

Vol. 61 • No. 8

August 2018

# Microwave Journal



**EuMW2018**  
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MICROWAVES

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MICROWAVE WEEK**  
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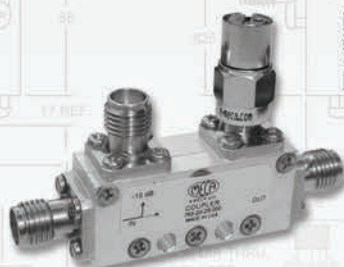
# BETTER COMMUNICATION SOLUTIONS

## MECA 5G Products & Equipment

MECA Electronics designs and manufactures an extensive line of RF/Microwave Equipment and components with industry leading performance including D.A.S. Equipment, Low PIM Products, supports 5G & Millimeter-Wave, Power Dividers & Combiners, Directional & Hybrid Couplers, Fixed & Variable Attenuators, RF Terminations, Circulators/Isolators, DC Blocks & Bias Tees, Adapters & Jumpers. Models available in industry common connector styles: N, SMA, 2.92mm, TNC, BNC, 7/16, 4.1/9.5 & 4.3/10.0 DIN as well as QMA, Reverse Polarity SMA, TNC and various mounting solutions.

Since 1961 MECA Electronics (Microwave Equipment & Components of America) has served the RF/Microwave industry with equipment and passive components covering Hz to 50 GHz. MECA is a privately held ISO9001:2015 Certified, global designer and manufacturer for the communications industry with products manufactured in the United States of America. We stock products so that you do not need to.

### Directional Couplers/Hybrids



0.4 - 40 GHz  
SMA, 2.92, QMA, N,  
TNC, BNC, RPTNC & 7/16  
Up to 500 watts  
MIL-DTL-15370 Available

### Attenuators



Up to 40 GHz  
SMA, 2.92, QMA, N,  
TNC, BNC, RPTNC & 7/16  
Up to 150 watts

### Power Divider/Combiner



20 MHz - 40 GHz  
SMA, 2.92, QMA, N,  
TNC, BNC, RPTNC 4.1/9.5 & 7/16  
Up to 120 watts

### Circulators/Isolators



Up to 40 GHz  
SMA, 2.92, N, & 7/16  
Up to 250 watts

### Terminations



Hz-18 GHz  
N, SMA & 7/16  
Up to 250 watts  
MIL-DTL-3903E

### Power Divider/Combiner



20 MHz - 40 GHz  
SMA, 2.92, QMA, N,  
TNC, BNC, RPTNC 4.1/9.5 & 7/16  
Up to 120 watts  
MIL-DTL-23971 Available



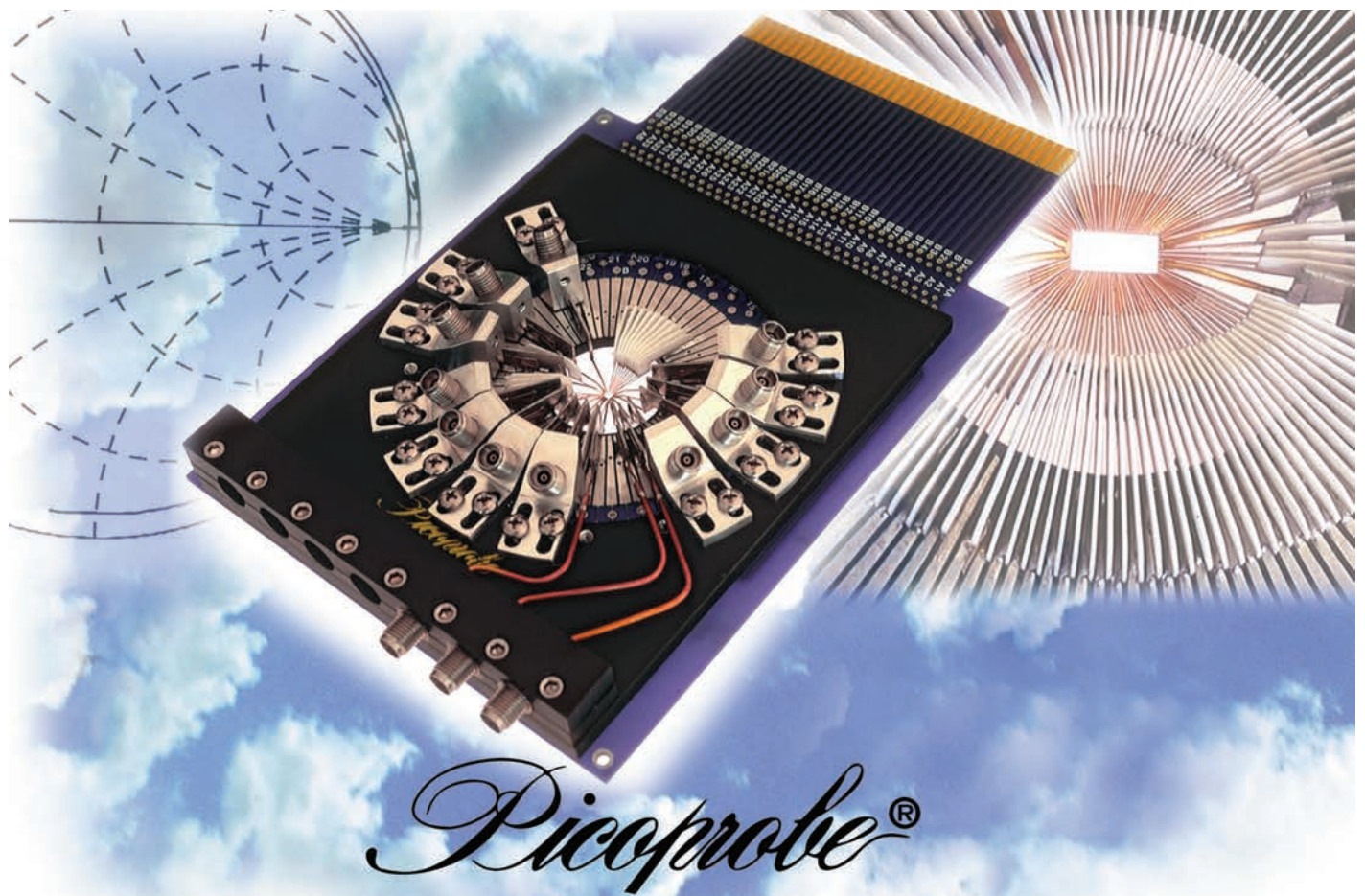
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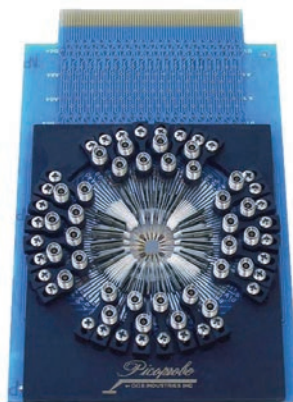
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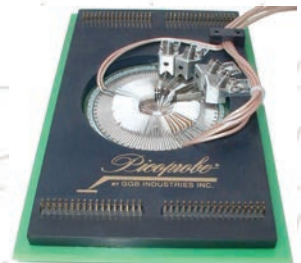


Our patented probe structures provide the precision and ruggedness you require for both production and characterization testing. And only Picoprobe® offers the lowest loss, best match, low inductance power supplies, and current sources on a single probe card.

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Typical Specs	10GHz	20GHz	40GHz
Insertion Loss	0.6 dB	0.8 dB	1.3 dB
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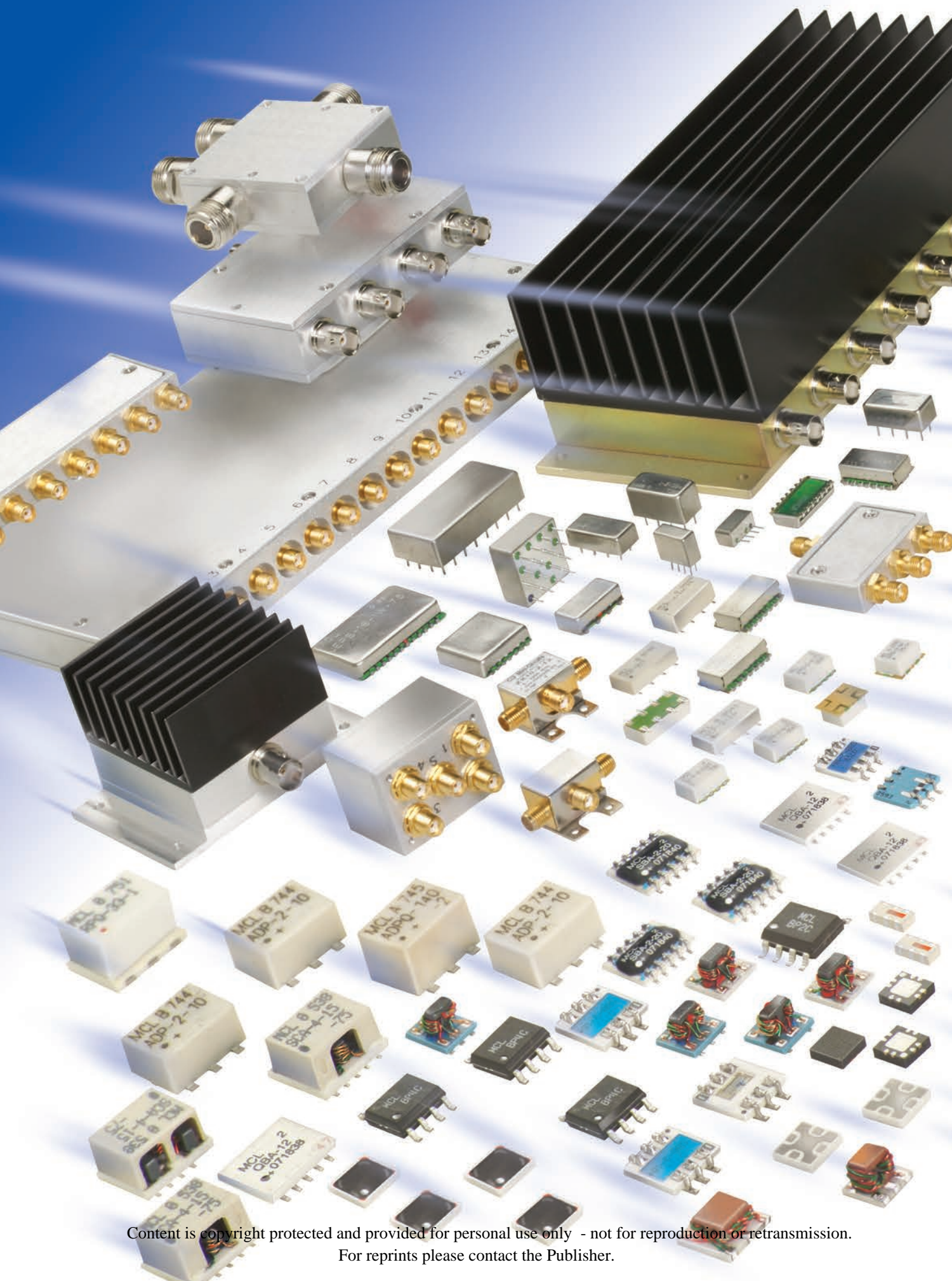
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# POWER SPLITTERS/ COMBINERS

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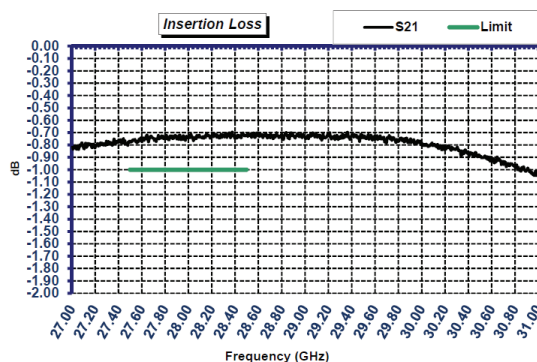
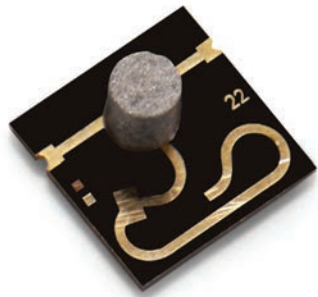
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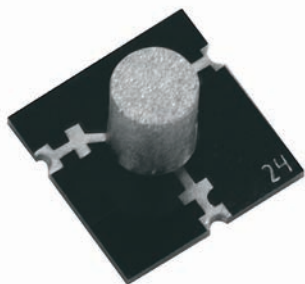


# Designed For 5G MIMO Active Antenna!!!

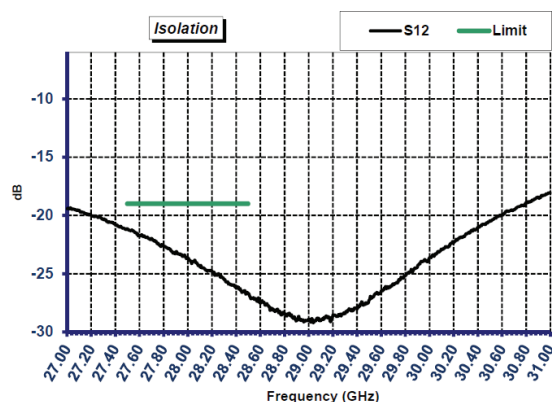
## The World First SMT Microstrip Patented Isolator/Circulator at 28GHz & 38GHz



- No Metal Bias Needed
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- No Expensive Wire Bonding



- 200kpcs Sold For Similar Array Application
- Proven Technology



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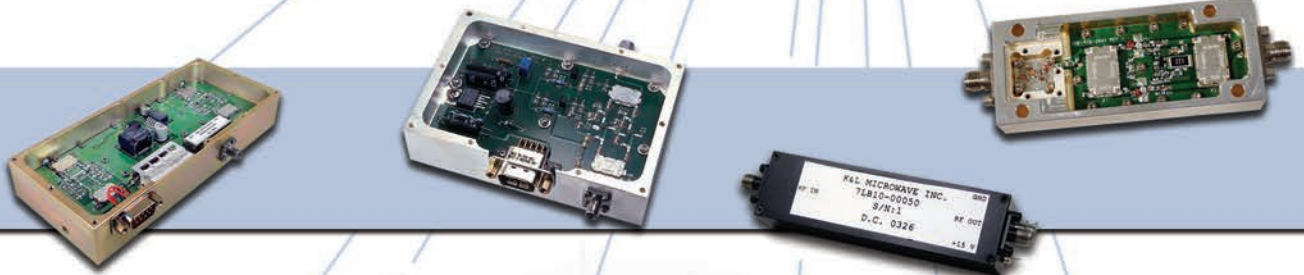
# Get Where You're Going with...



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 - 65°C to +125°C Operating Temperature  
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## MICROWAVE COAXIAL SWITCHES

- SPDT, Transfer, Multi-Throw
- Switches and Switch Matrices
- SP3T-SP10T
- Low PIM Switching
- DC to 40 GHz
- 5M Cycle-life
- Custom products



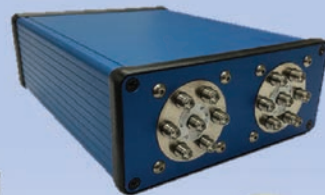
## RF SWITCH MATRIX

- Multiple Standard and Custom configurations
- Failsafe, Latching, or Normally Open Configurations
- Integration with Filters, Attenuators, Splitters, Dividers, etc.



## MINIATURE SWITCH MATRIX

- USB/Ethernet Mini-Switch Modules
- DC-18GHz, 26.5 GHz, or 40 GHz options
- SPDT, Multi-throw, and Transfer switch options
- Multiple RF Connectors Available
- USB/Ethernet Controllable
- Off-The-Shelf Product, Short Lead Times



## ELECTROMECHANICAL RELAYS

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- Loopback Relays with bypass path for ATE Applications
- SPDT, DPDT, 4PST Configurations
- Magnetic Latching and Failsafe Options



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- DC-18 GHz Electromechanical Relays
- Electromechanical Switch Matrix



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Made in USA

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### 0.1-22GHZ ULTRA BROADBAND SSPA

RFLUPA01M22GA  
4W 0.1-22GHZ



RFLUPA0218GA  
10W 2-18GHZ

### EMC BENCHTOP POWER AMPLIFIER



140W 6-18GHZ  
SOLID STATE BROADBAND

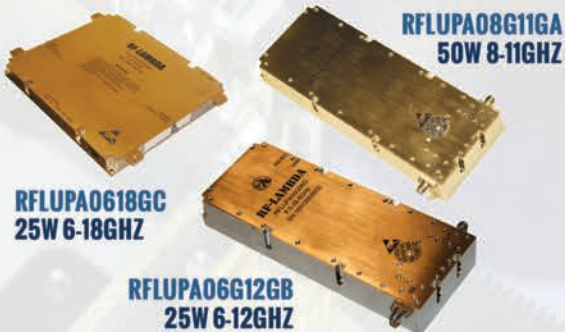
### 0.01-6GHZ VHF, UHF, L, S, C BAND

RFLUPA02G06GC  
100W 2-6GHZ



RFLUPA0706GD  
30W 0.7-6GHZ

### 6-18GHZ C, X, KU BAND



RFLUPA08G11GA  
50W 8-11GHZ

RFLUPA0618GC  
25W 6-18GHZ

RFLUPA06G12GB  
25W 6-12GHZ

### 18-50GHZ K, KA, V BAND



RFLUPA18G47GC  
2W 18-47GHZ

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15W 27-34GHZ

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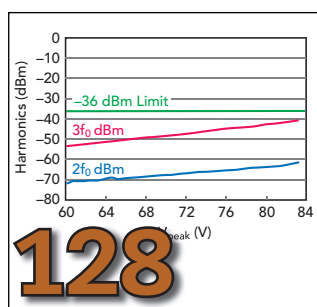
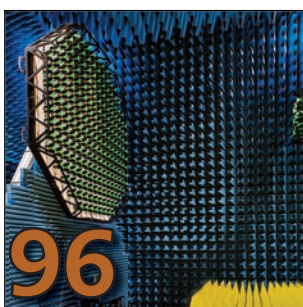
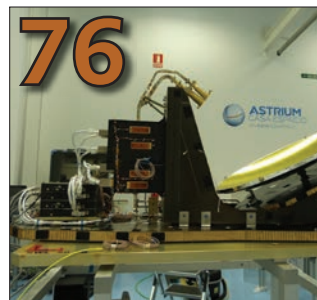
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*Compiled by Patrick Hindle, Microwave Journal Editor*

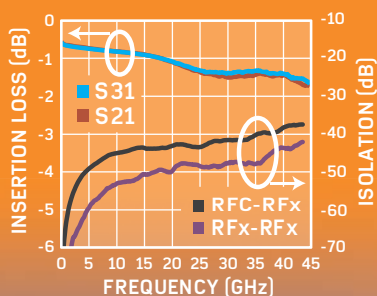
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# 44GHz SILICON SWITCH

## ADRF5024/25 ULTRAFAST SPDT SWITCH WITH LOW INSERTION LOSS

- ▶ 9nS Switching
- ▶ 1.5dB Insertion Loss
- ▶ 37dB Isolation at 44GHz
- ▶ High Power Handling: 27dBm
  - ▶ 50dBm IP3
- ▶ CMOS Control Interface



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*ADRF5024/25 Saves 50%  
Area and Bias Power*



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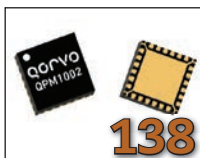
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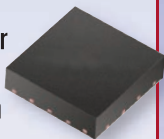
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- SPnT
- Semiconductor
- Mechanical
- High Isolation
- High Power
- GaN • Die



### RF AMPLIFIERS

- Gain Blocks
- Coaxial Module
- Low-Noise
- Linear Drivers
- High Power
- Variable Gain



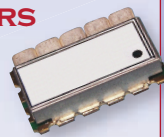
### RF TRANSISTORS

- GaN
- LDMOS
- GaAs
- Bipolar
- High Power
- High Frequency



### RF FILTERS

- Monoblock
- SAW / BAW
- HP / LP / BP
- Ceramic Resonator
- Duplexer / Diplexer
- Cavity



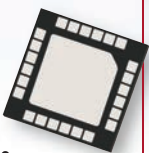
### RF OSCILLATORS

- OCXO
- VCXO
- TCXO
- PLL Synthesizers
- RF Generators

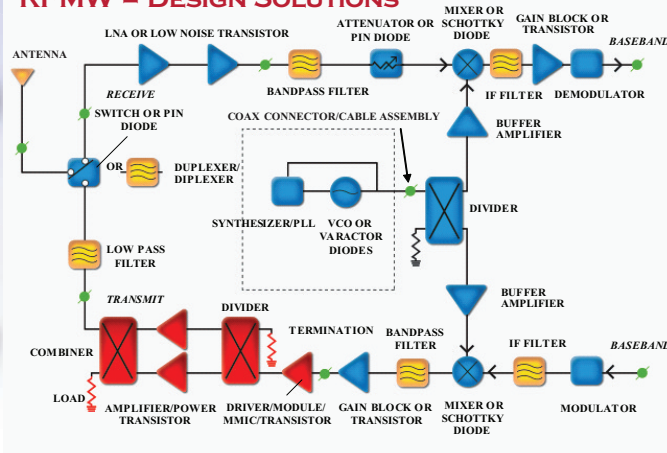


### RF ATTENUATORS

- Fixed
- Digital
- Coaxial
- Chip
- Voltage Variable
- Temperature Variable

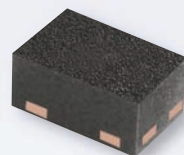


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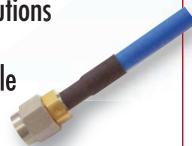
### RF DIODES

- PIN
- Schottky
- Varactor
- Limiter
- Gunn



### RF CABLE ASSEMBLIES

- High-Performance Test
- In-Box Solutions
- Pigtails
- Conformable
- Flexible
- Semi-Rigid



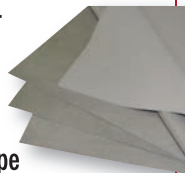
### TEST & MEASUREMENT

- USB Controlled
- Signal Generators
- Power Meters
- Switches • Attenuators
- Vector Modulators
- Cable Assemblies
- Coax Components



### EMI / RFI

- RF Absorber
- RF Gaskets
- Wire Mesh
- Fingerstock
- Shielding Tape
- Filtration Panels
- Shielded Windows



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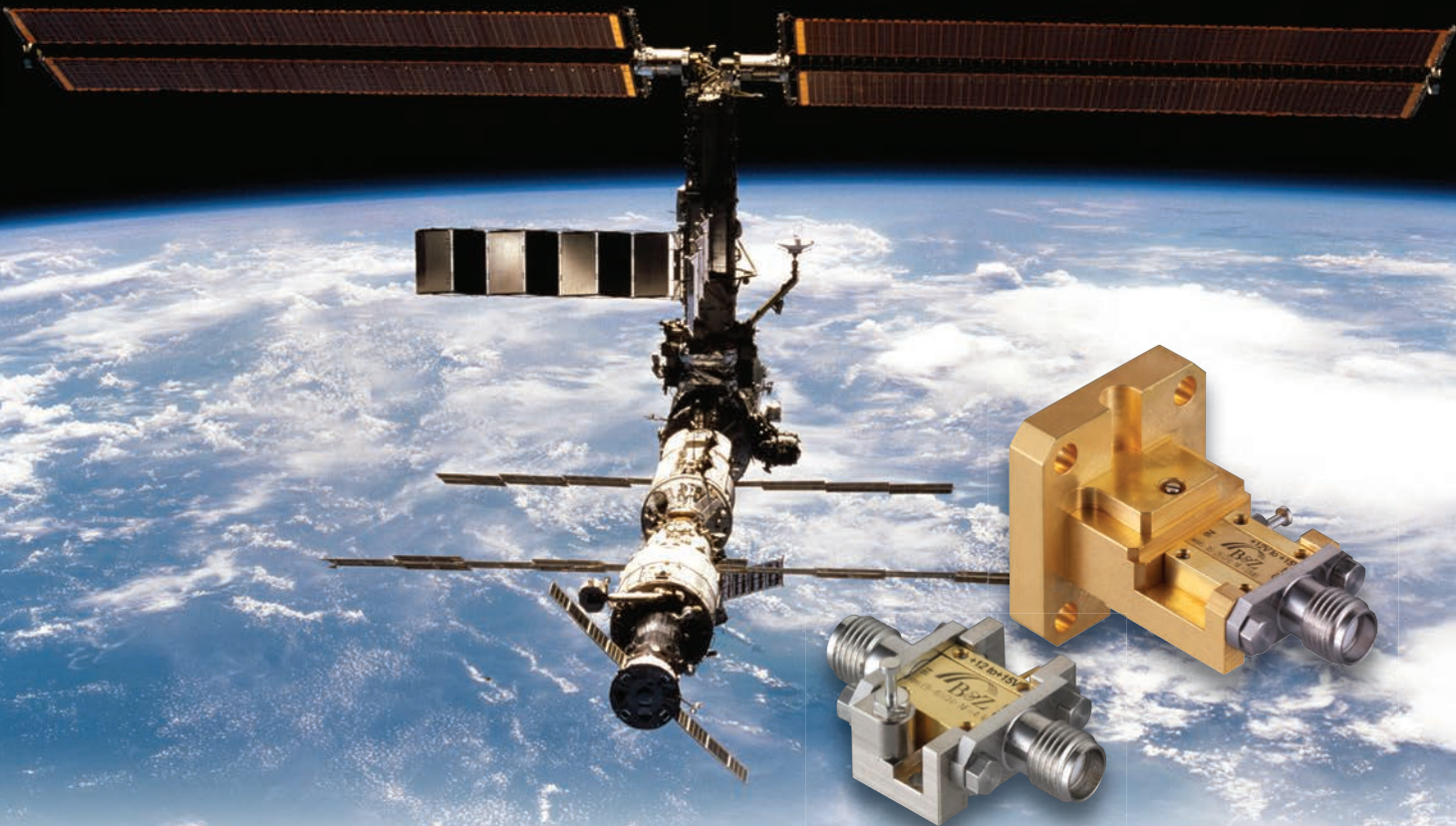


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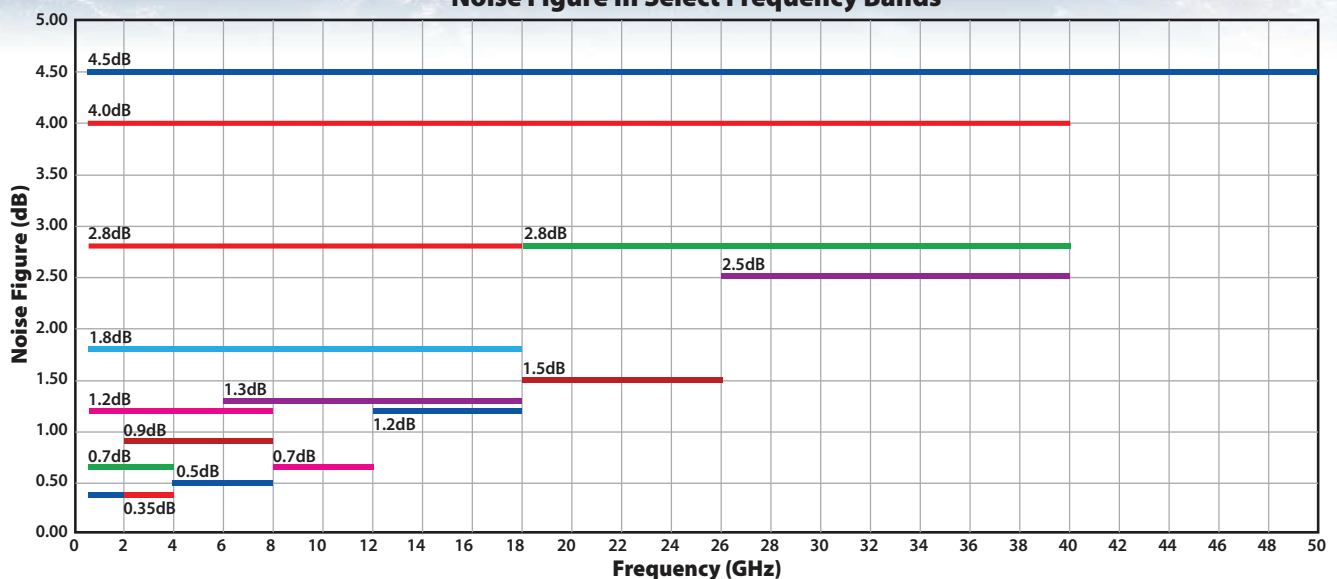
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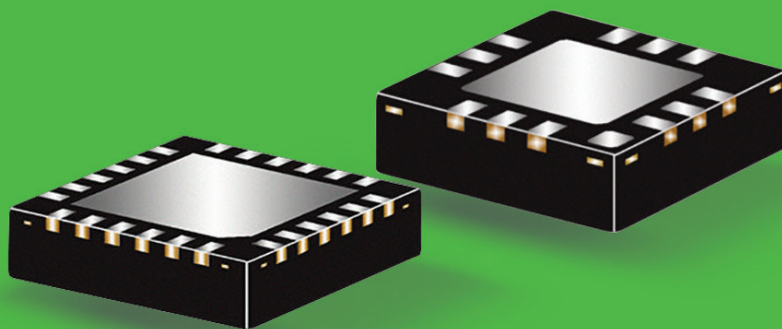
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Datasheet

STEP File

Quick view

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# European Cooperation in Defence Capabilities and Technology Research: Avoiding the Tower of Babel Effect

Ignacio Montiel Sánchez  
*European Defence Agency, Brussels, Belgium*

**Disclaimer:** The content of this article does not reflect the official opinion of the European Defence Agency. Responsibility for the information and views expressed therein lies entirely with the author.

**T**he European Union (EU) is facing an unprecedented paradigm change regarding Defence Capabilities and Technology Research to be produced in collaboration between a variate set of Ministries of Defence (MoD), industries and universities. All these actors now work along with EU institutions which have the role to steer, fund, implement, monitor and support EU Member States in the Research and Capability fields. Because of this new context, numerous initiatives like the Permanent Structured Cooperation (PESCO) or the Coordinated Annual Review on Defence (CARD) are being launched. The most prominent one is the continuation of the EU Defence Fund for 2021-2027, with a proposed total amount of €13 billion from the EU budget apart from the national contributions, covering the Research and Capability windows.<sup>1</sup>

These new initiatives are going to impact all the European Defence Capability and Technology Research ar-

reas including, by and large, the community addressed by the microwave industry. This article will highlight the challenges related to collaborative Research and Development (R&D), describe the existing frameworks and the lack of a common Overarching Technical Framework (OTF) under which an efficient and effective cooperation can occur.

To solve many of the issues connected to R&D cooperation for complex systems, the use of Interoperable Modular and Scalable Architectures (IMOSA) is proposed. IMOSA requires the establishment of Cooperation Frameworks covering Systems Engineering and Architectural views embracing Model Based Systems Engineering (MBSE) methodologies to decrease risks in design, development, validation and verification, avoiding in summary the Tower of Babel effect. The project Electro Optic and RF (EORF) sensors will be used to illustrate the IMOSA concept and related requirements.

## EU INVESTMENT IN DEFENCE CAPABILITIES AND TECHNOLOGY RESEARCH COOPERATION

One of the most prevalent challenges that cooperative projects face at international level is maintaining reliable and accurate communication between different parties. That communication issue can affect very complex systems projects formed by disparate teams from different countries and cultures, implying a high risk of failure.

A good metaphor to refer to this challenge is the Tower of Babel myth. In Genesis 11:1-9 of the Bible, it is explained how God scattered people from Babylonia over all the earth by confusing their language. In order to diminish the Tower of Babel effect, it is important to adopt and use common frameworks. MBSE can significantly de-risk cooperation projects. To establish it, a common Systems Engineering and Architectural Framework (SE/AF) is required, including technology and

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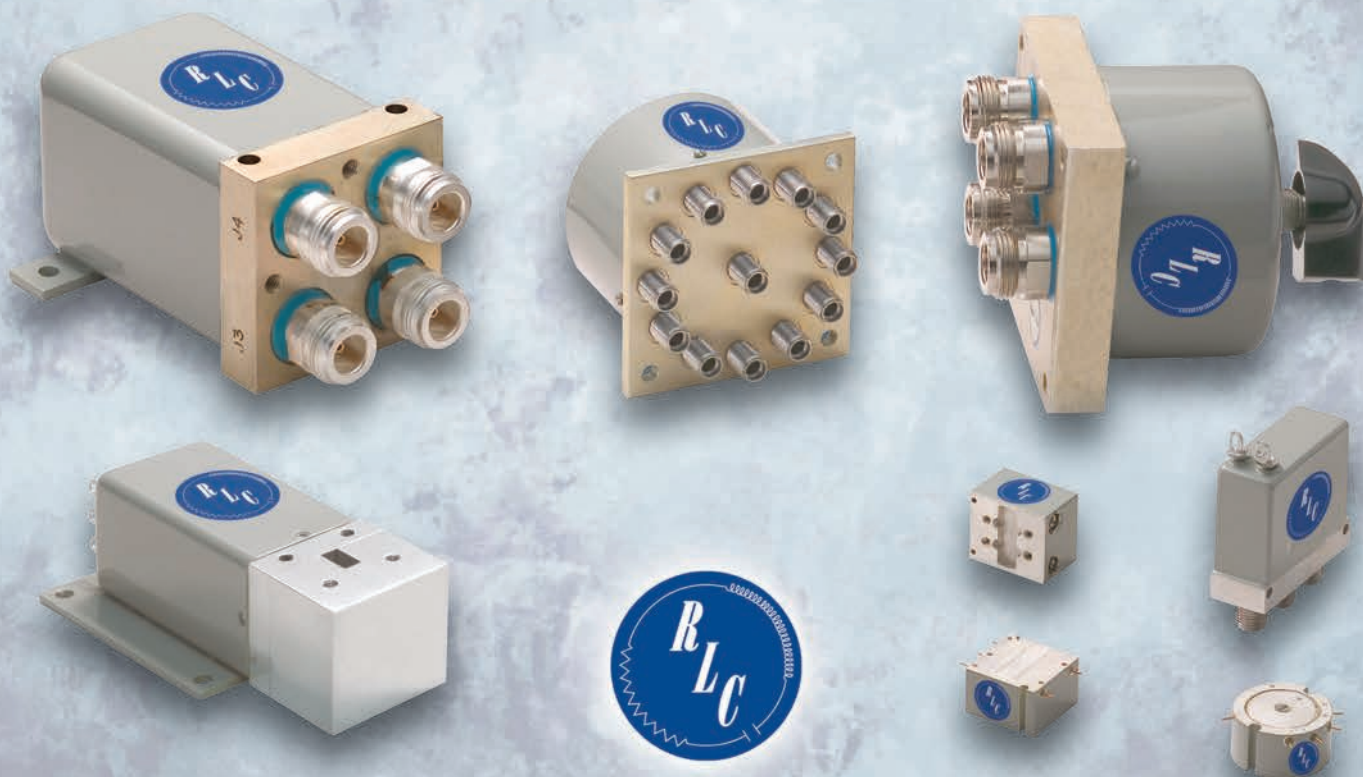
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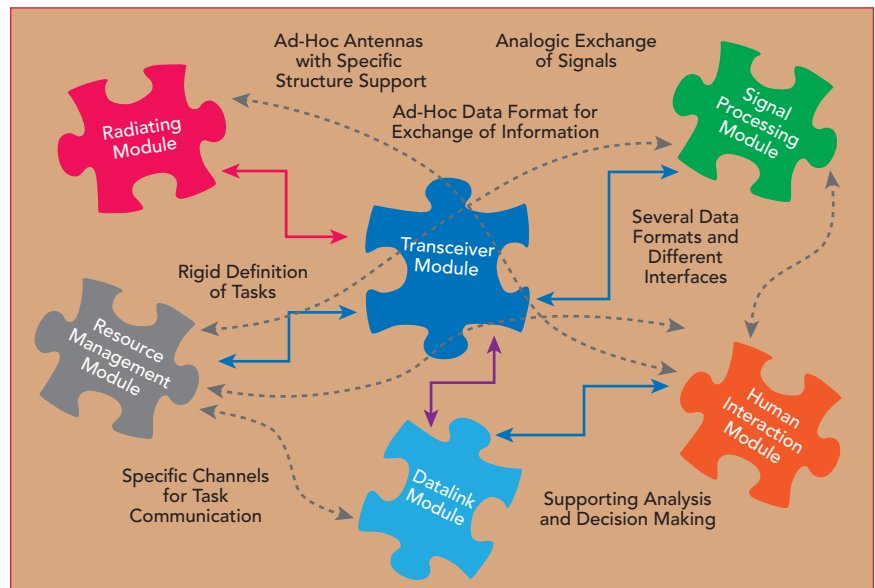
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## CoverFeature



▲ Fig. 1 Traditional systems exemplification.

capability taxonomies together with agreed ontologies.

