has launched more than 60 startups. Sabonnadiere has more than 25

years of executive leadership experience in a variety of large technology environments and joined Leti from CEA Tech, where he led the industrial-partnership program. He brings a strong background in new technology development with broad private-sector expertise in operational excellence, team building and guiding multicultural organizations in business transformation in Europe and globally.



▲ Landon Garne

Taoglas, a provider of IoT and automotive antenna products, has announced the appointment of Landon Garner to the newly created position of chief marketing officer (CMO). As CMO, Garner is tasked with growing awareness of Taoglas' global presence, and will oversee all aspects of brand communications, product strat-

egy and marketing and demand generation. Garner joined Taoglas from Ingenu, where he was responsible for overseeing Ingenu's corporate launch in 2015, as well as supporting the rollout of the company's technology and networks to a global audience.

Test sourcing specialist **Microlease/Livingston** continues to strengthen its commercial operations in the key markets of Central Europe, with the appointment of a new sales director for the DACH countries. **Michael Prax** has been given the task of building the Microlease/Livingston customer base in Germany, Austria and Switzerland—developing its presence in key sectors



▲ Michael Prax

such as automotive, semiconductor, avionics and defense, as well as consolidating its extensive presence in the telecom sector. Prax brings considerable industry experience with him, having spent over 25 years in the EMEA test and measurement business. Previously he held high-lev-

el management positions at Tektronix, Ametek and JDSU (now known as Viavi).

REP APPOINTMENT

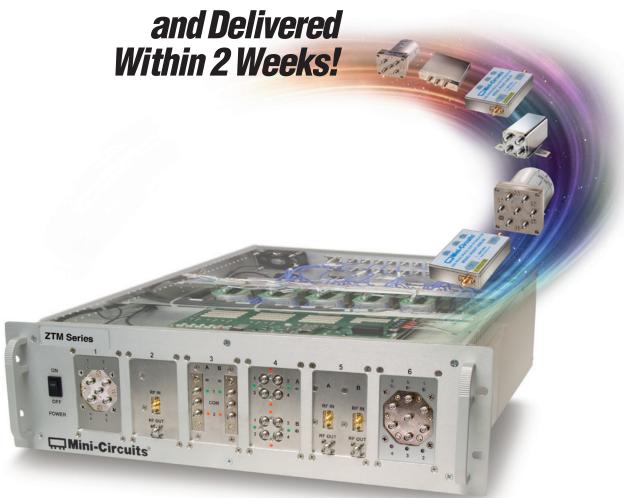
NAI has appointed **Trilogy** as its manufacturer's sales representative in the Midwest. Effective immediately, Trilogy will represent NAI's unique capabilities in the design and manufacturing of cable assemblies and harnesses. Trilogy has been in business for 27 years and has a large sales team with excellent customer relationships throughout the territory. NAI will leverage Trilogy's capabilities to grow its business in Trilogy's main markets: medical, military/aerospace, IoT and industrial technologies. These are strategic market segments for NAI, so the alignment and synergy were immediately attractive to both parties. Trilogy will cover five states for NAI, including Michigan, Indiana, Ohio, Kentucky and western Pennsylvania.

PLACES

Mercury Systems Inc. celebrated the grand opening of its Advanced Microelectronics Center (AMC) located in Phoenix, Ariz. Arizona Congressman Ruben Gallego (D), State Senator Catherine Miranda (D) and State Representative Reginald Bolding (D) joined Mercury President and CEO Mark Aslett and Mercury's Board of Directors for a ribbon cutting ceremony, reception and facility tour. The company's new AMC facility is a high-tech, 115,000 square foot design and manufacturing center of excellence for advanced digital microelectronic solutions addressing the defense industry's most rigorous performance and quality standards.

ThinkRF Corp. announced their expansion to Europe with an office outside London. This expansion will be the base for the company's growth into key markets in Europe. With over 25 years of experience in the RF, networking and defense industries, Steve Blades joins ThinkRF to run the European headquarters. He brings his responsive and consultative approach to help wireless communication providers, spectrum regulators and aerospace and defense companies find the right solutions to solve their spectrum analysis challenges.

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Evaluating 77 to 79 GHz Automotive Radar Radome Emblems

Steffen Heuel, Tobias Köppel and Sherif Ahmed Rohde & Schwarz, Munich, Germany

> dvanced driver assistance systems (ADAS) in cars assist the driver and increase road safety, and these systems are widely deployed in many modern vehicles and car types. Currently, autonomous driving is a major focus of the automotive industry, and R&D institutes are making headlines with fully automated cars driving hands-off along the highway—even in cities with dense traffic. It is certain that autonomous driving will become reality in the near future.

> Camera, LiDAR and radar sensors are key enabling technologies in this area. Millions of automotive radars are produced every year, and car manufacturers are starting to deploy them as standard equipment in all higherclass cars. Today, automotive radar sensors

Fig.1 Radar mounted behind the front emblem, which is

are mainly used to increase driving comfort and prevent crashes. Most automotive radar sensors that enable adaptive cruise control (ACC) operate in the conventional 76 to 77 GHz frequency range to sense other cars and objects far ahead. Advanced radar capabilities, however, demand larger bandwidths, with coverage up to 81 GHz to enable 360 degree radar vision around the vehicle. This is required for ADAS functions such as lane change assistance and blind spot detection, where high resolution and a wide operating angle are essential. Additionally, extending the automotive frequency band to 81 GHz helps mitigate interference. Altogether, this puts pressure on radar system integration to be functional across a wider frequency band than in the past.

Automotive radars must be masked by a cover, known as a radome, which is constructed from a transparent RF material. Radomes can be an emblem or a car bumper, with the radar behind it as illustrated in *Figure 1*. Although an emblem may be underestimated and dismissed as a simple plastic cover, it is actually a sophisticated RF element that often degrades radar detection range and accuracy. Emblems need to satisfy the requirements of aesthetic appearance, often including the 3D shape of the car logo. However, this is usually in conflict

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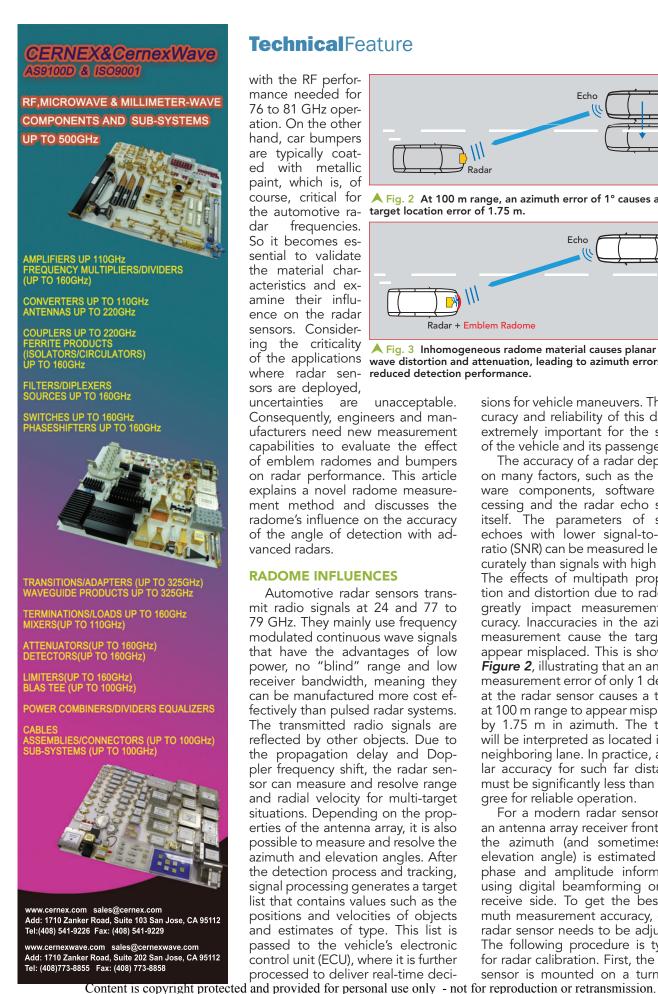
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with the RF performance needed for 76 to 81 GHz operation. On the other hand, car bumpers are typically coated with metallic paint, which is, of frequencies. So it becomes essential to validate the material characteristics and examine their influence on the radar sensors. Considering the criticality sors are deployed,

uncertainties are unacceptable. Consequently, engineers and manufacturers need new measurement capabilities to evaluate the effect of emblem radomes and bumpers on radar performance. This article explains a novel radome measurement method and discusses the radome's influence on the accuracy of the angle of detection with advanced radars.

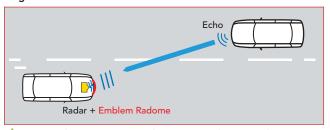
RADOME INFLUENCES

Automotive radar sensors transmit radio signals at 24 and 77 to 79 GHz. They mainly use frequency modulated continuous wave signals that have the advantages of low power, no "blind" range and low receiver bandwidth, meaning they can be manufactured more cost effectively than pulsed radar systems. The transmitted radio signals are reflected by other objects. Due to the propagation delay and Doppler frequency shift, the radar sensor can measure and resolve range and radial velocity for multi-target situations. Depending on the properties of the antenna array, it is also possible to measure and resolve the azimuth and elevation angles. After the detection process and tracking, signal processing generates a target list that contains values such as the positions and velocities of objects and estimates of type. This list is passed to the vehicle's electronic control unit (ECU), where it is further processed to deliver real-time deci-

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Echo

course, critical for A Fig. 2 At 100 m range, an azimuth error of 1° causes a the automotive ra- target location error of 1.75 m.



A Fig. 3 Inhomogeneous radome material causes planar of the applications wave distortion and attenuation, leading to azimuth errors and where radar sen-reduced detection performance.

sions for vehicle maneuvers. The accuracy and reliability of this data is extremely important for the safety of the vehicle and its passengers.

The accuracy of a radar depends on many factors, such as the hardware components, software processing and the radar echo signal itself. The parameters of signal echoes with lower signal-to-noise ratio (SNR) can be measured less accurately than signals with high SNR. The effects of multipath propagation and distortion due to radomes greatly impact measurement accuracy. Inaccuracies in the azimuth measurement cause the target to appear misplaced. This is shown in Figure 2, illustrating that an angular measurement error of only 1 degree at the radar sensor causes a target at 100 m range to appear misplaced by 1.75 m in azimuth. The target will be interpreted as located in the neighboring lane. In practice, angular accuracy for such far distances must be significantly less than 1 degree for reliable operation.

For a modern radar sensor with an antenna array receiver front-end, the azimuth (and sometimes the elevation angle) is estimated from phase and amplitude information using digital beamforming on the receive side. To get the best azimuth measurement accuracy, every radar sensor needs to be adjusted. The following procedure is typical for radar calibration. First, the radar sensor is mounted on a turntable

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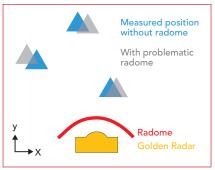
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in an anechoic chamber. A corner reflector in the far field at a known distance is commonly used as a reference target. The radar pattern is then measured and flashed into the radar sensor's memory. Later, this information is used by the detection algorithm. This ensures high azimuth measurement accuracy when the radar sensor completes production. The car manufacturer integrates this calibrated radar sensor into the car, often behind an emblem or the bumper, where the radome material influences the RF attenuation. The radome's transmission loss increases the two-way attenuation of the radar signal, which reduces the maximum detection range of the radar. The power level of a transmitted radar signal is reduced by the range, R, to the target and by R⁴ on the return. For a 77 GHz radar system with 3 W output power, 25 dBi antenna gain, a target with a 10 m² radar cross-section and a minimum detectable signal of -90 dBm, the maximum range would be 109.4 m, according to the range equation. If the radome has 3 dB two-way attenuation, the maximum range of the same radar measuring the same target would decrease to 92.1 m. That is approximately 16 percent less range.

It is not only material attenuation that has a great impact. The material reflectivity and homogeneity also play important roles. Reflections and RF mismatch of the material cause direct signal reflections in close range to the radar. The signals are received and down-converted in the receiver chain, reducing the radar's detection sensitivity. Many car manufacturers try to mitigate this effect by tilting the radomes—not only for design reasons—to reflect the transmitted radar signal somewhere other than directly back into the receiver front-end. This solution, of course, has mechanical limitations, not to mention the expected loss of RF energy from these parasitic reflections. Another problem comes from material inhomogeneities that disturb the echo signal wavefront used to estimate the azimuth value. Inhomogeneous material distorts the wavefront, which results in less accurate angular measurements.

The radar sensor calibration is no longer sufficient, since the previously and provided for personal use only in



♠ Fig. 4 Testing with a golden radar identifies some errors and signal degradation caused by the radome.

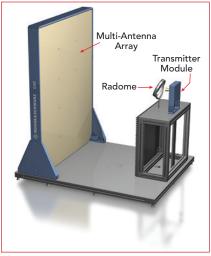


Fig. 5 Radome test using the R&S QAR system.

calibrated radar can be mounted behind any indeterminate radome from a different manufacturer (see *Figure 3*).

MATERIAL CHARACTERIZATION

Radome manufacturers typically test their units with a known or golden" radar. For this test, several corner reflectors are mounted in front of the radar at predetermined ranges and azimuth positions (see Figure 4). A differential measurement is conducted with and without the radome, and these measurements are compared. For the radome to pass the test, the range/ azimuth positions and echo signal levels must be within defined limits. However, this approach only tests certain azimuth angles and does not account for possible inhomogeneity or blind spots.

Another measurement method relies on a functional test. The radar sensor with the radome is mounted on a turntable and a corner reflector is placed in front of them. By turning the complete unit, every



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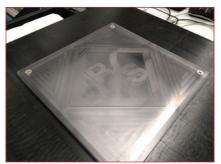
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azimuth and elevation angle can be measured and compared to the radar-only standard. This method is as accurate as the positioning of the turntable; however, the test takes a long time and is not feasible for production tests.

Instead of testing transparent radar material with a golden device, a proposed novel measurement method combines a transmission measurement with three-dimensional, high resolution radar imaging in the 77 to 79 GHz frequency band used by the radar itself. This is done using the R&S QAR system (see Figure 5). A multi-antenna array consisting of several hundred transmit and receive antennas operating from 75 to 82 GHz is used. This measurement system can measure the range, azimuth and elevation with millimeter resolution. It operates in the same frequency band as the automotive radar and "sees" what the automotive radar would see if it also had hundreds of transmit and receive antennas. Thanks to the large aperture, the resolution of the test system is much higher than that of the automotive radar, and it can visualize the measurement as an image. The radome is placed in front of the test system, which performs a two-stage measurement.

Reflectivity

First, a reflectivity measurement determines the amount of energy reflected by the radome material; this



▲ Fig. 6 Demonstration radome where the logo is 0.5 mm thicker than the radome material, causing an impedance mismatch at 77 GHz.

is energy that does not pass through the radome and contributes to performance degradation. Reflected signals decrease the performance of the radar and can even interfere with the received signals. Areas with high reflectivity can have various causes, such as material defects, air gaps, undesired interaction between layers of material, excessive amounts of certain materials or foreign objects. The measurement method achieves a spatially resolved reflectivity measurement for a radome by linking the information collected by the distributed, coherent transmit and receive antennas. The receive signals are gated and processed for all receive antennas, which results in a high resolution 3D radar image. The resulting mmWave image enables intuitive as well as quantitative evaluation of the radome's reflection behavior.

To illustrate the approach, a radome was manufactured where the

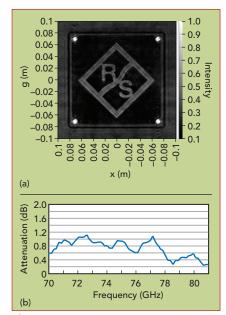
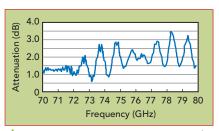


Fig. 7 High-resolution mmWave image (a) and one-way attenuation (b) of the demonstration radome.



♠ Fig. 8 Transmission measurement of a commercial, multi-layer radome with a complex 3D design.

R&S logo was milled with different thickness, as shown in *Figure 6*. The high resolution radar image in *Figure 7a* visualizes what an auto-

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MBD2057-C18	200	300	0.30	750	130	2.5	410	130
MBD3057-C18	300	400	0.30	500	80	2.5	400	125
MBD4057-C18	400	500	0.30	275	65	2.5	400	120
MBD5057-C18	500	600	0.30	250	60	2.5	400	110

The MBD series of planar back (tunnel) diodes are fabricated on germanium substrates using passivated, planar construction and gold metallization for reliable operation up to +110 °C. Unlike the standard tunnel diode, I_p is minimized for detector operation and offered in five nominal values with varying degrees of sensitivity and video impedance.