Some of the challenges faced by international cooperation are:

**a) Exploitation:** The bridge from research results to exploitation required to increase the impact of the investment made in Research Programmes is one of the main issues to solve. The need to link the end-users to the projects for further uptake is not new. Even if operational users can be consulted and involved in the process, several points remain open as procurement is rarely linked to research projects. This is the well-known "Valley of Death"<sup>2</sup> issue occurring to the research results which cannot follow the path to exploitation.

**b) Intellectual Property Rights (IPR):** IPR sharing rules of Research Programmes sometimes preclude achieving cooperative results close to the exploitation path.<sup>3</sup> Involved companies or entities are sceptical to share their core IPR requested to develop complex systems within consortia. This is needed to allow working together and to facilitate the integration of the different components of the System. Consequently, meaningful cooperation is preferred not to be faced under these kind of schemes.

**c) Complexity:** With regard to the System's needs, the ever-increasing complexity of battlefield scenarios results in requirements

for disparate interoperable systems from different manufactures to be integrated into coalition operations where modifications and updates have to be quickly implemented, with verification and acceptance tests being planned as part of a fast V-cycle. In such a complex development environment, information degradation is likely to happen as it circulates between very different partner companies used in different procedures, cultures, languages, expertise, insufficient requirements and results understanding, rounding errors, etc.

**d) Status Quo:** Some characteristics of the currently used system architectures are (see **Figure 1**):

- Duration from months to years of the certification of new integrated capabilities.
- High vulnerability to cyber threats because of too slow implementation of updates.
- Long time to update and test causing systems rigidity.
- High cost of upgrade due to increasing licensing fees provoking sustainment challenges.
- Software duplication with more than 80 percent communality estimation.
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### THE IMOSA CONCEPT

The concept of IMOSA is proposed to solve the issues mentioned above.

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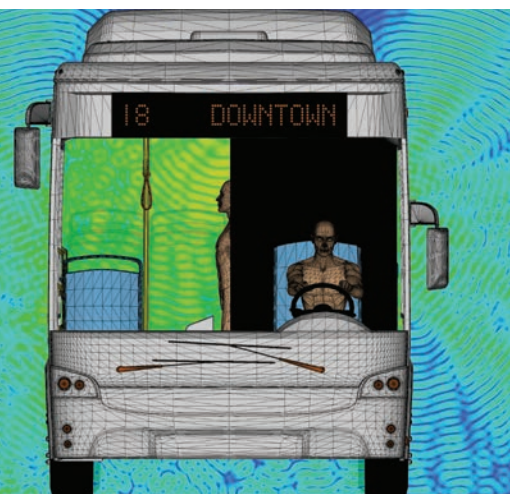
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GC5075A	5	2.1	-5	-20	-25	-35

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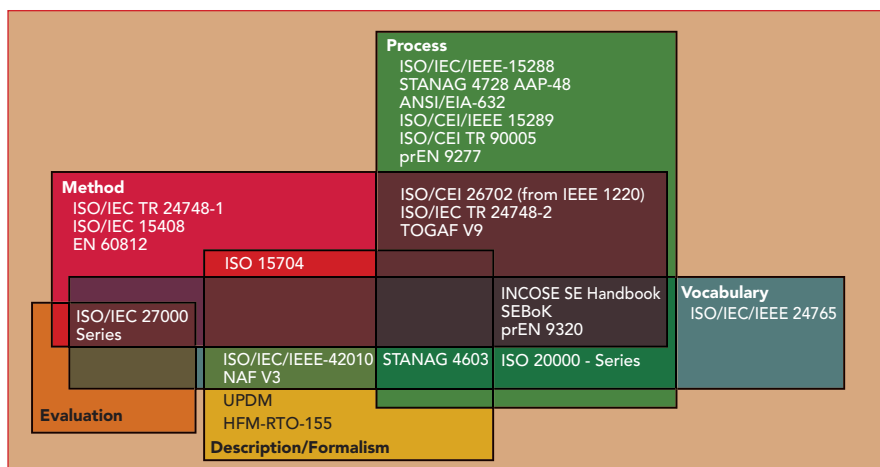
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## CoverFeature



▲ Fig. 2 EG20 Characterisation MAP for identified standards-Summary Table.

tioned above being based on the following aspects:

**a) Modularity** defines the way to design a system based on elements named Building Blocks (BB) which are described by their functionality and interfaces with other BB, the system as a whole and with other systems as well. The great advantage in research programmes is the possibility to isolate the work on BBs that can be easily integrated later if compliant with the specifications.

**b) Scalability** implies that different amounts of the same hardware or software items—BBs—are used to create systems with increased performance or additional capabilities. Both architecture and BBs should have the scalability character from their definition and design. The character of scalability would suit very well to a research programme as the system can be validated at a reduced size and later escalated for an operational system. The degree of granularity of BB is a fundamental issue in the design.

**c) Interoperability** is ensured through the definition of these architectures under a defined SE/AF considering the Life Cycle of the Systems and a defined verification and validation scheme. The description of the different architectural views needed by the several actors and stakeholders in the process can support in a much better way the understanding and collaboration of all communities. The advantages of using IMOSA

in a Cooperative Research Programme can be summarized in the following:

- It allows for collaboration projects facilitating the development of complex systems while protecting the IPR of the partners.
  - It could be a solution to ensure participation of smaller parties without a strong Defence Technological and Industrial base.
  - It would create a level playing field for all suppliers and partners independent of their size and influence.
  - The prime contractors from different countries could benefit from the investment in developing IMOSA and then have the possibility to national implementations integrating specific BBs when demanded by a certain procurement programme.
  - It allows for more cost-effective procurement based on a truly competitive landscape in possible follow-on projects.
  - Through-life maintenance and upgrades can be open to competition as the future integration can be realized without any constraints.
  - Systems can be redesigned and upgraded in a dynamic way, keeping up with the commercial world and the innovation enabled by new technologies.
- The challenges to introduce IMOSA are mainly:
- The architecture has to be robust and sound as there is a trade-off amongst characteristics given that flexibility, modularity and scalability could come at the cost of reduced performance.
  - Lack of conviction from primes

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of the need to open participation to all partners including SMEs and international collaboration. Most of the benefits seem to be for governments rather than industry but, the need to work in cooperation and the possibility to integrate innovative and cost-effective solutions for BBs has to be considered by primes.

- Ownership, definition and evaluation of the desired architectures should come from collaboration between industries and governments in an integrated approach.
- Once the degree of openness and availability of the architectures is agreed, the rules and agreements embracing the use of IMOSA for subsequent contracts must be established.

### HOW TO IMPLEMENT THE IMOSA CONCEPT? WHAT SE/AF SHOULD BE CONSIDERED FOR THE OTF?

To undertake the IMOSA concept, it is required to select and adopt specific SE/AF. SE is an interdisciplinary approach governing the total technical and managerial effort required to transform a set of customer needs, expectations and constraints into a solution and to support that solution throughout its life.<sup>4</sup> To establish the way of working in SE several frameworks exist like NASA and EIA632 (freely available), ISO15288 and IEEE 1220 (both requiring subscriptions) and INCOSE (an extension of ISO 15288) which requires membership.

SE grows more necessary as the system becomes more complex. Take the example of development and integration of a swarm of heterogeneous UAVs equipped with different sets of payloads and providing ISR functions. Its design, development and operation involve such complexity that is not possible to manage without SE/AF. The first step is to create their architecture (or Enterprise Architecture) as a structured abstraction of reality and its detailed representation with the correct level of granularity in a way that is commonly agreed and unambiguous.

AF provides the guidance and rules for developing, representing and understanding comparable architectures based on common denominators and multinational boundaries. Several AF exist like Zachman, DoDAF, MODAF, TOGAF, IAF, FEF, TEAF, SCOR, NAF, UAF.<sup>5</sup> Those structured engineering approaches are requested, not only to clarify how things are designed, built and maintained, but as well to get a common description understandable by all the stakeholders and to ensure interoperability through a set of standards and specific methodologies.

The complexity and variety of standards can be displayed in the representation of **Figure 2** from the European Defence Standards Reference System (EDSTAR) which is a repository of references to "best practice" standards and "standard-like" specifications.<sup>6</sup>

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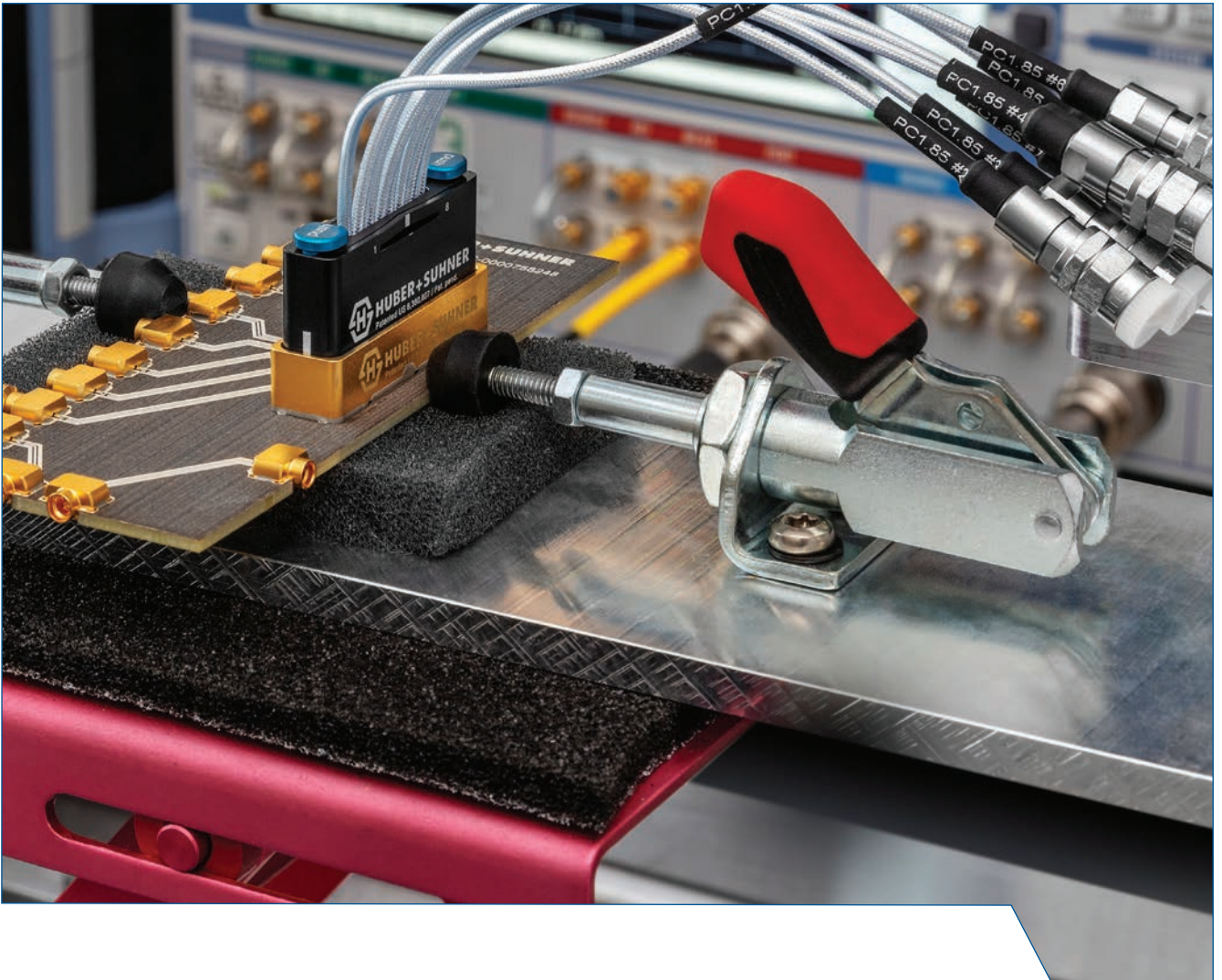
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Port to Port Variation	dB	1.0
Port to Port Isolation	dB	25



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## CoverFeature

arching, compatible and interoperable Unified Architecture Framework (UAF) as a way to link with other AFs. The relationship to be made between DoDAF, MoDAF, NAF and UAF<sup>7</sup> can be seen in **Figure 3**.

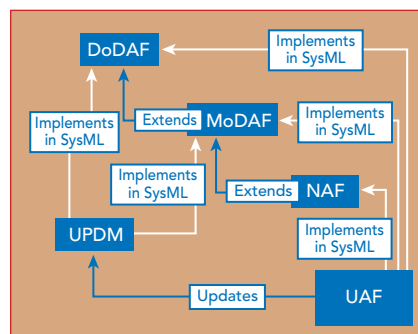
The wish from part of the Defence community would be to align the evolutions of MODAF v1.2.004 (U.K.) and MODEM v1.1 (MODAF Metamodel) into NAFv4.0 (NATO). That would be the basis of UAF v1.0 as an overarching framework which would be complemented from DoDAF 2.x (U.S. DoD) and DNDAF (Canada). This would be supported with the modelling language for Enterprise Architecture Archimate.

ISO/IEC/IEEE42010<sup>8</sup> provides means to define and specify AF in a uniform manner and develops a core ontology for the description of architectures. An architecture description language (ADL) is any form of expression for use in archi-

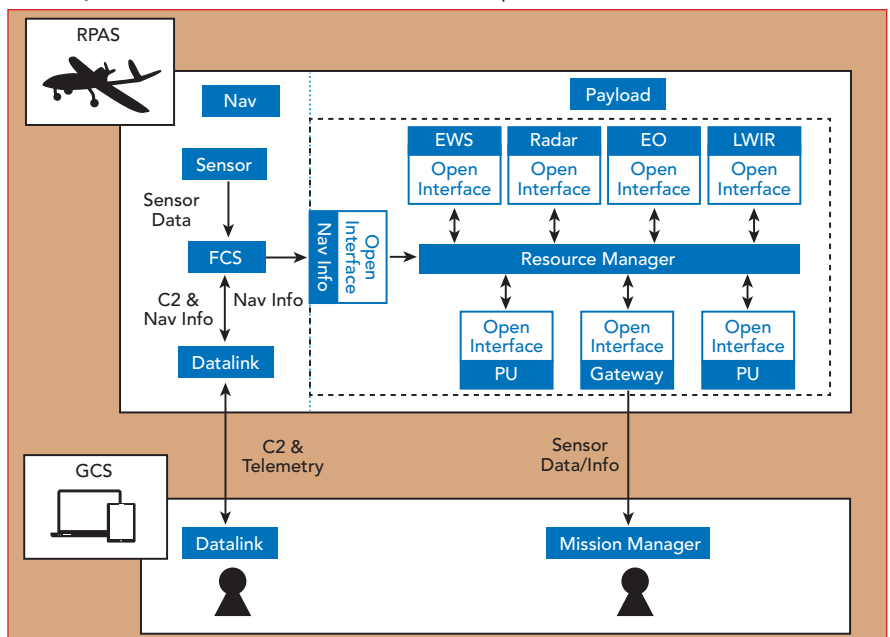
ture descriptions. More recently, "wide-spectrum" ADLs have been developed which support a wider range of concerns like AADL, UML, BPMN, SysML or ArchiMate.

The Unified Modelling Language (UML) is a graphical language for visualizing, specifying, constructing and documenting the artifacts of a software-intensive system. It includes conceptual things such as business processes and system functions as well as concrete things such as programming language statements, database schemas and reusable software components.

There is a need to define and agree on an OTF to establish the common grounds for cooperation. The understanding and embracement of these concepts by all the involved communities is strongly required, at least from a high-level perspective. Stakeholders include those organizing and selecting research programs and projects together with the experts from Armed Forces and Procurement Organizations. This should normally be done through incremental approaches. The complexity of these methodologies is in contrast with their aim to ensure an unambiguous common understanding. The frameworks selected should be as simple and clear as possible only ensuring the coverage of the needs they are supposed to resolve. EDA projects related to these concepts are SMRF, SIMPLE, AMBAS-



▲ **Fig. 3** Relationship between DoDAF, MoDAF, NAF and UAF.



▲ **Fig. 4** Architecture of the System.

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**AN EXAMPLE OF IMOSA—  
THE EORF PROJECT:  
"ARCHITECTURES FOR  
MULTIFUNCTION RF &  
OPTRONICS SENSORS  
ONBOARD RPAS PLATFORMS"**

EORF<sup>9</sup> was launched to explore the feasibility to define the IMOSA concept to achieve interoperability within payloads for small and medi-

um RPAS (NATO class I and II). The BB defined, could be analysed and implemented in successive projects.

System advantages included the maximization of sensor data fusion performance, enhancing the RPAS capabilities in hostile environments and the improvement of the payload sensors interoperability and integration together with higher reliability, flexibility and lower product life-cycle costs for both manufacturers and final users.

Standards are essential to ensure adequacy of technical interface definitions, to allow comparisons and interoperability across vendors and systems and to create a shared competitive ecosystem. Examples of related standards are STANAG 4586 Unmanned Control System (UCS) UAV interoperability or STANAG 4626 covering modular and open avionics for architectures.

This would accommodate different payload configurations on the basis of combinations of sensors and weapons when needed; each one specifically designed in accordance with the intended results of the mission. **Table 1** shows the list of the most common and currently available sensors for RPAS applications.

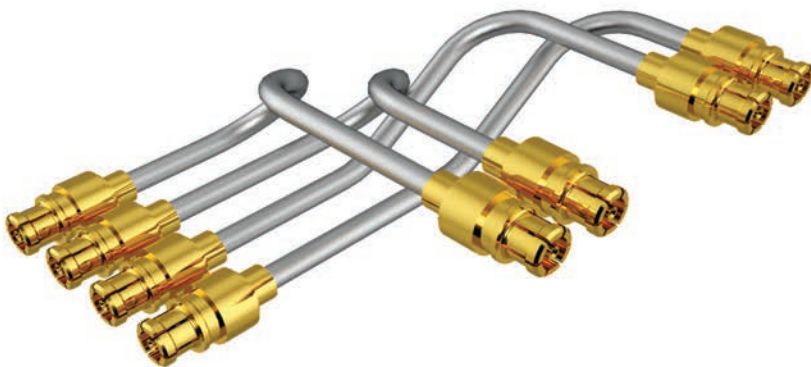
After the analysis of the existent frameworks and methodologies, TOGAF<sup>10</sup> was selected as being an open framework specialized in Systems/Enterprise architectures being the best one fitting the requirements of the project. TOGAF needs to be complemented with another framework aimed at vertical business domains and horizontal technology or specific application areas. NAF was chosen for that purpose.

The EORF architecture is shown in **Figure 4**. The conceptualization of the BB is key in the definition of the target system architecture in order to make it modular and scalable. A certain combination of BB will be arranged for each mission/scenario. Consequently, "swapability," understood as the possibility to use different kinds of sensors under the same interface, is needed. The BB have been divided into four different categories according to TOGAF: business, data, application and technology. As these four categories cannot be described in this article only the technology view is shown. Its aim is to define the interfaces and standards to be used at physical and logical level.

NAF NSV-2b (System to System Port connectivity) is shown in **Figure 5**. It describes the communication protocol and the physical port specification of each port on the system, having all BB in the IMOSA the same communication and power unit protocol. Two possible implementations have been proposed, one based on Ethernet and another based on RapidIO as shown in **Table 2**.

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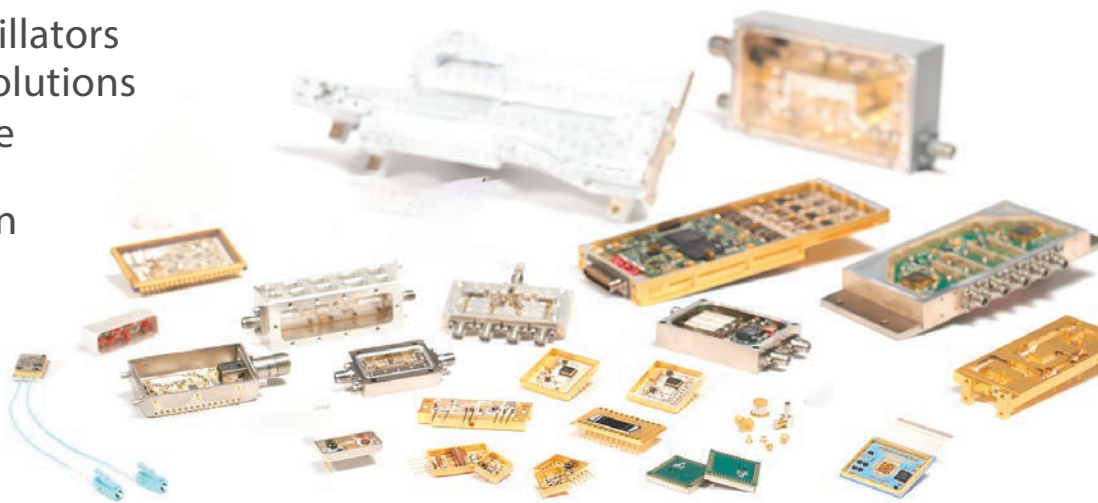
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## CoverFeature

### THE NEED TO PROMOTE AND USE MBSE FOR COLLABORATIVE PROGRAMMES

MBSE is a SE paradigm that emphasizes the application of rigorous visual modelling principles and best practices to SE activities throughout the System Development Life Cycle (SDLC).<sup>11</sup> New Defence Systems require iterative processes for development in a way that incremental verification has to be applied during design. Given the cost and scale of

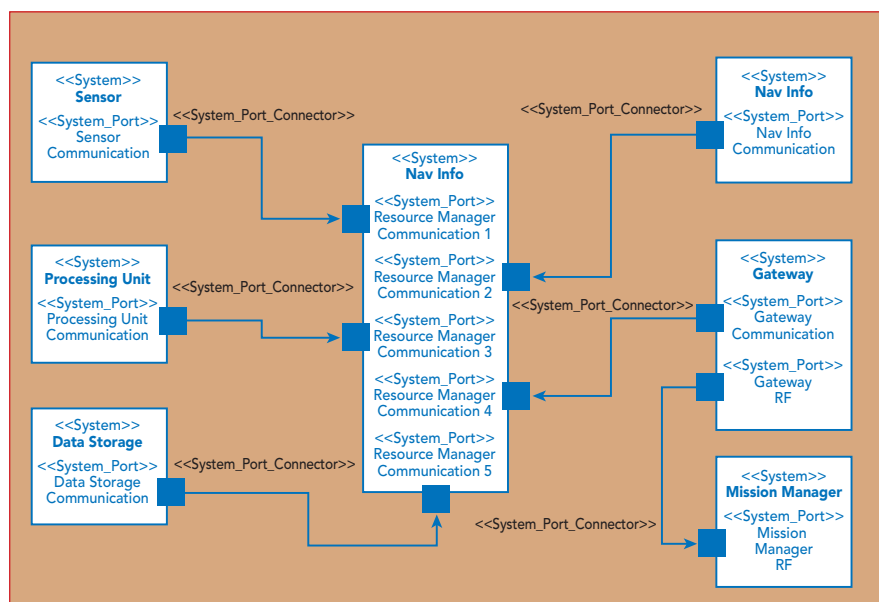
investment to create a system, the life-cycle is becoming increasingly important affecting the operation and standards to create the product and the distribution of responsibilities amongst many defence contractors. The product acquisition life-cycle has to be tackled at all stages to properly cover all the needs of the stakeholders, so these methodologies have to be taken into account as of the pure research phase.

The production process needs to include Through Life Cost (TLC)

**TABLE 1**

#### SENSORS FOR RPAS APPLICATIONS

Sensors	Modes of use	
Optical	Infra-Red (IR) Sensor- <b>IR</b>	Colour/Monochrome Daylight Electro-Optical TV- <b>EO</b>
	Image-Intensified TV- <b>IITV</b>	Passive Night Optics- <b>NVD</b>
Radar	Multi-mode Maritime Surveillance Radar- <b>MSR</b>	Ground/Dismount Moving Target Indicator- <b>GMTI/DMTI</b>
	Synthetic Aperture Radar- <b>SAR</b>	Air-to-Air
Laser	Laser Rangefinder- <b>LR</b>	Laser Imaging Detection and Ranging- <b>LIDAR</b>
	Laser Target Designator- <b>LTD</b>	
RF Signals	Intelligence of Communications System- <b>COMINT</b>	Electronic Support Measures- <b>ESM</b>
	Electronic Intelligence System- <b>ELINT</b>	Electronic Counter Measures- <b>ECM</b>
	Automatic Identification System- <b>AIS</b>	Air/Ground Data Link- <b>A/GDL</b>
Others	Chemical, Biological, Radiological & Nuclear Weapons Detector- <b>CBRN</b>	
Less Mature Sensors	Target Location Accuracy- <b>TLA</b>	Foliage Penetration <b>FP</b> in 2D or 3D
	Detect And Avoid Radar- <b>DAAR</b>	Electronic Sensing & Effects- <b>ESE</b>
	Infra-Red Search & Tracking for RPAS- <b>IRST</b>	Material/Ground Penetrating Radar- <b>M/GPR</b>



▲ Fig. 5 NAF NSV-2b (System to System Port connectivity).

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with all maintenance, disposal and training costs in addition to the cost of creating the product. MBSE as software-based data exchange methodology with extensive and traceable validation and verifications strategies is essential to ensure that the product fulfils the customer requirements. Apart of the entire design and development process, a modelling of the system should be used throughout the life-cycle considering simple models of the design parameters and how information is passed and maintained throughout the design and development stages.

This methodology facilitates both to provide feedback to the customer and to support the work of multiple partners upon the same material. AMBASSADOR,<sup>12</sup> a project of the European Defence Agency, predicted reductions in costs and time using MBSE by about a third and the decrease of associated risks in development cost and schedule by about two thirds which would suppose an impressive advantage.

## CONCLUSIONS & RECOMMENDATIONS

Defence Capabilities and Technology Research in the EU require an overarching effort to structure

and coordinate the several and different collaborative initiatives from a technical perspective to facilitate interoperability and ensure a successful outcome. From the author's experience, a commonly agreed OTF including SE/AF and Simulation frameworks with common methodologies and tools would facilitate the cooperative work and improve interoperability. Among the methodologies to be used, MBSE is extremely powerful for cooperation and to de-risk the whole capability development process supporting verification and validation. Through the use of IMOSA and MBSE, research could be linked to capability development and very complex systems and systems of systems could be tackled, covering the TLC from a comprehensive perspective that could pave the way to future European Defence Capabilities. ■

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**TABLE 2**

**EXAMPLE OF IMPLEMENTATION BASED ON ETHERNET OR RAPIDIO**

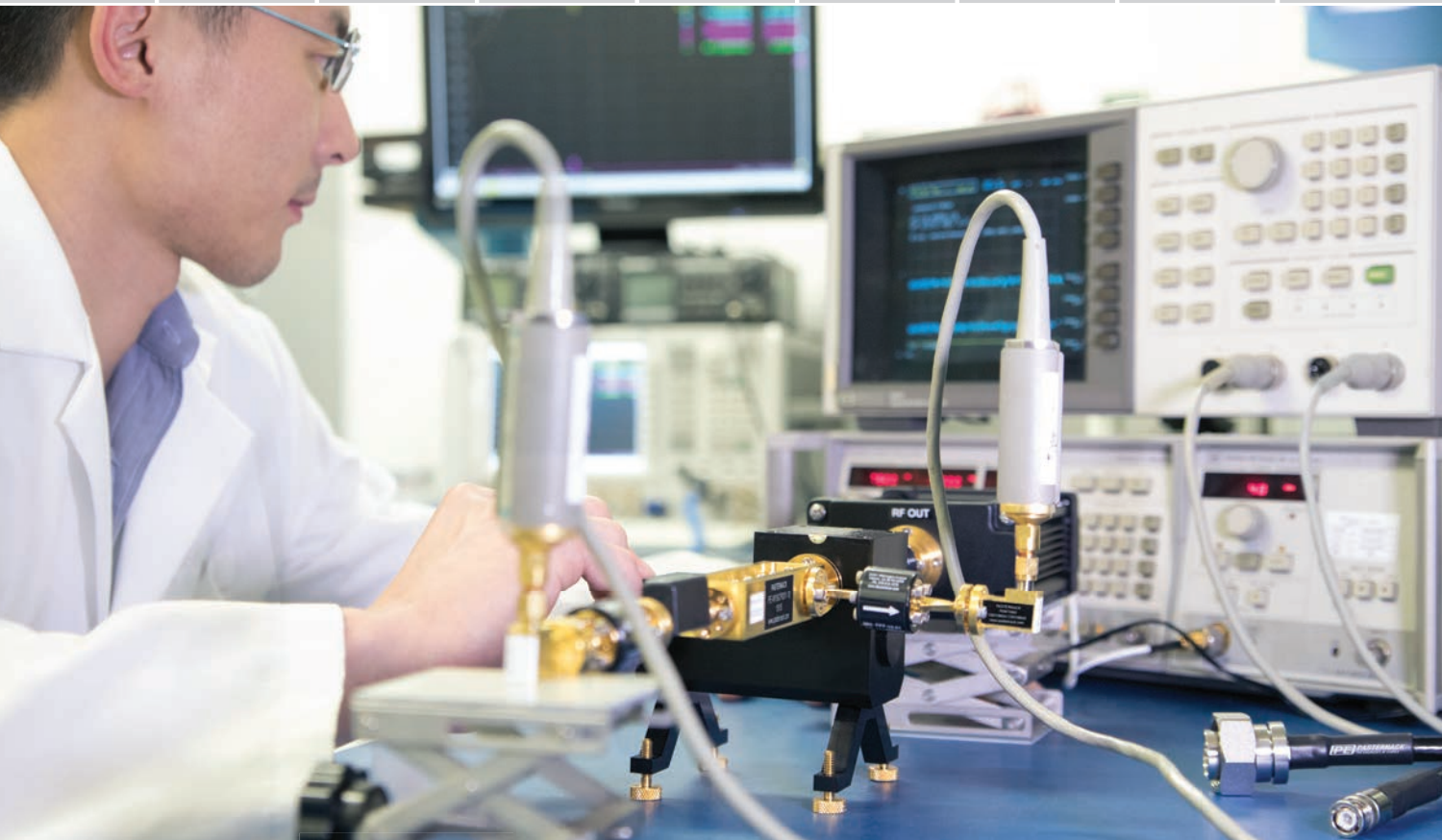
		Ethernet-based example		RapidIO-based example	
		«System_Port» Communication	«System_Port» RF	«System_Port» Communication	«System_Port» RF
Logical	Application Layer	✓Encapsulation* ✓Encryption (AES-256)	✓Encryption (AES-256)	✓Encapsulation* ✓Encryption (AES-256)	✓Encryption (AES-256)
	Middleware Layer	✓ROS	✓ROS	✓JAUS over DDS (ARP6227)	✓JAUS over DDS (ARP6227)
	Network Layer	✓TCP/IP-MAC ✓UDP/IP-MAC	✓TCP/IP-MAC ✓UDP/IP-MAC	✓RapidIO	✓RapidIO
Physical	Electronical Layer	✓1000 Base-T(GigEthernet)	✓RF @ 2, 4 GHz	✓XAUI ✓OIF CEI	✓RF @ 2, 4 GHz
	Mechanical Layer	✓8P8C (RJ-45) ✓Circular MIL connector	✓SMA-F	✓LP-LVDS ✓LP-Serial	✓SMA-F
		«System_Port» Power Unit		«System_Port» Power Unit	
Connector		✓8P8C (RJ-45) ✓Circular MIL connector		✓LP-LVDS	
Power Supply		✓+3.3, +5, +12, +24, +48 VDC		✓+3.3, +5, +12, +24, +48 VDC	

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CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
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CA23-3111	2.2-2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7-2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7-4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4-5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25-7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0-10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75-15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35-1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1-3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9-6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0-12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0-12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2-13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0-15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0-22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

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

## LIMITING AMPLIFIERS

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

## AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

## LOW FREQUENCY AMPLIFIERS

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

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## Miniature Hit-to-Kill Interceptor Matures to Development Stage

**T**he U.S. Army Cruise Missile Defense Systems Project Office awarded Lockheed Martin (LM) a \$2.6 million dollar contract to mature the Miniature Hit-to-Kill (MHTK) interceptor, evaluate its effectiveness and demonstrate manufacturing readiness as part of the Extended Mission Area Missile Program. Announced by the company at the Eurosatory exhibition, this award marks the MHTK's transition from the Science and Technology (S&T) phase to the Development phase.

Previous S&T contracts with the U.S. Army, together with LM investment, helped mature the MHTK missile from basic research to a concept demonstration with two configurations—a semi-active RF seeker and an active RF seeker. MHTK has conducted a dozen flight tests with a combination of investment and contract funds. The most recent controlled flight test in January at White Sands Missile Range, N.M., demonstrated the interceptor's increased agility and validated performance of the airframe and electronics, which are now common between MHTK's two configurations to drive affordability.

The MHTK missile is designed to defeat rocket, artillery and mortar targets through body-to-body contact without a warhead at ranges projected to exceed those of current and interim systems. The missile is just under two and a half feet in length, an inch and a half in diameter and weighs about five pounds at launch. The compact size allows multiple rounds to be packaged in a very small footprint to effectively combat complex threat situations like saturation attacks. The MHTK interceptor complements the LM family of Hit-to-Kill missile interceptors by delivering close range lethality with proven success for truly layered defense.