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motive radar sensor would perceive when covered by this radome. The color scale shows the reflectivity, where the dark color indicates minimal reflectivity and bright high reflectivity. Metal, which cannot be penetrated by automotive radar signals, appears as white (e.g., the screws in the four corners). The radome image indicates high reflectivity and the inhomogeneity of the logo, showing the increased thickness of 0.5 mm in the logo area is sufficient to cause major disturbances in radar performance on the street. In this example, calculating the mean reflectivity in the middle area, where the radar sensor is usually mounted, yields approximately -11 dB with a standard deviation of -17.7 dB. In many practical cases, this reflection is too high to maintain acceptable radar operation. In practice, the expected reflectivity depends on the sensitivity of the radar and the maximum detection distance to be covered.

Transmission

In a second test, the frequency matching and attenuation of the radome material is measured. A transmitter module is located behind the radome on the table. The transmitter uses a frequency sweep to cover a selected frequency span. This allows the radome's transmission frequency response to be measured. The frequency response delivers detailed information about the RF matching of the radome at the frequencies intended for radar operation. It is independent of the signal waveform used by the radar, which facilitates the testability and optimization of the radome itself.

The measured one-way attenuation versus frequency of the radome is shown in *Figure 7b*. Since automotive radars operate in the 76 to 81 GHz band, attenuation should be low across this range. Depending on the thickness of the material, its air gaps and RF matching, a good radome should maintain low attenuation across the desired frequencies. The logo example shows 0.64 dB one-way attenuation with better matching at 79 than at 76 GHz. A more sophisticated example for commercial radomes with a 3D

design typically results in a transmission measurement, as shown in *Figure 8*. This radome would have various performance issues:

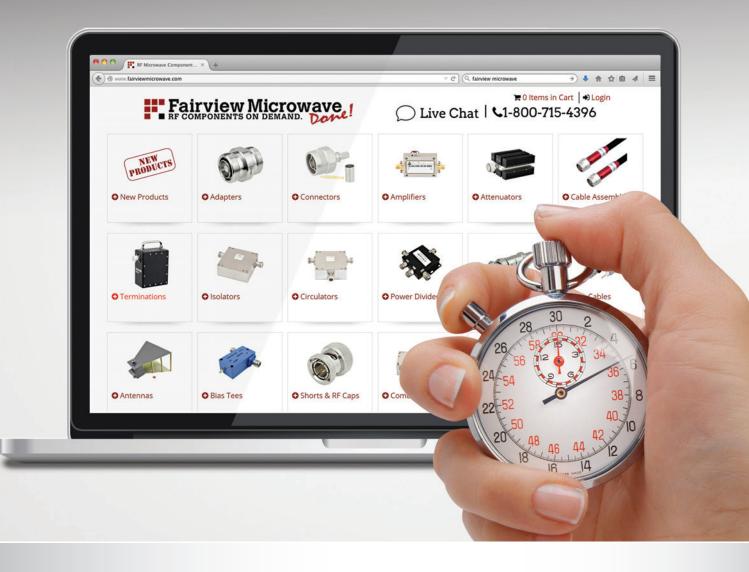
- Frequency matching is incorrectly placed around 71 instead of 76 GHz, which is often caused by increased thickness of some radome layers
- Significant increase in the standing wave ratio within the 79 GHz band, which identifies high reflections at the radome boundaries and a strong interference phenomenon
- Overall one-way attenuation is relatively high, which results in a significant reduction in the detection range.

SUMMARY

Researchers are already driving autonomous cars on the highway and in city traffic. Due to the allweather capability of radar sensors, their reliability and their price, these sensors are essential in automotive applications. Integration behind bumpers and emblems also makes them attractive for car designers. Without highquality radomes, objects with low radar cross-sections, such as pedestrians, will likely be undetected and may even appear at erroneous azimuth angles. Even larger objects at far distances may be incorrectly identified and measured at different positions when the radar signal is distorted by the inhomogeneous radome material.

This article presented a novel measurement method that can be applied for any kind of automotive radome operating in the 75 to 82 GHz band, such as the ones used in emblems, bumpers or front grills that cover automotive radar sensors. Using a massive multistatic array, within a few seconds this method measures and calculates the mean reflectivity and standard deviation of a defined area (homogeneity) and the transmission loss over the complete frequency range. The visualization of the results as an image assists radome designers and R&D labs, while determining a pass/fail result based on the radome's RF performance significantly speeds production, especially at end-of-line testing.

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Progress and Challenges of Test Technologies for 5G

Zhengbo Jiang, Wei Hong, Nianzu Zhang and Chao Yu Southeast University, Nanjing, China

Tianze Su Shanghai Transcom Instrument Technologies Co. Ltd., Shanghai, China

The 5G test system must closely integrate pre-research results with practice at all stages, providing researchers and developers with flexible, efficient and reliable test platforms and test data to accelerate the commercialization of 5G products. In this article, we introduce the testing requirements and challenges running through different processes in the 5G industry. Combined with various test scenarios, the test industry's current R&D status is summarized, technical challenges faced by instrument researchers and developers are highlighted and the potential development of 5G test is forecast.

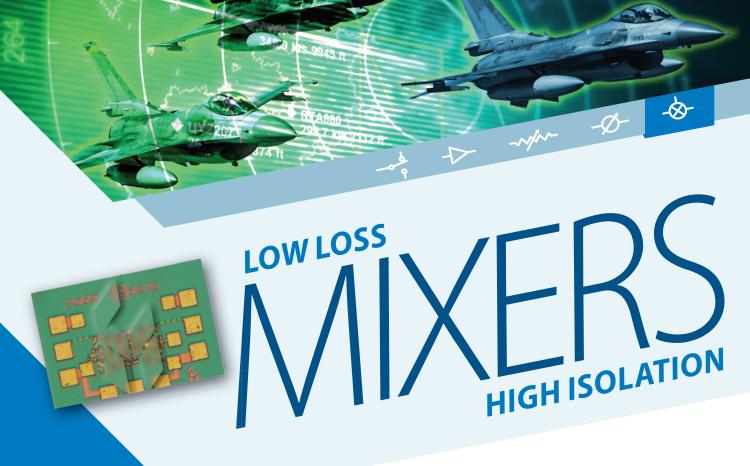
he information and communications industry is facing great change due to the rapid development of applications, leading to an explosive growth in data traffic. Traditional transmission technologies and architectures for wireless communications are challenged by a variety of smart devices and different connectivity requirements. 1-2 The fifth generation mobile communications system (5G) imposes diverse scenarios and extreme performance requirements. Its main operational scenarios include seamless wide area coverage, high capacity hotspots, low power massive connections and low latency with highreliability.3-4

The 5G technology roadmap contains two parts: a new air interface and a 4G evolution air interface. In the 5G air interface technical framework, the key technology areas include massive MIMO, ultra-dense network (UDN), new multiple access and full spectrum access. As one of the most important enabling technologies for seamless wide area coverage, massive MIMO efficiently utilizes spatial dimension resources to dramatically increase system spectral efficiency and enhance the user experience.

UDN significantly reduces cell interference through inter-microcell collaboration and expands network capacity in local hot spots. Novel multiple access technologies increase equipment connectivity and reduce signaling overhead, as well as user equipment (UE) power consumption through grant-free mechanisms. Full spectrum access, which supports a hybrid network integrating low and high frequency bands, can simultaneously meet the requirements of high data rates and large capacity.

Since 2013, the U.S., European Union, Japan, South Korea and other countries or regions have launched 5G R&D programs. Since 2014, the Chinese government has supported domestic 5G technology research via the National 863 plan, as well as major science and technology projects. These national or regional initiatives strive to establish favorable positions in future 5G technology and business competitions.⁶ To establish standards, 3GPP launched 5G research projects in early 2016 and plans to complete the first version of the 5G standard (3GPP Release 15) in 2018. The IMT-2020 group, which consolidates the efforts of industry-university research, was estab-

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lished to promote 5G research and international cooperation. It has released a series of white papers, including 5G Vision and Requirements, 5G Concept, 5G Wireless Technology Architecture and 5G Network Technology Architecture. In January 2016, the IMT-2020 Promotion Group launched 5G R&D experiments to evaluate key technology candidates and facilitate the formulation of technical standards. It plans to complete R&D trials of technologies and products in 2018 and 2020, respectively.

Test technology development has accompanied the development of enabling technologies for each generation of mobile communications, leading to collaborative development. All kinds of test instruments and systems support the multiple needs of the wireless communications industry, from research to verification and production. 5G test and measurement technologies are expected to appear before network and UE products, guiding product design and standard formulation. At present, the first and second phases of developing 5G wireless test specifications have been completed under the organization of the IMT-2020 Promotion Group.

In recent years, research institutions, operators, equipment, IC and instrument manufacturers around the world have carried out key 5G

technology validation and prototype testing in succession.⁸ According to China's 5G R&D test plan, the next step will be testing technical solutions introduced by manufacturers and, finally, system testing for typical 5G services based on smallscale networks.

Compared to traditional testing in the 3G/4G era, three technical characteristics of 5G impose enormous challenges on test instruments and methods:

- the introduction of microwave and mmWave bands above 6 GHz
- the generation, reception and storage of ultra-wideband signals with bandwidths of hundreds of MHz or even GHz; and
- the design and application of large-scale antenna arrays, with 64, 128 or more channels.

5G TEST TECHNOLOGIES

The following sections explain the influences these characteristics have on 5G test instruments and test technology with respect to different test scenarios for 5G wireless communications. Existing solutions are introduced as well.

5G Channel Sounding and Modeling

The wireless channel is one of the core components of the wireless communications system. Physical properties of the wireless channel are characterized by a series of parameters, such as channel impulse response, path loss, Doppler delay, power delay profile and angle of arrival. Channel sounding can help extract these MIMO channel parameters and provide an important reference for subsequent 5G channel modeling and standardization. The basic structure of the channel sounding system is shown in *Figure 1*, which includes the signal transmission/receiving instruments and measurement/analysis software.

With the development of 5G technology, the traditional 3G/4G channel sounding system can neither cope with new test challenges nor be upgraded to achieve better performance. Characteristics of mmWave channels are not yet fully explored or understood, and the upgrade of traditional dedicated channel sounding equipment is likely to be costly, due to inadequacies dealing with flexible testing from 6 to 100 GHz. The ability to generate, receive and store ultra-high speed baseband signals will need to be greatly improved, as well. The introduction of large-scale antenna arrays significantly increases the required computational capacity of channel sounding instruments, making new multi-channel RF transceiver components the inevitable choice. Hardware and software platforms must support massive data analysis and channel parameter extraction.

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In recent years, enterprises and academic institutions around the world have proposed a variety of solutions for 5G channel sounding based on a combination of existing products. Keysight Technologies proposed a mmWave MIMO channel sounding system. Rohde & Schwarz (R&S) proposed a scheme that supports fast measurement of both indoor and outdoor time domain channels with operating frequencies up to 100 GHz and band-

widths as wide as 2 GHz.¹⁰ Various research projects are investigating 5G mmWave channel measurements and modeling, including METIS, NYU WIRELESS,¹¹ mmMAGIC, MiWEBA and 3GPP.

Several popular channel models, such as WINNER, ¹² COST 2100¹²⁻¹³ and METIS 2020, ¹³ have attracted more attention due to their scalability and reasonable complexity. These 5G channel models are adapted to specific scenarios and frequency

bands. Although the mathematical methods used are not the same, these models are based on the analysis of a large number of channel sounding results. At the 3GPP RAN meeting held from June 13 to 16, 2016 in Bushan, Korea, the first standard for the mobile broadband 5G high frequency (6 to 100 GHz) channel model was approved. So far, there has been no unified 5G channel model integrating both low and high frequency bands, which

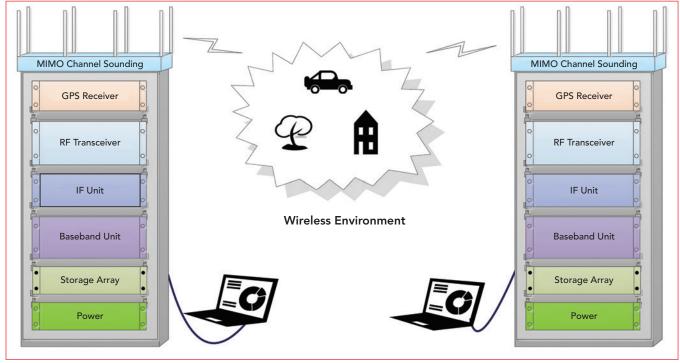
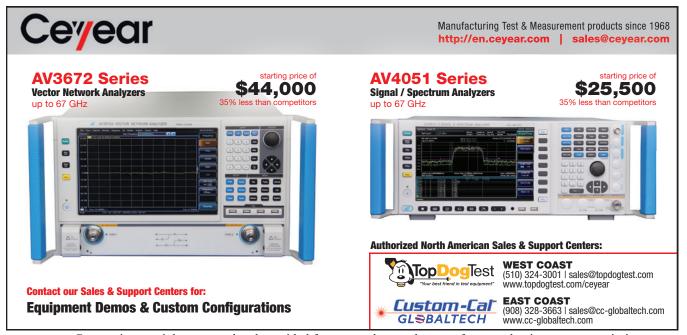


Fig. 1 5G channel sounding system.



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requires the corresponding aspects of 5G wireless technology to be taken into account. Extensive work on theoretical and practical channel modeling has been done during the past few years, but most research results are constrained by spatial correlation and mutual coupling between adjacent antennas. Arrangement of antenna elements is relatively simple and assumptions about propagation conditions and antenna characteristics are too idealistic and limited to specific application scenarios. Therefore, it is difficult to accurately extract a variety of actual channel characteristics.

Channel Emulation

When conducting field tests for wireless communications systems in the real channel environment, there are many shortcomings, such as climate effects, poor mobility, high cost and unrepeatable test processes. The MIMO channel emulator (see Figure 2) enables researchers to emulate typical wireless channel environments in the lab, flexibly controlling and changing channel parameters, to identify performance problems as early as possible, reduce test costs and significantly improve efficiency.¹⁴ Therefore, manufacturers have always included channel emulation as a critical part of the deployment of each generation of mobile communications technology, including 5G.

As a key technology for 5G, massive MIMO greatly reduces transmission power while improving channel capacity and specefficiency.¹⁵ Nevertheless, required number of network equipment antennas is 10 to more than 100x that of existing MIMO system antennas, becomes a major bottleneck in the

upgrade and optimization of current 4G/LTE channel emulators. The inherent "pilot contamination" problem of massive MIMO technology directly affects the baseband channel estimation algorithm, feedback mechanism, interference control and synchronization scheme. 16-18 Data throughput in the channel emulator increases sharply with expanding antenna array size, requiring extremely high-level computational resources, storage capacity and bus speed for the baseband processing unit. The RF system design must ensure isolation and amplitude/phase consistency among multiple channels, which greatly increases channel calibration complexity.

Currently, Propsim F32, an advanced channel emulator from Anite

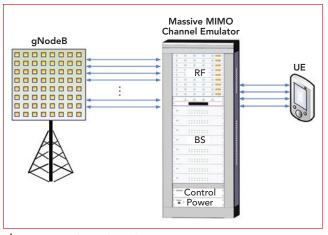


Fig. 2 5G channel emulator.

(acquired by Keysight in 2015), is only able to support 32 RF channels at most and realize 64 × 8 MIMO channel emulations by combing multiple instruments. Unfortunately, this only covers operating frequencies below 6 GHz and a maximum bandwidth 80 MHz; it is unable to cope with the high frequency and large bandwidth challenges of 5G test. Another channel emulator, Vertex, released by Spirent in 2016, is configured with 32 RF channels and 100 MHz bandwidth to meet the requirements of MIMO beamforming, MIMO over-the-air (OTA) and massive MIMO test, but the maximum operating frequency to 5.925 GHz merely satisfies low frequency 5G test demands.

Over the years, a handful of Chinese instrument manufacturers

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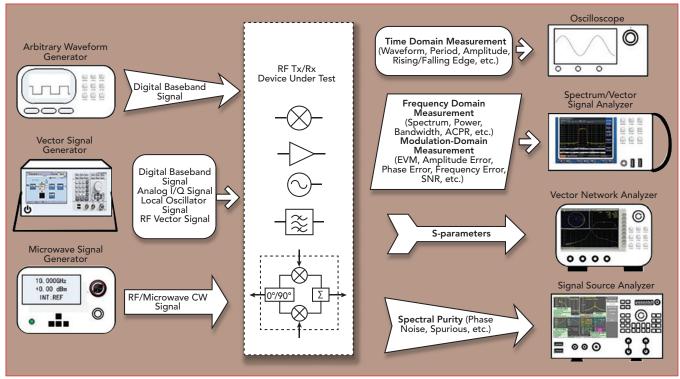












▲ Fig. 3 Instruments used to test RF T/R components.

have launched 8 × 8 MIMO channel emulators for 4G testing, laying a hardware platform and algorithm

architecture foundation for the development of 5G channel emulators. Future channel emulator tech-

nology must achieve bandwidths of hundreds of MHz, cover frequency bands beyond 6 GHz and contain multiple channel models.

RF Module and Antenna Array Test

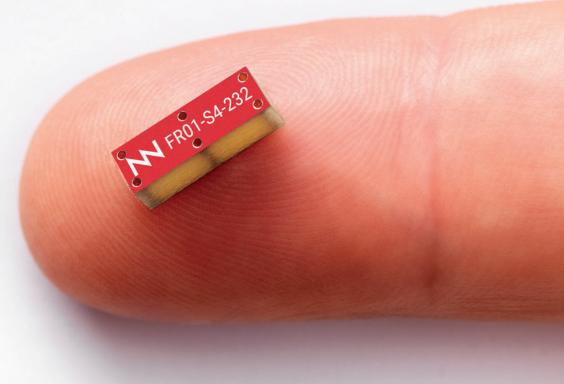
Large-scale antenna arrays and RF front-ends are essential 5G subsystems, consisting of digital-to-analog converters (DAC), analog-to-digital converters (ADC), frequency synthesizers and transmit/receive (T/R) multi-beam antenna arrays. The T/R array contains RF components such as filters, mixers, power amplifiers and low noise amplifiers, each with its own set of performance specifications and corresponding test methods.

Figure 3 shows the classes and functions of the excitation/source instruments and receiving/analysis instruments commonly used in RF test. Among them, the vector signal generator (VSG) and signal analyzer provide the most comprehensive measurement and analysis of a communication system's overall performance. The operating frequency range must cover from DC to approximately 110 GHz, while supporting 200 MHz to several GHz of vector signal bandwidth. Regarding frequency coverage, the Keysight E8267D PSG and the R&S FSW85 signal analyzer have reached



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44 and 85 GHz, respectively. A breakthrough was announced at Mobile World Congress in February 2016: R&S exhibited the world's first VSG (SMW200A) with a maximum frequency of 40 GHz and a modulation bandwidth up to 2 GHz. The maximum signal analysis bandwidth of two well-known signal analyzers products, i.e., FSW from R&S and UXA from Keysight, is 2 and 1 GHz, respectively. Further bandwidth expansion requires the assistance of other components. To generate/analyze signals with ultra-large (GHz) bandwidths, the main technical difficulties include RF channel equalization, high sampling rate ADCs, high speed digital signal processing and high data rate transmission.

For antenna array testing, the vector network analyzer (VNA) is a key instrument. Due to the lack of a single, 64-port VNA, three methods are usually adopted. The first is a step-by-step test using a single, multi-port VNA, which is relatively inexpensive but sacrifices test speed and ignores the coupling character-

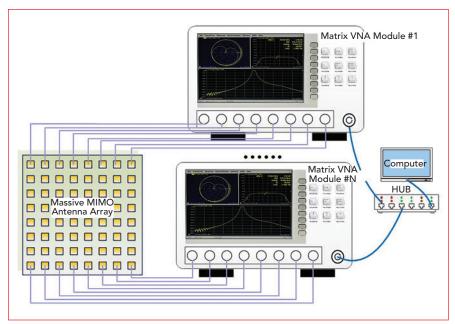


Fig. 4 Using multiple VNAs to test a massive MIMO antenna array.

istics between antenna elements. The second involves cascading several multi-port VNAs, e.g., a 64-element antenna array is tested with eight, 8-port VNAs cascaded (see *Figure 4*). This approach can accu-

rately test the actual S-parameters of each antenna element after calibration and greatly increases test speed. Still, there are some technical difficulties: the crosstalk between ports restricts dynamic range, and calibration time impacts test efficiency. The third scheme uses the conventional dual-port VNA with a switch matrix, which is a compromise between the prior two options. Cost is relatively low, but the speed is somewhat slow and the switch matrix introduces measurement errors. A few manufacturers are developing a single multi-port VNA to provide new solutions that address crosstalk between channels, fast calibration, cost and other aspects.

OTA test¹⁹ is another important aspect of 5G antenna array testing, for two reasons. First, directional indicators of the antenna array, e.g., effective isotropic radiated power (EIRP) and effective isotropic sensitivity (EIS), must be tested by OTA, which is consistent with 4G MIMO OTA test principles. Second, since 5G will use the microwave and mmWave bands, the antenna array and T/R elements will likely be integrated to reduce loss and improve matching. In this situation, most T/R component characteristics cannot be evaluated without wired conduction tests, and measures of performance such as RF circuit transmit power and sensitivity may interact with the characteristics of the anten-



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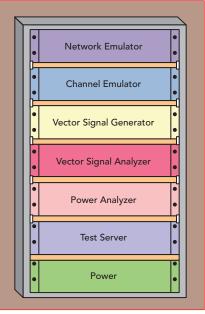
na, making individual assessment difficult.

IC, Network and User Equipment Test

Although 5G-related technologies and standards are not yet clear, IC, UE and network equipment manufacturers, as well as operators, are in full swing conducting R&D of 5G prototypes to launch competitive solutions. Among the existing 5G prototype UEs, some support high speed transmission of several Gbps and some support as low as millisecond latency. The battery life of certain UEs (particularly IoT terminals) has been extended to nearly 10 years. Qualcomm, Spreadtrum, MediaTek and other IC manufacturers are developing 5G chips, and Qualcomm has announced prototypes. Because of the emerging 128-channel integrated network equipment, the corresponding test technology has been placed on the agenda. Three features, including UE diversity, scenario complexity and massive connections, challenge the testing of ICs, UEs and network

equipment,²⁰ and available 4G/LTE test instruments can hardly fulfill these 5G tasks.

The integrated UE tester is used to emulate partial functioning of the network, then test the RF performance of the UE under network conditions or, with the signal generators, signal analyzers (including spectrum analyzer) and other conventional test instruments, perform conformance testing such as RF, protocol and radio resource management. How to emulate massive UEs is likely to be a huge challenge for UE emulator design. 5G UE diversity means that existing test instruments must have superior scalability and compatibility. Additionally, typical application scenarios of the IoT, such as intelligent water meters and smart parking call for low power consumption testing to assess battery self-discharge and sleep mechanisms. The industry is presently lacking a mature test methodology to quantify UE power consumption characteristics. Other test systems, such as the NV-IoT test

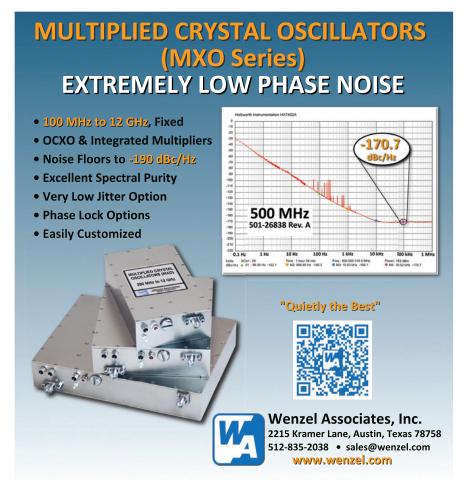


▲ Fig. 5 Integrated system for 5G terminal testing.

system, 5G terminal card interface test system and signaling monitors, are all indispensable components of 5G UE test. Note that 5G UE test tends to be integrated; it will be a comprehensive test system to replace multiple sets of discrete systems, as shown in *Figure 5*.

Similar to UE test, the IC manufacturers' desire for 5G test instruments is strong throughout all phases, from chip development to product certification and mass production. Specifically, test instruments are required to simulate network functions, verify and evaluate RF solutions, complete chip function/performance authentication and perform final production test. To facilitate the operation, further needs include installing software with a project configuration and results display, integrating other instruments to build test systems and supporting remote control. Also, driven by continuous module redesign, configuration changes and reduced IC R&D cycle times and costs, the traditional IC test system is faced with the need to be flexible, to reduce test costs and improve production efficiency.

Network equipment testing is used to verify compliance with a communications system's quality specifications, interface requirements with other devices and electromagnetic compatibility, both intra-system and inter-system. A 5G







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network equipment test requires general instruments, such as a VSG, spectrum analyzer, power meter, UE emulator and channel emulator to build a massively connected test system with broad coverage. The aim is to test the load capacity limit and overload coordination capabilities of specific uplink and downlink service models and to evaluate system performance under different channel conditions. In the future, these test instruments must follow corresponding 5G test specifications with continuous optimization and upgrade capability, satisfying the performance needs of 5G and supporting a wider range of application scenarios.

CONCLUSION

Driven by considerable market demand, 5G test has made rapid progress. Top instrument suppliers around the world are working closely with universities and other research institutions. The entire industry is inspired by recent research achievements and products. Still, there are

some fundamental problems to be solved, including the establishment of new test specifications, the exploration of 5G measurement principles and the development of new measurement platforms.

ACKNOWLEDGMENT

This work was supported by the National Natural Science Foundation of China (61627801) and China National S&T Major Project (2015ZX03001011).

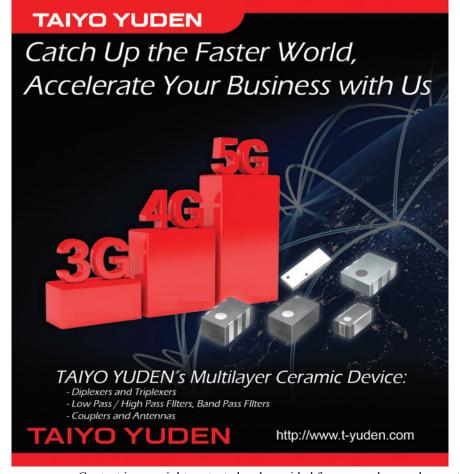
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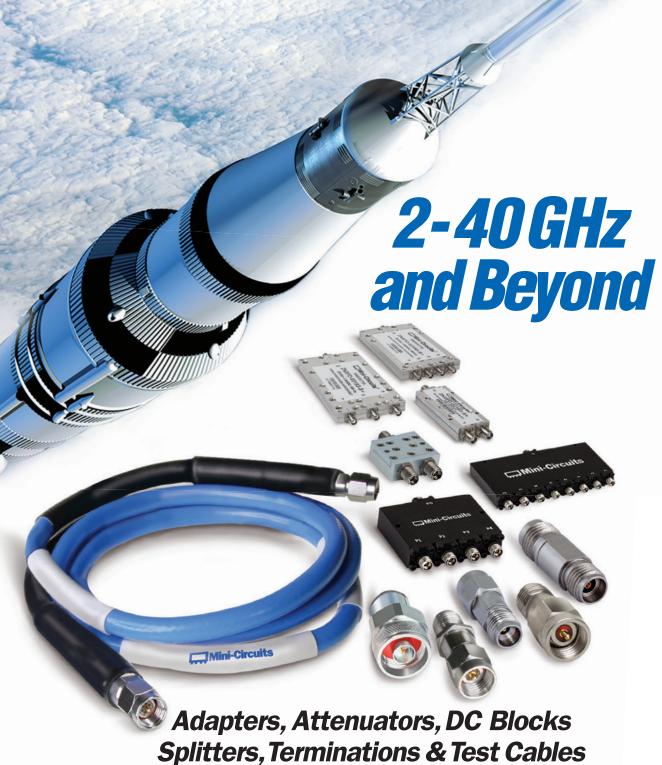
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Meeting High-Power and High Frequency Challenges with Adhesives and Potting Compounds

Venkat Nandivada and Rohit Ramnath MasterBond Inc., Hackensack, N.J.

lhe market is demanding all sorts of optical and electronic systems for military, aerospace, communications and consumer systems. These systems rely on high-power semiconductors, diodes, converters, amplifiers, radio devices, antennas, high frequency ID tags and optoelectronics devices. Electronics fabrication and assembly typically requires the use of adhesives, die-attach compounds, glob-top encapsulants, underfills and potting compounds. Since many materials exist, engineers should be familiar with how the material affects design performance. In the following discussion, we examine the unique requirements high-power and high frequency communications electronics place on adhesives and encapsulants, as well as the material characteristics needed to satisfy performance objectives.

MANAGING THERMAL PERFORMANCE

To dissipate the heat that can degrade device performance and transfer heat across components, many designs use heat sinks combined with other cooling methods and technologies. These techniques often require thermal adhesives and potting compounds that exhibit excellent thermal conductivity and provide good structural

integrity. Thermally conductive adhesives or potting compounds aid in transferring heat from the electronics to the heat sink or other cooling system that dissipates it. This reduces the thermal load on these components, especially useful when there are many heat-sensitive components.

Thermally conductive adhesives can either be electrically conductive, act as insulators or provide electromagnetic shielding, driven by the specific application requirements. The die attach of a high-power semiconductor application may need either an electrically conductive or an electrically insulative die attach. Typically, an extremely fast cure at temperatures from 125°C to 200°C is also desirable. On the other hand, a high frequency application such as an antenna system may need an adhesive that shields against electromagnetic interference (EMI). Often, a conductive coating is applied to housings to provide the desired shielding, even at extremely high frequencies, e.g., to 18 GHz. In these cases there is similarity in the thermal properties, because most of these applications have high heat dissipation. In applications where electrical insulation is necessary, high volume resistivity and high dielectric strength are often prerequisites.¹

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ApplicationNote

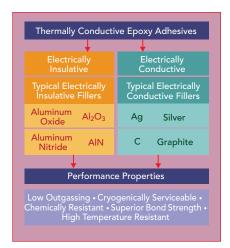


Fig.1 Insulative and conductive adhesives.

ADHESIVES

Many adhesive chemistries are available today, such as epoxies, silicones, polyurethane and polysulfide-based materials. Typically, the bulk thermal conductivities for these systems falls in the 0.1 to 0.2 W/(m•K) range, essentially making them behave as thermal insulators. To make these materials transfer heat, i.e., act as heat dissipaters, various fillers can be used depending on the application. Fillers play the critical role of increasing the thermal conductivity of these chemical systems. Potentially, the thermal conductivity can be increased by 10 to more than 20x, depending on the type of filler and the chemistry used to blend the filler. A few examples of fillers are aluminum oxide, aluminum nitride and silver and graphite based fillers (see Figure 1). Aluminum oxide and aluminum nitride increase thermal conductivity while providing electrical insulation. Silver and graphite based fillers boost heat conduction while providing electrical conductivity. The material surrounding the filler prevents oxygen penetration and the formation of oxides. The compounds are formulated and mixed in a way that ensures air is not entrapped and voids are minimized, to give maximum particle-to-particle contact and maximize the surface area. This ensures the best thermal conductivity performance, as well as either electrical conductivity or insulation.

The particle size of the filler has a significant impact on the thickness of the bond line that can be achieved, which plays an important role in realizing good heat transfer. The particle size of standard fillers may be 40, 50 or 100 μm . On the other hand, it is possible to create fillers with maximum particle sizes

Compounds

The following are some practical, commercial examples of adhesives and potting compounds currently offered.

Adhesives

A thermally conductive adhesive that performs well in many high frequency, power applications is silver-filled epoxy EP3HTSDA-1. This NASA-rated, low outgassing product, which has been used in vacuum systems, is both a thermally and electrically conductive adhesive system.

Particularly useful for die attach applications, an electrically insulating adhesive is Supreme 3HTND-2DA (see *Figure S1*). It is a one component epoxy with an extremely fast cure time at 125°C.

MB600S (see *Figure S2*) is a one part, sodium-silicate based material that can be used to coat devices in high frequency applications to achieve EMI shielding up to 18 GHz.

EP21TCHT-1 is a widely used aluminum oxide filled insulating adhesive, even

in cryogenic applications.

A graphite-filled epoxy system, EP75-1 can be used for bonding and sealing. Supreme 18TC is a specially formulated one component epoxy with the largest particle size of just 10 to 15 μ m. The small particle size enables very thin bond lines, increasing heat transfer and lowering thermal resistance.

Potting compounds

EP121AO (see *Figure S3*) is a potting compound that has good flow properties

EP30TC has a low viscosity and is good for high temperatures. It is a very stiff, high modulus material, which is key in many applications. Even though it is a two part chemistry, it can be pre-mixed and packaged in a specified amount in a frozen syringe, to speed the production process.

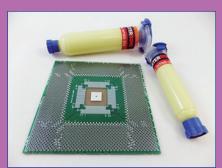
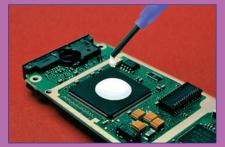


Fig. S1 Supreme 3HTND-2DA is a fast curing, no mix, insulating epoxy system for die attach applications.



Fig. S2 MB600S is a silver containing, aqueous based, sodium silicate system used as a coating in applications where the highest level of EMI shielding is required.



 \triangle Fig. S3 EP121AO is a thermally conductive, electrically insulating epoxy resin system for potting, encapsulation, coating and sealing.

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ApplicationNote

of 10 to 15 μ m and average sizes of 2 to 3 μ m. In R&D labs, technologists are experimenting with fillers containing nano-sized particles. To understand the impact of particle size, consider two thermally conductive epoxies with the same thermal conductivity, say 1.0 W/(m°K) and both with an aluminum oxide filler. The only difference between the two is the maximum particle size of their fillers; one has particles

50 μm or smaller, the other 10 μm or smaller. Even though the bulk thermal conductivity of both fillers is the same, the epoxy with 10 μm size particles can achieve much thinner bond lines—theoretically about 20 percent the thickness of the 50 μm fille—resulting in higher heat transfer and lower thermal resistance.