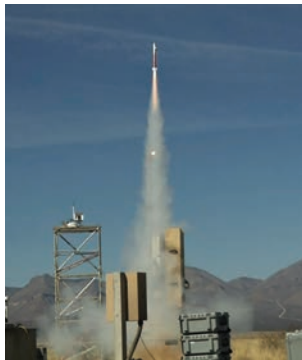
## Bringing Autonomous Technology to the Battlefield

**T**he U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) awarded Oshkosh a \$49 million contract to integrate existing Palletized Load System (PLS) vehicles with scalable autonomous technology as part of the U.S. Army's Expedient Leader Follower (ExLF) program.

The ExLF program addresses the needs of the Leader Follower Directed Requirement and Program of Record by removing soldiers from the vehicle while operating in highly-contested areas. Oshkosh autonomous technology was designed with the flexibility to be operated in a variety of modes, including leader-follower, fully autonomous and teleoperation, to support manned or unmanned operations.

"The PLS has been an integral part of the U.S. Army's resupply and distribution fleet for over 25 years," said Pat Williams, VP and GM of Army and Marine Corps programs for Oshkosh Defense. "By equipping these vehicles with autonomous capabilities, we can significantly reduce our soldiers' exposure to enemy threats by taking them out of the vehicle altogether."

Under the contract, Oshkosh will integrate an initial 70 autonomy kits for Program Development and Operational Technical Demonstrations (OTD). The contract holds an option to procure up to 150 autonomy kits.



MHTK Interceptor (Source: Lockheed Martin Corp.)



LVSR (Source: Oshkosh Corp.)

## Building the Future, One RoboBoat at a Time

**T**eams of students representing 13 schools from six different countries tested their engineering skills by developing autonomous boats during the recent 11<sup>th</sup> annual International RoboBoat Competition in Daytona Beach, Fla.

Sponsored by the Office of Naval Research (ONR) and the AUVSI Foundation, RoboBoat is an annual robotics contest where the next generation of engineers puts autonomous surface vehicles (ASV) through a series of advanced, water-based challenges that mirror real-world maritime operations.

"The challenges might seem simplistic, but before the boats even make it to the water to try and complete the course, there's a lot of complex engineering that goes into the ASVs' development," said Kelly Cooper, a program officer in ONR's Ship Systems and Engineering Research Division and a RoboBoat judge. "This competition really showcases the technical ingenuity of the students."

According to the recently-released DoN Strategic Roadmap for Unmanned Systems (short version), the goal is to "transform modern warfare" by seamlessly



integrating unmanned systems into the naval services and across all domains. This is something ONR is already doing—pushing the path forward for autonomous technologies like swarming boats, aerial vehicles and unmanned surface ships and helicopters.

"RoboBoat showcases the talents of future engineers and serves as a basic introduction to some of what the Navy needs its autonomous systems to do," said Cooper. "We know there will be a strong pull from the commercial sector to have these kids come work for them, but we want the participants to know that the future is bright with the naval services as well. We have the jobs and we need their talent, too."

As in the past, this year's teams were largely composed of university students and were evaluated on their vessel design and performance. The design component focused on innovation, quality of engineering and craftsmanship. The performance component tested a vehicle's ability to execute specific missions on the water without any human interaction. As part of the performance challenge, the ASVs had to demonstrate their speed and navigation capabilities by passing through a set of gates before competing for any mission challenge points.

The mission tasks demonstrated the maritime systems' autonomous behavior in different scenarios, in-



RoboBoat (Source: U.S. Navy Photo)

cluding: speed; automated docking, which demonstrated the ability to launch and communicate with an aerial drone; finding a path in a crowded area; target identification; precise navigation; and, finally, return to dock.

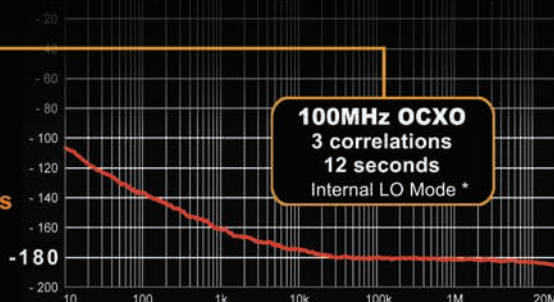
Institut Teknologi Sepuluh Nopember (Indonesia) was this year's biggest winner, bringing home the top prize of \$6,000. Georgia Institute of Technology won second prize and \$5,000; Hagerty High School (Florida) took third and \$3,000; and Embry-Riddle Aeronautical University (Florida) came in fourth, earning \$2,000.

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## France, U.K. Regulators Position for 5G

**R**egulators in France and the U.K. are taking steps to enable the deployment of 5G services in their respective countries.

In France, the government released a roadmap for 5G, articulating several goals: launching pilot projects in several regions, hosting “pioneer” industrial applications, allocating new spectrum and ensuring the commercial rollout in at least one major city by 2020 and coverage of the main transport routes by 2025. To accomplish these goals, the country’s telecommunications regulator Arcep has identified four steps, including allocating spectrum, launching pilot projects in 2019 and streamlining 5G rollout.

For sub-6 GHz coverage, Arcep plans to allocate 3.4 to 3.8 GHz and move existing users to other bands. For higher data rates, the 26.5 to 27.5 GHz band has been identified, which is consistent with European efforts to establish a standard mmWave band for 5G. Arcep is also considering using 1.5 GHz, planning to explore the feasibility beginning this summer.

5G pilot projects are being planned or have been launched in 11 French communities, and 11 new trials were recently announced, including three connected vehicle use cases. Arcep is open to expanding the number of trials in France, the only limitation being available frequencies in the region.

Arcep’s “5G Work Programme” is available to download from the agency’s website: [www.arcep.fr](http://www.arcep.fr).

Across the Channel, Ofcom published a report defining the U.K.’s five-year plan for spectrum to meet the demands of fixed wireless links, such as backhaul for mobile base stations, “last mile” broadband services, TV program distribution from studio to transmitter, emergency services and private networks. The report follows a process of consulting with stakeholders to identify existing and emerging needs for spectrum. Ofcom identified secular and technology trends during the study, including:

- 5G will require greater bandwidth, both for services to users and the backhaul to support them.
- Financial services firms are using direct wireless links to minimize latency, a differentiator in financial transactions.
- There’s increasing interest in the spectrum at 60 GHz, for new use cases, and above 92 GHz, for high capacity backhaul networks.

The Ofcom study evaluated frequency uses and projected needs below 20 GHz, between 20 and 45 GHz and above 45 GHz. The most urgent needs identified are above 45 GHz, prompting Ofcom to take “immediate steps” to allocate new spectrum from 66 to 71 GHz to support new 5G use cases and make the 57 to 71 GHz band “license exempt,” to allow rapid deployment.

The Ofcom report can be downloaded from the agency’s website: [www.ofcom.org.uk](http://www.ofcom.org.uk).

## Asia to Lead 5G Subscribers by 2025

**W**ith initial 5G standards now finalized by the 3GPP, mobile operators are deploying infrastructure to prepare for the availability of mobile devices and other user equipment in 2019. GSMA, the mobile industry’s trade group, estimates the Asia-Pacific region will lead the world with 5G connections by 2025—some 675 million, which will be more than half of the world’s 5G connections. China, South Korea, Japan and Australia will drive the region’s growth.

Despite the buzz, 5G will not replace LTE, which will continue to grow, as it is adopted in emerging markets such as India, Indonesia, Thailand and Vietnam. In 2017, LTE surpassed 2G to become the leading mobile technology in the region and, by 2025, GSMA estimates 62 percent of Asia’s mobile connections will be on LTE, compared to 14 percent on 5G.

With China and India, the two largest mobile markets, the Asia-Pacific region is home to more than half of the world’s mobile subscribers. The number of unique mobile subscribers in the region is estimated to have been 2.7 billion at the end of 2017 and is forecast to grow by 424 million to 3.2 billion in 2025. Almost half of the new subscribers will be in India, nearly 3× the new subscribers in China.

GSMA’s analysis and forecast for the Asia-Pacific region are contained in a recently published report, “The Mobile Economy: Asia-Pacific 2018,” which is available from the GSMA website at [www.gsma.com/mobileeconomy/asiapacific](http://www.gsma.com/mobileeconomy/asiapacific).

## Handsets Drive WIN Semi’s Growth

**T**aiwan-based WIN Semiconductors, the world’s largest GaAs foundry, reported strong second quarter and first half revenue growth driven by the handset market. However, the company said inventory corrections across all markets will cause third quarter revenue to decline around 10 percent compared to the second quarter.

Second quarter net revenue was NT\$4,567 million (approximately \$149 million), 20 percent above the prior year’s quarter and 2 percent above the first quarter. First half revenue was NT\$9,031 million (\$295 million), 27 percent above the prior year period, as MMICs for smartphones grew by double-digits. WIN said approximately 35 to 40 percent of second quarter revenue was from the cellular market, 25 to 30 percent from Wi-Fi, 15 to 20 percent from infrastructure and approximately 16 percent from other markets.

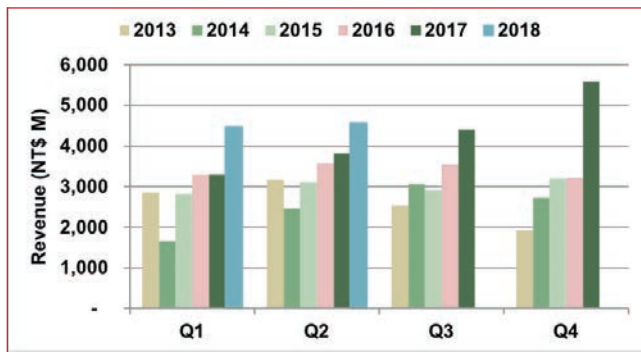
To complement RF/microwave applications, WIN has been developing optoelectronic process technol-



## InternationalReport

ogy to fabricate photodiodes and laser diodes for the growing 3D sensing market.

WIN reported second quarter gross margin of 32.4 percent, down from 34.1 percent in the first quarter, and operating margin of 20.7 percent, compared to 23.3 percent in the first quarter. The company attributed the declines to product mix. Net income increased almost 24 percent sequentially and year-over-year, which WIN said reflected the favorable foreign exchange rate with the U.S. earnings per share (EPS) was NT\$2.16, compared to NT\$1.74 in the first quarter and NT\$1.85 in the prior year's quarter.



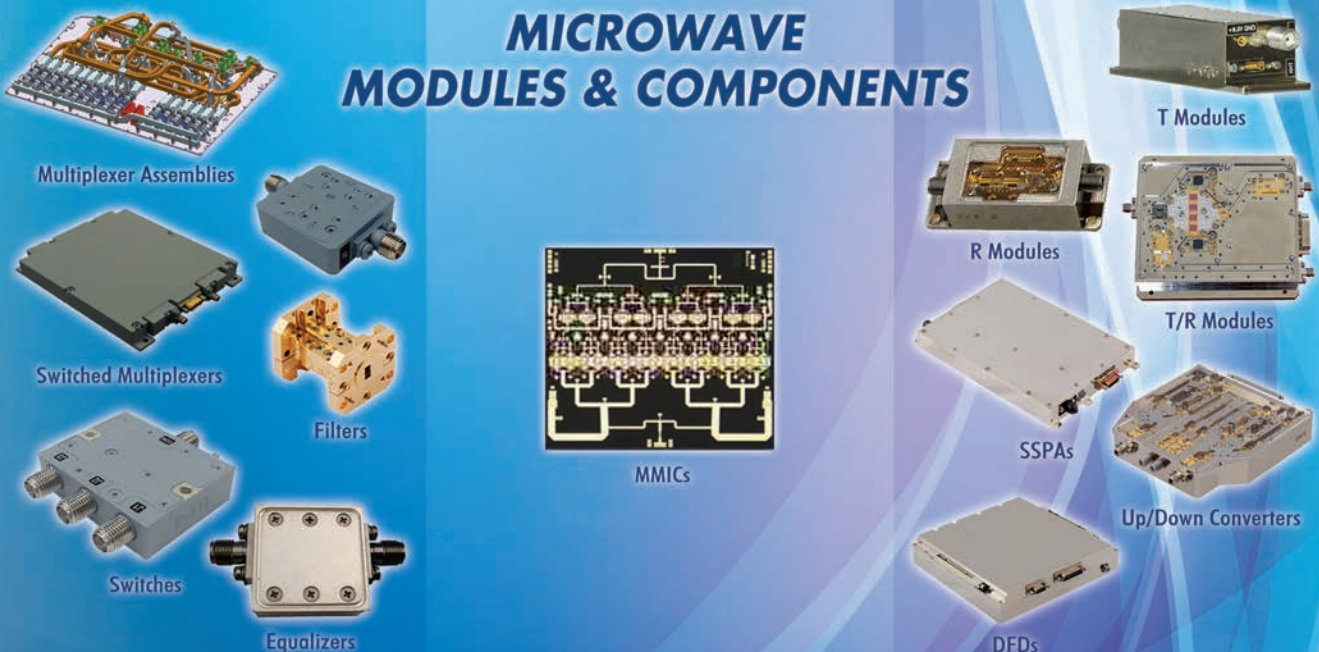
## LTE via Balloon Over Kenya

**T**elekom Kenya and Loon, an independent business unit of Alphabet, have signed an agreement to use Loon's high altitude balloons to provide LTE service to rural regions of Kenya. The agreement with Telekom Kenya will be Loon's first in Africa, beginning in 2019 with a pilot over central Kenya, which has limited service because of the mountainous terrain.

Using balloons avoids the cost of installing terrestrial infrastructure in areas of low population density, and the balloons fly well above aircraft and weather—in the stratosphere at 60,000 feet. The balloons carry solar-powered base stations that send and receive LTE signals to users on the ground. Backhaul to the service provider is accomplished via a relay network among the balloons.

In 2017, Loon demonstrated its capability with Telefonica, providing internet connectivity to tens of thousands of people in Peru who were displaced by extreme rains and flooding. Loon also worked with AT&T and T-Mobile to connect more than 100,000 people in Puerto Rico after the island was ravaged by Hurricane Maria.

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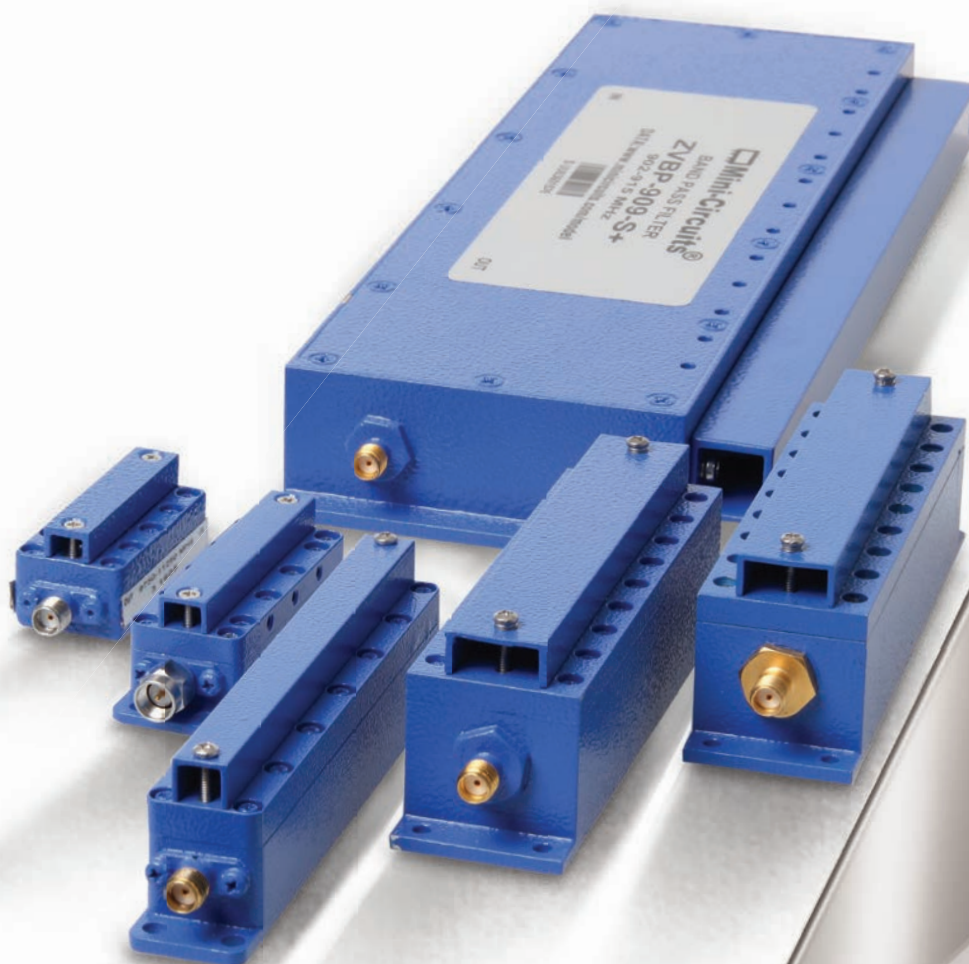
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## NB-IoT, CAT-M, SIGFOX and LoRa Battle for LPWA Network Dominance

**C**ellular and non-cellular LPWA network connections will grow globally at a 53 percent CAGR until 2023, driven by market growth in smart meters and asset trackers, according to a new report from ABI Research. In 2017, smart meters and asset trackers contributed to almost three-quarters of all LPWA network connections, dominated by non-cellular LPWA network technologies. However, by 2023, non-cellular LPWA will cede its market share dominance to NB-IoT and LTE-M, as cellular LPWA moves to capture over 55 percent of LPWA connections. Regionally, although Western Europe and North America witnessed early deployments of public LPWA networks, the Asia-Pacific, especially China, has been a pivotal market for driving large-scale adoption of NB-IoT and LoRa.

"LPWA network technologies are making it feasible to build simple, small and low-cost footprint devices

**Drives global LPWA network connections to pass 1B by 2023**

that can track and monitor everything from sea-freight containers to bicycles, patients to pets, supermarket trolleys to pallets, paving the way

for new innovative solutions and business opportunities," says Adarsh Krishnan, principal analyst, ABI Research. Asset tracking, which includes tracking stationary or slow-moving assets, will have the largest share of LPWA connections in 2023, accounting for over 45 percent worldwide.

Smart meters deployed by energy and water utilities will be the second largest vertical IoT application in 2023, contributing over one-third of the global LPWA device connections. Early adoption from meter vendors such as Sensus, Itron, Kamstrup, Arad and Holley metering means that non-cellular LPWA technologies are well positioned to capture two-thirds of the LPWA connections in smart meters by 2023.

In 2017, SIGFOX had the largest share of public LPWA connections worldwide benefiting from its first mover advantage in Europe. "SIGFOX has continued to stay a step ahead in public LPWA networks with the roll-out of the Monarch cognitive network service in early 2018. The Monarch service enables SIGFOX devices to automatically adapt to RF changes allowing for seamless roaming across SIGFOX networks," Krishnan explained. Louis Vuitton's Echo travel bag tracker was the first commercial SIGFOX device to leverage the Monarch service in over 100 airports across 26 countries. In contrast, LoRa gained significant market share as a popular connectivity technology for private networks, witnessing over 54 percent year-on-year growth in 2017.

Private LPWA networks, built to address a single vertical application or an individual enterprise, have been a

popular choice for over a decade and accounted for 93 percent of LPWA connections in 2017. LoRa and other non-cellular LPWA technologies have benefited from the decreasing cost of ICs, low implementation costs and flexibility of private networks that can be tailored to meet specific enterprise IoT applications. LoRa has witnessed exponential growth in APAC, especially in China where ZTE has deployed China LoRa Application Alliance (CLAA) LoRa networks in 40 cities and is starting to ramp up deployment of smart meters, parking sensors, air-quality monitoring sensors and other smart city solutions. However, as the geographic footprint of public networks rapidly expands, cellular and non-cellular public networks will capture over 70 percent of LPWA connections by 2023.

## 80M Smart Home Thermostats Linked to Smart City Grid Control by 2022

**T**he growing power of smart home devices and services will increasingly extend their influence outside of the home and into wider smart city programs, finds ABI Research. Over the next five years, smart home and smart city providers will increasingly leverage the overlap between these two traditionally separate markets as smart home services provide a ready and expandable Smart City IoT resource.

"So far, smart city programs have been dominated by broad, large-scale implementations. Either these projects will expand to embrace smart home partners or they will see some of the primary applications encroached upon by progressive smart home providers," says Jonathan Collins, research director, ABI Research.

By 2022, a global install base of nearly 300 million smart homes will put smart home providers in the position to provide a ready data source for smart city applications. Current smart city projects typically address applications including transportation, healthcare provision, environmental management and more. Increasingly, smart home providers are showing they can deliver similar functionality by adding additional application capabilities for their smart home customer base.

Perhaps the best current example of smart home deployments engaged in driving smart city benefits is the integration of smart thermostats into utility demand management programs. Instead of utilities developing their own direct to consumer smart home plays, they have instead turned to smart home players such as Nest, Honeywell and others to deliver the remote control over end-user heating and cooling demands to help manage peak loads. ABI Research finds that worldwide by 2022, more than 80 million homes with smart thermostats are set to have control of the heating and cooling in the home linked to smart grid control.

Already home security smart home players Vivint



## CommercialMarket

and Ring (now part of Amazon) are providing video surveillance features using external smart home cameras. Vivint's Streety app provides shared video access to subscribers within a fixed neighborhood, replicating smart city video monitoring of public spaces but through a crowdsourced model. Other applications are still in their earliest stages. Parking manage-

ment is an often-tackled smart city application, but the rise of crowdsourced parking solutions presents another smart home opportunity. Although still in its earliest days, the potential for crowdsourced parking services to be integrated into wider smart home management features such as access control or electric vehicle charging could prove compelling integration drivers.

## 5G Not Enough for Mobile Service Providers to Enter Smart Manufacturing

**D**espite high ambitions for the smart manufacturing sector, mobile service providers (MSP) are currently secondary players in this market. Consequently, their short-term opportunity in manufacturing is forecasted to be only \$2.6 billion by 2022, according to ABI Research.

"The manufacturing market has grown without MSPs so far, and if they don't play their cards right, it will continue to do so," said Pablo Tomasi, senior analyst at ABI Research. "UnTelco—the need for MSPs to think and act beyond their traditional boundaries—in manufacturing is about entering a well-entrenched sector developing new market strategies and partnerships. MSPs have a chance to enter the smart manufacturing market building from the ground up, gaining trust as partners and proving that the value of their offering is beyond what is currently delivered in the market. 5G is a promise, but alone is not enough and with doubts on what business model will support it, 5G's ability to integrate with legacy technologies and the actual results delivered in harsh factory environments, there is much uncertainty about whether 5G will be a game-changer for MSPs in manufacturing."

Partnering with market leaders will be essential—the recently announced partnership between Orange and Siemens is an example of what should be a growing trend. 5G will not be in the factory for a few years, and to be successful, a wider alignment between industrial vendors and MSPs is essential. Even the private LTE solutions currently available are only at a very early stage in manufacturing and still lack the success stories needed to prove their value in the market.






"The manufacturing market looks for enhancements, not disruption, and for solutions, not technologies. MSPs should tailor their offerings, including 5G, to these enhancements and solutions," Tomasi concluded.

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250W				Model 2194										
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100W				Model 2198			Tri-Band (100/100/40W)							
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## Around the Circuit

Barbara Walsh, Multimedia Staff Editor

### MERGERS & ACQUISITIONS

**Carlisle Interconnect Technologies** announced the purchase of **Tenencia Ltd.** Tenencia is an EASA Part 21 Design and Production organization based in Coventry, U.K. Tenencia operates under AS9100 and carries CAA part 21 production approval and is approved to both AS9100D and BS EN ISO 9001:2008. Tenencia specializes in the integration and certification of electrical/avionics systems, cabin systems, internal and external structure, VIP interiors and commercial aerospace applications on a wide range of aircraft. In acquiring Tenencia, CarlisleIT broadens its global capabilities for design certification of commercial aircraft to both EASA and FAA design and production requirements.

**Baylin Technologies Inc.** announced that it has entered into a share purchase agreement to acquire all of the issued and outstanding shares of **Alga Microwave Inc.** for total consideration of \$27 million, consisting of up-front cash consideration of \$21 million, \$4 million in Baylin shares and \$2 million in deferred consideration, as well as a related agreement to purchase Alga's operational facilities in Kirkland, Quebec. Baylin is to purchase all of the outstanding shares of Alga, through a newly incorporated subsidiary, for up-front consideration of \$25 million, subject to customary adjustments.

### COLLABORATIONS

**Keysight Technologies Inc.** announced that the company is extending its collaboration with **UNISOC Inc.** to participate in the CMCC 5G large-scale trials. Keysight is helping UNISOC accelerate 5G New Radio (NR) chipset development with substantial support from GTI. Both UNISOC and Keysight achieved 5G NR PHY layer interoperation based on the latest 3GPP Release 15 5G NR standards in the CMCC 5G Innovation Center Lab, and demonstrated this achievement at the 22<sup>nd</sup> GTI workshop. The event brought together mobile operators, vendors and companies from vertical industries to address and discuss key issues and the latest progress in 4G and 5G technology development.

**AccelerComm** has announced its 5G NR polar IP has been adopted by **National Instruments (NI)**. The IP has been selected for use in NI's USRP RIO software defined radio family of products, which are used by wireless researchers in academic and industrial teams working across a range of mobile and communication technologies to accelerate product development. The USRP RIO uses 2 × 2 MIMO transceivers, each tunable to independent frequencies between 50 MHz to 6 GHz with 40 or 120 MHz per channel, giving a real-time bandwidth of 80 dB of dynamic range.

**Planar Monolithics Industries Inc. (PMI)** has signed an agreement with **Pasternack Enterprises** who will private-label a selection of PMI manufactured products under the Pasternack brand name. Through Pasternack, this selection of products will be available off-the-shelf for immediate shipping. This new partnership will provide customers with urgent RF product needs access to an extensive inventory of industry-leading components through Pasternack, along with Pasternack's 24/7 sales and technical support, online purchasing and same-day shipping.

**Leti, Transdev** and **IRT Nanoelec** announced a pilot program to characterize and assess LiDAR sensors to improve performance and safety of autonomous vehicles. In the pilot program, Leti teams will focus on perception requirements and challenges from a LiDAR system perspective and evaluate the sensors in real-world conditions. Vehicles will be exposed to objects with varying reflectivity, such as tires and street signs, as well as environmental conditions, such as weather, available light and fog. In addition to evaluating the sensors' performance, the project will produce a list of criteria and objective parameters by which various commercial LiDAR systems could be evaluated.

At Mobile World Congress Shanghai 2018, **China Unicom** and **Huawei** announced a 5G strategic partnership agreement, culminating in a signing ceremony at the Shanghai's Kerry Center. In a release issued by the companies, the two said, "Huawei and China Unicom will fully leverage their respective innovative strengths in 5G and focus on cooperation in E2E 5G technical verification, cooperation with vertical industry partners, building of the 5G ecosystem and 5G service incubation and promotion."

### ACHIEVEMENTS

**Custom MMIC** announced their recognition by **Raytheon Co.**, with an award in May during the Raytheon Integrated Defense Systems (IDS) 2018 Supplier Excellence Conference. Raytheon's annual Supplier Excellence Awards program recognizes suppliers who have provided outstanding service and partnership in exceeding customer requirements. Award candidates are judged on certain criteria, including overall quality, on-time delivery and demonstrated commitment to continuous improvement. A 5-Star recognition is the highest level of recognition a Raytheon IDS business supplier can achieve for excellence in quality and performance, and Custom MMIC was one of nine companies selected.

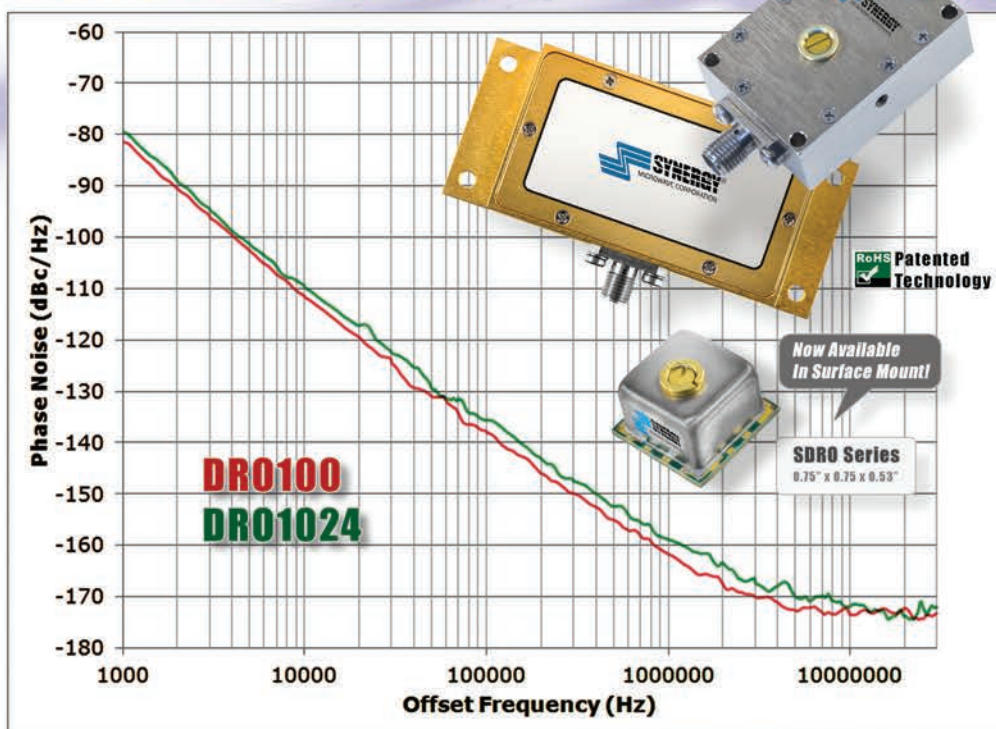
**Orbital Research Ltd.**, a provider of high performance frequency conversion products for SATCOM industries, announced they have been certified under ISO 9001:2015 as of May 28.

BAW filter manufacturer **Akoustis Technologies** has completed the qualification of its first-generation XBAW wafer technology and the attendant single crys-

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SDRO1000-8	10.000	1 - 15	+8.0 @ 25 mA	-107
SDRO1024-8	10.240	1 - 15	+8.0 @ 25 mA	-105
SDRO1118-7	11.180	1 - 12	+5.5 - +7.5 @ 25 mA	-104
SDRO1121-7	11.217	1 - 12	+5.5 - +7.5 @ 25 mA	-104
SDRO1130-7	11.303	1 - 12	+5.5 - +7.5 @ 25 mA	-104
SDRO1134-7	11.340	1 - 12	+5.5 - +7.5 @ 25 mA	-104
SDRO1250-8	12.500	1 - 15	+8.0 @ 25 mA	-105
<b>Connectorized Models</b>				
DRO80	8.000	1 - 15	+7.0 - +10 @ 70 mA	-114
DRO100	10.000	1 - 15	+7.0 - +10 @ 70 mA	-111
DRO1024	10.240	1 - 15	+7.0 - +10 @ 70 mA	-109
KDRO145-15-411M	14.500	*	+7.5 @ 60 mA	-100

\*Mechanical tuning only  $\pm 4$  MHz

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## Around the Circuit

tal materials process at its Canandaigua, N.Y. wafer fab. The XBAW-1 (XB1) process is the industry's first single crystal BAW technology for the expanding RF filter market for 4G/LTE, 5G, Wi-Fi and military radar. The XB1 process supports applications from 1.5 to 7 GHz and provides wide bandwidth and high linearity. The process uses patented, single crystal piezoelectric materials and MEMS wafer manufacturing and is compatible with both conventional and flip-chip packaging.

Finnish telecommunications company **Elisa** has become the first operator in the world to begin commercial use of a 5G network and to start offering 5G subscriptions. The first person to use the 5G network was Finland's Minister of Transport and Communications, Anne Berner, when she made a video call to Kadri Simson, the Minister of Economic Affairs and Infrastructure in Estonia. The world's first commercial 5G networks have now been launched in the Finnish city of Tampere and Estonia's capital city Tallinn, and Elisa is also updating its network to be 5G-ready across Finland.

**Raytheon IDS** held a Supplier Excellence Conference and presented awards to recognize suppliers who have provided outstanding service and partnership in exceeding customer requirements. **KMED** (via its General Microwave facilities in Israel and New York) was one of 55 companies recognized by Raytheon's IDS business for 4-Star honors.

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## CONTRACTS

**Harris Corp.** has been awarded three multi-award IDIQ contracts with ceilings totaling \$1.5 billion to provide the **National Geospatial-Intelligence Agency (NGA)** with geospatial data services for up to 10 years. Harris will create, manage and disseminate high-quality geospatial-intelligence (GEOINT) information for use by the U.S. intelligence community and military worldwide under contracts that cover all three areas of NGA's JANUS program—geography, imagery and elevation.

**Altamira Technologies Corp.** has been awarded the **Air Force Research Laboratory's (AFRL)** \$24.6 million Distributed Radio Frequency Sensing (DRS) contract to provide next-generation RF sensing technologies through advanced R&D of RF systems and sub-systems. The five-year CPFF contract will support the development of innovative solutions applying DRS to contested and congested spectrum environments.

**CACI International Inc.** announced that it has been awarded a \$48 million task order to provide engineering and technical related services (ETRS) to the **Naval Surface Warfare Center, Indian Head Explosive Ordnance Disposal Technology Division**. The five-year, single-award contract, awarded under the U.S. Navy's SeaPort II Omnibus Engineering and Technical Support Services contract vehicle, represents continuing engineering services work in CACI's surveillance and reconnaissance market area.

**Teledyne Wireless**, a business unit of the Teledyne Defense Electronics Group, has been awarded a \$4.4 million sole source contract from the **Naval Supply Systems Command (NAVSUP)** for maintenance and repair operations involving traveling wave tubes (TWT) utilized in AEGIS systems supporting SPY-1 Radar. Execution of the contract award will be performed at Teledyne's 160,000 square foot production facility in Rancho Cordova, Calif.

## PEOPLE



▲ Paul J. Fego

**Qorvo®** announced the appointment of **Paul J. Fego** as corporate vice president, global operations, effective immediately. Fego will report to Bob Bruggeworth, president and CEO of Qorvo, and will assume responsibility for Qorvo's global operations, including internal and external wafer fabrication, assembly and test technology and manufacturing. Fego most recently served as vice president and manager of the Worldwide Manufacturing Group at Texas Instruments, where he managed all of its wafer fabrication, assembly and test operations in nine countries.