This illustrates that not just the bulk thermal conductivity of the filler material is important. The particle size of the filler determines thickness, and the thickness determines thermal resistance. This relationship is expressed by the formula

R = t/K

where R is the thermal resistance, t the thickness and K the thermal conductivity of the material. The lower the thermal resistance, the better the heat transfer and heat dissipation. The bottom line is that the thinner the bond thickness, the lower the thermal resistance and the better the heat transfer. An added benefit is with smaller particle size, less material is needed.

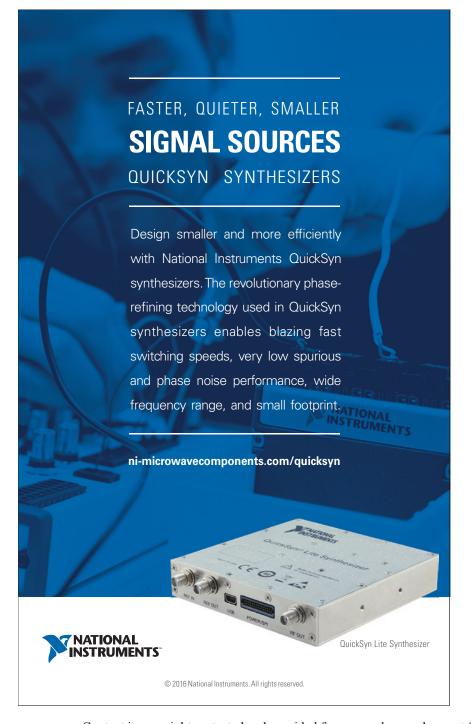
POTTING COMPOUNDS

Unlike adhesives, where the main goal is to provide a bond between devices, potting compounds isolate and protect components from outside contact or contamination, both electrical and mechanical. Potting is common for both power and high frequency devices. For potting, the most important parameters to consider for electrical insulation properties are volume resistivity, dielectric constant, dissipation factor and overall dielectric strength. Heat dissipation properties also play an important role, depending upon the application.

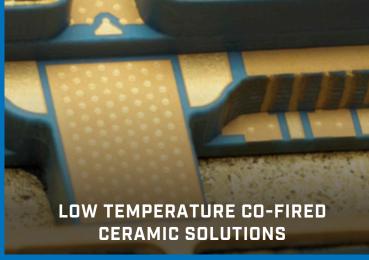
From a manufacturing standpoint, other properties to consider are viscosity, or flow properties, and working life or gel time. Typically, lower viscosity helps minimize air bubbles or voids and avoid arcing. Low viscosity is also beneficial in enabling the potting compound to wick in and around intricate components. In a production environment, using syringe applicators and automated dispensers increases the speed of the process, even if it is a two part potting system. Various packaging and dispensing options are available to get the best results.

DESIGN CONSIDERATIONS

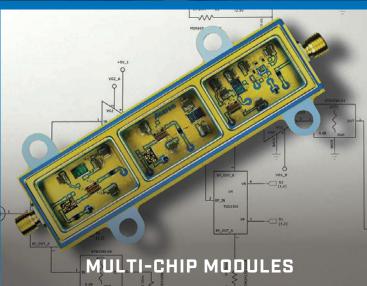
What are the different product parameters designers should consider when choosing a thermally conductive adhesive or potting compound? Start with the substrates and the design dimensions, combined with the operating temperature range and processing and handling requirements.











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ApplicationNote

Much depends on design specifics. For example, when bonding two components made of different materials, e.g., a circuit board and a chip or IC, the adhesive must handle mismatches in the coefficients of thermal expansion (CTE). This is important for the end product use, as well as while the product is being manufactured and undergoes processes such as wave soldering and stress testing. Using adhesives and

potting compounds with high thermal conductivity can be a particular benefit, because the thermally conductive filler helps to effectively reduce the CTE mismatches between different materials.

From application to application, the requirements for cure time and temperature can vary. Some products can be cured at room temperature, others require a moderately elevated temperature and some

high temperatures. Working life/pot life is also an important consideration, especially in larger volume potting applications, where it is necessary to have sufficient working life so the potting compound does not set up too soon. In such cases, compounds with more than 12 to 24 hours of working life at room temperature are available. This provides sufficient time after mixing for de-gassing and application to achieve a void-free bond.

Other production-related factors include compound handling and packaging. Many different packaging options are available, even for two part chemistries. For example, these chemistries can be packaged in pre-mixed and frozen syringes. For production applications potting about 10 cc per assembly, the compound can be packaged as a pre-mixed and frozen system in a syringe, so the required amount of material is used at one time. By eliminating the need for measuring, mixing, de-gassing and other operations, the production process can be faster, while still providing the desired properties.

When selecting a supplier of adhesives or potting compounds, designers should also consider how much design support the supplier is willing to provide. While it is best to contact a supplier early in the design phase, a strong supplier will help at different stages of the life cycle. Even if a system is in production, the supplier can help improve an existing process or product.

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Venkat Nandivada has been the manager of technical support at Master Bond since 2010. He has a master's degree in chemical engineering from Carnegie Mellon University. His work consists of analyzing application issues and providing product solutions for the aerospace, electronics, medical, optical, OEM and oil chemical markets.

Rohit Ramnath is a senior applications engineer for Master Bond. Also a graduate of Carnegie Mellon University, with a master's degree in chemical engineering, he analyzes application issues and provides product support to the same industries.

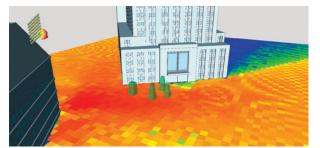




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Synthesizing MIMO Antennas for Compact Devices

AWR Group, NI El Segundo, Calif.

rowing demand for wireless connectivity and the Internet of Things (IoT) relies more and more on customized antenna solutions optimized for performance, cost and size. Multiple-input-multiple-output (MIMO) is a technique that provides greater throughput and communications reliability, which is desired for many IoT applications. However, MIMO requires multiple antennas on a single device, and ensuring high performance requires not only good antennas, but also high isolation between them. Isolation can be achieved simply by separating the antennas, but doing so can make the device guite large and require external antennas. Between closely spaced internal antennas, high isolation can be achieved by using chokes, matching networks and other techniques, each having advantages and drawbacks.

Isolating antennas while maintaining good performance, squeezing down size and optimizing everything by hand to meet multiple performance metrics—impedance matching, coupling, radiation efficiency, operating bandwidth—is time consuming, involving numerous iterative simulations and significant design knowledge. With demand

for design experience greatly exceeding the supply of antenna engineers, an alternative is needed. This article presents new features and functionalities in the latest version of AntSynTM, the automated antenna design, optimization and synthesis tool that enables designers to automatically synthesize compact MIMO antenna arrays from user requirements.

ANTENNA DESIGN BY REQUIREMENTS

AntSyn combines advanced optimization algorithms, expert systems and electromagnetic (EM) simulation into a user-friendly tool that operates on a "what you want is what you get" principle, where the user inputs the antenna requirements, rather than a parameterized physical design. With AntSyn, the specifications are items like frequency band, target impedance match or return loss, coupling and size or form factor. These are input into the intuitive "spec sheet" user interface, which is automatically organized into a project file. By running the spec sheet, AntSyn returns one or more optimized antenna designs, with the results presented in a customizable dashboard for rapid evaluation (see Figure 1). The user-specified dashboard

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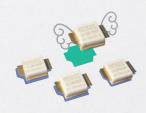
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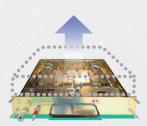


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can be set to view the proposed 3D model and input impedance versus frequency, maximum gain versus frequency, radiation pattern cuts and qualitative star rating, all of which help identify good performers quickly. AntSyn has been used to develop a wide range of antenna types, including single-, dual- and multi-band; broadband and ultrawideband (>100:1); high efficiency; loaded; electrically small; phased array; wire; patch; conformal; handset; horn; dual-polarized and multifunction.

The latest release of AntSyn has over 35 improvements and 42 new antenna types. Several new features in this release were specifically developed to generate compact MIMO designs, including improved accuracy and features for ground planes, multifunction computergenerated mesh antennas with multiple ports and augmented matching network optimization allowing each port to be separately matched and optimized.

The new mesh antennas are particularly unique and flexible, comprising a set of four new antenna types with either two or three ports. These ports can be independently assigned to different bands that have very diverse RF requirements, such as different polarization, gain pattern and frequency. The antenna mesh is optimized by AntSyn for the given specifications, and the software is sufficiently flexible to essentially invent new antennas. Images of the mesh antennas are shown in Figure 2. The two standard versions of the mesh antenna can be placed on any corner or edge on the ground or in the center, as shown. The ground can be solid beneath the antennas, or it can be an opti-

mized mesh, as well. The coplanar monopole version does not have a ground beneath the mesh; it is expected to project over one edge of the ground, which can be useful in many applications.

EXAMPLES

The following examples use the coplanar monopole, known to have excellent bandwidth and flexibility, to demonstrate how AntSyn uses these antennas to synthesize high performance MIMO arrays with good isolation and impedance match. Leveraging the new features in the latest release, AntSyn was used to create two- and three-port MIMO antennas on a notional compact device. This notional device had the following characteristics and requirements:

- Dual-band Wi-Fi (2.4 and 5 GHz)
- Compact, planar IoT device pack-

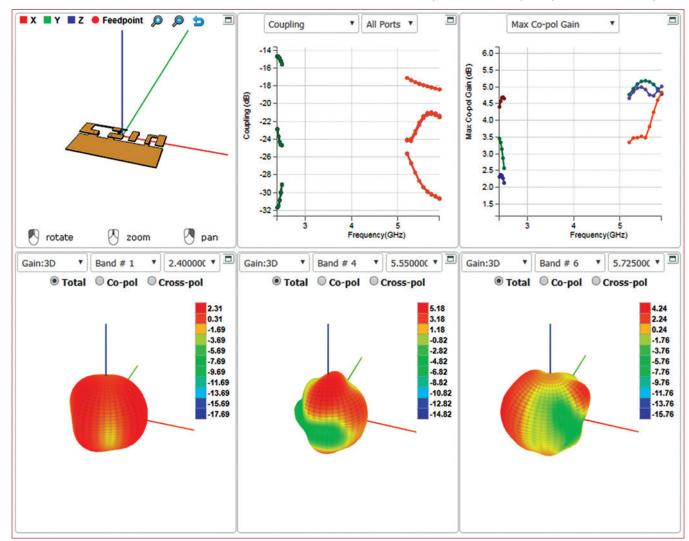


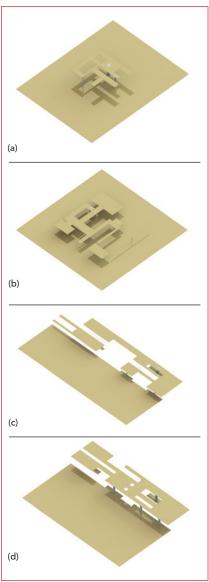
Fig. 1 AntSyn generates optimized antenna designs, shown with performance in a customizable dashboard. Content is copyright protected and provided for personal use only - not for reproduction or retransmission. MWJOURNAL.COM ■ JANUARY 2018 106 For reprints please contact the Publisher.

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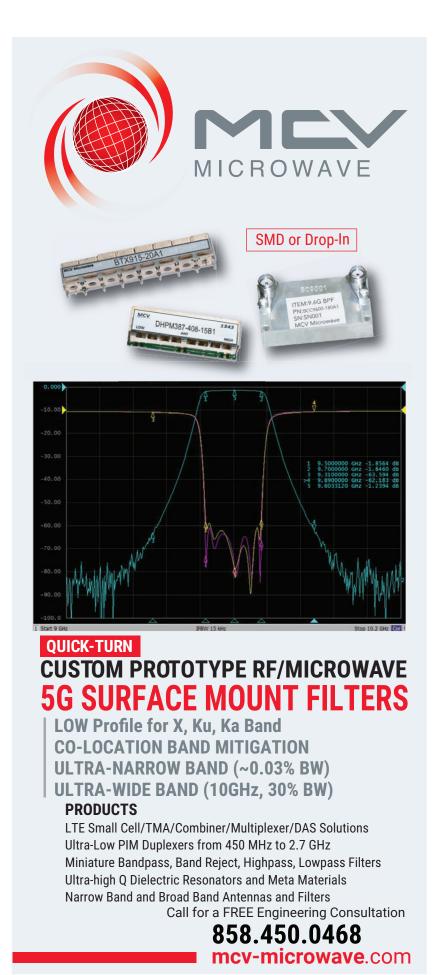
age, approximately the size of a business card (90 mm x 50 mm)

- Antenna integrated with electronics, with the antennas placed along the long edge
- MIMO, with two- or three-port antennas for transmit and receive on each device and maximum isolation between ports to create decoupled channels.

First, a two-port MIMO antenna using the multifunction mesh coplanar monopole type was optimized, using air as its dielectric. The resulting antenna and its predicted performance is shown in *Figure 3*. This antenna has reasonably good VSWR and isolation for the dual-band



▲ Fig. 2 New mesh antennas: two-port standard (a), three-port standard (b), two-port coplanar monopole (c) and three-port coplanar monopole (d).



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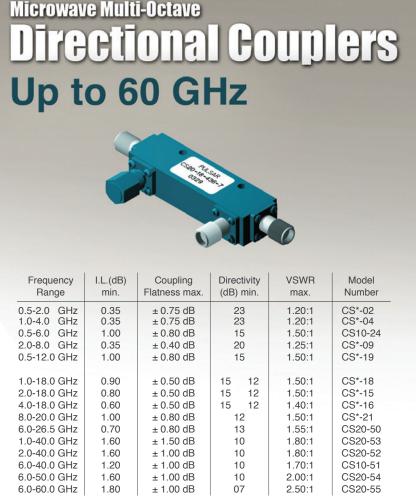
Wi-Fi frequencies for both ports, with a maximum VSWR of about 1.8:1 and a maximum coupling of about -16.5 dB. At the lowest frequency, the antenna edges are separated by less than 0.093 λ , and the ports themselves are only 0.41 λ apart. As can be seen, the shapes of these two elements have some similarities, but they are not identical. This is expected and improves the isolation.

The antenna was imported into

NI AWR Design Environment, specifically Microwave Office circuit simulator, and further simulated using AXIEM 3D planar EM solver from 2 to 6 GHz. The results match well with AntSyn's predictions; the worst-case coupling is -16.8 dB. Although coupling and VSWR do rise between the Wi-Fi bands, in-band performance is very good.

AntSyn was also used to optimize a three-port antenna using a

matching network to improve performance with the tighter spacing. The maximum VSWR was about 1.8:1, while the maximum coupling was -14.7 dB, which occurs between the two ports closest together (the right and center ports in Figure 4). The spacing is only 0.163λ at 2.4 GHz between these ports, with a minimum spacing of 0.048 λ between the elements. The distance from the center to the left port is also 0.31λ . Even more than in the two-port antenna example, the shapes of these antennas are very diverse. Essentially, AntSyn created a different antenna for each port, placing a parasitic fence between the center and left ports. This com-



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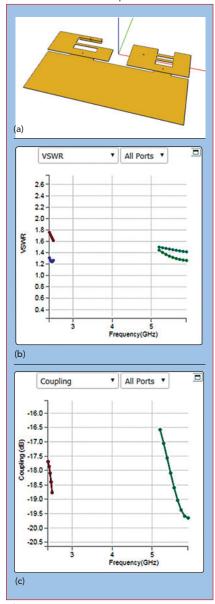


Fig. 3 Two-port MIMO antenna (a) with predicted VSWR (b) and coupling (c).



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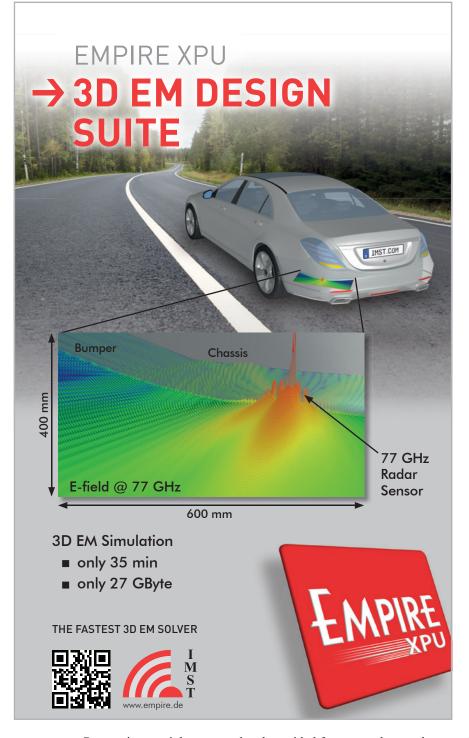
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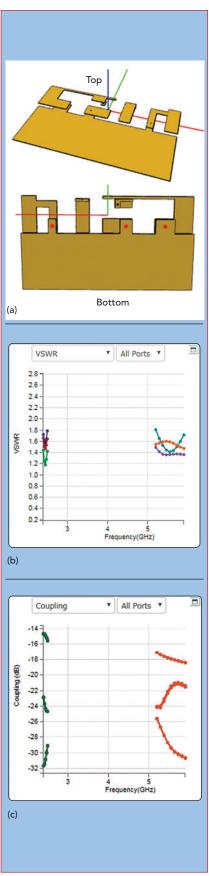
plexity was created automatically by AntSyn, demonstrating the inherent strength and robustness of the genetic algorithm, enabling the design space to be fully explored to produce MIMO antennas with optimal performance.