**Insulated Wire Inc. (IW)** announced that, following the retirement of a French delegate, IW Microwave Products Division President **John Morelli** has been appointed as the secretary for IEC/SC46F, a subcommittee of IEC/TC46. IEC/SC46F is responsible for RF and microwave connectors and components international standardization. Morelli, who is sponsored by IW, brings significant

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(DC to 9 GHz)



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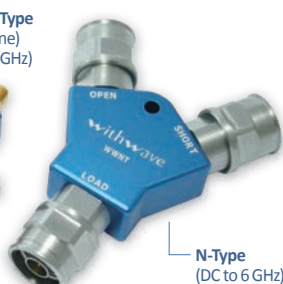
- GSG, GS Configurations
- 0.8, 1.5, 2.5 mm pitch range
- Pogo pin structure



3.5 mm Type  
(All-in-one)  
(DC to 9 GHz)



N-Type  
(DC to 6 GHz)



### Specifications

- Return loss (Load) : < -38 dB
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## Around the **Circuit**

RF and microwave connector and component experience to the position. Morelli had been serving as the chief technical advisor for the U.S. National Committee's Technical Advisory Group to IEC/SC46F.

## REP APPOINTMENTS

RFE announced the appointment of the following regional manufacturer's sales representatives: **WLM Components** covering New England and Upstate New York and **Radar Systems Technology** covering international. RFE is an original design manufacturer (ODM) serving military, industrial and commercial markets with a product line of small profile, high performance converter and synthesizer sources.

**RFMW Ltd.** announced a distribution agreement with **Integrated Device Technology (IDT)** effective immediately. Under the agreement, RFMW is franchised for worldwide marketing and sales of IDT's portfolio of RF, microwave, mmWave and RF timing products. IDT offers high linearity RF components including modulators and demodulators, mixers, synthesizers, attenuators, switches, amplifiers and phase locked loops. RFMW is a specialized distributor providing customers and suppliers with focused distribution of RF and microwave components as well as specialized component-engineering support.

**Richardson RFPD** announced that it has entered into an expanded agreement with **Maxwell Technologies Inc.**, a developer and manufacturer of capacitive energy storage and power delivery solutions. The new agreement builds on the long-term relationship between the two companies, and completes Richardson RFPD's global network by adding Europe, Japan and Korea to its ultracapacitor sales regions. For over 50 years, Maxwell's world-class research and product development teams have established the company as a global leader in developing, manufacturing and marketing energy storage and power delivery solutions for automotive, grid energy storage, wind and industrial applications.

**W. L. Gore & Associates Inc. (Gore)** announced that **WireMasters** is the first authorized distributor of select GORE® Space Cables for high data rate applications. Product offerings in stock at WireMasters include Type GBL (Balanced Shield Line) for dataline applications and Type SpaceWire for satellite, telescope observatories and other critical spaceflight operations. Headquartered in Columbia, Tenn., WireMasters is an industry leader in the sales and distribution of Mil-Spec BMS and EN wire, cable, tubing and accessories. They have provided best-in-class, value-added services to the aerospace and defense market for 30 years.

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# Welcome to EuMW 2018: Find Your Passion for Microwaves in Madrid

Magdalena Salazar Palma and José Ignacio Alonso Montes

*General Co-Chairs EuMW 2018*

Ivar Bazzzy

*President, Horizon House Publications*

**For complete coverage of the EuMW 2018 conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show daily at [mwjournal.com/eumw2018](http://mwjournal.com/eumw2018)**

**A**s part of the microwave industry, we all have a "Passion for Microwaves," which is the theme for this year's European Microwave Week (EuMW). The co-chairs and organizer of EuMW 2018 welcome you to Madrid, the economic and cultural centre of Spain and the third largest city in the European Union. This is the 21<sup>st</sup> EuMW, and takes place at IFEMA Feria de Madrid from Sunday 23 to Friday 28 September. After the very successful 2017 event in Nuremberg, the EuMW comes to the lively, cosmopolitan and friendly city of Madrid. This conference event was started by the European Microwave Association (EuMA) in 1998, and is made up of the 48<sup>th</sup> European Microwave Conference (EuMC), taking place from 25 to 27 September, the 13<sup>th</sup> European Microwave Integrated Circuits Conference (EuMIC), taking place from 24 to 25 September, and the 15<sup>th</sup> European Radar Conference (EuRAD), running from 26 to 28 September. The three conferences are accompanied by the three-day trade show covering RF and microwave technology that attracts about 300 exhibitors and is the largest in Europe.

Over 430 reviewers and the 110 members of the Technical Program Committee selected an excellent program comprising of 521 presentations. The program also includes six special sessions. We are proud to host in particular the special session celebrating the 20<sup>th</sup> anniversary of EuMW, which encompasses presentations by our esteemed colleagues who launched this successful event as envisioned by a recently established EuMA back in 1998. Two other special sessions will highlight the research activities in Latin America and 5G technology in the Asia-Pacific Region. Two more special sessions present the latest research on additive manufacturing and high frequency flexible bendable electronics for wireless communication systems. Finally, a special session is devoted to radar projects at the European Defense Agency.

The regular program is organized in 87 oral sessions and five interactive sessions. The program is complemented by 33 workshops and eight short courses, covering the most relevant topics ranging from mmWave circuits to 5G, from power amplifiers to automotive radar and from THz technology to

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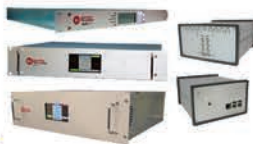
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SATCOM, from Sunday 23 to Friday 28 September.

This year's Defence, Security and Space Forum (DSS) is devoted to "Integrating Unmanned Aerial Vehicles (UAV) into Defence and Security Scenarios." The DSS Forum organizers have succeeded in attracting high-level speakers to discuss the need from a defense and security perspec-

tive of integrating UAVs into current air traffic control and air defense systems, together with related technological challenges and solutions.

Internationally renowned speakers will discuss the latest trends and developments in their keynotes at the conferences' plenary sessions. At the opening session of the EuMW, Enrique Blanco, Telefónica Global

CTIO, will outline how the 5G technologies will impact future communication networks. The EuMIC opens with presentations by Chuck Campbell, engineering senior fellow with the Infrastructure and Defense Products Division of Qorvo, U.S., on the progress and problems of GaN MMIC design, and by Sebastián Gómez-Díaz, from University of California, Davis, U.S., on THz nanoplasmonics with 2D materials. Bill Deal, distinguished engineer in the RF and Mixed Signal Department of Northrop Grumman, U.S., will close the EuMIC with a review on THz transistors and their applications. During the EuRAD opening, which is held in conjunction with the DSS Forum, M. Carmen Barbero, head of Naval Radar Programs, Indra Sistemas, Spain, will present the new radar generation for the F-110 frigate integrated masts, and Stefano Pirandola, from York Centre for Quantum Technologies, U.K., will discuss quantum radar. Domingo Castro, Rafael Casado and Jacobo Martínez-Villa, from Indra Sistemas, Spain, will present the S3T Spanish ESA (European Space Agency) Radar facility for space debris at the EuRAD closing session. The EuMW will close with a presentation by Giuliano Gatti, space segment manager of ESA Galileo Satellite Navigation Program.

The traditional Women in Microwave Engineering (WiM) event, co-sponsored by the IEEE MTT-Society, will focus on communications technology for space exploration, and both women and men are welcome. Attendees will visit one of the following two centers located near Madrid: the NASA-MDSCC (Madrid Deep Space Communications Complex) or the ESA-ESAC (European Space Astronomy Centre). Besides visiting the center, presentations will be given by scientists working at MDSCC or ESAC. As initiated during EuMW 2017, the WiM attendees will have the opportunity to interact with high school students who are invited to participate in this event. Early registration is encouraged, as the number of participants is limited.

EuMW 2018 will host several events especially for younger en-

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gineers. These include the very stimulating and successful Student Challenge, which will have the same format as in previous years. The Student Design Competition comprises two tasks to be prepared in advance. It will also feature a design task to be carried out on-site. This will take place in the form of a hands-on design experience event. The latter is

also part of the Student and the Doctoral School, which both start with a high-level, half-day lecture program. The Career Platform will continue the successful format of previous years. Finally, two sessions devoted to young professionals are offered.

The week would not be the "Week" without its traditional social events. These include Mon-

day's EuMIC Get-Together, which this year will be held at a beautiful restaurant located in the heart of Madrid's modern downtown, Tuesday's Welcome Reception, sponsored by Keysight Technologies, which will also be held off-site at the Palacio del Negrlejo and the EuRAD Lunch on Friday. In addition, a private visit to the Thyssen-Bornemisza Museum, one of Madrid's Golden Triangle of Art, together with the Prado and the Reina Sofía national galleries, followed by a cocktail dinner, has been organized for Wednesday evening.

The Week's program will let you enjoy Europe's microwave event in 2018 and will give you plenty of opportunities to satisfy your professional "Passion for Microwaves." Do not forget to explore the friendly city of Madrid, where everyone feels at home. Madrid's rich artistic and natural heritage, cutting edge transport network, quality accommodation, fine cuisine and the passion locals show when enjoying their city's day and nightlife make it one of the most attractive cities in the world. If time permits, we invite you to visit some of the many nearby landmarks, from Alcalá de Henares, where Miguel de Cervantes, the well-known author of *Don Quijote de la Mancha*, was born 471 years ago, to Segovia, Toledo and more. ■

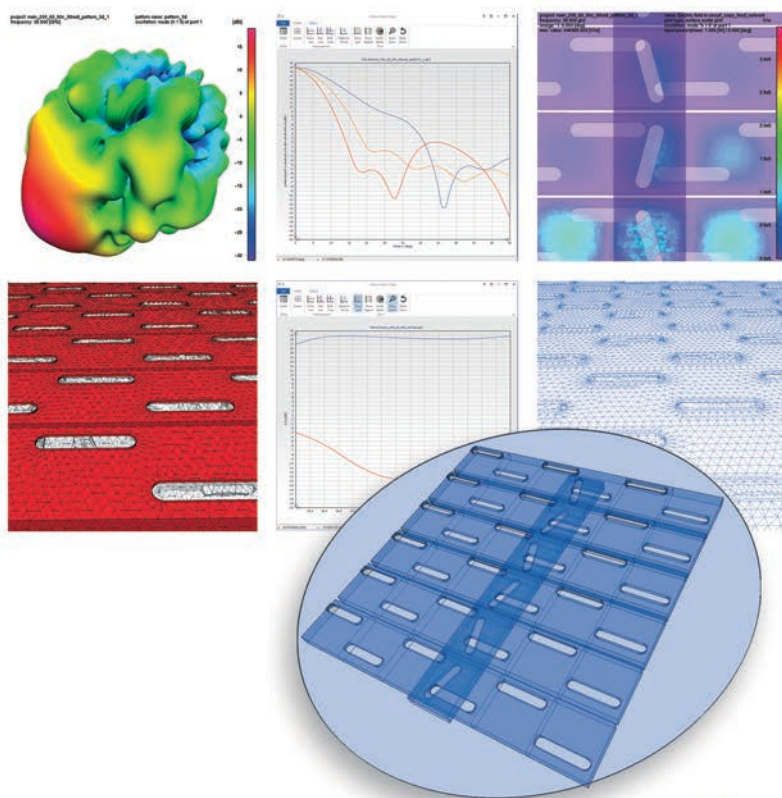


Clockwise from top left:

Magdalena Salazar Palma

José Ignacio Alonso Montes

Ivar Bazy



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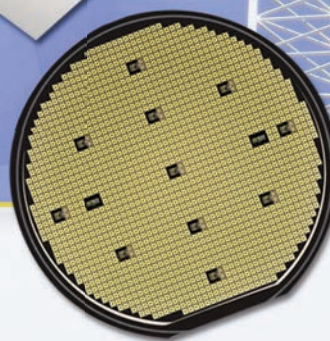
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# Attending European Microwave Week 2018

Compiled by Patrick Hindle  
Microwave Journal Editor

**E**uropean Microwave Week (EuMW) 2018 is being held in the exciting city of Madrid, Spain for the first time ever. Bringing industry and academia together, EuMW is a six day event, including three cutting edge conferences, workshops and an energetic trade exhibition featuring leading players from across the globe. EuMW 2018 provides access to the very latest products, research and initiatives in the microwave sector. It also offers you the opportunity for face-to-face interaction with those driving the future of microwave technology.

## CONFERENCES

The conference event is made up of the 48<sup>th</sup> European Microwave Conference taking place from 25 to 27 September, the 13<sup>th</sup> European Microwave Integrated Circuits Conference taking place from 24 to 25 September and the 15<sup>th</sup> European Radar Conference running from 26 to 28 September. The conferences encompass a wide range of topics including:

- Microwave, mmWave and sub-mmWave systems
- Antennas and propagation
- Wireless technologies
- Telecommunication (RF, microwave and optical)

- ICs, semiconductor materials and packaging
- Radar architectures, systems and subsystems
- Sensors and remote systems
- Test and measurement

## European Microwave Conference (EuMC) 25-27 September

In its 48<sup>th</sup> year, the European Microwave Conference (EuMC) comes again to Spain, after 25 years. The last Spanish edition of the EuMC was held in Madrid in 1993, and in that time the flagship conference of the current EuMW was not associated to the European Radar Conference (EuRAD) and to the European Microwave Integrated Circuits Conference (EuMIC). In its present format, the EuMC is able to reach a wider audience, since its traditional and widespread set of covered topics (mainly focused on microwave and wireless components, systems and technologies) is enriched with radar technologies and microwave integrated circuits (in this edition through four joint sessions with EuMIC and nine with EuRAD).

The simultaneous celebration of the three conferences during the same week, plus the high number of technical workshops, short courses, associated events, as well as

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the industry exhibition, will contribute to the continuous success that EuMW, and particularly EuMC, experiences yearly. The entire team of the EuMW 2018, and particularly the EuMC 2018 team, with the help of the Technical Program Committee members and paper reviewers, have done a great job in creating a coherent, balanced and complete program for this year's conference, with special emphasis on the latest trends in microwave, mmWave, THz and wireless technologies. In summary, 355 papers grouped in 51 technical sessions or presented in the four interactive forums, nine industrial session keynotes, 28 workshops and eight short courses have been accepted in the present edition of EuMC. Moreover, five special sessions will be held in the following selected domains: "20<sup>th</sup> Anniversary of the European Microwave Week," "Microwave Research in Latin America," "5G Technology in Asia-Pacific," "Additive Manufacturing" and "High Frequency Flexible Bendable Electronics for Wireless Communication Systems."

Conference delegates are also encouraged to attend the opening and closing sessions of EuMC (which are also the main plenary sessions of the whole EuMW) on Tuesday and Thursday where

prominent speakers have been invited. Enrique Blanco, Global CTIO of Telefónica, Spain, will give a plenary talk on Tuesday, 25 September on 5G networks and communication systems. Giuliano Gatti, Galileo Space Segment Manager at European Space Agency (ESA), will contribute with a presentation about the Galileo global satellite navigation system during the closing session to be held on Thursday, 27 September. EuMC 2018 will close with the traditional awards ceremony, when the best paper prizes will be announced. Hopefully after the Week, you experience a higher motivation and passion for microwaves.

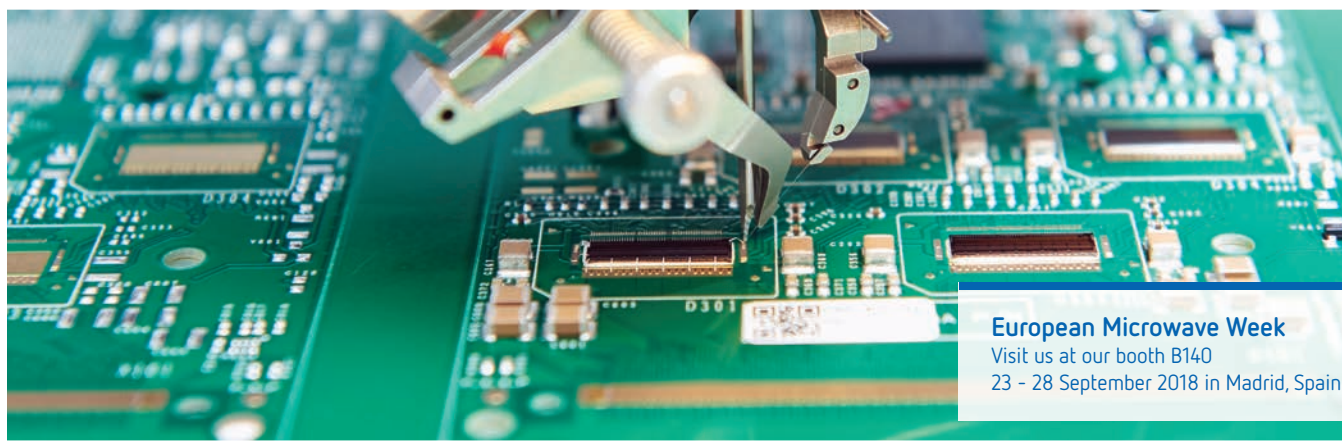


## European Microwave Integrated Circuits Conference (EuMIC) 24-25 September

This is the 13<sup>th</sup> European Microwave Integrated Circuits Conference, EuMIC 2018. EuMIC arrives to Spain after a long journey that started in Rome in 1990, organized by the GAAS® Association, and continued, after 2004, in the framework of the EuMW.

The scientific conference is composed of 12 regular EuMIC sessions and three EuMC/EuMIC joint sessions covering topics from device to system level. mmWave technologies have gained an important presence in this edition, reflecting their role in paving the way for 5G and beyond. Device modeling is also present with four regular sessions, showing how a classic topic remains a challenge for our community. The five sessions on amplifiers will focus on system level issues. The interactive poster session has been organized jointly with the EuMC and will be held on Tuesday, enjoying the lively atmosphere of the exhibition. There are also short courses and workshops.

EuMIC has included three relevant industrial keynotes thanks to the kind participation of prominent speakers from Cree, GLOBALFOUNDRIES and Televés. Invited



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manufacturers will take the floor during the traditional "Foundry Session," hosted by the GAAS® Association. The EuMIC opening and closing plenary sessions will feature three invited speakers, world-class in their fields. During the opening ceremony Charles F. Campbell, engineering senior fellow with the Infrastructure and Defense Products Division of Qorvo, U.S., will present a realistic perspective of the present challenges that GaN monolithic designs faces. In addition, J. Sebastián Gómez Díaz, assistant professor in the Electrical and Computer Engineering Department of the University of California, Davis, U.S., will address the use of graphene and other 2D materials as a powerful, reconfigurable, CMOS compatible and miniaturized on-chip platform for THz device fabrication.

During the closing session William R. Deal, distinguished engineer in Northrop Grumman's RF and Mixed Signal Department, U.S., will talk about the status of transistor-based electronics operating above 100 GHz and will describe recent progress in communications and sensors at these frequencies. Also during the closing ceremony, the best contributed paper to EuMIC 2018 and the Young Engineer Prize will be awarded by the EuMIC Tech-

nical Program Committee and the EuMW Steering Committee. Three GAAS® Association PhD student fellowships will also be celebrated.

#### European Radar Conference (EuRAD) 26-28 September

This is the 15<sup>th</sup> edition of the European Radar Conference, after walking a path of continuous growth, both in absolute terms and its weight and significance within the EuMW. Top professionals will present their latest research and development, and discuss the present status and future trends in the fields of radar technology, system design and performance, radar components, radar propagation and target modeling, advanced sig-



nal processing techniques, as well as the most innovative radar architectures, concepts and applications. In the opening session on Wednesday, M. Carmen Barbero, from Indra Sistemas, will present their radar global concept for the next generation of F110 frigates for the Spanish Navy, in which advanced concepts such as full digital implementation using software-defined radio concepts and multiple function front-end sharing are included. Next, Dr. Stefano Pirandola, from the University of York, will present a more long-term vision of their technologies, exploring the capabilities of the quantum radar concept. For the closing session, keynote speakers, Domingo Castro, Rafael Casado and Jacobo Martínez-Villa, from Indra Sistemas, Spain, will describe the new radar facility for space debris surveillance that is starting to be installed in Spain.

This year, 156 papers were submitted to the conference, and after a rigorous selection process, the 93 accepted papers were organized into 22 oral sessions and two interactive sessions, some of them shared with EuMC. Prominent industrial keynote speakers will open four of these sessions, showing the latest industry approaches to the addressed technologies. A special



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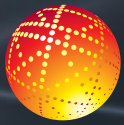


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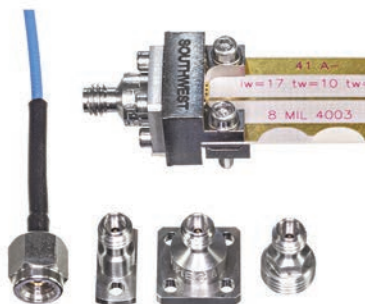
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session about radar projects in the European Defence Agency (EDA) has been organized by Dr. Roland Krebs, project officer, RF Sensor Technologies at EDA, to present their framework of R&T collaboration. The most relevant outcomes of recent projects in the frame of the RF Sensor Technologies CapTech will be presented by top level speakers, representing the European cooperation in this domain. An attractive topical workshops program will be running alongside the conference program.

### Defence, Security and Space (DSS) Forum 26 September

The Defence, Security and Space Forum is jointly organized by the European Microwave Association (EuMA) and *Microwave Journal*, to complement EuMW's activity in the defence, security and space sector. This year, local input has been welcomed from: Fundación Círculo (Circle of Technologies for Defence and Security Foundation), TEDAE (Spanish Association of Technological Defence, Aeronautics and Space Companies) and UPM (Universidad Politécnica de Madrid). Each year the DSS Forum focuses on a hot topic that is engaging industry, academia and organizations/agencies to develop, test and implement leading edge technology. This year's topic is "Integrating Unmanned Aerial Vehicles (UAV) into Defence and Security Scenarios." The popularity of UAVs is growing due to a reduction in costs and the increasing capabilities and benefits provided by such systems.

Currently, the estimated number of existing UAVs is believed to be a few million, with that figure estimated to grow exponentially in coming years. From a defense and security perspective, there is the need to provide UAVs with innovative technologies enhancing performances for safe and secure systems, and to defend against threats posed by terrorists and insurgents utilizing UAVs to achieve their own objectives. Microwave technologies are essential to meeting these challenges, by providing UAVs with

new and more advanced sensors and communications equipment. However, going forward, the development of such systems also anticipates the use of new technologies, such as big data and artificial intelligence, which will result in a high level of autonomy that using the data obtained by the sensors will provide the ability to learn from the environment and their own errors, eventually facilitating autonomous decision making in a constantly evolving environment.

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

The industry session will reflect the effort and investment that is being made to innovate, develop and bring UAV technologies to market. Specific areas of activity include radar systems being developed for UAV security—detection, identification and denial and obstacle detection for autonomous flying and crash avoidance. From an industry perspective, the emphasis will be on development at system and sub-system level, with particular focus on sub-system integration, not forgetting the significant role that test and measurement has to play in moving the sector forward.





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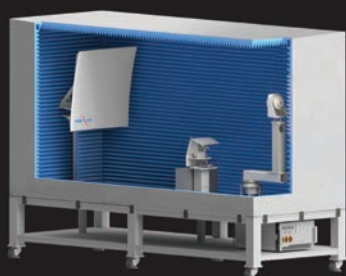
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At the end of the day, the Executive Forum will present the points of view of the different established and regulatory bodies that allow coexistence between the different aerial platforms and describe the activity of the different players already established and emerging in the field.

### REGISTRATION

Delegates can register for one, two or all three of the conferences. Registration at one conference does not allow any access to other conference sessions. Those who wish to register for two or more conferences will receive a discount on these registrations.

### INTERACTIVE SESSIONS

The interactive poster papers will be presented on electronic screens, which are located in the conference area on Monday and Friday, and in the exhibition as signposted on Tuesday, Wednesday and Thursday.

### EXHIBITION

The exhibition area will be located in Hall 9 (North Entrance) and comprised of more than 250 companies and organizations showing off their latest technologies and products. The exhibition area will also host the MicroApps Sessions and Exhibitor Workshops. The MicroApps will be three days of sessions given by various experts from exhibiting companies. The Exhibitor Workshops will be made up of instructional presentations, such as amplifier and filter design, in addition to the basics of making RF and mmWave measurements. As a registered delegate you will have full access to the exhibition area so be sure to take time and see what new products and technologies the industry is offering.

### Exhibition Hours

**Tuesday, 25 September 9:30–18:00**  
(followed by the Welcome Reception)  
**Wednesday, 26 September 9:30–17:30**  
**Thursday, 27 September 9:30–16:30**

### EVENTS

#### EuMIC Get-Together

**Date:** Monday, 24 September  
**Duration:** 20:00–22:00  
**Location:** Larumbe, La Terraza, 4th Floor, Centro Comercial ABC Serrano, Serrano 61  
**Cost:** Free to EuMIC delegates

Following the tradition of the EuMIC, delegates are invited to enjoy an informal dinner that will be offered by a first-class catering service in a unique location—Edificio ABC Serrano. A 19th century building located in the heart of Madrid, facing Serrano Street and Paseo de la Castellana, Edificio ABC Serrano is an unrivalled setting to have a good time with colleagues and friends, and taste the excellent Spanish cuisine.

#### Welcome Reception

**Date:** Tuesday, 25 September  
**Duration:** 18:30–21:30  
**Location:** Palacio del Negrlejo, Ctra. San Fernando a Mejorada, km 3, 28522 Rivas-Vaciamadrid  
**Cost:** Free to conference delegates & invited exhibitors

All registered conference delegates, as well as invited representatives from companies participating in the exhibition, are invited to the EuMW 2018 Welcome Reception, sponsored by Keysight Technologies, Horizon House Publications and EuMA. Delegates will need to bring their badge and exhibitors their invite along with them to gain entrance. The evening will begin with drinks at 18:30 followed by the General Chairs' handover from EuMW 2018, Madrid to EuMW 2019, Paris as well as an address from the Platinum Sponsor, Keysight Technologies. The open-buffet dinner will be served at 19:00. Bus transportation to and from Palacio del Negrlejo will be provided.

#### Private Visit to the Thyssen-Bornemisza Museum and Cocktail Dinner

**Date:** Wednesday, 26 September  
**Duration:** 19:30–21:00  
**Location:** Museo Thyssen-Bornemisza, Paseo del Prado, 8  
**Cost:** €45 for delegates, €60 for exhibitors



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A private visit to the Thyssen-Bornemisza Museum, one of Madrid's Golden Triangle of Art together with the Prado and the Reina Sofia national galleries, has been organized, followed by a cocktail dinner. With over 1,600 paintings and sculptures, the Thyssen-Bornemisza was once the second largest private collection in the world, after the British Royal Collection. The Museum now houses the core of the collection and fills the historical gaps in its counterparts' collections. Guides will be available through the different rooms of this magnificent museum. This unique experience will be complemented with a cocktail dinner. Subsidized tickets, €45 for delegates and €60 for exhibitors, are limited, so register as soon as possible.

#### Young Professionals Meet-Up

**Date:** Thursday, 27 September

**Duration:** 19:30–22:00

**Location:** A downtown Cafeteria, TBA

**Cost:** Free to all YPs

#### EuRAD Lunch

**Date:** Friday, 28 September

**Duration:** 12:30–13:50

**Location:** Retiro Toom, IFEMA

**Cost:** Free to EuRAD delegates and Friday WS/SC delegates

#### HOTEL RESERVATIONS

Horizon House has teamed up with Connex Hotels and Events, the official hotel booking supplier, to offer you the

ability to reserve your accommodation for EuMW 2018 at the most competitive rates available. Visit [connexhotelsandevents.com/eumw-2018-madrid.html](http://connexhotelsandevents.com/eumw-2018-madrid.html) or email [sally@connexhotelsandevents.com](mailto:sally@connexhotelsandevents.com) to make your accommodations. You will find a wide range of offerings to suit every budget.

#### GETTING TO IFEMA-FERIA DE MADRID CONVENTION CENTRE

The city of Madrid is located in the geographic center of Spain and it is well connected to the European motorway, rail and flight networks. IFEMA-Feria de Madrid Convention Centre can be accessed through a variety of transportation means. Madrid-Barajas Airport is located only 10 minutes from the exhibition complex, and just 15 km from the city centre which it is connected by Metro (airport stations T-1, T-2, T-3 and T-4).

Access to Feria de Madrid is possible from anywhere in the city by means of Feria de Madrid station on Line 8, whose exit is at the South Entrance of the complex. Line 8 also connects the venue with the different terminals of Barajas International Airport. A wide bus network provides access to Feria de Madrid from different points in the city: Route 112-Feria de Madrid-B° Aeropuerto. Route 122-Avda. de América-Feria de Madrid. Route 828 Universidad Autónoma-Alco-

bendas-Canillejas-Feria de Madrid.

In order to facilitate the delegate transportation to and from IFEMA, a shuttle bus route has been organized from local hotels as well as from the South Entrance (metro) to the North (EuMW) Entrance. For the complete time tables, please check the EuMW website.

#### ENJOY MADRID

The first historical record of Madrid dates back to the year 865, when Emir Muhammad I commissioned the construction of a fortress in the village of Mayrit, on the banks of the river Manzanares. Mayrit means "plenty of waterways," and belonged to the Islamic world until 1083, when Alfonso VI of Castile took over the city.

Today, Madrid is a dynamic business center that goes hand-in-hand with its vibrant atmosphere, tourist appeal and passionate cultural and recreational life. While visiting, discover its historical sites, iconic museums and spectacular range of restaurants, plus enjoy its endless nightlife and the flood of designs, fashion and trends you will find in the shops of one of Europe's leading capitals. A great city that boasts a rich treasure of art, culture and natural environments, set in a region packed with history and modernity. Visit [esmadrid.com/en](http://esmadrid.com/en) for information on top attractions and tips for your stay.■

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# The 2018 Defence, Security & Space Forum At European Microwave Week

**Wednesday, 26 September – IFEMA Feria de Madrid, Spain**

## **A one-day focused Forum addressing the integration of unmanned aerial vehicles (UAV) into defence and security scenarios.**

The popularity of Unmanned Aerial Vehicles is growing due to a reduction in costs and the increasing capabilities and benefits provided by such systems. Currently, the estimated number of existing UAVs is believed to be a few million, with that figure estimated to grow exponentially in coming years. From a Defence and Security perspective, there is the need to provide UAVs with innovative technologies enhancing performances for safe and secure systems, and to defend against threats posed by terrorists and insurgents utilizing UAVs to achieve their own objectives.

### **Programme:**

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

**10:10 – 10:50 Coffee Break**

**10:50 – 12:30 New Concepts, Technologies and Systems for UAV Integration and Their Role in Future Hybrid Scenarios**

Moderator: **Alfonso Farina**, IEEE Fellow

- *Technological Demonstrator of Enhanced Situation Awareness in Naval Environment with the Use of Unmanned Systems* – **Dr. Tony Arcelli**, Ocean 2020 Project Coordinator, Leonardo S.p.A.
- *UAV Integration: European and Spanish Situation, Challenges and Potential Solutions* – **Isabel Maestre**, Executive Director of Spanish Aviation Safety and Security Agency (AESA)
- *Anti-UAV Defence Systems* – **Miguel Acitores**, Director of Security Business Development, Indra

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

*The Implications of Expanding the UAS Mission Envelope in Military and Civilian Airspace* – **Asif Anwar**, Strategy Analytics

**13:50 – 15:30 Microwave Journal Industry Panel Session**

This session offers a perspective on the endeavour, innovation and investment that industry is committing to the development of UAVs in the defence and security sector. Speakers will offer an insight into such areas of activity as microwave sensors/sub-systems, the test and measurement challenges that are being addressed and the issue of UAV identification and detection.

- *Improving the SWAP-C Advantage in UAVs for Defense & Security* – **Dean White**, Qorvo
- *Designing Systems and Sensors for Counter Drone Operations* – **Tobias Willuhn**, R&S
- *Radar Systems for UAV Detection* – **R. Cardinali, A. Di Lallo, A. Farina, G. Palumbo, L. Timmoneri, and D. Vigilante** Leonardo, Land & Naval Defence Electronics/Security and Information Systems
- *Detect and Avoid: An Industrial Perspective Technical and Certification Considerations for UAVs* – **Andrea Maccapani and Maurizio Goiak**, Leonardo S.p.A., Airborne and Space Systems Division

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**Room N101-N102, 08:30 to 18:30**



**15:30 – 16:10 Coffee Break**

### **16:10 – 17:50 Round Table: Efforts & Investment Needs to Drive UAV Technologies to Market**

High level speakers from key governmental agencies and commercial companies involved in the development of UAV systems and technologies and their implementation and integration into security and defence markets will offer their opinions and outline the opportunities and challenges that can be expected in coming years. Speakers will also focus on the research needs and technological trends that will define the architectures and technical characteristics of future unmanned systems. **Moderator: Ignacio Montiel**, Project Officer Information Technologies, European Defence Agency (EDA). **Speakers: Paolo Salieri**, Principal Scientific and Policy Officer in the Directorate General for Enterprise and Industry of the European Commission. **Fernando Mijares**, Head of Future Projects of AIRBUS Defence & Space. **Juan Besada**, Professor, Information Processing and Telecom Center, Universidad Politécnica de Madrid (IPTC-UPM). Member of SESAR Scientific Committee. **Fernando Arias**, Senior Expert, ISDEFE.

**17:50 – 18:30 Cocktail Reception**

**Registration fee is €20 for those who registered for a conference and  
€60 for those not registered for a conference.**

The Conference Special Events section of the EuMW website will give further details and updates.

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# The Spanish Microwave Industry: Specialists in Space, Defense & Telecoms

Helen Duncan  
MWE Media Ltd., U.K.

**F**or many of us in the wireless and microwave community, the mention of Spain initially brings to mind Mobile World Congress (MWC), the huge trade show in Barcelona that attracts around 100,000 visitors each February. However, Spain has had a thriving RF and microwave industry of its own since well before MWC relocated there over a decade ago, and it is currently growing rapidly. The country's particular strengths include aerospace, defense and antennas, as well as telecoms, and this article will highlight just a few of Spain's companies and institutions, along with the developments they are contributing to the European microwave community.

It has been 25 years since the European Microwave Conference (EuMC)—then a much smaller event than the present, multi-conference European Microwave Week (EuMW)—last took place in Madrid in 1993, and as the conference returns there, we reflect on some of the changes Spain's market has seen in the intervening years. **Figure 1** shows the Puerta de Alcalá in Madrid, one of dozens of stunning historical monuments and buildings in Spain's capital city that people can visit while attending the conference.



▲ **Fig. 1** European Microwave Week 2018 will take place in Madrid, Spain, on 23–28 September.

## EARLY 5G DEPLOYMENTS

Possibly the company name most familiar to the wireless industry is **Telefónica**, the Spanish-headquartered, multinational telecoms operator that is parent to the O2 and Movistar brands in Europe and Latin America. In addition to its mobile networks, Telefónica has operations in satellite media distribution in Spain and Latin America, and also a chain of R&D centers located around the world.

Telefónica announced in January this year that it is progressing well along the path to 5G with early deployments in two Spanish cities—Segovia and Talavera de la Reina—in partnership with Nokia and Ericsson. Under the 5G Technological Cities project, these two cities will become “living laboratories” for developing the capabilities of 5G. The plan is to deploy the network over the next three years, increasing peak data speeds over mobile to 10 Gbps and reducing latency to less than 5 ms, while in parallel carrying out testing of new use cases. Initially the network will be non-standalone 5G NR, supported by the existing 4G network, but will eventually evolve to a standalone 5G network.

An open research and innovation laboratory called **5TONIC**, located in Madrid, is a joint venture between Telefónica and Imdea Networks that aims to create an open environment where industrial and academic par-



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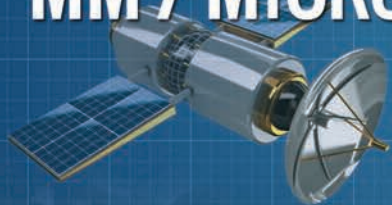
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ticipants from around the world can work together on research projects related to 5G technologies.

**Telefónica I+D**, the research and development company of the Telefónica Group, also has a technology center in Madrid, as well as offices in Barcelona, Granada, Huesca and Valladolid in Spain and in other locations around the world. Its mis-

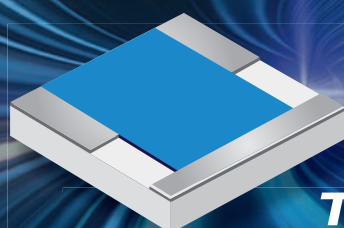
sion is to help improve the Group's competitiveness and to keep up-to-date with technological innovation, as well as developing new products and services. Not surprisingly, its current projects include 5G and M2M developments, longer-term innovation programs on human behavior and mobility and on future networks as well.

Telefónica's Global CTIO, Enrique Blanco, will present a keynote address in the EuMW 2018 Opening Session, outlining how 5G technologies will impact future communication networks.

## SPACE AND DEFENSE

Spain has long been an influential player in the defense and aerospace sector, with many Spanish companies being active contributors to various European Space Agency (ESA) programs. Madrid is home to three divisions of the aerospace giant **Airbus**, including Airbus Defense and Space (Airbus DS) that incorporates Airbus DS-CASA Espacio—formerly part of EADS-Astrium. This company specializes in antenna design for satellites, radiometers and radar.

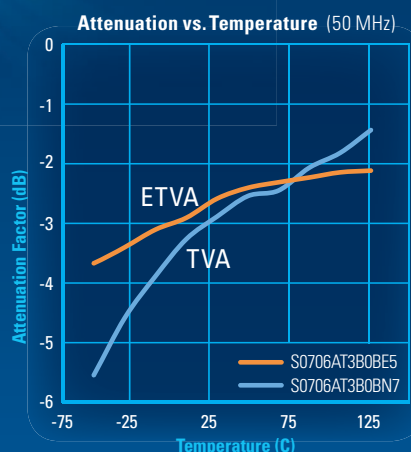
Carlos Montesano, senior expert on antennas and head of R&D at Airbus DS, said, "Our satellite antenna developments are focused in two main areas, large reflector parabolic antennas and active arrays. In active arrays, one of the company's most important projects is the receive antenna for the Eutelsat Quantum<sup>1</sup> satellite, billed as the first fully flexible telecom satellite. Eutelsat Quantum offers both Ku-Band channels for commercial use and X-Band channels for government applications. The active array architecture means that coverage, bandwidth, power, frequency and orbital slot are all reconfigurable in orbit, allowing Quantum to serve any region of the world and



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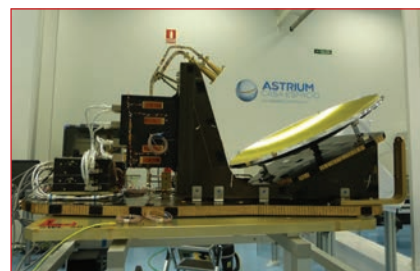
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▲ Fig. 2 The MWR K/Ka-Band radiometer developed by Airbus DS-CASA measures atmospheric propagation delay over the ocean.



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Dynamic Range (BW=10Hz, dB, typ) (BW=10Hz, dB, min)	120 110	120 110	120 110	120 110	120 110	120 110	120 110	115 100	115 105	100 80	110 100	100 80	65 45
Magnitude Stability (±dB)	0.15	0.15	0.15	0.15	0.15	0.25	0.25	0.3	0.3	0.5	0.5	0.8	0.5
Phase Stability (±deg)	2	2	2	2	2	4	4	6	6	8	8	10	6
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to adjust to new demands without needing to launch an entirely new satellite.

## RADIOMETERS AND RADAR

Airbus DS's current radiometer programs in Madrid include the MWR nadir-looking sounder and the ICI mmWave instrument, which

is being developed for the remote sensing of high altitude ice clouds. MWR, shown in **Figure 2**, operates at 23.8 and 36.5 GHz (K/Ka-Band), covering a bandwidth of 200 MHz in each channel and is designed to measure water vapor and cloud water contents in the field of view of the altimeter, in order to com-

pensate for the propagation delay these cause in radar measurements. It does this by measuring the brightness temperature of the Earth's radiation. These corrections can only be made over the ocean, where the background noise is stable and can be measured. Over ice and land surfaces, wet troposphere corrections based on global meteorological data and dedicated models are used instead.

Airbus DS-CASA Espacio was selected by ESA as the prime contractor for the ICI instrument, which is a total power sub- and mmWave conically scanning radiometer. It provides brightness temperature measurements in 11 heterodyne receiver channels, including two dual-polarization channels, ranging from 183 to 664 GHz. It is designed to monitor the exchange mechanisms in the Earth's upper troposphere and lower stratosphere, focusing in particular on the remote sensing of high altitude ice clouds. Although this technique for measuring ice clouds was first proposed in 1995, this will be the first radiometer of its kind to have been developed for Earth observation from space.

Another recent Airbus project, PAZ—the radar satellite of the Spanish National Earth-Observation Program—was launched earlier this year by a SpaceX Falcon 9 rocket. The PAZ satellite, shown in **Figure 3**, was primarily intended to address civilian surveillance needs as well as to cover defense and security applications. "Paz" is the Spanish word for peace.

Using Synthetic Aperture Radar (SAR) imaging instead of a camera, the satellite is able to capture images with equal clarity by day and

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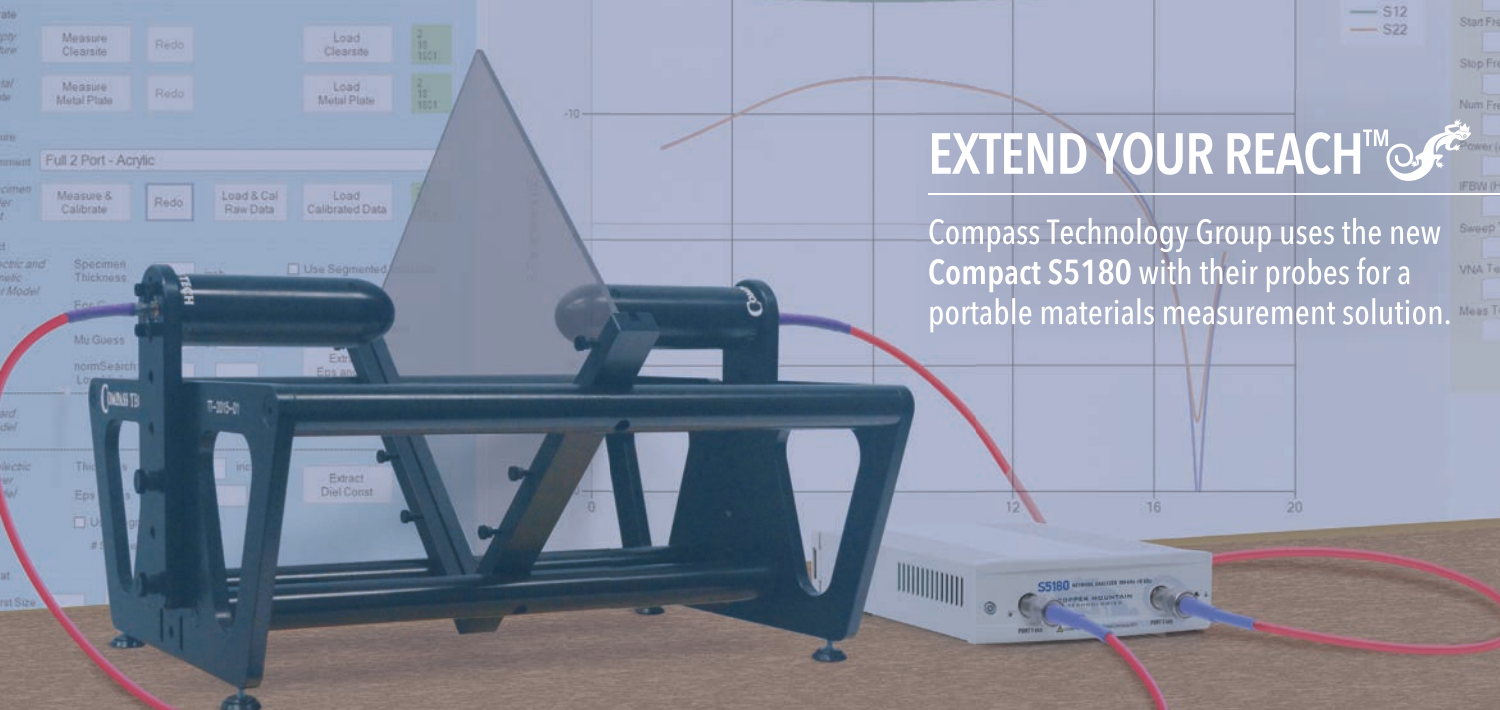
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▲ **Fig. 3** The PAZ satellite uses SAR to collect images day and night for both military and civilian applications.



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night under any meteorological conditions. Operating in the military X-Band spectrum, it can capture more than 100 images each day with up to 1 m resolution. During its five-and-a-half year mission, PAZ will cover an area of over 300,000 km<sup>2</sup> per day from its slightly inclined quasi-polar orbit, covering the entire globe on

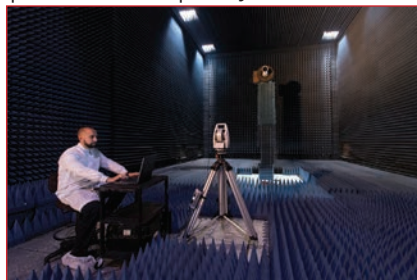
average in 24 hours. Its diverse range of tasks include: terrestrial monitoring; high resolution cartography; border control; tactical international support; crisis management; risk analysis; evaluation of natural disasters; environmental control; marine environment analysis; and marine wildlife monitoring.

## PARTICLE ACCELERATOR COMPONENTS

**Tryo Group** is a Spanish-headquartered RF and microwave specialist, consisting of two divisions—Tryo Aerospace and RYMSA RF—and has facilities in Madrid as well as in other cities including Bilbao and Barcelona, along with international offices. **Figure 4** shows an anechoic chamber, part of Tryo Group's facilities for the design and qualification of antennas and RF equipment for both broadcast and space applications. Tryo Aerospace designs and manufactures antennas and subsystems, while the product portfolio of RYMSA RF includes antennas, filters, combiners and air traffic control systems.

In recent months, RYMSA has secured contracts with two important European scientific organizations for components for particle accelerators. In May, the European Organization for Nuclear Research (CERN) selected RYMSA as its sole supplier for the manufacturing, integration and cabling of 2,752 sets of output filters and high frequency transformers for the proposed upgrading of the modular converter R2E-LHC, which is a key component of the Large Hadron Collider.

In a similar application, the GSI Helmholtz Center for Heavy Ion Research (GSI) in Germany selected RYMSA for the supply of several 9 3/16 EIA directional couplers and coaxial parts for the RF powerlines of GSI/FAIR Proton LINAC (linear accelerator) project. The seven RF powerlines each feed the RFQ cavity with 2.5 MW of forward power and a maximum of 5.5 MW of reflected power at a frequency of 352 MHz.



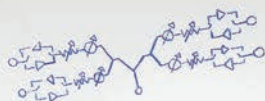
▲ **Fig. 4** Tryo Group has facilities for the design and qualification of antennas and RF equipment for both broadcast and space applications.

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<b>RMF090100PA</b>	9~10GHz / Tx/Rx Gain: 27/17dB / Psat: 18dBm / 6-bit PS / 5-bit Att
<b>RMF090100PA4CH</b>	9~10GHz / Gain: 13.7 / 10.2dB, Psat: 16dBm, 6-bit PS, 5-bit Att
<b>RMF120160PA</b>	12~16GHz, Gain : 2dB, Psat : 0dBm, PS/Att
<b>RMF140160PA</b>	14~16GHz, Gain: >5dB, 6-bit PS/Att
<b>RMF150170PA</b>	15~17GHz, Gain: >5dB, 6-bit PS/Att
<b>RMF040160PA</b>	4.0~16.0GHz, Gain: 10dB, 6-bit TTD/Att
<b>RMF060180PA</b>	6~18GHz, Gain : >4dB, 6-bit TTD/Att



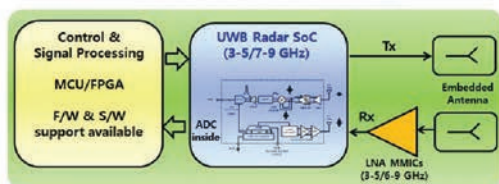
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<b>RUWB7901M</b>	7~9GHz / Bandwidth: 0.5~1.4GHz / Detection Range: 15m / Detection Resolution: 7.5cm



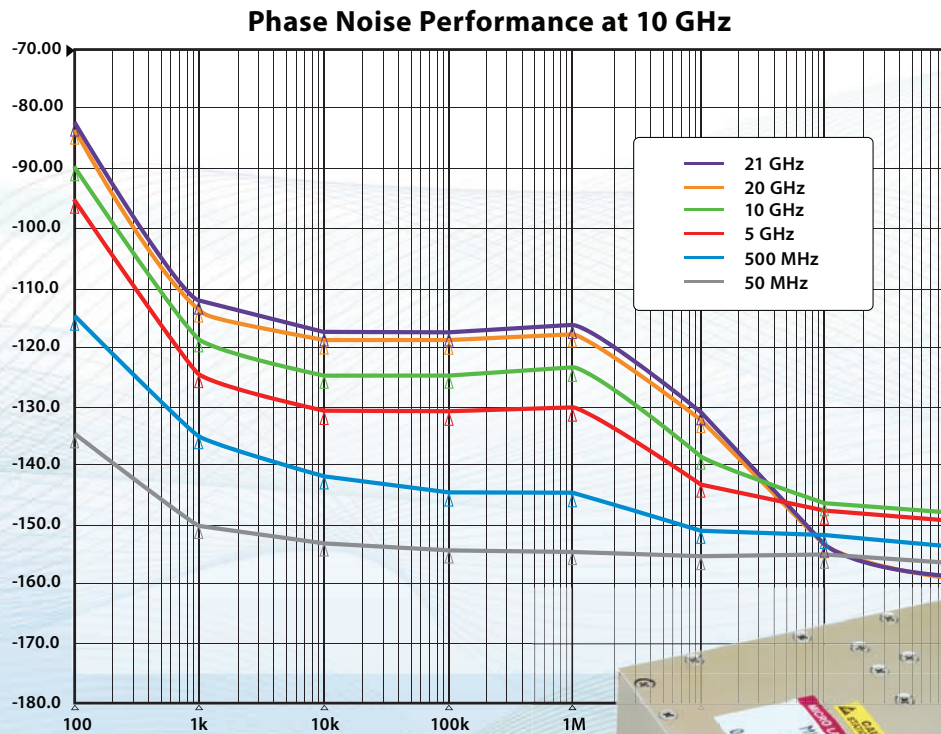
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In June of this year it was announced that Tryo Group had been acquired by Sener, a Spanish engineering and construction group with a division specializing in aerospace. The merger brings together aerospace businesses with a combined turnover of almost €120 million.

## UNMANNED VEHICLES, AIRBORNE AND UNDERWATER

**Indra Sistemas** is a Spanish multinational IT and defense systems company headquartered in Madrid. With a broad portfolio in developing end-to-end technology in fields such as defense and security, transportation, energy, telecommunica-

tions and media and healthcare, the company has a total turnover of more than €3,000 million.

Indra is particularly active in air-traffic control systems and radar and the company will exhibit at EuMW 2018. Miguel Acitores, Indra's director of security business development, will speak in the Defence, Security & Space Forum on Wednesday, 26 September on the topic of anti-UAV defense systems. Indra speakers will be featured in both the opening and closing sessions of EuRAD: Maria Carmen Barbero, head of naval radar programs, will present the new radar generation for the F-110 frigate integrated masts, focusing specifically on the advances made in the development of the primary S- and X-Band radar, secondary radar and other sensors. Jacobo Martínez-Villa will describe the S3T Spanish ESA radar facility for space debris surveillance that is just starting to be installed. There will also be a speaker from Indra in the EuMW Career Platform session on Tuesday, 25 September.

**TTI** has its headquarters in Santander on the North coast of Spain, supported by additional facilities in Madrid and Seville. It specializes in designing and developing customized antennas ranging in frequency from L- up to Ka-Band. These include printed antennas for linear and circular polarizations, active phase array antennas and waveguide and horn antennas, many of which are aimed at SATCOM applications. Complete hybrid systems in X-, Ku- and Ka-Bands are also produced for "on-the-move" SATCOMs.

TTI is a member of the EU SWARMs consortium, for the robotic remote control and operation of unmanned underwater and surface vehicles. Final integration and validation were performed for the European Commission at Trondheim in Norway during June of this year. These final tests demonstrated the performance of integrated acoustic and radio communications networks for two autonomous underwater vehicles (AUV) and a unmanned surface vehicle (USV), including both



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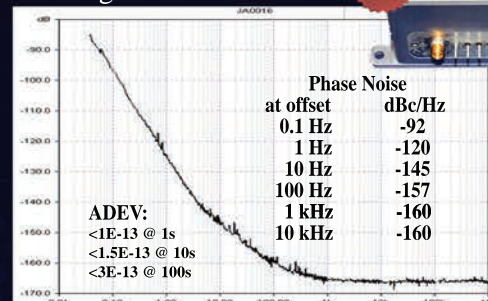


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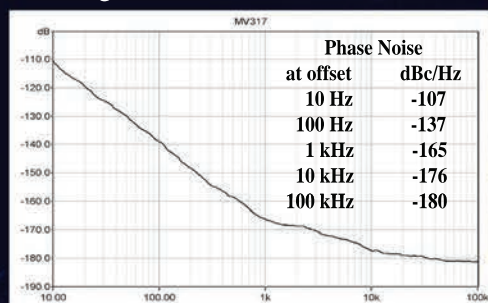
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**New**



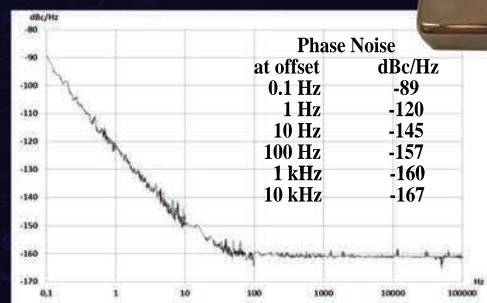
MV317 100 MHz, +5V/+12V

- Temperature Stability: 1E-8
- Aging:  $\pm 1E-7$  per year
- Package: 25.8x25.8x10.3 mm



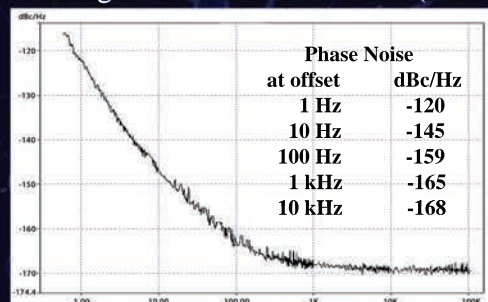
MV341 10 MHz

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



MV272M 10 MHz

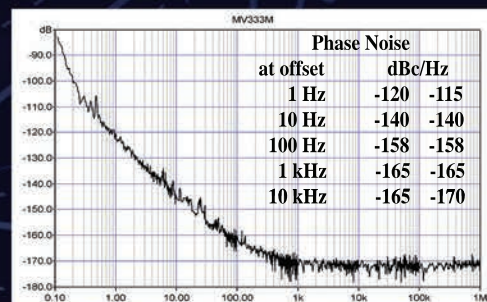
- Temperature Stability: 1E-9
- Allan Deviation:  $< 4E-13$  per sec.
- Package: 41.0 x 30.0 x 17.0 mm (SMD)



MV333M 10 MHz

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

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ATTENUATORS(UP TO 160GHz)  
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LIMITERS(UP TO 160GHz)  
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CABLES  
ASSEMBLIES/CONNECTORS (UP TO 100GHz)  
SUB-SYSTEMS (UP TO 100GHz)



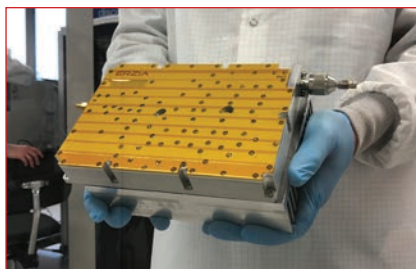
remote control of the USV and the execution of specific AUV missions controlled from the onshore command and control center.

## AMPLIFIERS

**ERZIA**, which has its headquarters in Santander, makes microwave and mmWave modular high-power and low-noise amplifiers, and also integrated subsystems, operating up to over 100 GHz. Its portfolio includes a range of standard amplifier modules, as well as offering customization for both amplifiers and high-specification integrated assemblies for aerospace, commercial, military and scientific systems.

Applications have included electronic warfare (EW) systems for a number of European defense system main integrators for land, air and naval platforms, and space-qualified amplifiers and systems have been supplied for missions such as LISA Pathfinder, Change 3 and 4, SEOSAR PAZ, Exomars and Venus Express. Another product line is long-range line-of-sight datalink systems for unmanned aerial vehicles (UAV) and combat aircraft, which has been flight qualified on F-16 fighters.

ERZIA will introduce at EuMW 2018 its latest product line of X-Band pulsed solid-state power amplifiers (SSPA) for radar applications. Based on GaN devices, the new SSPAs have output powers of 50, 100, 200 (see **Figure 5**) and 400 W, and are part of a range that already included CW SSPAs and space-qualified amplifiers at X-Band. The company will also give a presentation at the MicroApps seminar about its high-power X-Band amplifier design work.



▲ **Fig. 5** 200 W X-Band pulsed SSPA for radar applications, being launched by ERZIA at EuMW 2018.

## ANTENNAS

Barcelona-based **Fractus Antennas SL** designs, manufactures and commercializes miniature, off-the-shelf antennas for smartphones, short-range wireless and connected IoT devices. Founded as an independent antenna product business in 2015, Fractus Antennas was born out of the main Fractus operation, and combines a respected R&D team with proven manufacturing capabilities and scale to bring to market a new generation of antenna products to meet the mobile and wireless connectivity needs of OEMs. Fractus Antennas' most recent launch was a new reference design that explains how to use the TRIO mXTEND™ chip antenna component to get the GNSS and Mobile frequency bands at the same time. TRIO mXTEND™ is the newest member of the Virtual Antenna™ family and it is also the only one with a multiport configuration.

## RESEARCH CENTERS

The industrial and manufacturing base in Spain is supported by an active research base, both in universities and research institutions, many of which are involved in a number of EU-sponsored R&D programs.

The **Universidad Politécnica de Madrid** (UPM, Polytechnic University of Madrid) is the highest-ranked technical university in Spain, and, as well as its degree programs, it is very active in a number of EU projects in telecoms and microwave technology. Naturally, as the event is taking place this year in its home city, UPM has a number of representatives on the EuMW 2018 Organizing Committee.

**Ceit-IK4** is a non-profit research center that was set up in 1982 by the University of Navarra with a mission to work closely with the R&D departments of industrial clients to carry out applied research projects. It also has an academic role in training doctoral students within the framework of industrial research projects, and in publishing and disseminating non-confidential results. One of its projects is the IoTSpace initiative, an open laboratory to

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Tel: (408) 773-8855 Fax: (408) 773-8858



promote training and innovation in young researchers working on real-life projects related to the IoT.

## 25 YEARS ON

For an overview of the microwave industry in Spain, and how it has changed over the past 25 years, I spoke with Michael Chadwick of **SpanTech**, a specialist distributor of microwave components that was first launched onto the market at the 23<sup>rd</sup> EuMC in Madrid in 1993, and will celebrate its 25<sup>th</sup> anniversary by exhibiting at this year's event.


"The RF and microwave industry in Spain has changed beyond all recognition since 1993, when there was a limited market here, mostly for standard components. Now Spain is challenging the market in integrated systems as well as exporting leading-edge microwave components," said Chadwick.

In conclusion, the RF, microwave and mmWave market in Spain seems particularly buoyant at the moment, fueled by a growing level of European and global investment in satellite technology, which is one of Spain's traditional areas of excellence. In contrast to the 1993 exhibition, which was a small and somewhat niche event, the breadth of technology expected to be on show at EuMW 2018 reflects how much this core microwave expertise has spun out into telecoms and wireless. This has positioned Spain among the leaders in developing 5G technology, as well as retaining its status in aerospace and defense applications.

Company	EuMW Stand #
STONIC	Stand 284
Indra	Stand 16
TTI	Stand 248
Airbus DS-CASA Espacio	Stand 141
ERZIA	Stand 12
Tryo	Stand 214
Spantech	Stand 335

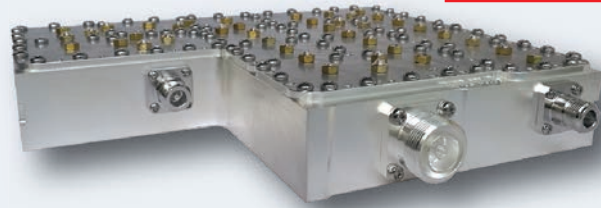
## Reference

1. Eutelsat Quantum, [http://news.eutelsat.com/blog\\_posts/four-things-you-should-know-about-eutelsat-quantum-69078](http://news.eutelsat.com/blog_posts/four-things-you-should-know-about-eutelsat-quantum-69078).

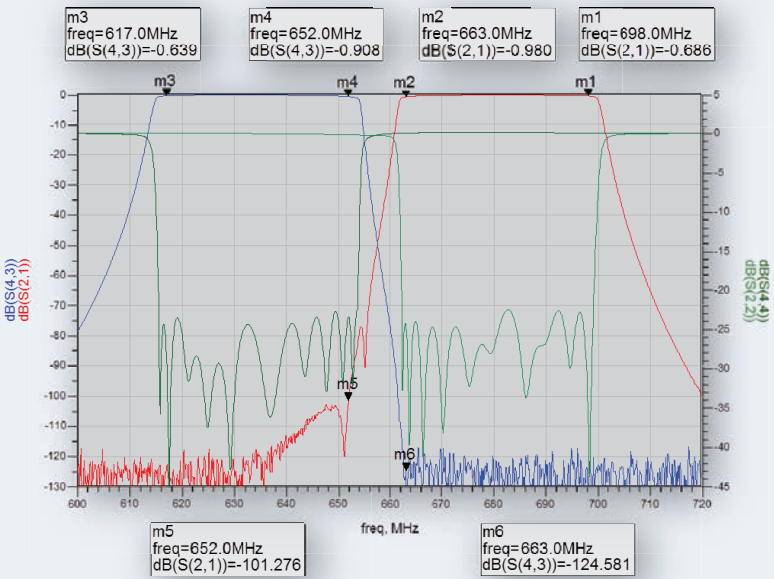


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For complete coverage of the EuMW 2018 conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show daily at [mwjournal.com/eumw2018](http://mwjournal.com/eumw2018).

CST

Stand 21

### VENDORVIEW CST STUDIO SUITE



CST STUDIO SUITE is a package of high performance software for the simulation of EM fields in all frequency bands. Its growing success is based on a combination of leading edge technology, user-friendly interface and knowledgeable support staff.

CST solutions are used by market leaders in a diverse range of industries including aerospace, automotive, defense, electronics, healthcare and telecommunications. CST is part of SIMULIA, a Dassault Systèmes brand.

[www.cst.com](http://www.cst.com)

Rohde & Schwarz  
GmbH & Co. KG

Stands 23, 26

### VENDORVIEW Automotive Radome Tester



Integrating automotive radar sensors into cars is very challenging. Radars operate behind bumpers, design emblems or other plastic parts. All radome materials

need to be sufficiently transparent and homogeneous for automotive radars. Rohde & Schwarz has developed the R&S QAR quality automotive radome tester, a tailored solution for radar integration testing. It is a mmWave imaging system operating in the E-Band automotive frequency range. Thanks to its spatially resolved reflection measurement capability, it provides a very intuitive yet powerful way to evaluate radome performance.

[www.rohde-schwarz.com](http://www.rohde-schwarz.com)

Maury Microwave

Stand 28

### Measurement and Modeling Device Characterization Solutions



Exceptional companies have superior labs—complete your lab with Maury Microwave! Maury, a leader in measurement and modeling device characterization solutions, VNA calibration accessories and interconnections, will be showcasing active

and hybrid-active harmonic load pull solutions, LXI™-certified mechanical impedance tuners, pulsed IV/RF compact transistor modeling as well as coaxial and waveguide VNA calibration kits and metrology adapters, in-stock color-coded precision and daily-use adapters and test-port, phase-stable and value cable assemblies. Visit the company for details, demos, deals and NPIS!

[www.maurymw.com](http://www.maurymw.com)

Copper Mountain Technologies Stand 35

### S5180 VNA



The S5180 VNA delivers lab grade performance in a compact package. This portable network analyzer can be battery powered and used in the field, in the laboratory, and in production testing. S5180 VNA includes an RF measurement module and software application which runs on a PC, laptop or tablet, connecting to the measurement hardware via USB interface. Software can be installed on multiple computers, making it easy to share the use of the analyzer measurement module.

[www.coppermountaintech.com](http://www.coppermountaintech.com)

NI AWR

Stand 101

### VENDORVIEW Design Environment V14



Visit Stand 101 to preview NI AWR Design Environment V14, featuring network synthesis for developing impedance matching circuits of multi-band amplifiers and more, enhanced

automation for editing imported PCB designs, new capabilities for EM analysis and an expanded phased-array/MIMO antenna wizard. The NI AWR Design Environment platform includes Visual System Simulator™ system design software, Microwave Office/Analog Office circuit design software and AXIEM and Analyst™ EM simulators. The broader NI AWR software portfolio also includes AntSyn™ antenna synthesis software and AWR Connected™ third-party solutions.

[www.ni.com/awr](http://www.ni.com/awr)

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

HUBER+SUHNER

Stand 130

### VENDORVIEW Multicoax Testing Solutions



HUBER+SUHNER offers a broad range of high-end RF test components and assemblies, developed and optimised for high

speed digital testing. Its latest MXPM multicoax testing solution is a pioneering and future-proof solution that supports testing up to 67 GHz (with option to 85 GHz). By offering a high density (2.5 mm) pitch, the MXPM guarantees a satisfying experience with its user-friendly magnet mount connection, making performance and reliability affordable. It allows eight or 16 channel measurements.

[www.hubersuhner.com](http://www.hubersuhner.com)

Ingun

Stand 130

### RF Test Solution for IoT & 5G



The HFS-856 series offers a reliable RF test solution for IoT and 5G applications. Unlike OTA measurements, the signal can

be tapped directly from the PC board. The mechanical sturdiness makes it suitable for harsh production environments. The test probes have particularly good, repeatably-accurate RF features. The VSWR is at least 1.3 in specified frequency ranges, the insertion loss is maximum 0.6 dB. A SMA connector or, for smaller grid sizes, a SMPM (-T) connector is used to connect the probes to the test system. A flange makes assembly in test fixtures especially easy. Tolerances are balanced out of by the test probe's floating mount. The modular design allows the test probes to be modified for other applications.

[www.ingun.com](http://www.ingun.com)

WIN Semiconductors USA

Stand 137

### 0.45 μm GaN Power Process for 5G Applications



WIN Semiconductors has expanded its GaN process capabilities to include a 0.45 μm-gate technology that supports current and future 5G

applications. The NP45-11 GaN on SiC process provides 50 V operation with superior power density and efficiency. It allows customers to design hybrid Doherty

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**Klystron Transmitters**  
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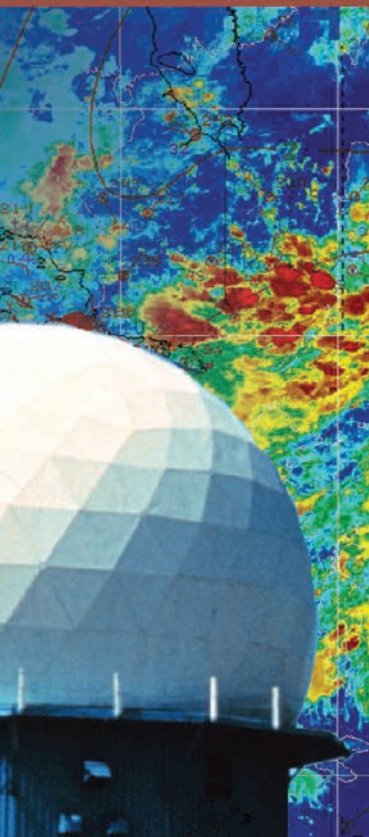
**Magnetron Transmitters**  
S, C, X, Ku - Bands

**TWT Transmitters**  
S, C, X, I/J - Bands

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C, X - Bands

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## RADAR & EW



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## EuMW PRODUCT SHOWCASE

power amplifiers used in 5G applications including massive MIMO wireless antenna systems. Similar to macro-cell applications, MIMO base stations often combine Doherty power amplifiers with linearization techniques to meet demanding linearity and efficiency specifications of today's wireless infrastructure.

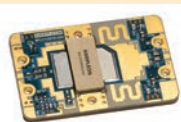
[www.winfoundry.com](http://www.winfoundry.com)

**RFMW**

**Stand 139**



### RF Energy Pallet Amplifier



Ampleon's BPC-2425M9X250Z Power Module offers 250 W CW power for RF cooking applications at 2450 MHz. With 61%

efficiency and 17 dB gain, this high efficiency module has integrated temperature sensing and bias temperature compensation networks. Operating from a 32 V supply, the input and output are matched to 50 ohms for ease-of-use, providing a cost effective solution with minimum design work and easy connectivity in multi-pallet applications.

[www.rfmw.com](http://www.rfmw.com)

**Cicor Group**

**Stand 140**

### DenciTec®



DenciTec® enables the production of very high-density circuits. DenciTec® makes further miniaturization possible. Possibilities

include line widths and spacings down to 25  $\mu\text{m}$  (1 mil) with copper thicknesses of 20  $\mu\text{m}$  (0.8 mil)  $\pm$  5  $\mu\text{m}$  on all conductive layers, laser-via diameters of 30  $\mu\text{m}$  (1.2 mil), annular rings of 30  $\mu\text{m}$  (1.2 mil) for the inner layers and 20  $\mu\text{m}$  (0.8 mil) for the outer layers. Cicor complements its spectrum of services with a solution that delivers highly miniaturized circuits of the highest reliability.