AntSyn provides an automated antenna design, synthesis and optimization tool well-suited for complex antennas, including compact MIMO arrays. It helps designers address the challenges of next-generation antenna design and integration within mobile devices and IoT components.

VENDORVIEW

AWR Group, NI El Segundo, Calif. www.awrcorp.com/antsyn





▲ Fig. 4 Three-port MIMO antenna and matching networks (a) with predicted VSWR (b) and coupling (c).

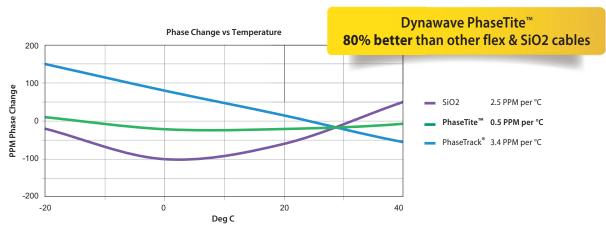


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Large Target, Far-Field Radar Signature Analysis

ANSYS Canonsburg, Pa.

NSYS HFSS 19.0 features a significant new capability to model the radar signatures of electrically large targets and scenes with the integration of HFSS SBR+. Shooting and bouncing rays (SBR) is a ray tracing technique within the physical optics (PO) framework and is suitable for efficiently solving electromagnetic (EM) problems that are hundreds and thousands of wavelengths in size. Integration of HFSS SBR+ to the available high frequency EM solver technologies in ANSYS Electronics Desktop allows radar designers to apply the best analysis technologies for predicting the radar signatures of structures ranging from sub-wavelength to kilo-wavelengths.

With ANSYS 19.0, existing HFSS customers can use the SBR+ solver in addition to the time-tested flagship HFSS finite element method (FEM) and integral equation (IE) solvers. Empowered by advanced diffraction physics from the physical theory of diffraction (PTD) and uniform theory of diffraction (UTD), HFSS SBR+ provides accurate and efficient large-scale EM modeling for structures containing metals and dielectrics, as well as structures with dielectric losses, multi-layer dielectrics and absorbing materials. ANSYS now provides a single framework for all high frequency EM solvers, facilitating a smooth and unified workflow to solve these complex EM problems. For radar signature analyses, HFSS SBR+

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7.9-11 GHz, 15 Watt GaN Power Amplifier	QPA1010
7.9-11 GHz, 25 Watt GaN Power Amplifier	QPA1011
8-11 GHz, 100 Watt X-Band GaN Power Amplifier	TGM2635-CP
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17-20 GHz, 10 Watt GaN Power Amplifier	TGA4548-SM
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ProductFeature

features monostatic and bistatic radar cross-section (RCS) modeling capabilities with the implementation of plane wave excitations.

Efficient modeling of RCS in ANSYS HFSS SBR+ can help determine and control the radar signature characteristics of commercial and military platforms, such as air-

(b) SBR SBR+PTD+UTD

▲ Fig. 1 RCS of an 11.5 m × 2 m × 2 m missile at 10 GHz: copolarization response with the missile (a), co-polarization axial cut (b) and co-polarization SBR compared to SBR+PTD+UTD.

craft, ships, ballistic missiles, submarines, ground vehicles and satellites. Taking RCS measurements on full vehicles is a costly and time-consuming process; simulation cuts down on prototype measurements and shortens vehicle concept design cycles. RCS reduction of large aircraft, vessels and missiles is critical in radar stealth technology, to reduce detection probability; simulation is essential in this endeavor, as RCS data obtained through simulation can predict detection.

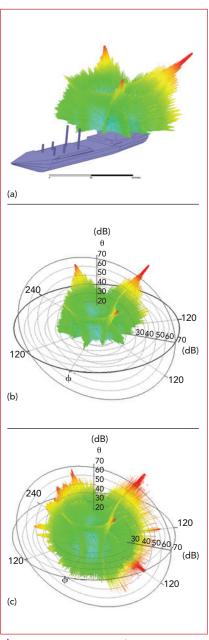
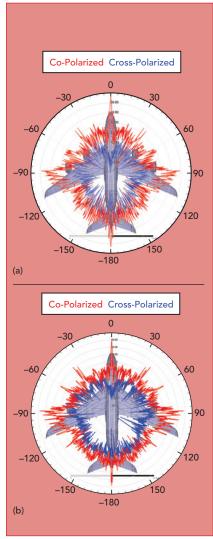


Fig. 2 Bistatic RCS of a 104.6 m × 16 m × 18.5 m ship at 1 GHz (a). The RCS of the isolated ship (b) vs. the ship with seawater (c).

Simulation can also help develop specifications for radars, to detect commercial maritime shipping vehicles and determine methods to mitigate radar clutter in air traffic control radars caused by wind turbines. ANSYS Electronics Desktop provides features for target model building, computer-aided design (CAD) import and healing, simulation, distributed computing and post-processing.

These simulation technologies can be dramatically quickened through ANSYS high performance computing (HPC), using multi-core parallel processing and graphics processing unit (GPU) acceleration on both high-end GPU appliances and consumer video graphics adapters. With this highly effi-



▲ Fig. 3 Simulated co-polarized and cross-polarized RCS for an Airbus 380 aircraft 79.62 m × 72.84 m × 21.62 m at 2.8 GHz (a) and 10 GHz (b).



RF Solutions for the Internet of Things



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SKY85743-21	5 GHz 802.11ax High Power WLAN Front-end Module	5.150 to 5.925
SKY85755-11	5 GHz 802.11ax WLAN Front-end Module	5.150 to 5.925

High linearity, high gain solutions for challenging CATV and infrastructure applications.

Part Number	Description	Frequency Range (GHz)
ACA2140	High Output Push-Pull Amplifier	1.200
ACA2778	High Output GaN Power Doubler Amplifier	1.000



Small Cells

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Part Number	Description	Frequency Range (GHz)
SKY6629x	Family of High Efficiency Power Amplifiers	0.700 to 6.000
SKYFR-xxx	Circulators and Isolators	0.700 to 5.800



Wearables and IoT

Solutions for fitness/smart watches, trackers, wireless headphones, in-home appliances, smart thermostats, alarms, lighting, sensors and more.

Part Number	Description	Range (GHz)
SKY66114-11	Front-end Module for Bluetooth® Low Energy / 802.15.4 / ZigBee®	2.400 to 2.500
SKY66403-11	Front-end Module for ZigBee® / Thread / Bluetooth®	2.400 to 2.485

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ProductFeature

cient solution, ANSYS HFSS SBR+ users can simulate across many design variations to thoroughly study and optimize the complex radar signatures of large vehicles.

To illustrate, consider the RCS analysis of a missile in ANSYS Electronics Desktop, shown in **Figure 1**. The results show the monostatic RCS of a missile with an electrical size of 385 $\lambda \times 70~\lambda \times 70~\lambda$, comparing the monostatic RCS solutions obtained from the standard SBR with results from the SBR solver with PTD and UTD. The addition of the extended physics for SBR+ reveals a larger response for the monostatic RCS in some regions, notably near the front of the missile. Even with the extended physics applied, the simulations were fast and extremely efficient. The standalone SBR simulation required just nine minutes on a quad-core computer with 0.075 GB RAM. As the results in Figure 1(c) indicate, advanced diffraction physics is important for accurate results at nose-on angles.

A second example shows the bistatic RCS of a shipping vessel analyzed at 1 GHz with a plane wave incident at θ = -45 degrees and ϕ = -45 degrees (see **Figure 2**). The vessel was modeled in isolation, then compared to a second simulation with a finite extent of sea water. To account for reflections from the water surface, a 400 m × 400 m seawater surface was

modeled with appropriate lossy material properties. This electrically large problem of 1333 $\lambda \times$ 1333 λ was solved in ANSYS HFSS SBR+ in just 86 seconds on a quad-core computer, requiring only 0.5 GB RAM.

A final example shows the RCS of an Airbus 380 aircraft at 2.8 and 10 GHz, and the co-polarized and cross-polarized monostatic RCS responses are shown in **Figure 3**. At 2.8 GHz, the 743 $\lambda \times$ 680 $\lambda \times$ 202 λ structure was solved in two hours using 0.1 GB RAM. At 10 GHz, the electrical size was 2,654 $\lambda \times$ 2,428 $\lambda \times$ 721 λ .

The addition of HFSS SBR+ solver to the portfolio means HFSS users can extend the frequency range for analyzing the radar signatures of their designs. The flow is highly automated and tightly integrated into the same Electronics Desktop as HFSS, meaning current users will have an easy time adopting this new solver technology into the simulation flow. HFSS SBR+ can be a key contributing tool in any design flow where stealth and radar signature analysis of structures with large electrical size and at very high frequencies is a critical performance metric of the system.

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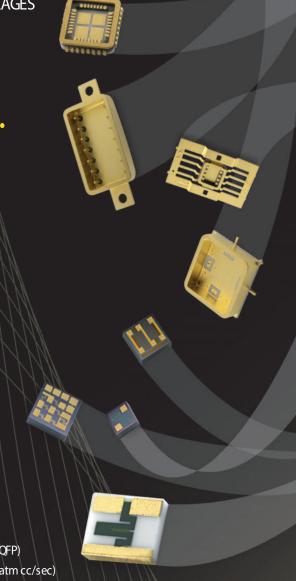
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Next Generation 16-Bit Digitizers

Spectrum Instrumentation GmbH Grosshansdorf, Germany

ver the years numerous customers have incorporated digitizers into their applications, their research setups, even their own products as original equipment manufacturer (OEM) components. While the general design concept is still a perfect fit for many applications, the technical realization is nowadays no longer state-of-the-art. Components are discontinued, technology has evolved and customers demand improving the hardware.

To adapt to current and future requirements, Spectrum Instrumentation is addressing these issues with the introduction of a newly designed digitizer card series. It consists of the new M2p platform board, which will be the PCI Express (PCIe) base for all future products from Spectrum. The first analog module series available for the M2p platform is the new 59xx module family, which consists of four different speed options of 20, 40, 80 or 125 MSPS and the choices of 1, 2, 4 or 8 channels. This creates 16 different digitizer products, and all cards can be switched by software between single-ended and differential inputs. These products will be the heart of a new midrange digitizer series, designed to cover signal frequencies from 1 to 60 MHz.

HALF LENGTH CARD FORMAT

The existing cards in Spectrum's M2i and M3i series comply with PCle specifications; however, such full size, 312 mm cards are being sidelined by system vendors scaling down systems to a smaller footprint. With

the M2p platform, even the smallest and compact PC system can be equipped with high performance measurement hardware as long as the systems offer full height slots and reasonable cooling. Only 167 mm long, the new half length PCIe card format saves space, enabling it to fit into much smaller PC systems than before—perfect for compact OEM solutions—yet it offers more features than previously available. Each channel has a separate analog-to-digital converter and a fully individual programmable input amplifier with ranges between ±200 mV and ±10 V, programmable input offset for unipolar measurements, programmable input termination of 50 Ω and 1 M Ω and an integrated calibration circuit (see Figure 1). Models are available with up to eight single-ended and up to four differential channels.

The interface is PCI Express with four lanes, reaching a continuous streaming speed of more than 600 Mbps, or more than 75 MSPS continuous streaming for four channels. This extends the large on-board memory of 1 GB and enables applications that need continuous data storage or fast online calculations. Intelligent acquisition modes are incorporated in the FPGA: multiple recoding for segmented acquisition, gated sampling for time specific acquisition and ABA (dual time base) for a combination of half digitizer and flow chart recorder in one instrument. All modes can be combined with trigger time stamping. The combination of fast and slow continuous acquisition matches nearly every application demand.

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Procedure for how to use the SMA male and SMA female Push-On connectors. SMA Push-On Connectors mate with any standard connector of the same but opposite connector style.



1. Convert your standard cable assembly into a Push-On Assembly by threading the standard female side of the adapter onto the male connector of the assembly.



2. Your standard SMA male cable assembly is converted into an SMA male Push-On Assembly.



3. Just slide the Push-On SMA male Connector onto any standard SMA female. The connection is securely completed in seconds.



4. To disconnect, just pull the connector off.



Please contact us at: www.spectrum-et.com Email: sales@spectrum-et.com Phone: +49-89-3548-040 +49-89-3548-0490





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2. Your standard SMA male cable assembly is converted to a Push-On **SMA** female Cable Assembly.



3. Just slide the Push-On SMA female Connector onto any standard SMA male. The connection is securely done in seconds.



4. To disconnect, just pull the connector off.

Procedure for how to use the N, TNC and 7/16 Push-On male. Push-On Connectors mate with any standard female connector of the same connector style.



1. Convert your standard Assembly into a Push-On Assembly using the Nf to Nm Push-On Adapter.



2. Put your fingers firmly onto the knurls of the "Lock Nut".



3. Push "Lock Nut" forward and engage the Push-On end of the Adapter with the mating female. Back nut must be released.



4. The Connection has been completed, easy and fast. The connector has been locked Gostafety's copyright protected and stop reverse movement by antipology of the connection has been locked Gostafety's copyright protected.





6. Keep fingers on "Back Nut" to ensure that "Lock Nut" cannot slide rbackduational the assmission off.

Signal Integrity Journal

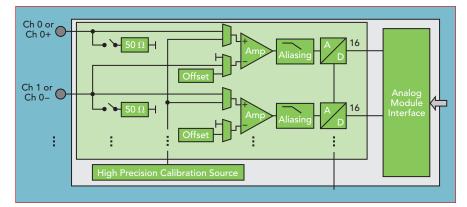
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Microwave Journal

ProductFeature



▲ Fig.1 The digitizer front-end amplifier can be switched between single-ended or true differential operation.

The versatile and proven piggyback module, called Star-Hub, (see Figure 2) allows systems to be created with up to 128 channels, all sharing a common clock and trigger, in one single chassis. For synchronization with external equipment, clock and trigger inputs and outputs are standard. For even more flexibility, four individually programmable connectors are available on the front plate that offer additional trigger inputs, status outputs, synchronous digital input lines, asynchronous I/O or a reference clock input for an integrated time stamping unit.

SOFTWARE SUPPORT

The new card is based on Spectrum's general driver application programming interface (API) that was introduced in 2006; more than 400 different products now share this common driver library, allowing easy switching from slow to fast products and combining PCIe, PXIe or Ethernet/LXI products with one common software interface. A complete software development kit (SDK) based on Windows and Linux is included standard. Also, drivers and examples for nearly every programming language are included, leaving the decision of the preferred programming interface to the customer. The current SDK includes C, C++, C#, Delphi, VB.NET, J#, Python, Java, LabVIEW, MATLAB and LabWindows/CVI.

Within the 1 to 60 MHz range, the new units smoothly replace the company's current 12-, 14- and 16-bit models, giving existing users an easy upgrade path with many technical advantages. As such, the applications for these new products



Fig. 2 The Star-Hub module enables systems with up to 128 channels.

include ultrasound, laser, LiDAR, radar, automotive and "big physics" experiments. All units are shipped factory tested and include a base version of Spectrum's SBench 6 software for control, display, storage, analysis and reporting. The professional license of the software adds full support of all acquisition modes, a large number of calculations and new displays, project control and reporting. Like all the company's digitizers, the new series has a five year warranty, with lifetime software and firmware updates and the company's SDKs offered for free.

VENDORVIEW

Spectrum Instrumentation GmbH Grosshansdorf, Germany spectrum-instrumentation.com

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A Substrate-Scalable **SMA Connector Model**

Modelithics Inc. Tampa, Fla.

odelithics has introduced a substrate-scalable connector model format enabling accurate simulations and de-embedding of microwave connectors in design simulations.