[www.cicor.com](http://www.cicor.com)

**Southwest Microwave**

**Stand 227**

### 1.85 mm PCB Compression Mount Connector

This new 1.85 mm (67 GHz) PCB compression mount connector requires no solder, is designed for microstrip or grounded coplanar designs and provides the superior performance only a Southwest Microwave



connector can offer. This connector can be vertically attached anywhere on the PCB surface and has no PCB thickness limitations. As with all Southwest Microwave PCB mount connectors, board layout assistance is available upon request.

[www.southwestmicrowave.com](http://www.southwestmicrowave.com)

**Focus Microwave Group**

**Stand 231**

### 2 kV Pulsed IV Characterization



Design and test engineers are looking for high performance, robust, narrow pulsed IV solutions. Auriga's new PHD2000-100 drain pulser head, available with the

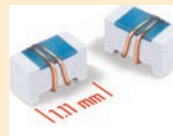
newly redesigned AU-5 Pulsed I-V measurement system, allows for pulsed DC characterization up to 2000 V and 100 A. This new high voltage offering is designed to meet the ever-changing requirements and is poised to handle the increasing demand from various industry verticals which include automotive, medical, industrial and telecommunications.

[www.focus-microwaves.com](http://www.focus-microwaves.com)

**Coilcraft**

**Stand 253**

### Ceramic Wirewound Chip Inductors



Coilcraft's new 0402DC Series ceramic wirewound chip inductors offer the industry's highest Q factors in an 0402

(1005) size—up to 162 at 2.4 GHz—for super low loss in high frequency circuits. They are offered in 26 standard inductance values ranging from 3 to 120 nH. An additional 73 values are available upon request, including 0.1 nH increments from 2.8 to 10 nH. Most values are available with 2 percent tolerance.

[www.coilcraft.com/0402dc.cfm](http://www.coilcraft.com/0402dc.cfm)

**SPINNER GmbH**

**Stand 266**



### Low PIM Switching Matrix



With the new SPINNER Low PIM Switching Matrix you can speed up testing in production, for

example of mobile communications antennas or filters. It lets you easily boost your output by concurrently measuring PIM and VSWR on separate test paths. And that is not all: thanks to the exceptional reliability of every measurement, you avoid having to frequently repeat tests to compensate for uncertain results. Visit SPINNER at Stand 266.

[www.spinner-group.com](http://www.spinner-group.com)

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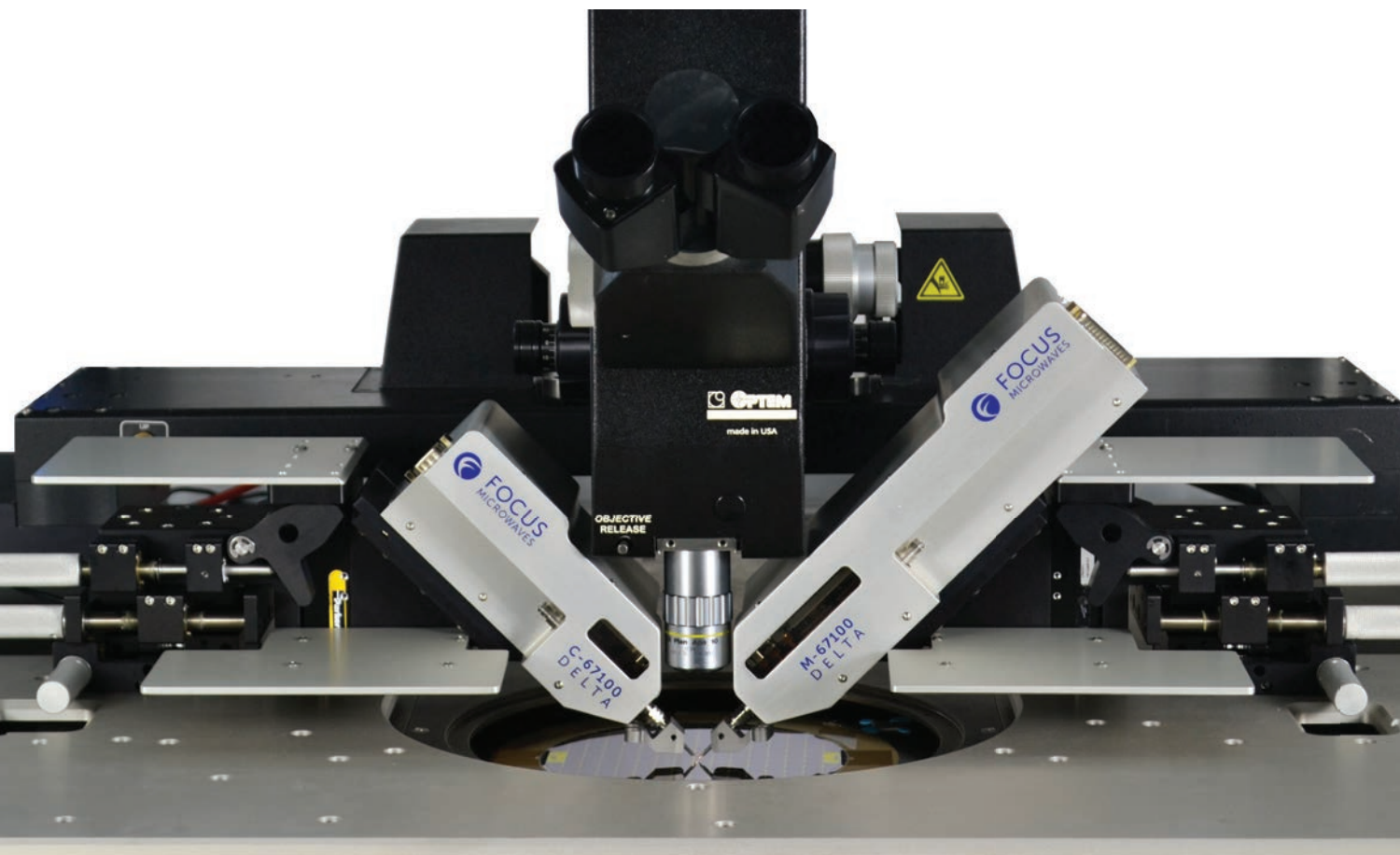
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## EuMW PRODUCT SHOWCASE

### Rosenberger

Stand 270

#### Test & Measurement



At EuMW 2018, Rosenberger highlights its latest test & measurement developments—equipment and devices for microwave and VNA measurements, calibration kits (full and industrial version), compact calibration kits such as MSO (open, short, load) and MSOT (open, short, load, thru), microwave cable assemblies and VNA test port cable assemblies, multiport mini-coax and spring loaded coax products for semiconductor testing or PCB connector systems. For aerospace applications the company provides coaxial connectors qualified according to ESCC and DIN EN 9100.

[www.rosenberger.com](http://www.rosenberger.com)

seals between center contact and outer conductor. This ensures complete hermeticity of the units. The adapters are normally used at vacuum chambers testing products that



are intended for outer space with the testing equipment and the personnel staying at regular environment. Available connector styles are 1.85 mm, 2.4 mm, 2.92 mm, N and TNC.

[www.spectrum-et.org](http://www.spectrum-et.org)

### Remcom

Stand 282

#### WaveFarer™ Automotive Radar Simulation Software



WaveFarer is a targeted software solution that simulates raw radar returns for drive test scenarios. High fidelity simulations predict scattered returns from a scene, with support for frequencies up to and beyond 79 GHz. Near-field propagation methods compute raw radar returns from target objects while considering multipath from

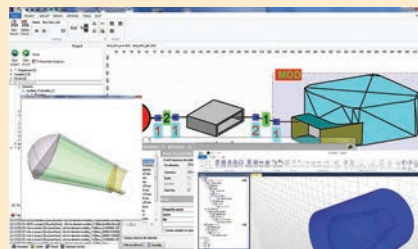
ground reflections. WaveFarer enables OEMs and Tier 1 suppliers to virtually test and refine results earlier in the design process, improving installed sensor performance.

[www.remcom.com](http://www.remcom.com)

### Mician GmbH

Stand 287

#### μWave Wizard Hybrid EDA Software Tools



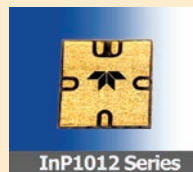
Mician, a developer of EM software tools for the analysis, synthesis and optimization of passive components like feeding networks, couplers, multiplexers and horn antennas, including reflectors, will show their μWave Wizard hybrid EDA software tools. The tools combine the flexibility of fast and powerful numerical methods with an appealing and ergonomic GUI that enables flexibility and openness including CAD export formats interfacing with most mechanical design tools.

[www.mician.com](http://www.mician.com)

### Teledyne Relays

Stand 299

#### Indium Phosphide HEMT RF Switch



InP1012 Series

Teledyne Relays introduces the InP1012-40, a new indium phosphide HEMT RF switch. This SPDT reflective switch has a 10 kHz to 40 GHz bandwidth, low insertion loss, high linearity and a switching time under 100 ns. The InP1012-40 can operate from -65°C to 125°C, tolerate up to 100 krads of radiation and its 9 mm<sup>3</sup> sized flip-chip packaging provides shock and vibration resistance. These features make this RF switch perfect for military and space applications, ATE systems and RF and microwave communication.

[www.teledynereleys.com](http://www.teledynereleys.com)

### Passive Plus Inc.

Stand 308

#### Capacitors

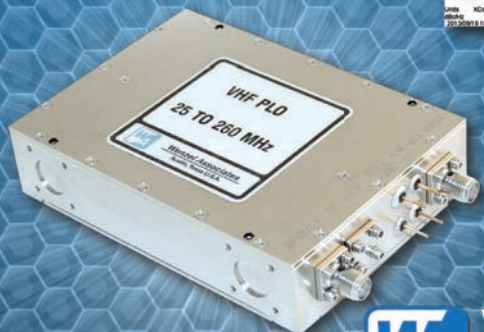
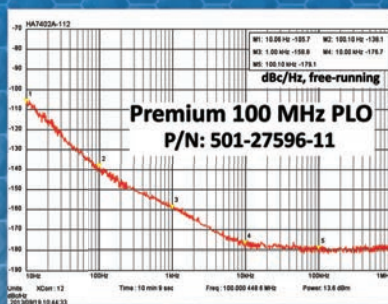


bandwidth, these capacitors have low ESR/ESL and high self-resonance. Uniquely

Passive Plus Inc. (PPI) is now offering the 0708N (0.065 in. x 0.080 in.) series capacitor. With vertical electrodes which increase

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It's host of features includes a 12-digit/s frequency counter, a DDS synthesized source with adjustable frequency and amplitude, built-in distribution amplifiers, and event time-tagging with respect to UTC or GPS.

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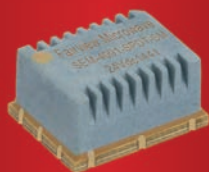
Waveguide



USB Controlled



Electromechanical



Surface Mount

- Coaxial, Waveguide and Surface Mount options available
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**Fairview Microwave**  
RF COMPONENTS ON DEMAND. *Done!*



## EuMW PRODUCT SHOWCASE

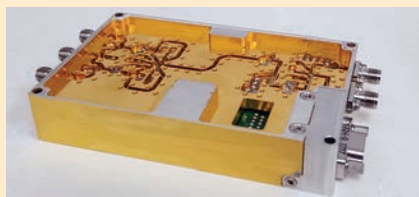
designed for excellent heat transfer in high RF applications, the 0708N offers ultra-stable performance over temperature. These capacitors are 100 percent RoHS compliant and also available in tin/lead termination.  
[www.passiveplus.com](http://www.passiveplus.com)

### Planar Monolithics Industries Inc.

Stand 321



### Matched Integrated Modules/Assemblies



These integrated modules are built in sets of four, and are phase and amplitude matched to industry leading levels of  $\pm 10$  percent change to  $\pm 10^\circ$  and  $\pm 1.5$  dB over the 0.5 to 18 GHz frequency range. Incorporating limiters, LNAs, switches and variable digital attenuators, these units allow for high and low gain paths, a calibration input and an auxiliary channel. A low noise figure and high output of +15 dBm OP1dB are achieved by utilizing system analysis software and in-house hybrid/MIC processes.

[www.pmi-rf.com](http://www.pmi-rf.com)

### AR RF/Microwave Instrumentation

Stand 333



### 0.7 to 18 GHz CW Dual Band Amplifiers



AR RF/Microwave put two of their state-of-the-art class A CW amplifiers in a single chassis, and now you can instantaneously go from 0.7 to 18 GHz with the reliability

of solid-state designs for EMC and EW applications. With up to 60 W in the first 0.7 to 6 GHz band split and up to 40 W output power in the 6 to 18 GHz split, the company put it together for you in one package that costs less, weighs less and takes up less space than two separate amplifiers.

[www.arwww-rfmicro.com/html/ps-dual-band-amplifiers.asp](http://www.arwww-rfmicro.com/html/ps-dual-band-amplifiers.asp)

### Dow-Key

Stand 337

### RF Matrix Systems



Dow-Key's ability to design and develop complex, high performance, high-power, custom RF matrix systems make them the ideal choice for communication and ATE applications.

Their standard switch matrix configurations are available in the DC to 40 GHz frequency range and are packaged in 19-in. rack-mountable enclosures with remote interface capabilities as well as a LCD touchscreen for easy control access. Dow-Key uses its own line of coaxial switches for these matrices, providing low loss and excellent isolation.

[www.dowkey.com](http://www.dowkey.com)

### K&L Microwave

Stand 337

### 7 Channel Switched Filter Bank



The 7SFB-225/Q512-0 is a 7 channel switched filter bank designed to filter spurious and harmonic content generated by high-power amplifiers

and transmitters in the UHF band. These interferers can degrade performance and even damage sensitive equipment. As communications band usage and amplifier technology power densities increase, this challenge becomes more formidable. K&L Microwave has leveraged core competencies in PIN diode based switches and high-power filters to develop a suite of high-power switched filter banks. Please consult the factory for custom filters, other bands or higher power levels.

[www.klmicrowave.com](http://www.klmicrowave.com)

### Holzworth Instrumentation

Stand 351



### Real-Time Phase Noise Analyzer



The HA7000 Series real-time phase noise analyzer products resolve the historical speed and accuracy issues in both R&D and high throughput

(ATE) manufacturing test environments. The HA7000 Series includes the HA7062C and the HA7402C Real-Time Engine. These versatile phase noise analyzers offer ease of test setup and high speed acquisition times without compromising on data accuracy or limitations in the measurement floor. An input range to 40 GHz and 100 MHz measurement offset capabilities will be demonstrated at EuMW 2018.

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# Software and Hardware Near-Field Transformations for 5G OTA Testing

Benoît Derat, Corbett Rowell, Adam Tankielun and Sebastian Schmitz  
Rohde & Schwarz, Munich, Germany

*Increased capacity in 5G mobile communications requires rolling out massive MIMO base stations with network and mobile terminals at both sub-6 GHz and mmWave frequencies. Dynamic beamforming and the absence of RF test ports on the devices being tested make over-the-air (OTA) measurement pivotal to 5G deployment. Fortunately, OTA testing solutions employing software and hardware near-field transformations are meeting the challenges.*

**5**G new radio (NR) communication systems will increase the capacity of mobile radio networks using frequency bands in the sub-6 GHz region, called frequency range 1 (FR1) by 3GPP, and the mmWave range (FR2). New technological approaches selected by the industry and 3GPP promise greater bandwidth at lower operational expense.

In FR1, the main innovation effort is focused on the base station, with the enabling of massive MIMO techniques.<sup>1</sup> 4G systems use single-user MIMO, where the user equipment (UE) calculates the inverse channel matrix to extract separate data streams. 5G multi-user MIMO (MU-MIMO) shifts the complexity from UEs to the base station by using a pre-coding matrix. Here, each data stream is received independently by separate receivers. Beamforming with antenna arrays of 64 to 512 elements reduces inter-

ference to adjacent users using MU-MIMO. In addition to facilitating the adoption of MU-MIMO to increase capacity, beamforming has other advantages. Its lower energy consumption brings a reduction in overall network operating costs by targeting individual UEs with their assigned signals.

Communication systems in the FR2 range use large available bandwidths at frequencies around 28 and 39 GHz. The impact is more than 60 dB path loss at 1 m distance and large electromagnetic field absorption in nearby objects. As with FR1 systems, the solution is to employ antenna arrays and beam steering, improving the gain on both the mobile device and base station sides of the network.

Whether for FR1 or FR2, 5G deployment relies on the performance of highly integrated solutions combining modem, RF front-end and antenna. The challenge

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is to define new methods and set-ups for performance evaluation, as RF test ports tend to disappear and beam steering technologies require system-level testing. In this context, both antenna and transceiver performance criteria must be measured OTA: effective isotropic radiated power (EIRP), total radiated power (TRP), effective isotropic sensitivity (EIS), total isotropic sensitivity (TIS), error vector magnitude (EVM), adjacent channel leakage ratio (ACLR) and spectrum emission mask (SEM). Assessing these OTA raises the critical question of the required measurement distance. Antenna characteristics are usually measured in the far field. Using direct far-field probing and applying the Fraunhofer distance criterion ( $R = 2D^2/\lambda$ ), a 75 cm massive MIMO device under test (DUT) radiating at 2.4 GHz should be evaluated in a chamber with at least 9 m range length. Even a 15 cm smartphone transmitting at 43.5 GHz needs a 6.5 m testing distance. This distance is required to create a region encompassing the

DUT where the impinging field is as uniform as possible and approaches a plane wave with phase deviation below 22.5 degrees, known as the quiet zone.

Research shows that actual far-field behavior in the peak directivity region can start much closer than the Fraunhofer distance.<sup>2</sup> These results proved, for example, that the far-field EIRP or EIS of a 15 cm DUT radiating at 24 GHz can be assessed at a distance as short as 1.14 m. Distance reduction of about 70 percent comes at the price of increased longitudinal taper error, caused by the deviation of the apparent phase center from the center of the measurement coordinate system. Also, sidelobe levels cannot be evaluated accurately at shorter distances.<sup>3</sup> While direct far-field measurements at shorter distances are not convenient for all applications, there is an incentive to do so when conditions of application are verified. This is because large OTA anechoic chambers have high costs of ownership and limited dynamic range. Typical

applications may be in the "white box" case, where the antenna location within the device and its aperture size are known.

### NEAR-FIELD TO FAR-FIELD

Direct far-field measurements under "white box" assumptions may be inappropriate when the radiation aperture is larger than the quiet zone, the antenna cannot be precisely identified within the DUT or multiple antennas transmit simultaneously, e.g., from two extreme edges of a DUT which does not fit within the quiet zone. The "black box" scenario must then be considered, where the radiating currents can flow anywhere within the DUT. A first efficient approach to treat such cases in a compact environment is to employ software near-field to far-field transformations (NF-FF), for which the quiet zone size question becomes irrelevant. Mathematical implementations of NF-FF may vary, but the concept is generally the same: at least two polarization components of the electromagnetic field (E, H or a mixture of the two) are measured in magnitude and phase over a surface encompassing the DUT. The measured data is processed using functions to propagate the fields toward larger distances and extract far-field radiation components. From the Huygens principle, the knowledge of two phasors is enough to reconstruct exactly all six field components outside the surface. Alternative transformation methods use spherical wave expansion, plane wave expansion or integral equation resolution, with techniques to improve computational efficiency or accuracy by taking parameters such as spatial sampling rate, scanning area or truncation into account.

**Figure 1** shows a commercial system capable of both direct far-field and near-field measurements with spherical scanning around the DUT using a conical cut positioner. On this system, the DUT is positioned on a turntable rotating in azimuth, while a dual-polarized Vivaldi antenna is mounted at the tip of a boom rotating in elevation. An RF test port available at the DUT connects one port of a vector network analyzer (VNA); the measurement antenna

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**CMD283C3**

**2 to 6 GHz**

## Ultra Low Noise Amplifier

Gain .....	27 dB
Noise Figure .....	0.6 dB
Output P1dB .....	16 dBm
Output Psat .....	18 dBm
OIP3 .....	26 dBm
Bias Voltage Vdd/Vgg .....	+2 to +5/+1.5 V
Bias Current .....	42 mA



**CMD280**

**DC to 30 GHz**

## Digital Attenuator

Number of Bits .....	5
Insert. Loss .....	.3 dB
Attn Range .....	15.5 dB
Input P0.1dB .....	24 dBm
Input IP3 .....	42 dBm
Control Voltage .....	0/-5 V



**CMD215**

**DC to 40 GHz**

## SPDT Reflective Switch

Insertion Loss .....	2.3 dB
Isolation .....	36 dB
Input P1dB .....	19 dBm
Return Loss .....	16 dB
Switch Speed .....	4 ns
Control Voltage .....	0/-5 V



**CMD240P4**

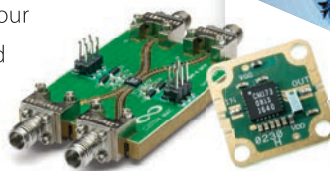
**DC to 22 GHz**

## Distributed Amplifier

Gain .....	15 dB
Noise Figure .....	2.2 dB
Output P1dB .....	19 dBm
Output Psat .....	22 dBm
OIP3 .....	28 dBm
Bias Voltage .....	+5 to +8/-0.65 V

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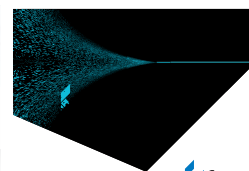
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## Low Noise Amplifiers (LNAs)

Part Number	Frequency (GHz)	Gain (dB)	Noise Figure (dB)	Output P1dB (dBm)	Output Psat (dBm)	OIP3 (dBm)	Bias Voltage (V)	Bias Current (mA)	Package
CMD228	2 - 6	30	1.2	12	14	23	3-5 / 3-5	45	DIE
CMD283C3	2 - 6	27	0.6	16	18	26	2-5	42	3x3 QFN
CMD228P4	2 - 6	28	1.5	13	14	25	3-5 / 3-5	45	4x4 QFN
CMD276C4 (GaN)	2.6 - 4	14.5	1.2	25.5	28	32	5-28 / -1.5	225	4x4 QFN
CMD185	4 - 8	15.5	1.9	15	17	29	2-5	75	DIE
CMD185P3	4 - 8	15.5	1.9	15	17	29	2-5	75	3x3 QFN
CMD270	4 - 8	15.5	1.8	16	17	30	2-5	60	DIE
CMD270P3	4 - 8	15.5	1.8	16	17	30	2-5	60	3x3 QFN
CMD219 (GaN)	4 - 8	23	1.0	18	26	28	5-28 / -2.3	75	DIE
CMD219C4 (GaN)	4 - 8	22.5	1.0	17	25.5	28	5-28 / -2.3	75	4x4 QFN
CMD277C4 (GaN)	5 - 7	20	1.2	26.5	29.5	33.5	5-28 / -1.5	200	4x4 QFN
CMD119P3	5 - 9	22	1.2	11	13	21	2-4.5	30	3x3 QFN
CMD218 (GaN)	5 - 9	22	1.1	21.5	26	30	5-28 / -2.7	80	DIE
CMD229	5 - 11	27	1.4	13	15	25	3-5 / 3-5	45	DIE
CMD229P4	5 - 11	26	1.5	13	15	24	3-5 / 3-5	45	4x4 QFN
CMD132	5 - 11	23	1.4	10	13	22	2-4.5	30	DIE
CMD132P3	5 - 11	21	1.4	10	13	22	2-4.5	30	3x3 QFN
CMD263	5 - 11	23	1.4	11	15	23	2-4.5	35	DIE
CMD263P3	5 - 11	22	1.4	11	15	21	2-4.5	35	3x3 QFN
CMD222	5 - 11	22	1.2	11	14	23	2-5	107	DIE
CMD186P3	6 - 11	18.5	2.1	17	20	28	2-5	78	3x3 QFN
CMD157	6 - 18	26	1.5	11	13.5	23	2-4.5	52	DIE
CMD157P3	6 - 18	26	1.5	11	13.5	23	2-4.5	52	3x3 QFN
CMD264	6 - 18	26	1.5	13	15	27	2-4.5	63	DIE
CMD264P3	6 - 18	26	1.7	13	15	24	2-4.5	63	3x3 QFN
CMD194	6 - 20	20	2.0	15.5	16.5	26	2-5	120	DIE
CMD194C3	6 - 20	20	2.0	15.5	16.5	26	2-5	120	3x3 QFN
CMD278C4 (GaN)	8 - 12	15	1.8	28	30	33	5-28 / -1.5	280	4x4 QFN
CMD167P3	8 - 16	16	1.8	11	13	23	2-4	50	3x3 QFN
CMD223	9 - 18	22	1.5	13.5	16	22.5	3-5	93	DIE
CMD161	10 - 14	19	1.05	5	12		2-4 / 1.5	20	DIE
CMD189P3	10 - 14	19	1.4	4	7	13	1-4 / 1.5	20	3x3 QFN
CMD159	10 - 17	26	1.1	4	10	14	2-4 / 1.5	29	DIE
CMD167	10 - 17	15	2.0	11	13	24	2-4	55	DIE
CMD224	16 - 26	23	2.2	7	13	18	2-5	110	DIE
CMD160	17 - 25	26.5	1.4	8	11	16	2-4 / 1.5	26	DIE
CMD160C4	17 - 25	26.5	1.6	8	11	16	2-4 / 1.5	26	4x4 QFN
CMD163	17 - 27	24	1.3	19	20	26	2-4 / 3	120	DIE
CMD163C4	17 - 27	23	1.7	18	19	26	2-4 / 3	120	4x4 QFN
CMD162	26 - 34	22	1.7	7	9	14	1-4	25	DIE
CMD188	26 - 34	20	1.4	6	8	15	1-4 / 2	20	DIE
CMD190	33 - 45	19	2.1	4	7	13	1-4 / 2	25	DIE

## NEW PRODUCT

## Low Phase Noise Amplifiers (LPNAs)

Part Number	Frequency (GHz)	Phase Noise (dBc/Hz @ 10kHz)	Gain (dB)	Output P1dB (dBm)	Output Psat (dBm)	OIP3 (dBm)	Bias Voltage (V)	Bias Current (mA)	Package
CMD245	6 - 18	-165	18	18	22	29	3-5 / 3	76	DIE
CMD245C4	6 - 18	-165	18	18	22	29	3-5 / 3	76	4x4 QFN
CMD274P4	2 - 20	-165	17	19	22	30	5 / 3	86	4x4 QFN
CMD246	8 - 22	-165	17	13	18	25	3-5 / 3	48	DIE
CMD246C4	8 - 22	-165	17	13	18	25	3-5 / 3	48	4x4 QFN
CMD275P4	DC - 26.5	-165	16	18	20.5	29	5 / 3	74	4x4 QFN
CMD247	30 - 40	<-160	13	13.5	15	21	2-4 / 2-3	28	DIE

## NEW PRODUCT

## Distributed Amplifiers

Part Number	Frequency (GHz)	Gain (dB)	Noise Figure (dB)	Output P1dB (dBm)	Output Psat (dBm)	OIP3 (dBm)	Bias Voltage (V)	Bias Current (mA)	Package
CMD173	DC - 20	15	2	18	20	28	5-8 / 3	78	DIE
CMD173P4	DC - 20	15	2	18	20	28	5-8 / 3	78	4x4 QFN
CMD192	DC - 20	19.5	1.9	24.5	26	31	5-8 / -1	200	DIE
CMD192C5	DC - 20	19.5	1.9	24.5	26	31	5-8 / -1	200	5x5 QFN
CMD201	DC - 20	12	3.4	29	30	38	10/-0.5/5	400	DIE
CMD201P5	DC - 20	11	3.4	27	30	38	10/-0.5/5	400	5x5 QFN
CMD249	DC - 20	13	3.4	30	31	38	10/-0.95	400	DIE
CMD249P5	DC - 20	13	3.4	30	31	38	10/-0.95	400	5x5 QFN
CMD233	2 - 20	9	4.5	20.5	22	24	3-6	120	DIE
CMD233C4	2 - 20	9	4.5	20.5	22	24	3-6	120	4x4 QFN
CMD238	2 - 20	14	4.5	26	27	34	5-8	360	DIE
CMD241	2 - 22	13.5	2.3	21	23	28	5-8/-0.65	74	DIE
CMD241P4	2 - 22	13.5	2.3	21	23	28	5-8/-0.65	74	4x4 QFN
CMD197	1 - 24	16	2.5	22	24	32	5-8	225	DIE
CMD197C4	1 - 24	16	2.5	24	25	31	5-8	225	4x4 QFN
CMD240	DC - 22	15	2.2	19	22	28	5-8/-0.65	80	DIE
CMD240P4	DC - 22	15	2.2	19	22	28	5-8/-0.65	80	4x4 QFN
CMD244	DC - 24	18	2.5	25	26.5	32	5-8 / -0.65	185	DIE
CMD242	DC - 40	11	4.4	18	21	27	5-8 / -0.32	100	DIE
CMD206	DC - 50	11	3.5	12	14.5	22	4 / 3	32	DIE

## NEW PRODUCT

## Driver Amplifiers

Part Number	Frequency (GHz)	Gain (dB)	Noise Figure (dB)	Output P1dB (dBm)	Output Psat (dBm)	OIP3 (dBm)	Bias Voltage (V)	Bias Current (mA)	Package
CMD231	2 - 6	14.5	4.5	13.5	16.5	23.5	3-8	45	DIE
CMD231C3	2 - 6	14.5	4.5	13.5	16.5	23.5	3-8	45	3x3 QFN
CMD232	2 - 9	15	4.5	17	18.5	23	5-6	90	DIE
CMD232C3	2 - 9	15	4.5	17	18.5	23	5-6	90	3x3 QFN
CMD191C4	4 - 10	20	4.5	21.5	22.5	30	5	123	4x4 QFN
CMD158	6 - 16	20	3.5	20	21	26	3-6	95	DIE
CMD158P3	6 - 14	19.5	4	19.5	20.5	26.5	3-6	95	3x3 QFN
CMD158C4	6 - 16	21	4	20	21	26	3-6	95	4x4 QFN



## NEW PRODUCT

Driver Amplifiers *Continued*

Part Number	Frequency (GHz)	Gain (dB)	Noise Figure (dB)	Output P1dB (dBm)	Output Psat (dBm)	OIP3 (dBm)	Bias Voltage (V)	Bias Current (mA)	Package
CMD200	9 - 13	15.5	3.25	15.5	17	20.5	5	38	DIE
CMD187	2 - 20	22.5	6	14	16	29	3 / 2	115	DIE
CMD187C4	2 - 20	22.5	6	13	16	29	3 / 2	115	4x4 QFN
CMD166	20 - 40	9	4.5	17	18	27	2-4	76	DIE
CMD207	20 - 40	35	5.5	18.5	21	29	4 / 3	270	DIE
CMD199	26 - 35	15	3.5	19.5	21.5	24.5	5	72	DIE
CMD243	26 - 35	15.5	4.4	21	22.5	26	3-5	90	DIE

## NEW PRODUCT

## Power Amplifiers (PAs)

Part Number	Frequency (GHz)	Gain (dB)	Noise Figure (dB)	Output P1dB (dBm)	Output Psat (dBm)	OIP3 (dBm)	Bias Voltage (V)	Bias Current (mA)	Package
CMD169P4	5 - 7	19	6.5	28.4	29.4	37	7 / 3	375	4x4 QFN
CMD170P4	7.5 - 9	30	6.5	28.3	29	34	7 / 3	365	4x4 QFN
CMD171P4	9.5 - 11	21	6.5	28.4	29	35	7 / 3	380	4x4 QFN
CMD216 (GaN)	14 - 18	16		37	38	43	28 / -3.4	550	DIE
CMD262 (GaN)	26 - 28	26		37.5	38.5		28 / -4	400	DIE
CMD217 (GaN)	28 - 32	20		36.7	39.3	41	28 / -3.4	580	DIE
CMD184 (GaN)	0.5 - 20	13		34.5	36.5	42	28 / -2.8/10	700	DIE
CMD201	DC - 20	12	3.4	29	30	38	10/-0.5/5	400	DIE
CMD201P5	DC - 20	12	3.4	27	30	38	10/-0.5/5	400	5x5 QFN
CMD249	DC - 20	13	3.4	30	31	38	10/-0.95	400	DIE
CMD249P5	DC - 20	13	3.4	30	31	38	10/-0.95	400	5x5 QFN

## NEW PRODUCT

## Voltage Variable Attenuators

Part Number	Frequency (GHz)	Insertion Loss (dB)	Attn Range (dB)	Input P1dB (dBm)	Input IP3 (dBm)	Return Loss (dB)	Control Voltage (V)	Max. Power (dBm)	Package
CMD172	18 - 40	1.6	37	15	25	12	0 / -3	30	DIE

## NEW PRODUCT

## Digital Attenuators

Part Number	Frequency (GHz)	Insertion Loss (dB)	Attn Range (dB)	Input P0.1dB (dBm)	Return Loss (dB)	Control Voltage (V)	Number of Bits	Package
CMD279	2 - 30	3.5	15.5	27	42	0 / +5	5	DIE
CMD279C3	2 - 18	3.5	15.5	27	42	0 / +5	5	3x3 QFN
CMD280	DC - 30	3	15.5	24	42	0 / -5	5	DIE
CMD280C3	DC - 18	3	15.5	24	42	0 / -5	5	3x3 QFN
CMD281	DC - 40	1.2	6	28	42	0 / -5	2	DIE
CMD281C3	DC - 18	1.2	6	28	42	0 / -5	2	3x3 QFN
CMD282	DC - 40	1.5	12	23	42	0 / -5	2	DIE
CMD282C3	DC - 18	1.5	12	23	42	0 / -5	2	3x3 QFN

## NEW PRODUCT

## Switches (Non-Reflective)

Part Number	Part Description	Frequency (GHz)	Insertion Loss (dB)	Isolation (dB)	Input P1dB (dBm)	Return Loss (dB)	Switch Speed (nS)	Control Voltage (V)	Package
CMD272P3	DPDT	DC - 10	1	43	25	14	4	0 / +5	3x3 QFN
CMD273P3	DPDT	DC - 12	1.7	42	25	13	12	0 / +5	3x3 QFN
CMD204	SPST	DC - 20	1	50	25	17	1.8	0 / -5	DIE
CMD204C3	SPST	DC - 20	1.3	48	25	15	1.8	0 / -5	3x3 QFN
CMD230	SPDT (refl)	DC - 26	1.4	40	21	16	3.4	0 / -5	DIE
CMD195C3	SPDT	DC - 18	2	37	25	13	1.8	0 / -5	3x3 QFN
CMD196C3	SPDT	DC - 18	1.5	46	23	17	1.8	0 / -5	3x3 QFN
CMD195	SPDT	DC - 20	2	41	25	17	1.8	0 / -5	DIE
CMD196	SPDT	DC - 28	1.75	46	23	15	1.8	0 / -5	DIE
CMD234C4	SP3T	DC - 15	2	40	21	9	66	0 / -5	4x4 QFN
CMD203	SP4T	DC - 20	2.4	39	21	9	66	0 / -5	DIE
CMD203C4	SP4T	DC - 20	2.4	39	21	9	66	0 / -5	4x4 QFN
CMD235C4	SP5T	DC - 18	2.5	40	21	9	66	0 / -5	4x4 QFN
CMD236C4	SP6T	DC - 18	2.5	42	18	9	60	0 / -5	4x4 QFN
CMD215	SPDT (refl)	DC - 40	2.3	36	19	16	4	0 / -5	DIE

## NEW PRODUCT

## Mixers

Part Number	Part Description	Freq. LO / RF (GHz)	Freq. IF (GHz)	LO Drive (dBm)	Conver. Gain (dB)	LO-RF Isolation (dB)	LO-IF Isolation (dB)	Input IP3 (dBm)	Package
CMD251C3	Fund. Mixer	4 - 8.5	DC - 2.2	+17	-7	45	36	21	3x3 QFN
CMD252C4	I/Q / IRM	4 - 8	DC - 2.4	+20	-6.5	52	27	25	4x4 QFN
CMD182	I/Q / IRM	6 - 10	DC - 3.5	+15	-6	46	20	18	DIE
CMD182C4	I/Q / IRM	6 - 10	DC - 3.5	+15	-6	46	20	18	4x4 QFN
CMD257C4	I/Q / IRM	6 - 10	DC - 3.5	+21	-5.5	40	18	25	4x4 QFN
CMD177	Fund. Mixer	6 - 14	DC - 5	+13	-6.5	43	37	16	DIE
CMD177C3	Fund. Mixer	6 - 14	DC - 5	+13	-6.5	43	37	16	3x3 QFN
CMD253C3	Fund. Mixer	6 - 14	DC - 5	+19	-6	43	39	23	3x3 QFN
CMD183C4	I/Q / IRM	7.5 - 13	DC - 4.5	+15	-5.5	43	23	18	4x4 QFN
CMD258C4	I/Q / IRM	7.5 - 13	DC - 3.5	+21	-5.5	38	20	25	4x4 QFN
CMD178C3	Fund. Mixer	11 - 21	DC - 6	+13	-6	45	45	16	3x3 QFN
CMD254C3	Fund. Mixer	11 - 21	DC - 6	+19	-6	48	44	22	3x3 QFN
CMD179	Fund. Mixer	16 - 26	DC - 9	+13	-6.5	40	48	17	DIE
CMD179C3	Fund. Mixer	16 - 26	DC - 9	+13	-6.5	40	48	17	3x3 QFN
CMD255C3	Fund. Mixer	16 - 26	DC - 9	+19	-6.5	40	33	24	3x3 QFN
CMD180	Fund. Mixer	20 - 32	DC - 10	+13	-7	36	36	18	DIE
CMD180C3	Fund. Mixer	20 - 32	DC - 10	+13	-7	36	36	18	3x3 QFN
CMD181	Fund. Mixer	26 - 45	DC - 12	+17	-6.5	37	29	22	DIE
CMD261	Fund. Mixer	30 - 46	5 - 20	+19	-8	30	20	21	DIE



## NEW PRODUCT

## Multipliers

Part Number	Part Description	Input Freq. (GHz)	Output Freq. (GHz)	Input Power (dBm)	Output Power (dBm)	Fo Isolation (dB)	3 Fo Isolation (dB)	Package
CMD225	Passive Freq. Doubler	4 - 8	8 - 16	15	3	48	50	DIE
CMD225C3	Passive Freq. Doubler	4 - 8	8 - 16	15	3	48	50	3x3 QFN
CMD226	Passive Freq. Doubler	7 - 11	14 - 22	15	5	44	46	DIE
CMD226C3	Passive Freq. Doubler	7 - 11	14 - 22	15	5	44	46	3x3 QFN
CMD227	Passive Freq. Doubler	8 - 15	16 - 30	15	4	40	43	DIE
CMD227C3	Passive Freq. Doubler	8 - 15	16 - 30	15	4	40	43	3x3 QFN
CMD214	Active Freq. Doubler	12 - 18	24 - 36	13	17	32	25	DIE
CMD213	Active Freq. Doubler	15 - 20	30 - 40	17	17	46		DIE
CMD256	Passive Freq. Doubler	14 - 20	28 - 40	15	0	38		DIE

## NEW PRODUCT

## Phase Shifters

Part Number	Frequency (GHz)	Number of Bits	Bit Resolu. (deg)	Insert. Loss (dB)	Return Loss (dB)	Phase Error (deg)	Input P1dB (dBm)	Input IP3 (dBm)	Package
CMD175P4	2 - 4	5	11.25	7	17	+/- 5	24	37	4x4 QFN
CMD174	3 - 6	5	11.25	7.6	15	+/- 2	26	36	DIE
CMD174P4	3 - 6	5	11.25	7.6	15	+/- 2	26	36	4x4 QFN
CMD176P4	13 - 17	4	22.5	8	14	+/- 5	26	41	4x4 QFN



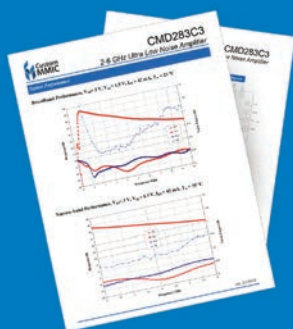
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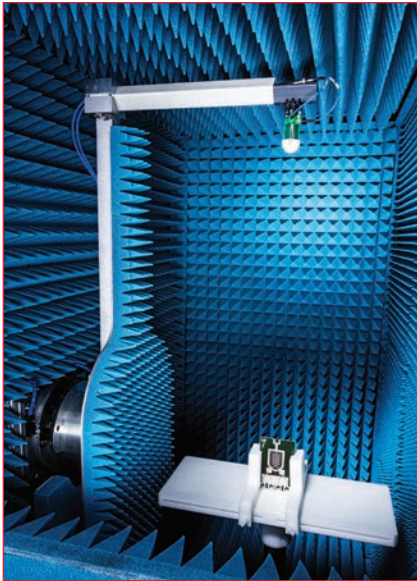
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**Fig. 1** Spherical measurement system (ATS 1000), capable of near-field software transformation, measuring a 28 GHz array.

ports connect to two other terminals of the VNA, enabling near-field assessment through measurements of complex S-parameters.

Near-field measurement methods often rely on underlying as-

sumptions about passive or RF-fed antenna testing:

- The antenna feed port is accessible with a signal fed to the antenna that is used as a phase reference.
- The RF signal is a continuous wave signal.
- Reciprocity applies so that transmit (Tx) and receive (Rx) patterns at the same frequency are identical.

There are workarounds available in Tx cases where such assumptions do not apply. For example, techniques can address the case of a DUT transmitting a modulated signal with no access to the antenna feed port. Hardware and processing implementations to retrieve the propagation phase vary, for example using interferometric techniques or multi-port phase coherent receivers<sup>4</sup> with the addition of a dedicated phase reference antenna. For systems like those in Figure 1, this antenna is typically attached to the azimuth turntable. Alternative approaches include phaseless meth-

ods when the phase information is retrieved from magnitude measurements.

However, the Rx mode is more complex. First, the reciprocity assumption does not apply to mobile phone and base station devices, as the Rx RF component chain is, in general, different from the Tx RF chain. For a DUT with no test port, the power available at the Rx input of the RF front-end generated by an impinging wave coming from the probe antenna (here used as the transmitter) cannot be straightforwardly predicted in the near field. In other words, it is not possible to isolate the intrinsic receiving properties of the DUT in the far field from near-field coupling effects resulting from the test setup. There is also no access to a phase reference, so the NF-FF software transformation becomes inapplicable. Therefore, EIRP can be evaluated accurately in the near-field using NF-FF software but not EIS.

### TRANSCIVER PERFORMANCE MEASUREMENTS

Another key question is the OTA evaluation of radio transceiver performance, such as EVM, ACLR or SEM. Software NF-FF approaches are designed for processing periodic portions of the RF signal (the carriers) that determine propagation. However, this part of the signal is of no interest to assess these performance parameters, so the challenge is to extract information from the carrier modulation.

The first difficulty is that these quantities depend strongly on the signal-to-noise ratio (SNR) at the receiver (a spectrum analyzer in the Tx mode or the DUT in the Rx mode). This can be overcome by first assessing the complete 3D Tx or Rx pattern to determine the peak direction. Demodulation and EVM or other measurements can then be conducted at this specific location. The question remains whether the obtained values are reliable and reflect the results obtained in the far field. In the case of a single transceiver, the near-field EVM must be the same as the far-field EVM so long as the SNR is above a certain threshold dependent on modulation scheme, e.g., better than

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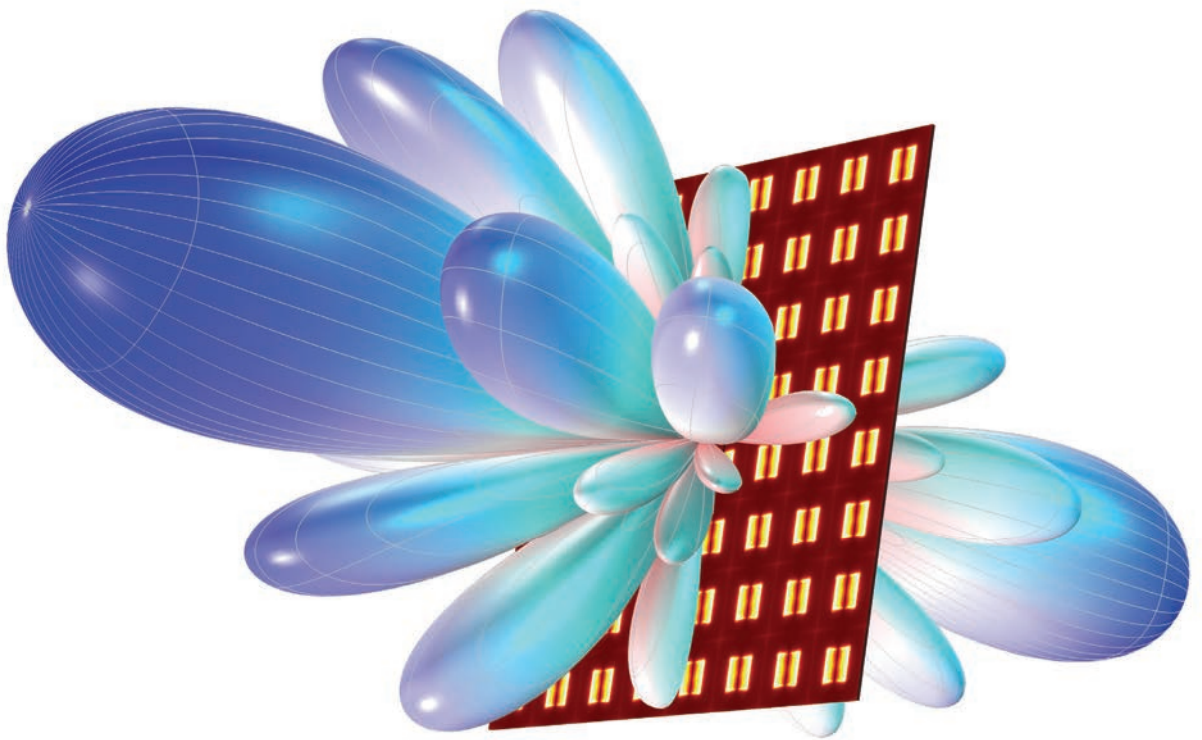
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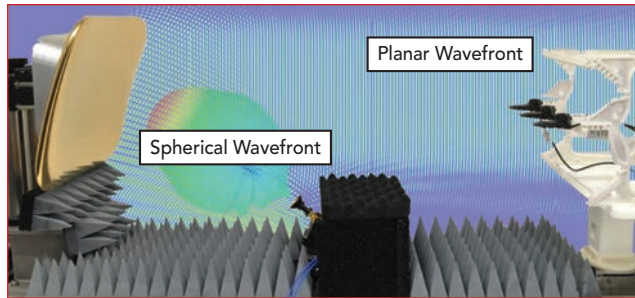


## TechnicalFeature

20 dB. For multiple independent transceivers operating simultaneously, the near-field EVM may not be straightforwardly related to the far-field EVM because of positional dependence of the noise figure in the near field.

### HARDWARE NEAR-FIELD TRANSFORMATIONS

Alternative testing methods enable OTA assessment in the near field without a software transformation, rather a hardware-based one. The idea is to physically create far-field conditions in a specified quiet zone region within a short range. This is known as "indirect far field." A compact antenna test range (CATR) uses a mirror to transform a spherical wave into a planar wave and vice-versa. Using Fermat's principle of least time, a planar wave can be focused on a single point using a parabolic mirror. If a measurement antenna is placed at this focal point, using the reciprocity principle, a plane wave can be generated as the parabolic mirror



▲ Fig. 2 Compact antenna test range with a roll-edge reflector collimating a spherical wavefront into a planar wavefront.

reflects a certain planar component of the incoming spherical wave from the measurement (or feed) antenna into the quiet zone where the DUT is placed (see **Figure 2**).

The error inside a CATR system comes from two main sources: the mirror geometry—the edge treatment and smoothness of the surface which limit the frequency range—and the feed antenna characteristics. If the reflector is built with a simple parabolic section, the sharp edges cause diffraction, which significantly contaminates the quiet

zone by producing ripples as large as 2 dB. Techniques to mitigate this phenomenon include serrations and rolled edges to scatter the energy away from the quiet zone. The size and shape of the serrated/rolled edges determine the lowest operating

frequency, where the surface roughness determines the upper frequency. Feed antenna pattern characteristics have a direct impact on the size of the quiet zone, as the mirror essentially projects the radiation pattern of the feed antenna onto the quiet zone. The reflector size with serrated/rolled edges is generally at least 2× the DUT/quiet zone size, where a reflector with sharp edges is 3 to 4× the size of the quiet zone. The optimum reflector to DUT separation distance is  $(5/3) \times$  the focal length of the reflector. An optimal focal length can be derived from the manufacturing shape tolerances with a range of roughly 0.3 to 1 for the ratio of focal length to parabolic diameter.

Since the quiet zone size is dependent on the reflector characteristics instead of range length, it is much easier to create a large quiet zone inside small enclosures. **Figure 3** shows the measured magnitude quiet zone size of 27 cm at 28 GHz of a CATR, similar to the one shown

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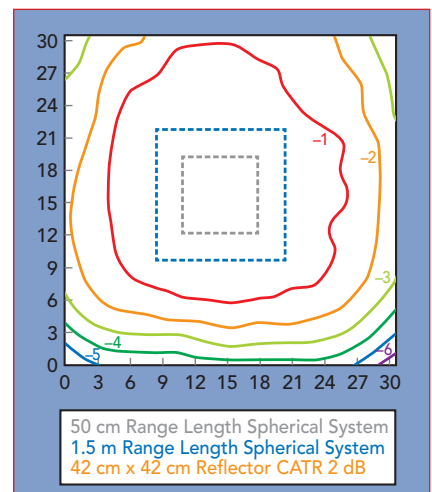


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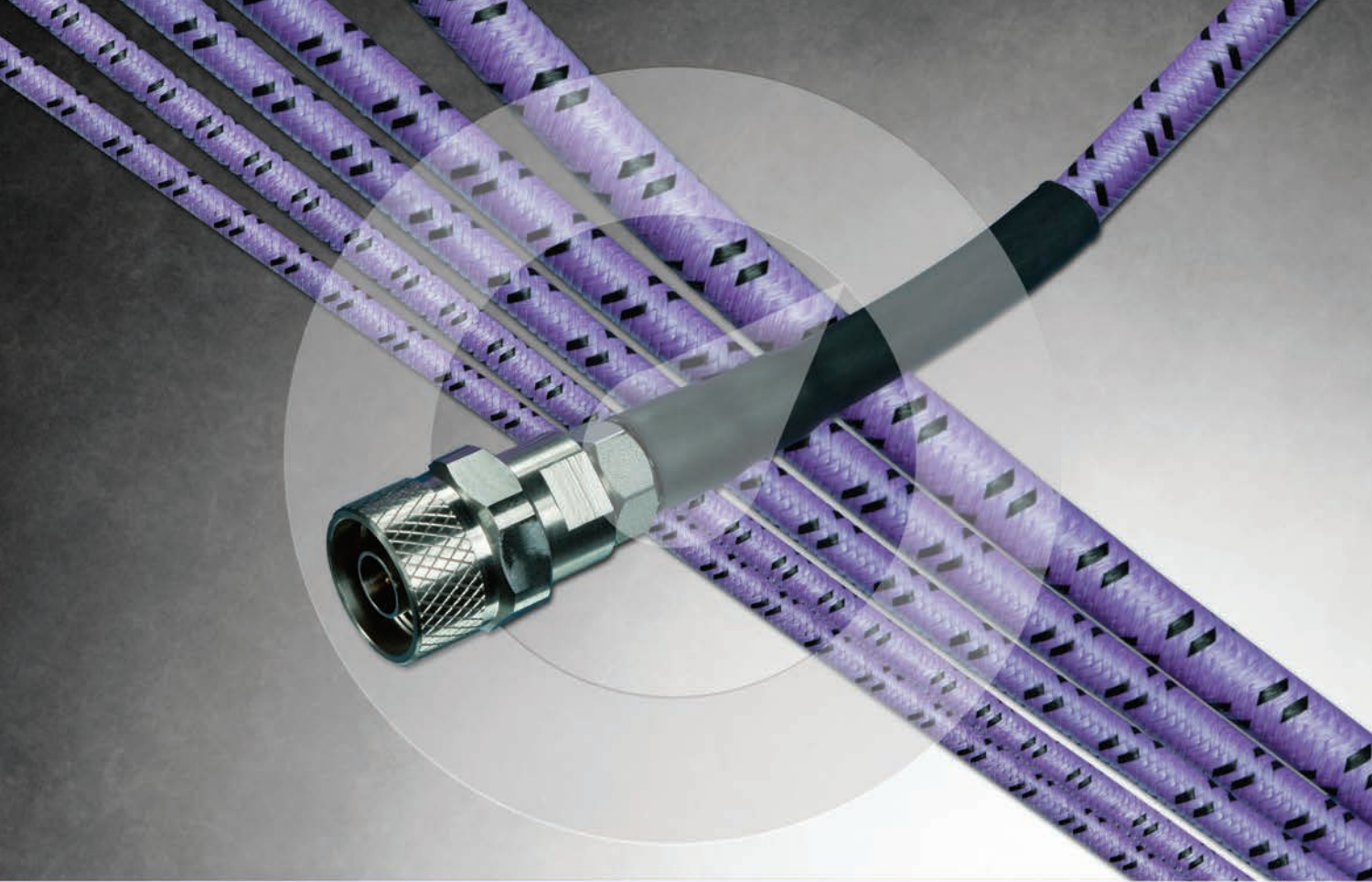


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▲ Fig. 3 28 GHz, 2 dB amplitude taper quiet zones for a roll-edge compact range system vs. direct far-field systems.



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in Figure 2, with a 42 cm × 42 cm reflector. This CATR setup fits within a chamber as small as 2 m × 1.5 m × 0.85 m. A direct far-field measurement system featuring the same quiet zone size would require a 14.5 m range.

Such technologies are of great interest for testing UEs or base stations operating in 5G NR FR2, promising a significant decrease in the size of test environments. In ad-

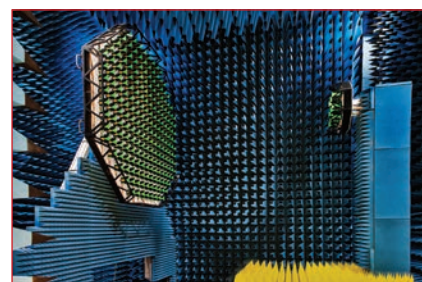
dition, CATR has the same capabilities as a far-field system, i.e., instantaneous and direct measurements of RF transceiver performance in both Tx and Rx. As the path loss of such a system only occurs between the limited region where waves propagate between the feed and the reflector, the dynamic range of a CATR system is better than a direct far-field approach. Using Figure 3 as an example, the CATR system has a

focal length of 0.7 m compared to the equivalent far-field range length of 14 m, resulting in a path loss difference of 26 dB.

### PLANE WAVE SYNTHESIS

A CATR reflector is typically built using a solid piece of aluminum to maintain the strict surface geometry requirements. The 5G FR2 DUT size requirements allow for compact and rather light reflectors (20 to 40 kg). In the 5G FR1 range, reflector weight significantly increases, up to hundreds of kilograms for base station DUTs. The cost, fabrication time and handling of large heavy mirrors becomes prohibitive. A lightweight and cost-effective alternative is to use an “electronic version” of the CATR mirror.<sup>3</sup> By combining the radiation of multiple antennas assembled in a phased array and fed with pre-determined signal magnitude and phase, a plane wave within a defined quiet zone is created. A version of this near-field focusing technique was used for several years for the measurement of large phased array radars at MIT Lincoln Labs and has been proposed as an OTA measurement baseline for base stations by 3GPP.<sup>5</sup>

Figure 4 shows the plane wave converting (PWC) system reported at the 2018 European Conference on Antennas and Propagation.<sup>3</sup> It comprises an array of 156 wideband Vivaldi antennas with a beamforming network of phase shifters and attenuators, located at the rear. This PWC array is 1.8 m wide and creates a spherical quiet zone of 1 m diameter at a distance as short as 1.5 m in the frequency range from 2.3 to 3.8 GHz. In the setup of Figure 4, the DUT (here the calibration antenna) is mounted on a combined axis positioner, enabling full spheri-



▲ Fig. 4 R&S PWC200 showing the PWC antenna array and calibration array mounted on a great-circle cut positioner.



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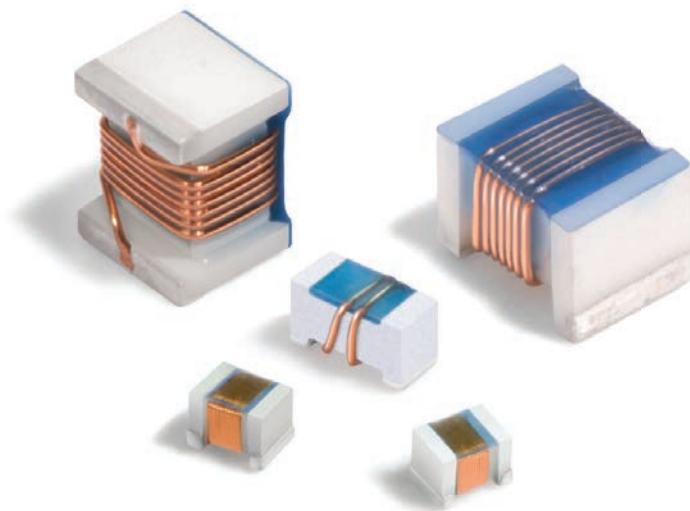
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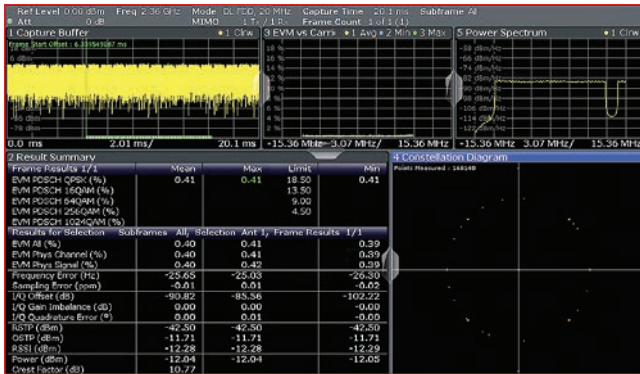
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◀ Fig. 5 EVM of a single 20 MHz carrier measured using the R&S PWC200.

cal measurement. The calibration antenna is used for evaluating the appropriate compensations of the individual RF channels of the



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PWC array, as well as determining the path loss of the entire test system. The PWC system is reciprocal and has only one RF input/output which can either be connected to a signal generator, a spectrum analyzer or a VNA, enabling measurement of devices with or without RF test ports.

Figure 5 shows the single-carrier EVM measured with the PWC for an OFDM signal with five 20 MHz carriers in the range of 2.35 to 2.45 GHz, using a Rohde & Schwarz vector signal generator. The output power is 5 dBm and fed into a 60 cm × 60 cm patch array DUT. The demodulation is carried out by a Rohde & Schwarz vector signal analyzer connected to the PWC, where the measurement span is 30.72 MHz. The EVM is as low as 0.41 percent, roughly corresponding to the internal EVM of the measurement instruments. EVM results were below 0.5 percent for the other four carriers, showing that the PWC adds negligible EVM to the measurement setup.

### SUMMARY

Near-field techniques employing software transformations are suitable for evaluation of EIRP and TRP quantities. When Rx or demodulation is involved with a DUT using multiple non-identical RF transceivers, methods utilizing hardware field transformations such as CATR and PWC overcome the limitations of software NF-FF. They also provide compact and reliable alternatives to direct far-field measurements, making them well-suited for 3GPP RF conformance testing of UEs and base stations. ■

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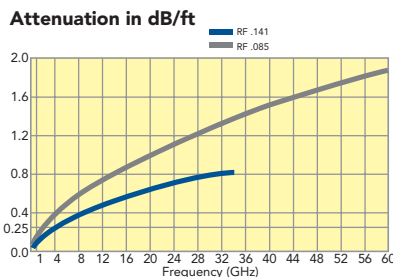
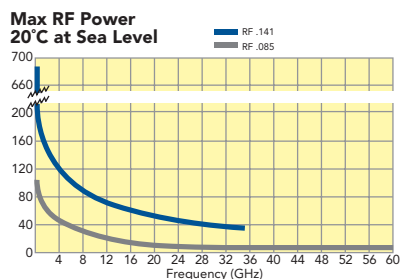
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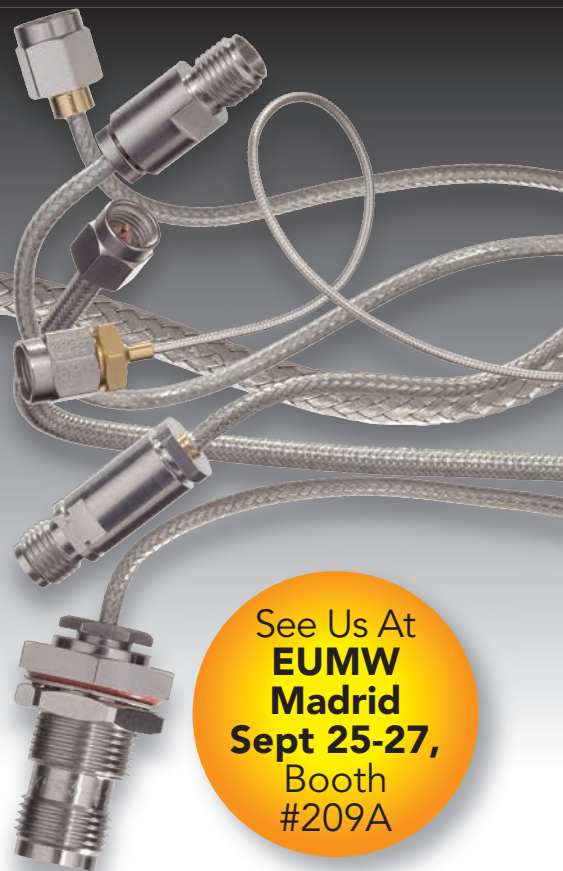
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# A High Linearity Doherty Power Amplifier Using Tunable Loaded Capacitor CMRC

Shiwei Zhao  
Chongqing University of Posts and Telecommunications

Xiaosen Dai  
Shanghai Radio Equipment Research Institute

*A high linearity Doherty power amplifier (DPA) substitutes a tunable, loaded capacitor compact microstrip resonant cell (CMRC) for the conventional  $\lambda/4$  transmission line at the output of the peak amplifier. Harmonics of the peak amplifier are suppressed, while its output phase is controllable. Measured results show third-order intermodulation (IMD3) distortion of -50 dBc with power-added efficiency (PAE) of 47.8 percent.*

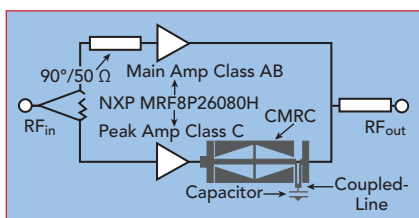
**T**he DPA is of interest for use in modern wireless communication networks to address the need for higher peak envelope power and better linearity. High efficiency is also desirable, but high efficiency with high linearity is difficult to achieve. Typical DPAs have high efficiency only at saturated output power. Efficiency is reduced at backed-off power levels to achieve the desired linearity. To improve linearity without reducing efficiency, class F and inverse class F amplifiers are employed.<sup>1</sup> In addition, asymmetric DPAs using model-based nonlinear embedding<sup>2</sup> and optimized asymmetrical DPAs<sup>3</sup> have been proposed. The real frequency technique is also used,<sup>4</sup> as well as a tunable

reactive capacitor for improving efficiency.

In this work, a new method to improve linearity employs a loaded capacitor CMRC structure. Because the CMRC exhibits a bandstop characteristic which can be used to reject undesired frequencies, it is used in the design of fourth subharmonic mixers.<sup>6</sup> It has also been used to improve the performance of a class F power amplifier<sup>7</sup> and a V-Band tripler.<sup>8</sup> For these applications, however, the CMRC is used only for harmonic suppression; phase cannot be modified easily. In this work, not only are harmonics suppressed, but phase is flexibly modified. This makes it possible to improve the linearity of the DPA without reducing efficiency.

## DPA DESIGN

The architecture is shown in **Figure 1**. The signal of the peak (class C) amplifier passes through the CMRC and is combined with the



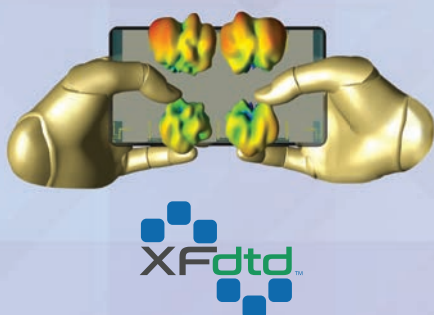
**Fig. 1** DPA using a tunable loaded capacitor CMRC.

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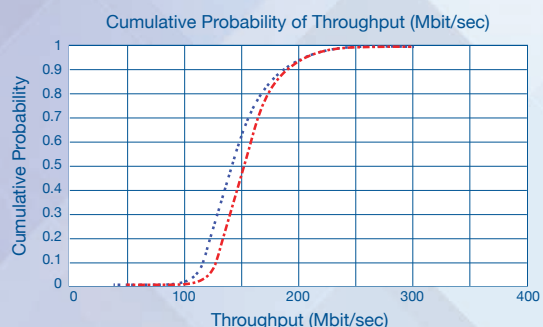
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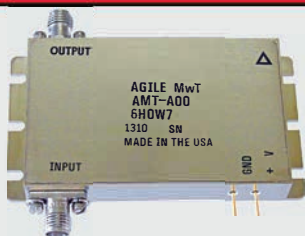
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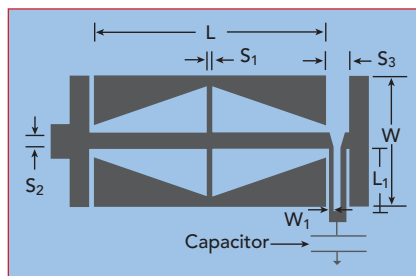
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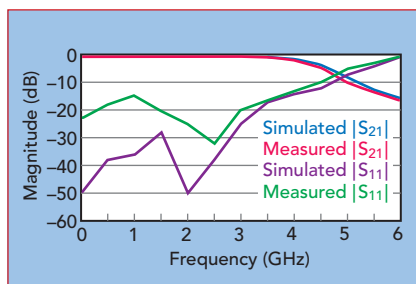
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## Technical Feature



▲ **Fig. 2** Tunable loaded capacitor CMRC structure.

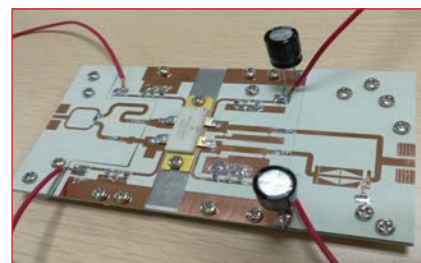
TABLE 1 LOADED CAPACITOR CMRC VALUES				
$L_1$ (mm)	$W_1$ (mm)	$D$ (mm)	$C$ (pF)	Phase (°)
8.2	0.5	0.4	0.8	89.1
8.2	0.3	0.4	1.2	88.7
8.4	0.3	0.4	1.3	106.3



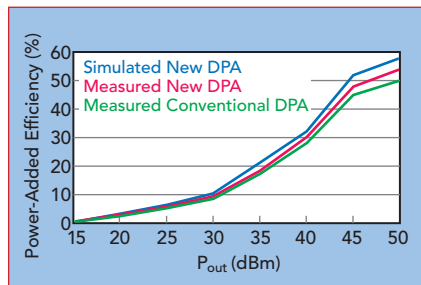
▲ **Fig. 3** Simulated vs. measured  $|S_{21}|$  and  $|S_{11}|$ .

signal from the main (class AB) amplifier at the output. The  $\lambda/4$  transmission line of the conventional DPA is replaced by the loaded capacitor CMRC, which performs the appropriate impedance transformation and phase delay offset. Because the peak amplifier operates class C, the main harmonic component and AM to PM distortion are generated at its output. Unlike a conventional DPA, however, the harmonic components are suppressed, while the AM to PM phase distortion of the peak amplifier can be corrected with a modified capacitor value in the CMRC.

The tunable loaded capacitor CMRC consists of the CMRC and a loaded capacitor coupled line (see **Figure 2**). The CMRC is a section of microstrip transmission line with an incorporated band gap structure. Its dimensions are  $L = 14.2$  mm,  $W = 4.8$  mm,  $S_2 = 0.3$  mm,  $S_1 = 0.13$  mm and  $S_3 = 2.2$  mm. The loaded capacitor coupled line has a length  $L_1$  and a width  $W_1$ . The slot between



▲ **Fig. 4** Tunable loaded capacitor CMRC DPA.



▲ **Fig. 5** Power-added efficiency of the new vs. conventional DPA.

the coupled lines (d) is 0.4 mm. Between the coupled line and ground is a tunable capacitor. The values of  $L_1$ ,  $W_1$  and the loaded capacitor are listed in **Table 1** for several phases in the frequency range of 2570 to 2620 MHz.

Simulated and measured S-parameters of the CMRC are shown in **Figure 3**. In the frequency range of 0.5 to 3.75 GHz, the simulated and measured insertion loss are less than 0.5 dB and the simulated and measured return loss is greater than 18 dB.

## FABRICATION AND MEASUREMENT

The DPA was fabricated on a Rogers 4350 substrate with a Freescale MRF8P26080H LDMOS transistor (see **Figure 4**).  $V_{DS}$  of the main and peak amplifiers was 28 V, while  $V_{GS}$  of main amplifier was 2.65 V and the  $V_{GS}$  of the peak amplifier was 2.28 V. The DPA was measured using a Keysight N9010A signal analyzer and E4438C vector signal generator.

Simulated and measured PAE of the DPA using a CMRC are compared with the measured PAE of a conventional DPA in **Figure 5**. The maximum measured PAE of the new DPA is 54 percent at 2.6 GHz. Compared to the conventional DPA, the new DPA demonstrates an improvement of 5 to 6 percentage points.