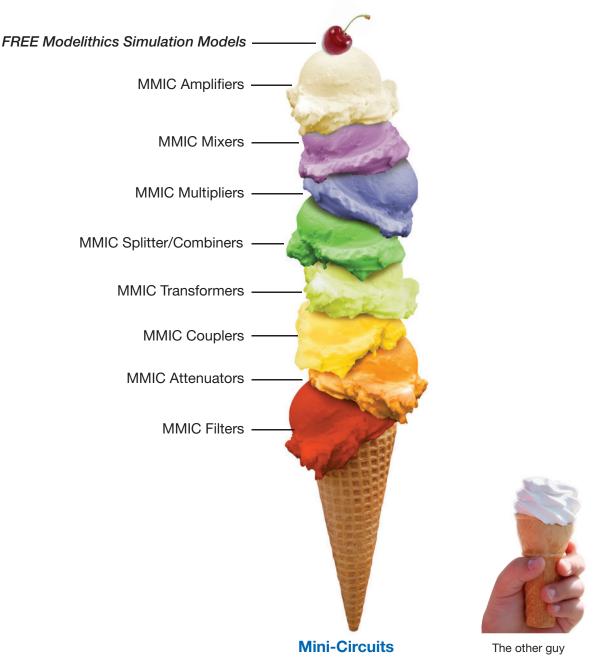
Coaxial connectorized measurements are a relatively easy and quick way to characterize circuits and components in the lab without getting into complicated fixture designs and on-board calibration standards. Coaxial connectors (e.g., SMA end-launch) provide a simple way to interface boardlevel designs to coaxial measurement systems; however, as with any measurement, not knowing where the measurement reference planes are and not being careful in calibration causes measurement and modeling inaccuracies. SMA connectors are designed to be low loss and minimize reflections, so the primary, but not only, effect is introducing a phase shift proportional to their electrical lengths. Their potential impact on performance is often overlooked during design, but like all other RF and microwave components, their actual performance will vary depending on the substrate they are mounted on. If the connector interface is not well matched, not only phase but the magnitude of transmission and reflection will be affected.

Connector effects can be accounted for and removed from the measurement in several ways. A calibration at the device under test reference planes can be performed, or the connectors and test fixture halves can be characterized separately and used to postprocess the measured data in a simulator. Another approach is to use 3D electromagnetic (EM) analysis of the connectors and test fixture, to model their effects on performance. However, these techniques require custom calibration standards or appropriate software, know-how and, in the case of EM analysis, detailed knowledge of the connector's geometry and manufacturing material. Not everyone has the time and access to characterize test fixture effects in such detailed ways.

Alternatively, connectors can be accounted for within a simulator with a suitably accurate connector model. For use with ADS. Modelithics has created a substrate-scalable equivalent circuit model for the popular GigaLane PSF-S00-000 SMA jack connector that scales with the microstrip substrate height and dielectric constant. With the model, potential performance degradation related to the substrate or connector can be dealt with prior to circuit fabrication and testing. Or, a coaxial calibration can be performed, with de-embedding of the connectors done within a simulator. This connector model covers a substrate thickness to dielectric constant range of 2.2 \leq h/ ε _r \leq 17.1 mil and has been validated with measurements to 18 GHz. Using several Rogers' substrates, an equivalent circuit model was developed from data for a feed-thru configuration (i.e., only the connector) and validated with a back-to-back configuration (i.e., a microstrip thru line with connectors mounted on both sides). Examples of the model of the feedthru configuration compared to measured performance are shown in Figure 1.

If the connector is poorly matched on a substrate (i.e., a return loss less than 15 dB), the connector will also affect the magnitude

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of the measured data. If the connector is relatively well matched on a substrate (i.e., a return loss greater than 15 dB), the connector will have less of an effect on the magnitude, except for the insertion loss; the effect is mainly a shift in reference planes. To illustrate this, Figure 2 shows the measured data at two different reference planes for a 3 dB attenuator mounted on 60 mil thick Rogers 4003C. The measurement reference planes of the blue trace are set by the coaxial calibration, while the measurement reference planes of the red trace are set by a thru-reflect-line (TRL) calibration within the fixture. Note that the measurement at the coaxial measurement reference planes has significantly more S₂₁ phase; it also shows that the return loss is very different between the two reference planes across the band and the insertion loss differs significantly at high frequencies.

To confirm that the multiple methods for removing connector and test fixture effects yield the same answer, Figure 3 compares different data sets for the same 3 dB attenuator on 60 mil thick Rogers 4003C, using the same reference plane. The red trace shows the measured data obtained from a TRL calibration with tapers de-embedded in post-processing. The blue trace shows de-embedded data from a coax calibration using characterized test fixture data and ADS microstrip line models. The green trace shows data from the coax calibration deembedded using Modelithcs' connector model with ADS microstrip line models. Excellent consistency is seen between the two connector removal methods though at least 5 GHz, with some difference in $|S_{21}|$ in the region above 5 GHz where the return loss is very poor.

When the physical construction and material properties are known, a full 3D simulation of the component on the test fixture is an alternative simulation option. The main challenge with a 3D simulation is that the geometry is often closely guarded by manufacturers. A recent solution from ANSYS is the ability to encrypt 3D models to protect the manufacturers' IP while allowing 3D component models to be shared

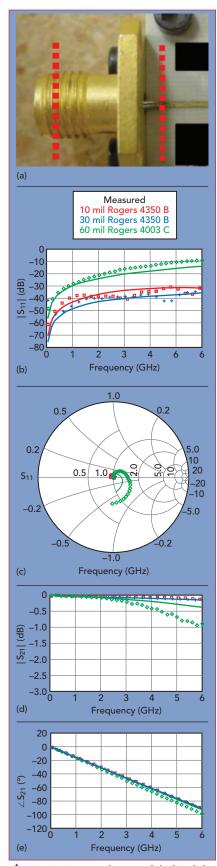


Fig. 1 Measured vs. modeled (solid lines) S-parameters for the feed-thru configuration (a) using several Rogers substrates. $|S_{11}|$ (b), S_{11} (c), $|S_{21}|$ (d) and

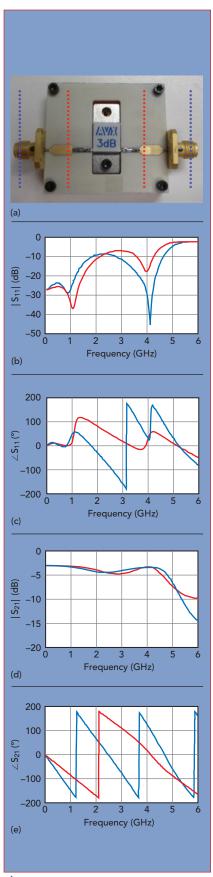


Fig. 2 Comparing reference plane measurements of a 3 dB attenuator on 60 mil Rogers 4003C (a). $|S_{11}|$ (b), $\angle S_{11}$ (c), $|S_{21}|$ (d) and $\angle S_{21}$ (e).

and simulated within the 3D environ- (c), $|S_{21}|$ (e). (c), $|S_{21}|$ (d) and $\angle S_{21}$ (e). (e). Content is copyright protected and provided for personal use only - not for reproduction or retransmission. MWJOURNAL.COM ■ JANUARY 2018 For reprints please contact the Publisher.



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RSGLP0120GA

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Tuning Step: 0.001Hz
Phase Noise @10KHz offset -116dBc/Hz
(@10GHz Output Frequency)

Control Interface : USB





ProductFeature

ment. Modelithics is now supporting encrypted 3D geometry model development for HFSS, in addition to the measurement-based equivalent circuit format. As an example, an encrypted 3D model for the GigaLane SMA jack connector is part of the Modelithics COMPLETE+3D Library for ANSYS HFSS.

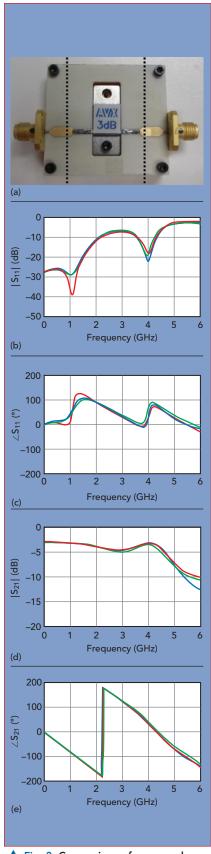
Designers have several techniques to accurately account for connector and test fixture effects. A simulation-based approach often is

the fastest path to design success. With accurate models, connectors and test fixtures can be accurately and quickly removed from the measurement, providing nearly equivilent results as using custom calibration standards and characterization software.

VENDORVIEW

Modelithics Inc. Tampa, Fla. www.modelithics.com





▲ Fig. 3 Comparison of measured and modeled S-parameters of a 3 dB attenuator (a). $|S_{11}|$ (b), $\angle S_{11}$ (c), $|S_{21}|$ (d) and $\angle S_{21}$ (e).

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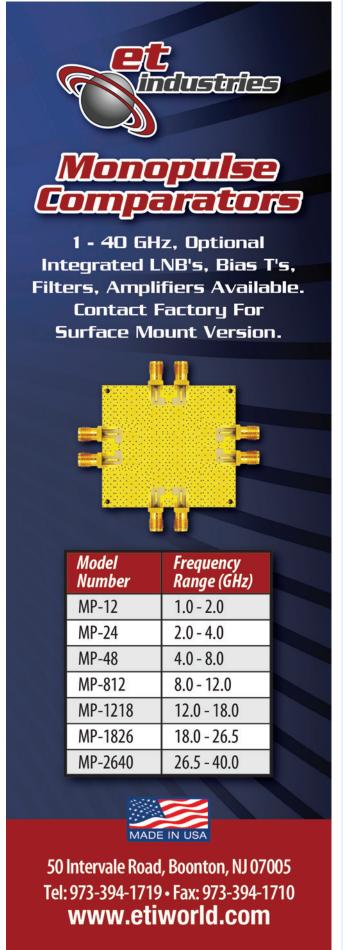






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TechBrief

RF Power Sensor Delivers Performance and Value

adyBug's LB5940L true RMS power sensor is a high accuracy sensor that performs a wide range of power measurements. The multi-path sensor uses diodes operating in their square-law region to make measure-



ments similar to thermal sensors, yet much faster and with greater dynamic range.

Covering frequencies from 9 kHz to 40 GHz, the LB5940L was designed with instrument calibration and electromagnetic compatibility testing in mind. Many devices produce high-power levels when range switching during calibration. The LB5940L sensor's damage level of 27 dBm continuous power and greater than 1 W for pulsed signals affords a measure of safety in these circumstances. LadyBug's patented zero and thermal technology eliminate drift associated with high sensitivity measurements. The sensor remains stable over its entire operating temperature range of 0°C to +55°C.

The LB5940'L includes triggering features that allow users to make advanced triggering measurements. Positive and negative trigger delay, trigger hold off, internal level controlled trigger and external TTL triggering are included features. Trigger count enables multiple measurements to be returned with each measurement. In its faster mode, gated measurements allow detailed signal analysis, and gated data can be averaged or the entire trace returned.

The LB5940L uses an advanced, composite USB interface, enumerating as both a USB human interface device (HID) and USB test and measurement class (USBTMC) device. This advanced feature allows great flexibility for programmatic users. Test system designers that have VISA IO libraries can use the USBTMC interface, and systems written in other environments can use the USB HID interface. This allows access on nearly any PC. The sensor is delivered with a full complement of software, including an easy-to-use application that supports multiple sensors and an interactive IO program to aid system developers. In addition to these tools, LadyBug provides support code to help developers get started quickly.

The LB5940L is a feature-rich sensor at an attractive price, providing customers with excellent value.

VENDORVIEW

LadyBug Technologies Santa Rosa, Calif. www.ladybug-tech.com



2018 IEEE SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY, SIGNAL AND POWER INTEGRITY



Get Your Ideas Published!

EMC+SIPI 2018 is a Technical Symposium. Technical Papers are the essence of our Technical Program. Original, unpublished papers on all aspects of EMC+SIPI are invited.

- Preliminary Full Paper Manuscript Submission Period: November 1, 2017 - January 14, 2018
- Notification of Acceptance: February 21, 2018
- Final Paper Due: May 3, 2018

Call for Experiments & **Demonstrations**

Experiments and demonstrations utilize hardware and software to demonstrate a principle or phenomena of EMI/EMC/SIPI. The presentations are informal and non-commercial and will be conducted in a specific area at the symposium.

Call for Abstract Reviewed Papers

Abstract Reviewed Papers provide opportunities to exchange experiences and ideas. Only an abstract is required for initial submission, papers are included in the conference proceedings; however, these papers are not published in the IEEE Xplore.

- Proposals Accepted:
- Acceptance Notification: March 27, 2018
- Final Paper Due: May 3, 2018



Call for Special Sessions

Special Sessions focus on targeted areas of interest. Acceptance criteria are the same as for Technical Papers, and Special Session papers are published in IEEE Xplore.

- Proposals Accepted:
- Notification of Acceptance: January 10, 2018
- Preliminary Papers Due: March 6, 2018
- Final Papers Due: May 3, 2018

Call for Workshops & Tutorials

Workshops and Tutorials are informal, interactive educational presentations, typically addressing the practical side of understanding and solving EMC/SIPI issues. These sessions typically are held on Monday and Friday.

- Proposals Accepted:
- Notification of Acceptance: February 21, 2018
- Final Presentations Due: May 3, 2018



www.emc2018usa.emcss.org

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TechBrief



emote Sensing Solutions has developed a gamechanging digital subsystem technology that transforms radar systems through significant miniaturization, unparalleled processing, adaptive sampling and seamless scalability. Not much larger than a smartphone, weighing ounces and consuming only 5 to 20 W, ARENA enables a new generation of microwave and mmWave unmanned aerial system radars with greater than 1 GHz of bandwidth, adaptive sampling and processing and continuous network connectivity—handling applications such as radar interferometry for target detection.

Today, the ARENA product line supports direct frequency generation and processing from baseband through C-Band. A single ARENA

Digital Subsystems Enable Software-Defined Radar

generates arbitrary waveforms, provides digital receiver and signal processing and creates timing and control signals. Combining multiple modules with patent-pending synchronization, ARENA transforms a phased-array radar into a reconfigurable, software-defined radar with state-of-the-art performance, providing real-time processing while significantly reducing size, weight and power.

ARENA is hardware, firmware and software reconfigurable. Through its credit-card-size, plug-in mezzanine cards, ARENA takes on capabilities with each new card; when a card is plugged in, the system automatically reconfigures itself from the hardware through its user applications, eliminating significant firmware and software development. Every function is encapsulated and controlled

through XML-based objects. With simple manipulation of these objects, new waveforms, digital receiver and signal processing methods, data products and timing signals can be formed pulse to pulse. This enables the radar to have adaptive sampling, in-mission reconfigurability and optimization.

With its network-centric design architecture, every object's data within each ARENA is available, providing new levels of simultaneous parallel and serial processing. With up to 100 Gbps communication capability, multiple ARENAs can share data and distribute processing. ARENA modules can also provide local data storage.

Remote Sensing Solutions Barnstable, Mass. remotesensingsolutions.com





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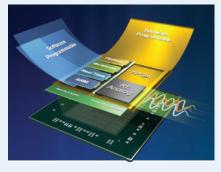
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TechBrief



ilinx Inc. has expanded its RF system on a chip (SoC) product family, initially introduced to support 5G development and production, cable broadband, radar and other high performance applications. The Zynq® UltraScale+TM RFSoC architecture integrates RF data converters and soft decision forward error correction (SD-FEC) blocks with high performance, programmable logic and an ARM® A53 multi-processing system into a 16-nm SoC that reduces board footprint and power consumption by 50 to 75 percent.

For cable broadband networks, distributed access architectures are

RF-SOCs for 5G Wireless, Cable Remote-PHY and Radar

moving physical layer (PHY) functions from the central headend to locations closer to consumers. With RF integration and an integrated, programmable SD-FEC signal chain, the RF SoCs meet remote PHY requirements, including the spectral efficiency prescribed by DOCSIS 3.1.

For radar—particularly active phased arrays—the Zynq Ultra-Scale+ RF SoCs provides the low latency and digital signal processing needed for rapid turnaround from detection to transmission, together with power, footprint and cost advantages from the improved performance-per-watt capabilities of 16-nm FinFET+ technology.

As 5G massive multiple-inputmultiple-output (MIMO) transceivers will incorporate a large number of antennas—from 32 to more than 1,000—the bill of materials and layout simplification using Zynq Ultra-Scale+ is significant. An integrated SoC platform dramatically reduces the design complexity and power associated with moving data between the RF and digital front-ends.

Devices in the RFSoC family offer eight, 4 GSPS or 16, 2 GSPS, 12-bit analog-to-digital converters; eight or 16, 6.55 GSPS, 14-bit digital-to-analog converters; integrated SD-FEC cores with low-density parity-check and Turbo codecs; a multi-core ARM A53 processing subsystem; 16-nm UltraScale+ programmable logic; up to 930,000 logic cells and over 4200 DSP slices.

Xilinx Inc.
San Jose, Calif.
www.xilinx.com/rfsoc







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CatalogUpdate

CST STUDIO SUITE EMSimulation for Defense

VENDORVIEW

CST STUDIO SUITE®'s range of solvers address the unique challenges faced by defense designers as they seek to ensure safe, reliable operation of equipment in difficult electromagnetic environments. Whether on land, air or sea, CST STUDIO SUITE® provides solutions for engineers to tackle tough electromagnetic design obstacles from antenna design and



placement and radar optimization to full system solutions for addressing electromagnetic environmental effects (E3) on large, electrically complex structures. View CST's flyer for complete details.

CST Computer Simulation Technology GmbH www.cst.com

New Product Catalog

K&L Microwave designs and manufactures a full line of RF and microwave filters, duplexers and subassemblies, including ceramic, lumped element, cavity, waveguide and tunable filters. K&L supplies many of today's most significant military and homeland security electronics pro-



grams. Applications include space flight, radar, communications, guidance systems and mobile radio base stations, as well as air traffic communication and control. Visit www.klmicrowave.com to download the complete catalog or sections of interest.

K&L Microwave www.klmicrowave.com

New High Accuracy Power Sensors Catalog



The broad range of high accuracy power sensors available from Lady-Bug Technologies is described in their catalog, available online. Three categories of sensors are available allowing measurements on any signal. True-RMS sensors make stable accurate measurements similar to thermal sensors. Peak and pulse sensors are designed specifically to make statisti-



cal pulse measurements. For time domain visualization of pulse stream, select a LadyBug pulse profiling sensor. LadyBug sensors are thermally stable and NIST traceable.

LadyBug Technologies, LLC www.ladybug-tech.com

Next Generation Product Brief

VENDORVIEW

New high-power solid state amplifier functions are described along with the available power/bandwidth combinations in the latest Empower RF Next Generation product brief. Automatic Gain Control, Automatic Level Control and Manual Gain Control output power modes are explained. When combined with user selectable measurement modes this amplifier



family becomes flexible and interoperable across applications allowing for optimal efficiency, maximum peak power, accurate metering and self-protection suited to your waveform environment.

Empower RF Systems Inc. www.empowerrf.com

Updated Spaceborne Product Brochure

L3 Narda-MITEQ's Spaceborne Product Brochure is now updated and ready to be downloaded! It is filled with loads of interesting information pertaining to the company's spaceborne products. Learn about all of their space ready products including amplifiers, frequency generation products, PIN diode switches, power dividers/combiners and more. Also included is information on the com-



pany's space heritage, their capabilities, the missions and programs they have been a part of, applications and more. Download the brochure at nardamiteg.com.

L3 Narda-MITEQ www.nardamiteq.com

New Product Manual

MIcable is a joint venture established by SSI Cable USA and Mitron China in 2006. The company provides high performance microwave cable assemblies for various applications up to 67 GHz, including flexible, handflex, semi-rigid and precision test cables. MIcable is especially good at those products requiring low loss, low VSWR, phase matching and phase tracking. MIcable's mission is to offer the global customer high quality products with the "Best in Class" customer service and cost saving solution.

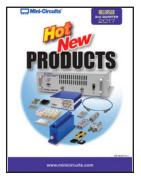


MIcable www.micable.cn/english/about.html

CatalogUpdate

Hot New Products VENDORVIEW

This new 20 page product guide provides a complete survey of Mini-Circuits' latest product releases from the second quarter of 2017. Highlights include everything from ultra-wideband coaxial LNAs, multi-channel programmable attenuation systems, highpower stripline 90° hybrids, ultra-wideband splitters up to 40 GHz and more! Mini-Circuits is continuously innovating new products to meet your

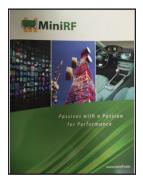


needs, and this informative product line update will help you stay up to date with their latest, coolest new model releases.

Mini-Circuits www.minicircuits.com

Updated Product CatalogVENDOR**VIEW**

The MiniRF catalog of products has been recently updated to include its latest broadband, CATV and wireless products. There are over 20 new passive products (RF transformers, splitters and directional couplers) that will help you achieve your RF and microwave sub-system specifications. Additionally, MiniRF recently introduced a new line of high performance custom air core inductors from VHF to



S-Band along with their custom RF chokes. Contact your local RFMW distributor for more details about fast turnaround!

MiniRF

www.minirf.com

New 2018 Catalog VENDORVIEW

Pasternack an industry-leading manufacturer and supplier of RF, microwave and mmWave products, has recently released their 2018 RF Product Guide. The company's latest 264 page catalog contains thousands of in-stock products including RF cable assemblies, RF amplifiers, an expanded portfolio of waveguide components, 60 GHz modules and systems and hundreds of other active



and passive RF components that are all available for same-day shipping worldwide.

Pasternack www.pasternack.com

New 2018 Main Catalog

VENDORVIEW

SAGE Millimeter's 2018 Main Catalog features 10 product families to offer total component and subassembly solutions for system integrations and applications. The 10 product families include antennas, amplifiers, frequency converters, control devices, ferrite devices, oscillators, modules and subsystems, test equipment and waveguide passive components. Custom designed products are also



available by contacting the sales department. Request a copy of their catalog at www.sagemillimeter.com.

SAGE Millimeter www.sagemillimeter.com

Hermetically Sealed Adapters Brochure

The new Hermetically Sealed Adapters Brochure, issued December 2017, from Spectrum Elektrotechnik shows the updated product spectrum. To the N, TNC and 2.92 mm series, the 2.4 mm and 1.85 mm units were added. The standard hermeticity specifies 10-8 atm. cm³/s minimum. As several applications do not need this high class hermeticity, more economical priced products with hermeticity



of 10⁻⁵ atm. cm³/s were added. All adapters use fused in glass seals between center contact and outer conductor. The adapters are normally used at vacuum chambers testing products that are undergoing tests for outer space applications.

Spectrum Elektrotechnik www.spectrum-et.org/NEW_WEB2/index.asp

PIM Testing Portfolio VENDORVIEW

The new PIM Testing portfolio catalog presents a sampling of SPINNER's large "low PIM" Test and Measurement portfolio. Over the years, SPINNER has developed a large portfolio of specialized equipment with outstandingly low PIM for testing and measurement. Nothing comparable is available anywhere else. It includes self-aligning connectors, diplexers, rotary joints, loads, switch matrices, reference standards



and more. SPINNER provides these products for hand-operated on-site testers and fully automated test systems in manufacturing environments to boost productivity while ensuring the highest standards of quality.

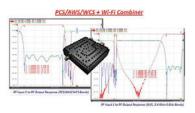
SPINNER www.spinner-group.com

NEW PRODUCTS

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COMPONENTS

PCS/AWS/WCS Plus Wi-Fi



3H's new PCS/AWS/WCS Plus Wi-Fi combiner offers low passband insertion loss of < 1 dB and sharp selectivity suitable for old and new in-building infrastructure and are available from stock.

3H Communication Systems www.3hcommunicationsystems.com

RF Switch/Coupler Assembly



Aethercomm model number SSHPS/C 0.020-1.000-150 is a high-power symmetrical RF switch/coupler assembly which is em-

ployed in electronic warfare systems where high-power, low loss and excellent isolation are required. A dual directional coupler is employed to measure forward and reflected power. This unit operates across the 20 to 1000 MHz range.

Aethercomm www.aethercomm.com

1.7 to 6 GHz SMT Hybrid Coupler



Electro-Photonics LLC has released a new broadband surface mount (SMT) hybrid coupler: Q3XB-4000R. This Q3XB-4000R, 90° hybrid coupler operates from 1.7 to 6 GHz, dissipates 85 W

and offers excellent coupling flatness and isolation for the most critical applications. This coupler has a very small package of 0.560 in. \times 0.200 in. (14.22 mm \times 5.08 mm). The Q3XB-4000R is manufactured in the U.S. and is RoHS compliant.

Electro-Photonics LLC www.electro-photonics.com

Waveguide Phase Equalizer



Exceed Microwave's waveguide phase equalizer can reduce the peak-to-peak parabolic and cubic phase distortions across a wide frequency band. The

phase equalizers are custom designed to each phase distortion requirement in digital systems. It has low insertion loss and can be provided with waveguide or coaxial interface. They are available in all waveguide sizes up to WR15.

Exceed Microwave www.exceedmicrowave.com

Low Pass and Bandpass Filters



Fairview Microwave Inc. has introduced a new series of low pass and bandpass filters for use with multiple popular frequency bands. Fairview's 13 new SMA coaxial filters

consist of seven bandpass filters and six low pass filters. The bandpass filters were developed for use in various applications including GPS, ISM, RFID and Wi-Fi systems and operate in several bands, some as low as 824 MHz and some as high as 5.875 GHz.

Fairview Microwave Inc. www.fairviewmicrowave.com

Solid-State Switch



I.F. Engineering Corp.'s (IFE) latest solid-state switch design features greater than 95 dB isolation at 70 MHz and operates over a fre-

quency range of 20 to 1000 MHz. It is designed for both commercial and military applications and has a high-reliability option. Its compact design of 1.04 cubic inches (excluding connectors and solder terminals) is small in size compared to other available products. The company offers standard configurations but its specialty is providing uniquely engineered products that will meet your specific needs.

I.F. Engineering Corp. www.ifengineering.com

Directional Coupler





KRYTAR's new 1 to 40 GHz directional coupler, Model 101040010SQ offers superior performance ratings including nomi-

nal coupling (with respect to output) of 10 dB, ± 1 dB and frequency sensitivity of ± 1.52 dB. The directional coupler exhibits insertion loss (including coupled power) of less than 1.3 dB (1 to 20 GHz) and 1.7 dB (20 to 40 GHz).

KRYTAR www.krytar.com

5G Ready mmWave ProductsVENDOR**VIEW**

MECA offers a family of components covering the various proposed bands for 5G and mmWave bands. Featuring power divider and



couplers covering 6 to 40 GHz with 2.92 and 2.4 mm interfaces along with supporting components such as attenuators, terminations. bias tee's. DC

blocks and adapters. With octave and multioctave units covering 1 to 18 GHz with SMA interfaces all built by J-Standard certified assemblers and technicians. Made in U.S. with a 36-month warranty.

MECA Electronics Inc. www.e-MECA.com

Coupler VENDOR**VIEW**



The RFCP5763 coupler is designed for applications that require small, low cost and highly reliable surface mount components. Applications may be

found in broadband, wireless and other communications systems. These units are built lead-free and RoHS compliant. S-parameters are available on request.

MiniRF

www.minirf.com

High-Power Coaxial Isolators > 1.5 Kw CW



The CI1833 is a conduction cooled L-Band isolator that operates at 1500 W CW forward and reverse with 0.2 dB loss and 23 dB isolation typical over the

1.2 to 1.4 GHz band. M Wave Design Corp. offers high-power coaxial isolators from 80 MHz to 40 GHz, and waveguide products from 1 to 65 GHz. Handling up to 100 Kw in coaxial and 2 Mw in waveguide.

M Wave Design Corp. www.mwavedesign.com

Cross Guide Couplers VENDORVIEW



Pasternack has introduced a new line of cross guide waveguide couplers with 4-, 3and 2-port with coax interface that work across C- to K-Bands.

Typical applications include instrumentation, test benches, product development and characterization. These couplers operate over eight waveguide bands in the 5.85 to 33 GHz frequency range. They are made with bronze waveguide bodies and are offered with EIA (CPR)-style flanges or UG-style flanges per mili-

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Passbands from 900 to 11400 MHz ** 19995

Need to separate signal from scramble? Mini-Circuits' FEATURES new ZVBP-series cavity filters are designed to give you razor sharp selectivity and high stopband rejection for bandwidths as narrow as 1% to keep your signal clean. These filters feature rugged construction and robust design with protection from accidental detuning, so you can put them to work with confidence in almost any environment, in the lab or in the field.

- Outstanding selectivity
- High rejection
- Rated for operation from -55 to +100°C
- Power handling up to 15W
- Rugged construction

They're available off the shelf for immediate shipment, so place your order today for delivery as soon as tomorrow! Need a custom filter? We've got you covered. Just send your requirements to apps@minicircuits.com for a fast response.



NewProducts

tary standard. These cross guide couplers are available with coupling factors from 20 to 50 dB. **Pasternack**

www.pasternack.com

Gain and Line Loss Equalizers



RLC Electronics' gain and line loss equalizers combine filter and attenuator technology to achieve a desired

response to 40 GHz. The typical curves that follow are representative of commonly requested responses, including both linear and half-sine responses. VSWR is dependent on frequency of operation, complexity of equalized response and bandwidth of response. Power handling is dependent on the physical size of the absorptive elements. Since these elements decrease in size with increasing frequency, power handling by 10 GHz is usually in the hundredths of watts.

RLC Electronics Inc. www.rlcelectronics.com

2 to 350 MHz Power Divider



The 2-way power divider, model DSK-7M2S, covers the HF and VHF bandwidth of 2 to 350 MHz is suitable for many signal splitting and low power applica-

tions. Built in a rugged SMA connector package, it can handle a moderate 1 W of power

when used as a power divider and can also be used as a combiner at lower RF power levels. It has excellent insertion loss of 0.8 dB maximum and isolation of 26 dB minimum.

Synergy Microwave Corp. www.synergymwave.com

1.3 A LDO Regulator

The 1.3 A TCR13AGADJ CMOS LDO regulator offers a typical dropout voltage of 92 mV (at 0.9 V, 1.0 A) and is supplied in a WCSP6F



package measuring $0.8 \text{ mm} \times 1.2 \text{ mm} \times 0.33 \text{ mm}$ (max), making it suitable for mobile and module applications that require

small footprints and low profiles. Its high typical ripple rejection ratio (90 dB at 0.9 V, 1 kHz) can help in drastically reducing ripple noise from DC-DC converters and PMIC. Using an external resistor, the output voltage of the regulator can be adjusted over a wide 0.55 to 3.6 V range.

Toshiba Electronics Europe www.toshiba.semicon-storage.com

CABLES & CONNECTORS

2.4 mm-Female to 2.4 mm-Male Adapter



Mini-Circuits' 24F-24M+ 2.4 mm-female to 2.4 mm-male adapter expands its portfolio of products in the 40 and 50 GHz range to give you more options and more capabilities.



This model provides 0.12 dB insertion loss with very flat response across the DC to 50 GHz range and 1.06:1 typical VSWR up to 50 GHz. The unit features

passivated stainless steel construction and measures only 0.72 in. (l) \times 0.36 in. (dia.). Mini-Circuits now offers 50 GHz 2.4 mm adapters in a variety of gender configurations, all offering industry-leading performance and value.

Mini-Circuits www.minicircuits.com

Expanded Connector Series



The high-precision RPC-1.00 connector series has been expanded, making waveguide-to-coaxial adaptors and flexible cable assemblies available

for challenging test and measurement applications, as well as inter-series adaptors RPC-1.00/RPC-1.35. The connectors are designed for industrial test and measurement applications up to 110 GHz and are characterized by excellent return loss values and a high number of mating cycles (> 500). The product portfolio also includes semi-rigid cable assemblies (with and without armoring), PCB connectors, in-series adaptors, inter-series adaptors RPC-1.00/RPC-1.35 and gauge kits.

Rosenberger www.rosenberger.com

AMPLIFIERS

Solid State Power Amplifier



dB Control introduced its first solid state power amplifier (SSPA), the dB-8002. Specs include: 150 W minimum

at 25°C, 2 to 6 GHz, conduction cooled. It is designed for electronic countermeasures (ECM), electronic warfare (EW) simulation, ground mobile and airborne platforms. Customization is available (contact swalley@dbcontrol.com). Info about dB Control's other products—including traveling wave tube amplifiers and microwave power modules—can be found at dB's website or by calling 510-656-2325.

dB Control www.dbcontrol.com

Solid State Low Noise AmplifierVENDOR**VIEW**



New solid state low noise amplifier module LNA5003 covering the 7.35 to 7.65 GHz frequency band at +25 dBm CW output. The

coaxial LNA5003 operates from a 9 VDC supply at 0.3A nom. with a noise figure of 1.5 dB max, a gain of 25 dB min. and a gain flatness of 1 dB max peak-to-peak. This module can also be packaged in a self-sustained system chassis (benchtop or rackmount configuration). Typical applications would include Sat-Com receive signal boosters, general small signal amplification and receiver testing.

Exodus Advanced Communications www.exoduscomm.com

High-Power GaN-on-SiC HEMT Transistor



Designed for S-Band radar applications, this high-power GaN-on-SiC HEMT transistor supplies 200 W of typical peak pulsed output power at 44 V drain

bias, with 14 dB gain and 54 percent efficiency, at 300 microseconds, 10 percent pulse conditions.

Integra Technologies www.integratech.com

Ultra-Wideband Coaxial LNA VENDORVIEW



Mini-Circuits' ZX60-153LN+ is an ultrawideband connectorized LNA providing low noise figure of typically 2.4 dB across the en-

tire 0.5 to 15 GHz frequency range, supporting a broad range of applications including Wi-Fi, LTE, S-Band radar, C-Band and X-Band SatCom, test instrumentation and more. It delivers 17 dB typical gain with ± 2.7 dB flatness, P1 dB of ± 16 dBm and ± 12 dBm IP3. The amplifier operates on a single ± 12 V supply with low current consumption and comes housed in a rugged, compact unibody case (0.74 in. \times 0.75 in. \times 0.46 in.) with SMA connectors.

Mini-Circuits
www.minicircuits.com



WWW.DSINSTRUMENTS.COM







Don't miss this year's exciting keynote speakers at the Microwave Week in Philadelphia!

IMS Plenary Session Speaker (Monday, 11 June 2018):



"The Hitchhiker's Guide To the Healthcare **Galaxy: The Actions That Changed the Healthcare Landscape in America From** 2017-2027"

Stephen K. Klasko, MD, MBA, President and CEO, Thomas Jefferson University and Jefferson Health

IMS Closing Session Speaker (Thursday, 14 June 2018):



"Extreme Platforms for Extreme Functionality"

Nader Engheta, PhD, H. Nedwill Ramsey Professor at the University of Pennsylvania

RFIC Plenary Session Speakers (Sunday, 10 June 2018):



"Compact Silicon Integrated mmWave Circuits: From Skepticism to 5G and Beyond"

Zachary J. Lemnios, Vice President, Science, Technology & Government Programs, IBM T.J. Watson Research Center



"The Road Ahead for Autonomous Cars -What's in for RFIC"

Lars Reger, Automotive Chief Technology Officer (CTO), Business Unit Automotive, **NXP Semiconductors**

IMBioC Opening Session Speaker (Thursday, 14 June 2018):



"Renal Denervation for Uncontrolled **Hypertension: Complexity After Symplicity**"

Dr. Nicholas J. Ruggiero II, MD

IMBioC Closing Session Speaker (Friday, 15 June 2018):



"Is There a Fundamental Law of Health and Disease?"

Dr. Chung-Kang Peng, Director of the Center for Dynamical Biomarkers at Beth Israel Deaconess Medical Center / Harvard Medical School (BIDMC/HMS)

REGISTRATION OPENS 1 FEBRUARY 2018!

FOR MORE INFORMATION, VISIT WWW.IMS2018.ORG

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NewProducts

Low Noise Amplifier VENDORVIEW

PMI model No. PE2-30-1R018R0-4R5-22-12-SFF-1 is a 1 to 18 GHz, low noise amplifier that typically provides 30 dB of gain while



maintaining a maximum gain flatness of ± 1.5 dB over the operating frequency. The noise figure is 4.5 dB maximum and offers an OP1 dB of 22 dBm minimum. The operating voltage is ± 12 to ± 15 VDC with a typical current draw of 500 mA. The unit is supplied with removable SMA(F)

connectors in its standard PE2 housing.

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

SOURCES

Oven Controlled SAW Oscillators



Rakon has released new oven controlled SAW oscillators in a miniature 25.4 mm \times 22 mm \times 12.7 mm SMD package, currently available in 400, 500, 600 and 800 MHz and 1 and 1.2 GHz and all designed to be soldered by reflow. Among them, the new LNO800E1 is a low noise, low power Oven Controlled, Voltage Controlled,

SAW Oscillator (OCVCSO) operating at 800 MHz and powered by a low ± 5 V supply. The 800 MHz signal is generated from a 400 MHz fundamental frequency, followed by a low noise frequency doubler.

Rakon Limited www.rakon.com

51 V Module

Richardson RFPD Inc. announced the availability and full design support capabilities for a new module from Maxwell Technologies. The BMOD-



0189P051B2A 51 V module is based on Maxwell's leading 48 V module platform and includes the benefits of DuraBlue™ advanced shock and



vibration technology, which combines Maxwell's unique and patented dry electrode formulation and manufacturing process with a robust proprietary cell structure, resulting in a cell that meets or exceeds some of the most demanding shock and vibration requirements of transportation markets.

Richardson RFPD www.richardsonrfpd.com

SOFTWARE

CST STUDIO SUITE 2018 VENDORVIEW



The latest version of CST's state-of-the-art electromagnetic and multiphysics simulation software has arrived and will be shipping in early 2018. CST STUDIO SUITE used by leading companies and research institutes in fields ranging from consumer electronics and healthcare to

automotive and aerospace. CST STUDIO SUITE 2018 offers even more technological prowess with a collection of new features for designing, managing and simulating complex devices and systems. Computer Simulation Technology (CST) is part of SIMULIA, a Dassault Systèmes brand.

CST

www.cst.com

PACKAGING

PCB Technology



The DenciTec® new technology platform enables a high density of integrated functions for printed circuit boards, with high throughput and attractive costs. The possibilities include conductor widths and spacings down to 25 μm with copper thicknesses of 20 \pm 5 μm on all conductive

layers, laser-via diameters of 35 μ m, annular rings with a diameter of 30 μ m for the inner layers and 20 μ m for the outer layers, copper-filled blind vias with the option of via stacking and vias-in-pads.

Cicor Group www.cicor.com

ANTENNAS

Broadband Directional AntennasVENDOR**VIEW**



AR RF/Microwave Instrumentation recently expanded its product line with the addition of its new division, SunAR RF Motion. SunAR can now provide Distributed Antenna Systems (DAS), globally, for the ever-growing demand for access to wireless communication systems. This is driving the need for improvements in wireless infra-

structure, most notably increased capabilities as required for 4G, WiMAX and LTE markets, for indoor and outdoor applications in urban and rural environments. Examples of DAS locations include: hospitals, office buildings, stadiums and subway systems.

AR RF/Microwave Instrumentation www.arworld.us

Broadband Horn Antenna



NSI-MI's broadband horn antenna (ANT-BHA) is suitable for a wide variety of applications that require stable antenna performance over extremely broad frequency bandwidths as high as 15 to 1. The best in class radiation patterns remain consistent across the operating frequency band for applications that require broadband performance. Each model is also designed to maintain VSWR across the complete fre-

quency bandwidth.

NSI-MI Technologies

www.nsi-mi.com

Conical Horn Antenna VENDORVIEW

Model SAC-0432433012-SF-S4-DP-QR is a quad ridge dual polarized conical horn antenna that operates from 4 to 24 GHz. The antenna offers a 12 dBi nominal gain, a typical half power beamwidth of 40 degrees on the Eplane and 30 degrees on the H-plane at



the center frequency of 14 GHz. The nominal side lobe levels are -12 dB or lower. The horn antenna is equipped with SMA(F) connectors to support both linear and circular polarized waveforms vertically and horizontally. Other antenna

ports such as 2.92 mm (K) or 2.4 mm connectors are available under different model numbers. The main application of the horn is being used as a feed horn for large reflector antennas. SAGE Millimeter Inc.

www.sagemillimeter.com

Compact MIMO Antennas VENDORVIEW



Southwest Antennas introduces two new compact MIMO sector antennas to their existing line-up of directional antenna solutions. Applications include MIMO/ MANET mesh radio sys-

tems, wireless infrastructure base stations, city wide and urban area mesh radio networks, emergency management and rapid deploy networks for event management and security. **Southwest Antennas**

www.southwestantennas.com

TEST & MEASUREMENT

CB-Series Crossbar Matrix



For complex test setups and signal switching, the software controlled CB-series crossbar matrix is an excellent choice. A crossbar system can route any input

signal to any output port such that the path between the I/O ports is unique at any given time. It allows testing of multiple UUT/DUT with many input/output signals or high speed communication buses without having to connect or disconnect them from the setup. Dow-Key's CB-Series start from 2 × 2 up to 12 × 12 and can be customized to support larger configurations.

Dow-Key Microwave Corp. www.dowkey.com

5G Two-Radio System



The Eastern OptX Series 2040+ 5G two-radio system is a test network which replicates the propagation

path for real-world applications. The system allows the user to test a variety of Air Interfaces using the same system without modification, and at the same time. This is not a signal emulator. The systems use low-loss fiber optic cable to create the propagation delay as-sociated with radio transmissions from 20 to 40 GHz. Two radios may be connected to the system allowing full duplex operation.

Eastern OptX Inc.

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BookEnd



Phased Array Antenna Handbook, Third Edition

Robert J. Mailloux

his completely revised third edition of an Artech House classic, "Phased Array Antenna Handbook," Second Edition, offers an up-todate and comprehensive treatment of array antennas and systems. This edition provides a wealth of new material, including expanded coverage of phased array and multiple beam antennas. It explores current technologies addressing a variety of applications, including large radar and communication systems, air and spaceborne applications, automotive radar and cell phone use. Readers will find updated material on advanced numerical designs of array apertures, as well as new contributions to scanning reflector and lens technology, reflectarrays and highly-thinned aperiodic ar-

rays. The author demonstrates how to size an array system with speed and confidence.

This edition also explores broadband antennas for arrays, including self-complementary structures, spirals, a variety of printed slot radiators, flared notches and broadband slot and dipole elements. Antenna system noise, updated numerical techniques for antenna pattern synthesis, developments in subarray technology and in-depth coverage of array architecture and components are new features of this book. Practitioners learn how to compute antenna system noise, design subarray geometries for given bandwidth, scan and sidelobe constraints and choose array illumination tapers for given sidelobe levels.

Supported with numerous equations and illustrations, this practical book helps evaluate basic antenna parameters, such as gain, sidelobe levels and noise.

To order this book, contact

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Chuck Boyd Northeast Reg. Sales Mgr. (New England, New York, Eastern Canada) 685 Canton Street Norwood, MA 02062 Tel: (781) 619-1942 FAX: (781) 769-5037 cboyd@mwjournal.com

Michael Hallman Eastern Reg. Sales Mgr. (NJ, Mid-Atlantic, Southeast, Midwest, TX)
4 Valley View Court
Middletown, MD 21769
Tel: (301) 371-8830
FAX: (301) 371-8832
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Pacific and Mountain Time Zones

Brian Landy Western Reg. Sales Mgr. (CA, AZ, OR, WA, ID, NV, UT, NM, CO, WY, MT, ND, SD, NE & Western Canada) 144 Segre Place Santa Cruz, CA 95060 Tel: (831) 426-4143 FAX: (831) 515-5444 blandy@mwjournal.com

International Sales

International Sales Richard Vaughan International Sales Manager 16 Sussex Street London SW1V 4RW, England Tel: +44 207 596 8742 FAX: +44 207 596 8749 rvaughan@horizonhouse.co.uk

Germany, Austria, and Switzerland (German-speaking)

WMS.Werbe- und Media Service Brigitte Beranek Gerhart-Hauptmann-Street 33, D-72574 Bad Urach Germany Tel: +49 7125 407 31 18 FAX: +49 7125 407 31 08 bberanek@horizonhouse.com

Korea

Young-Seoh Chinn JES Media International 2nd Floor, ANA Bldg. 257-1, Myungil-Dong Kangdong-Gu Seoul, 134-070 Korea Tel: +82 2 481-3411 FAX: +82 2 481-3414 yschinn@horizonhouse.com China

Shenzhen Michael Tsui ACT International Tel: 86-755-25988571 FAX: 86-10-58607751 michaelt@actintl.com.hk

Shanghai Linda Li ACT International Tel: 86-021-62511200 lindal@actintl.com.hk

Beijing Cecily Bian ACT International Tel: +86 135 5262 1310 cecilyb@actintl.com.hk

Hong Kong, Taiwan, Singapore Mark Mak

ACT International Tel: 852-28386298 markm@actintl.com.hk

Katsuhiro Ishii Ace Media Service Inc. 12-6, 4-Chome, Nishiiko, Adachi-Ku Tokyo 121-0824, Japan Tel: +81 3 5691 3335 FAX: +81 3 5691 3336 amskatsu@dream.com

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Anritsu's Microelectronics Fabrication Center Offers Performance, Quality and Flexibility



ince being formed in 1895, almost a decade before the vacuum tube was invented, Anritsu has earned an enviable reputation as a major supplier of RF/microwave test equipment. Developing equipment to make precision measurements from DC to terahertz frequencies is not easy, often requiring unique designs and manufacturing processes. To maintain leadership, Anritsu has established its own hardware and software capabilities, particularly for the microelectronics components that comprise the broadband front-ends setting the performance of the company's instruments.

While the mantra for Anritsu's microelectronics components is "performance, quality and flexibility," the manufacturing volumes do not consume the company's capacity, which allows Anritsu to develop symbiotic relationships with other companies needing the same advanced microelectronics design and manufacturing capabilities. The Microelectronics Fabrication Center, part of Anritsu's U.S. operation, fabricates thin film circuits, MEMS structures, GaAs and InP optoelectronics devices and offers machining, microelectronics assembly and testing services. The microelectronics team is proud of the support it provides, from process engineering to rapid prototyping—often developing a prototype in half the time quoted by other contract manufacturers. For production programs, Anritsu can manage the supply chain for a product, simplifying the procurement of a customer's bill of materials.

Thin film circuits can be fabricated on a range of materials: alumina, aluminum nitride, fused silica, sapphire, glass and chemical vapor deposition (CVD) diamond, as well as silicon, GaAs and InP. Etching processes include reactive-ion etching, plasma and wet etching of metal, silicon, nitride and oxide. Sputtering, e-beam evaporation, selective Au and AuSn electroplating are available for metal deposition, and plasma-enhanced CVD is used for dielectric layers. The thin film networks can incorporate polyimide, BCB and silicon nitride capacitors; laser-trimmed resistors; wrap-arounds and filled and plated-through vias. The facil-

ity also has the capability to align double-sided circuits.

The Microelectronics Fabrication Center has a complete range of chip-and-wire assembly processes: epoxy and eutectic die attach, ball bonding, manual and automated wedge bonding, gap welding and tack bonding. Soldering processes include AuSn, In, SnPb and AuGe, with RoHS-compliant material options available. In-house scanning electron and acoustic microscopy support process development and quality assessment.

Not surprisingly, Anritsu's suite of test capabilities is unmatched, spanning DC to 145 GHz and encompassing S-parameters, noise figure, phase noise, IP3, harmonics and dynamic range. Anritsu also offers a full complement of reliability testing to support development and production: IC thermal imaging, die attach void assessment, highly accelerated life testing (HALT), highly accelerated stress screening (HASS), burn in, temperature cycling, power cycling, drop testing, shear and pull testing and EMC/EMI assessment.

Based in Morgan Hill, Calif., the Microelectronics Fabrication Center contains a 25,000 square foot RF/microwave assembly area, 8,000 square feet of class 100 and 10,000 clean room, a machining center and offices. Anritsu's capability is IS09001/IS017025 certified and ITAR compliant. In addition to supporting Anritsu's own test equipment, the center manufactures products for the telecommunications, automotive, civil aerospace, defense, medical, biotechnology and solar industries. While most of the center's customers are within the U.S., several are international.

The Microelectronics Fabrication Center lets customers tap into Anritsu's microelectronics technology, developed over decades, and reap the same "performance, quality and flexibility" found in Anritsu's high performance test equipment.

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C5725

C9688

C7734

C8188

C3910

C8373

C7711

C7058

C8060

C7248

C8000

C8214

C10462

C10525

C10537

C10536

C10751

C10006

C10117

C10364

C10762

C10958

C10761

C8644

C10743

Type

Dual

Dual

Dual

Dual

Uni

Dual

Bi

Dual

Bi

Bi

Bi

Bi

Bi

Dual

Bi

Dual

Frequency

(MHz)

0.01-1000

0.1-1000

1-1000

30-2500

30-3000

80-1000

100-2500

100-3000

200-2000

200-6000

300-3000

600-6000

700-2500

700-4200

700-4200

700-4200

700-4200

700-4200

700-4200

700-6000

700-6000

1000-6000

1000-6000

1000-6000

1800-6100

2000-6000

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Coupling Insertion

Loss (dB)

0.45

0.5

0.5

0.35

2.4

0.2

0.8

0.35

0.3

1.1

0.35

0.4

0.35

0.2

0.2

0.2

0.2

0.2

0.2

0.2

0.2

0.2

0.2

0.2

0.4

0.2

(dB)

40

40

40

43

20

40

20

40

10

20

6

30

6

40

50

60

50

60

50

40

50

40

40

40

20

40

VSWR

(ML)

1.30:1

1.25:1

1.20:1

1.25:1

1.35:1

1.20:1

1.25:1

1.25:1

1.25:1

1.40:1

1.25:1

1.25:1

1.25:1

1.30:1

1.35:1

1.35:1

1.35:1

1.35:1

1.35:1

1.30:1

1.35:1

1.30:1

1.35:1

1.35:1

1.25:1

1.30:1

Flatness

 $(\pm dB)$

0.5

0.5

1.0

1.5

1.0

0.3

1.75

1.0

1.0

2.25

1.0

1.0

1.0

1.0

1.0

1.0

1.0

1.0

1.0

1.0

1.0

0.5

0.5

0.5

1.0

0.5

Size

(Inches)

6.7 x 2.27 x 1.69

5.2 x 2.67 x 1.69

6 x 2.2 x 2.2

3.5 x 2.6 x 0.7

6 x 1.5 x 1.1

3 x 3 x 1.09

9.58 x 1.48 x 0.88

3 x 2.2 x 0.7

6.4 x 1.6 x 0.72

4.8 x 0.88 x 0.5

6 x 2 x 0.85

1.8 x 1 x 0.56

6 x 2 x 0.85

2 x 2 x 1.06

2.15 x 2 x 1.36

3 x 3 x 1.59

2 x 2 x 1.06

2.15 x 2 x 1.36

2 x 2 x 1.06

2 x 2 x 1.06

2.15 x 2 x 1.36

1.1 x 0.75 x 0.48

2.15 x 2 x 1.36



Power

(W CW)

500

500

800

100

20

200

200

100

200

200

100

100

100

250

700

700

1000

1000

2000

250

500

300

400

600

60

500

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