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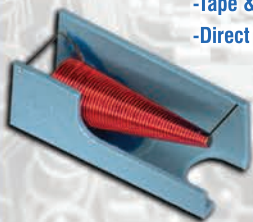
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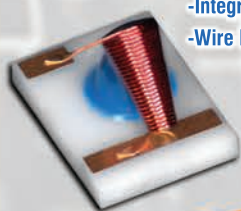
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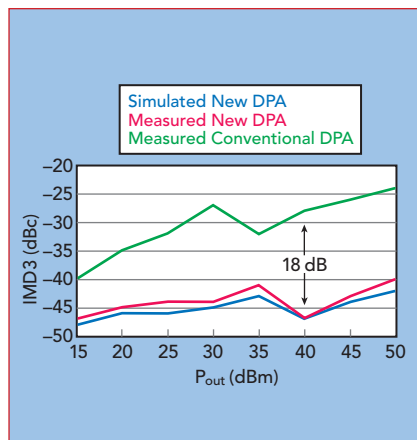
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▲ Fig. 6 IMD3 of the new vs. conventional DPA.

Figure 6 shows the simulated and measured IMD3 of the new DPA using a two-tone signal with a spacing of 5 MHz centered at 2.6 GHz. IMD3 is considerably improved compared to that of the conventional DPA due to the tuned loaded capacitor of the CMRC. The max IMD3 of the new DPA demonstrates an 18 dB improvement compared to a conventional DPA. Table 2 compares the performance of the new DPA design with several of the referenced works, showing that it simultaneously achieves low distortion and high PAE.

### CONCLUSION

A novel, high linearity DPA uses a loaded capacitor CMRC structure to perform phase tuning and filtering. The harmonics and AM to PM distortion of the peak amplifier are suppressed, improving linearity compared to a conventional DPA, while preserving PAE.■

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8. S. Lin, P. Y. Ke, H. C. Chiu and J. S. Fu, "High Performance 0.15  $\mu$ m Gate PHEMT V-Band Tripler Using Compact Microstrip Resonant Cell Technique," *TENCON 2011-2011 IEEE Region 10 Conference*, November 2011, pp. 1240–1241.

**TABLE 2**

### PERFORMANCE COMPARISON

Reference	Frequency (GHz)	Max PAE (%)	Max IMD3 (dBc)	$P_{out}$ (dBm)	Method
1	1	50.9	–30	36	Class F
3	1.92 to 2.17	53	–50	48	Asymmetric
4	2.2 to 2.96	60	–30	40	Broadband
This Work	2.57 to 2.62	54	–50	50	Tunable Loaded Capacitor CMRC



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# Spatial Multiplexing for 5G Wireless Communications

Honglei Chen and Rick Gentile  
MathWorks, Natick, Mass.

**I**ncreasing demand for higher data rates and channel capacity is driving the need to use the RF spectrum more efficiently. As a result, 5G wireless systems will use mmWave frequency bands to take advantage of the increased bandwidth. The higher operating frequencies enable large-scale antenna arrays, which can be used to mitigate severe propagation loss in the mmWave band. Large arrays can also be used to implement a MIMO system in which unique signals can be transmitted from different antenna elements in the array. MIMO systems enable spatial multiplexing techniques that can be used to improve data throughput.

The core idea of spatial multiplexing is to create multiple subchannels in scatterer-rich environments so that multiple data streams can be transmitted and recovered independently. This is achieved by applying a set of precoding and combining weights derived from the channel matrix. This concept is discussed first with an all-digital solution based on precoding in a MIMO-OFDM system that uses a spatial channel model. This channel model incorporates array pattern information to improve model fidelity.

Because 5G systems require large antenna arrays, applying digital weights on each antenna element is not always practical due to cost and space limitations. Hybrid beam-

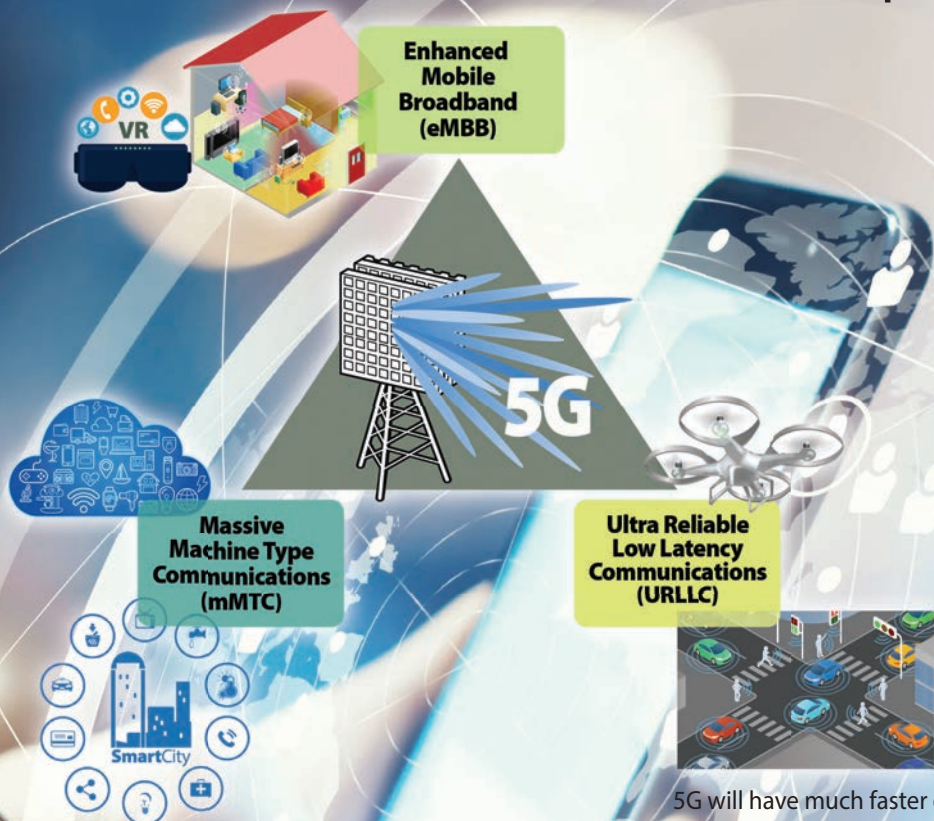
forming techniques can be applied in a mixed RF and digital beamforming system to alleviate these restrictions. In a hybrid beamforming system, both the precoding weights and the combining weights are combinations of baseband digital weights and RF band analog weights. On the transmit side, the baseband digital weights modulate the incoming data streams to form input signals at each RF chain, and the analog weights then translate the signal at each RF chain to the signal radiated at each antenna element. The process is reversed on the receive side. This article includes an example with hybrid weights and compares the achieved spectral efficiency with the all-digital case.

## SPATIAL MULTIPLEXING

The idea behind spatial multiplexing is that a MIMO system in a multipath channel with a rich scatterer environment can send multiple data streams simultaneously across the channel. For example, the channel matrix of a  $4 \times 4$  MIMO channel becomes full rank because of the scatterers. This means that it is possible to send as many as four data streams at once. The goal of spatial multiplexing is less about increasing the signal-to-noise ratio (SNR) and more about increasing the information throughput.

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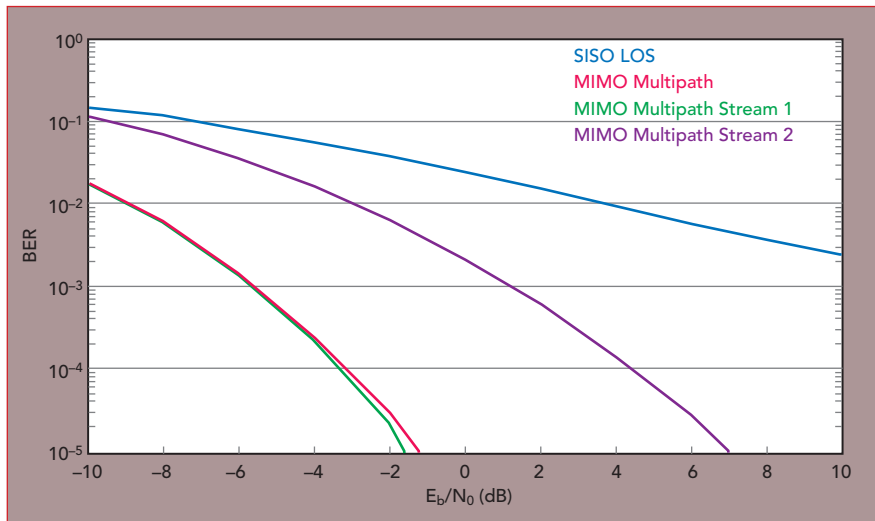
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▲ Fig. 1 BER of MIMO multipath streams compared to a single line-of-sight link.

The idea of spatial multiplexing is to separate the channel matrix into multiple modes so that the data stream sent from different elements in the transmit array can be independently recovered from the received signal. To achieve this, the data stream is precoded before the transmission and then combined after the reception. In the MATLAB models that follow, the precoding and combining weights can be computed from the channel matrix by:

```
[wp, wc] =  
diagbweights(mimompchan);
```

The information received by each receive array element is simply a scaled version of the trans-

mit array element, which results in multiple orthogonal subchannels within the original channel. The first subchannel corresponds to the dominant transmit and receive directions, so there is no loss in the diversity gain. In addition, it is possible to use other subchannels to carry information, as shown by the bit error rate (BER) curves in **Figure 1**, including the first two subchannels. The gain of the second data stream is not as high as the first stream, since it uses a less dominant subchannel. Still, the overall information throughput is improved. This concept will be applied to a MIMO-OFDM system.

## MIMO-OFDM SYSTEMS

MIMO-OFDM systems are common in wireless systems due to their robustness with frequency-selective channels and high data rates. With antenna arrays that implement spatial multiplexing, efficient techniques to realize the transmissions are necessary. As an example, consider an asymmetric MIMO-OFDM single-user system in which the maximum number of antenna elements on the transmit and receive ends are 1024 and 32, respectively, and up to 16 independent data streams. For clarity, a single link (one base station communicating with one mobile user) is modeled, but this structure could be extended for more complex configurations.

The link between the transmitter and receiver relies on channel sounding to generate the channel information needed for transmit beamforming. For a spatially multiplexed system, the availability of channel information at the transmitter allows for precoding to be applied to maximize the signal energy in the direction and channel of interest. Assuming a slowly varying channel, this process is facilitated by first sounding the channel with a reference transmission. The receiver then estimates the channel and feeds this information back to the transmitter, as shown in **Figure 2**. In this system, a preamble signal is first sent over all transmitting ele-

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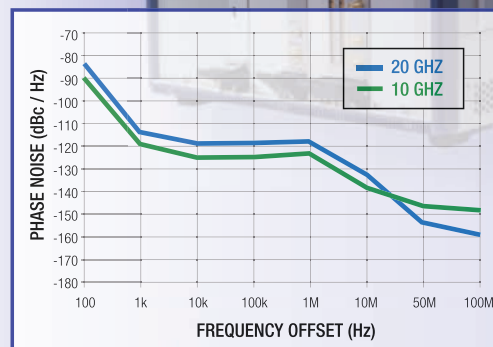
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<b>EWDM-2G8G-65-70MV</b> <i>CW Immune</i> <a href="http://www.pmi-rf.com/products-details/ewdm-2g8g-65-70mv">http://www.pmi-rf.com/products-details/ewdm-2g8g-65-70mv</a>	2 - 8	-71 dBm Max	70 ± 3	-65 to 0	SMA	2.82" x 2.25" x 0.5"
<b>ERDLVA-2G8G-65-70MV</b> <i>CW Immune</i> <a href="http://www.pmi-rf.com/products-details/erdlva-2g8g-65-70mv">http://www.pmi-rf.com/products-details/erdlva-2g8g-65-70mv</a>	2 - 8	-71 dBm Typ	70 ± 3	-65 to 0	SMA	2.82" x 2.25" x 0.5"
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ments. It is subsequently processed at the receiver after accounting for the channel effects. The receiver performs pre-amplification, OFDM demodulation, frequency domain channel estimation and calculation of the feedback weights based on channel diagonalization using singular value decomposition per data subcarrier. The specific system configuration is as follows:

the array geometry of the transmitter and the beam patterns in azimuth and elevation. For simplicity, assume the steering angle is known with respect to the mobile location. In actual systems, the steering angle would be obtained from an angle-of-arrival estimation at the receiver, as a part of the channel sounding or initial beam tracking procedures.

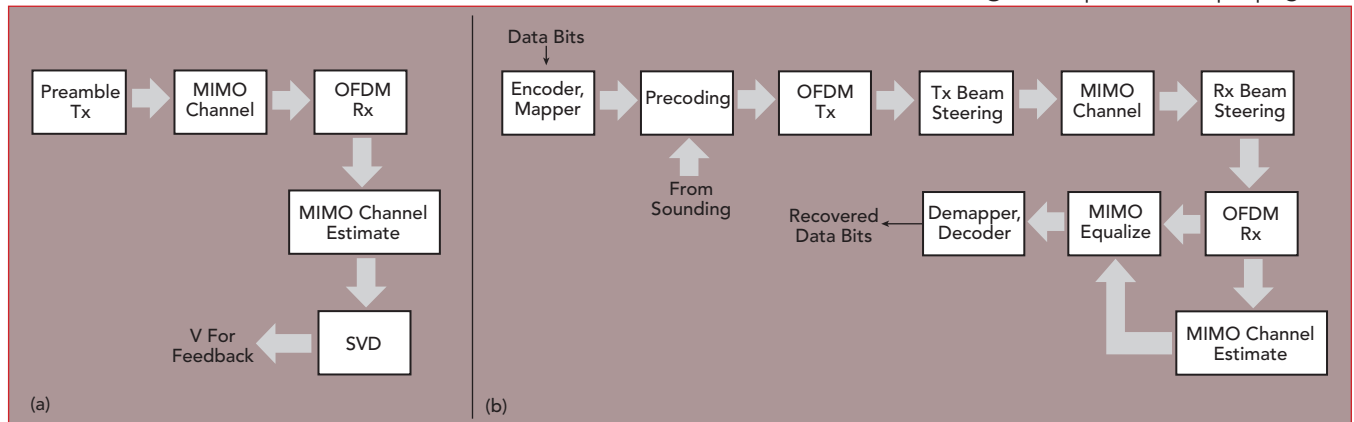
For example, 5G channel models and the WINNER II channel models are spatially defined MIMO channels where the array geometry and location information can be specified. For this discussion, consider scattering-based channels with a single-bounce path through 100 scatterers placed randomly within a circle between the transmitter and receiver. The channel model allows path loss modeling and both line-of-sight (LOS) and non-LOS propagation conditions. For this analysis, a non-LOS propagation and isotropic antenna element pattern with linear geometry are configured. The same channel is used for both sounding and data transmission. The data transmission has a longer duration controlled by the number of data symbols.

The receive antenna array, shown in **Figure 4**, passes the propagated

```
% Single-user system with multiple streams
prm.numSTS = 16; % Number of independent data streams, 4/8/16/32/64
prm.numTx = 32; % Number of transmit antennas
prm.numRx = 16; % Number of receive antennas
prm.bitsPerSubCarrier = 6; % 2: QPSK, 4: 16-QAM, 6: 64-QAM, 8: 256-QAM
prm.numDataSymbols = 10; % Number of OFDM data symbols
```

A rectangular array at the transmitter is used, based on the desired number of data streams and transmit antennas. **Figure 3** shows

Multiple options exist for modeling spatial MIMO channels, typically selected based on the level of fidelity that is needed for the analysis.

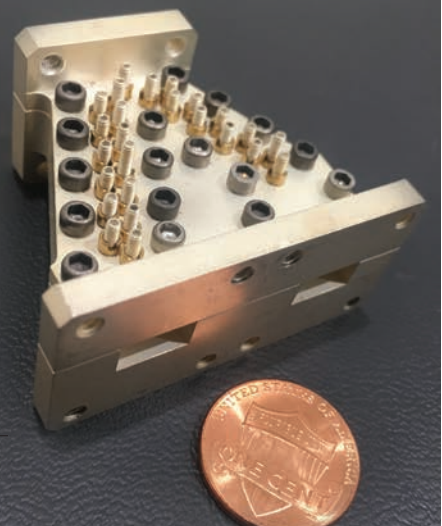
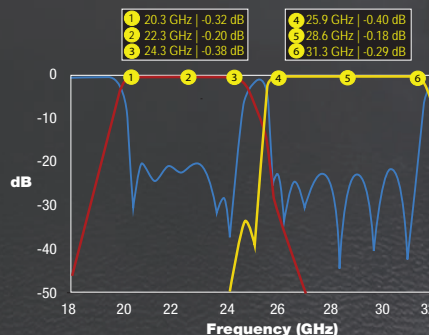


▲ Fig. 2 Channel sounding (a) and data transmission/reception (b) flow.

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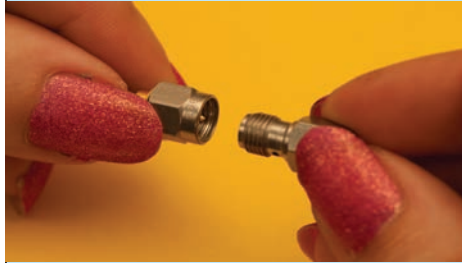
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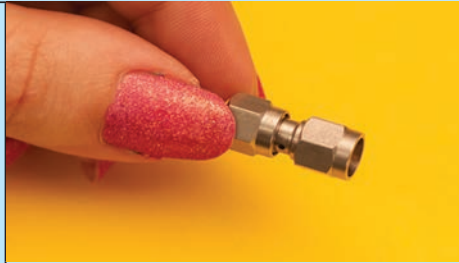
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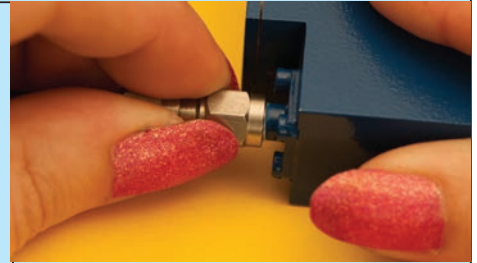
Procedure for how to use the **SMA male** and **SMA female** Push-On connectors. SMA Push-On Connectors mate with any standard connector of the same but opposite connector style.



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.



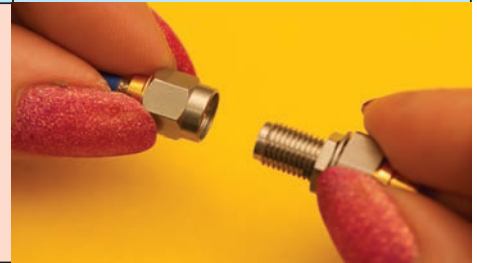
3. Just slide the Push-On SMA male Connector onto any standard SMA female. The connection is securely completed in seconds.



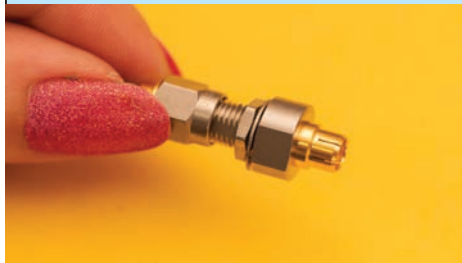
4. To disconnect, just pull the connector off.

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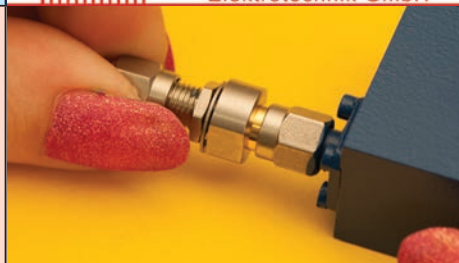
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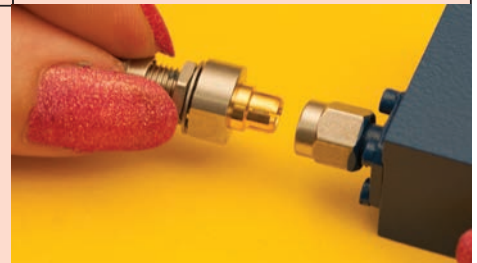
1. Convert your standard cable assembly into a Push-On Assembly by threading the standard female side of the adapter onto the male connector of the assembly.



2. Your standard SMA male cable assembly is converted 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 on safely.



5. To unlock (when "Back Nut" is in unlocked mode) push the "Lock Nut" forward and stop reverse movement by setting your fingers onto the "Back Nut".



6. Keep fingers on "Back Nut" to ensure that "Lock Nut" cannot slide back and pull the connector off.

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signal to the receiver to recover the original information embedded in the signal. Similar to the transmitter, the receiver used in a MIMO-OFDM

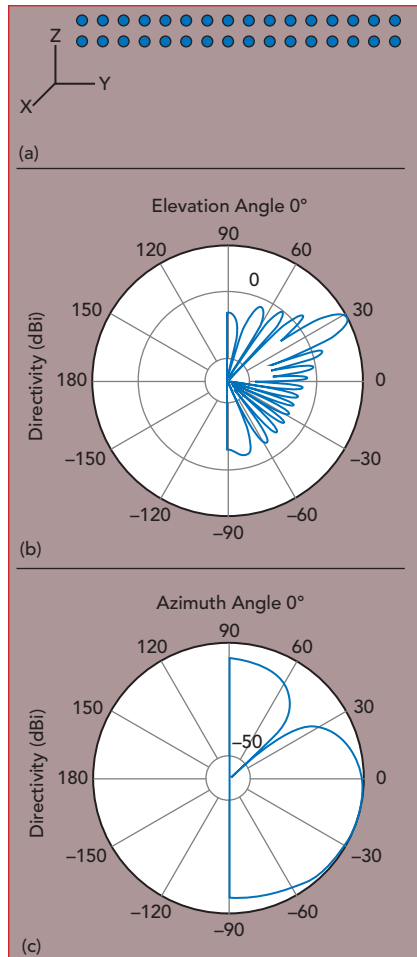
system contains many stages, including OFDM demodulator, MIMO equalizer, QAM demodulator and channel decoder. For this MIMO system, the displayed receive constellation offers a qualitative assessment of the reception. The actual BER offers the quantitative figure by comparing the actual transmitted bits with the received decoded bits (see **Figure 5**).

Parameters can be modified to vary the number of data streams, transmit/receive antenna elements, base station or array locations and

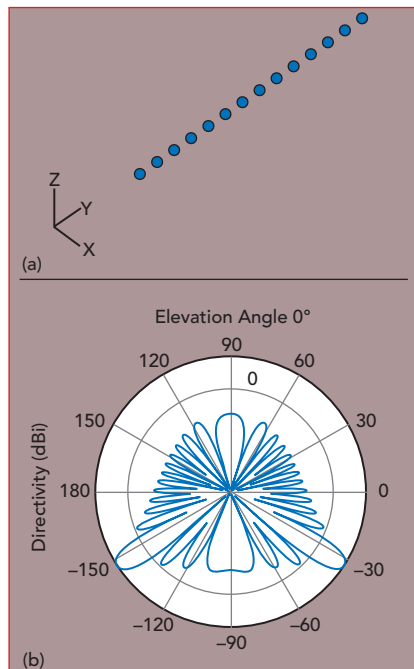
geometry, channel models and their configurations to study the parameters' individual or combined effects on the system. This framework can be used for further analysis but, so far, all of the precoding and combining were based on an all-digital system. As the antenna array size increases, an all-digital system may not be feasible, which leads to the use of hybrid beamforming.

## HYBRID BEAMFORMING

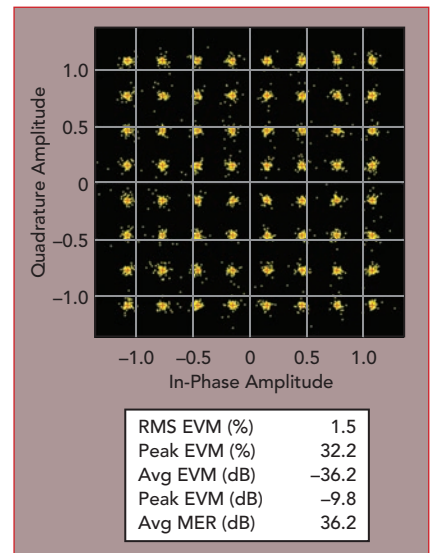
In a hybrid beamforming system, both the precoding weights and the combining weights are combinations of baseband digital weights and RF band analog weights. This type of architecture is shown in **Figure 6**.



▲ Fig. 3 Transmitter array geometry (a) with azimuth (b) and elevation (c) beam patterns.



▲ Fig. 4 Receiver array geometry (a) with azimuth beam pattern (b).



▲ Fig. 5 Constellation diagram for the MIMO OFDM system.

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MBD1057-C18	100	200	0.30	1,000	180	2.5	420	135
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

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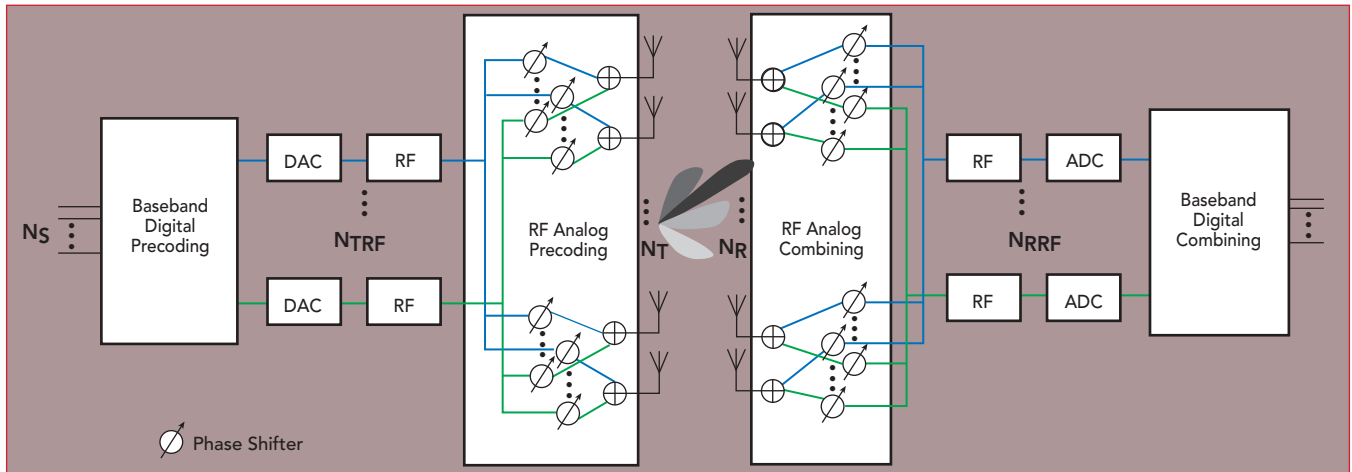
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For this discussion, assume a set of larger arrays: The transmitter consists of a 64-element square array with four RF chains, and the receiver is based on a 16-element square array with four RF chains. Each antenna is connected to all RF chains, which means that each antenna is connected to four phase shifters. This type of array can be modeled by partitioning the array aperture into four completely connected subarrays. To maximize the spectral efficiency in the system, each RF chain can be used to send an independent data stream. In this case, the system supports up to four streams.

A scattering environment with six scattering clusters randomly distributed in space is used to define the channel. Within each cluster, there are eight closely located scatterers, for a total of 48 scatterers. The path gain for each scatterer is obtained from a complex circular symmetric Gaussian distribution.

As described earlier, in a spatial multiplexing system with all-digital beamforming, the signal is modulated by a set of precoding weights, propagated through the channel and recovered by a set of combining weights. Mathematically, this process can be described by  $Y = (X^*F^*H+N)*W$  where



▲ Fig. 6 Hybrid beamforming architecture.

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## TechnicalFeature

- $N_s$  is the number of data streams.
- $N_t$  is the number of transmit elements.
- $N_r$  is the number of receive elements.
- $N_{rf}$  is the number of RF channels.
- $X$  is an  $N_s$ -column matrix whose columns are data streams.
- $F$  is an  $N_s \times N_t$  matrix representing the precoding weights.
- $H$  is the channel representation.
- $W$  is an  $N_r \times N_s$  matrix representing the combining weights.
- $N$  is an  $N_r$ -column matrix whose columns are the receiver noise at each element.
- $Y$  is an  $N_s$ -column matrix whose columns are recovered data streams.

Since the goal of the system is to achieve better spectral efficiency, obtaining the precoding and combining weights can be considered an optimization problem in which the optimal precoding and combining weights make the product of  $F^*H^*W$  a diagonal matrix, so each data stream can be recovered independently.

In a hybrid beamforming system, the signal flow is similar. Both the precoding weights and the com-

binning weights are combinations of baseband digital weights and RF band analog weights. The baseband digital weights convert the incoming data streams to input signals at each RF chain, and the analog weights then convert the signal at each RF chain to the signal radiated or collected at each antenna element. Note that the analog weights can only contain phase shifts. Mathematically, it can be written as  $F = F_{bb} * F_{rf}$  and  $W = W_{bb} * W_{rf}$ , where

- $F_{bb}$  is an  $N_s \times N_{tRF}$  matrix.
- $F_{rf}$  is an  $N_{tRF} \times N_t$  matrix.
- $W_{bb}$  is an  $N_r \times N_s$  matrix.
- $W_{rf}$  is an  $N_r \times N_{rRF}$  matrix.

Since both  $F_{rf}$  and  $W_{rf}$  can only be used to modify the signal phase, there are extra constraints on the optimization process to identify the optimal precoding and combining weights. Ideally, the resulting combination of  $F_{bb} * F_{rf}$  and  $W_{rf} * W_{bb}$  are close approximations of  $F$  and  $W$  that are obtained without those constraints. Unfortunately, optimizing all four matrix variables simultaneously is quite difficult. Many algorithms exist that arrive at suboptimal weights

with a reasonable computational load. This example uses an approach that decouples the optimizations for the precoding and combining weights. It first uses the orthogonal matching pursuit algorithm to derive the precoding weights. The hybrid weights can be computed as

$[F_{bb}, F_{rf}] = \text{helperHybridPrecodingWeights}(H, N_{tRF}, N_s, A_t);$

Once the precoding weights are computed, the result is used to obtain the corresponding combining weights. Assuming the channel is known, the unconstrained optimal precoding weights can be obtained by diagonalizing the channel matrix and extracting the first  $N_{tRF}$  dominating modes.

The transmit beam pattern for both cases is shown in **Figure 7**. The response patterns show that even in a multipath environment, the number of dominant directions is limited. The beam pattern using the hybrid weights is similar to the beam pattern obtained using the optimal weights, especially for the dominant beams. This result means

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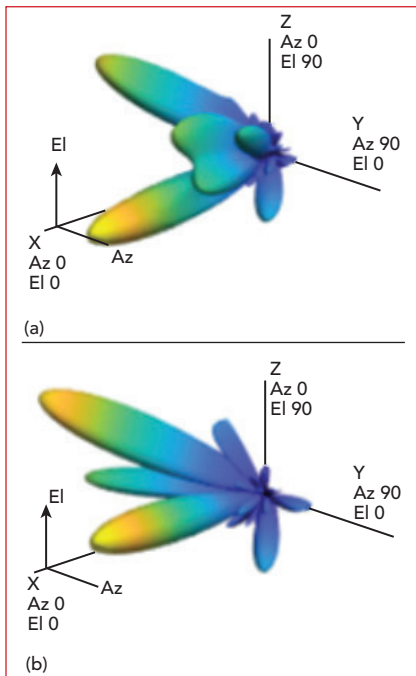
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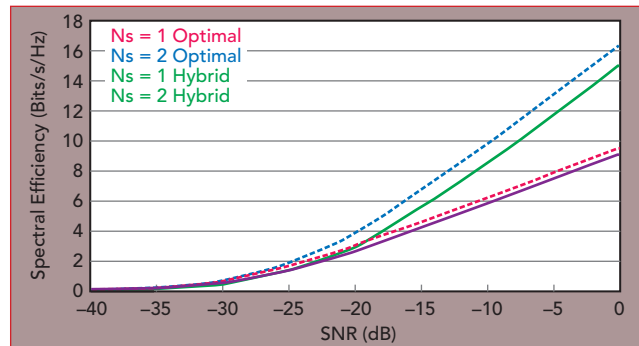
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▲ Fig. 7 Transmit patterns for all-digital (a) and hybrid (b) cases.

that the data streams can be successfully transmitted through those beams using hybrid weights.



▲ Fig. 8 Spectral efficiency of all-digital and hybrid systems.

One of the system-level performance metrics of a 5G system is the spectral efficiency. **Figure 8** compares the spectral efficiency achieved using the optimal weights with the proposed hybrid beamforming weights. The simulation assumes one or two data streams. The transmit antenna array is assumed to be at a base station, with a focused beam coverage of 60 degrees in azimuth and 20 degrees in elevation. The signal can arrive at the receive array from any direction. The resulting spectral efficiency curve is obtained from 50 Monte Carlo tri-

als for each SNR. **Figure 8** shows that the spectral efficiency improves significantly by increasing the number of data streams. In addition, hybrid beamforming can perform close to what optimal weights can offer and uses less hardware.

## SUMMARY

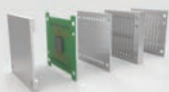
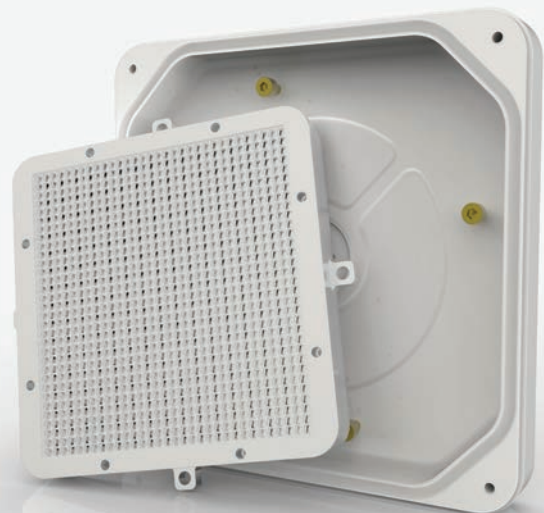
MIMO systems enable spatial multiplexing techniques that can be used to improve data throughput. This improvement is achieved by applying a set of precoding and combining weights derived from the channel matrix. Because 5G systems require large antenna arrays, applying digital weights on each antenna element is not always practical. Hybrid beamforming can be applied in a mixed RF and digital beamforming system to lower system costs. System modeling techniques can be used to explore system tradeoffs before any hardware is built, which can prevent costly errors and project delays. ■

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# Why $V_{\text{peak}}$ is the Most Critical Aperture Tuner Parameter

Skyworks Solutions, Inc.  
Irvine, Calif.

**T**here are multiple factors that designers of RF front-ends face. One of the most challenging is tuning an antenna for best performance. Good antenna design combined with aperture tuning enable wider bandwidth, increased data rates, lower power, longer battery life, smaller footprint and reduced bill of material cost. In this article, we discuss  $V_{\text{peak}}$ , or voltage handling, one of the most important antenna tuner parameters when choosing the right solution for antenna aperture tuning.

## DEFINITIONS

Important definitions, specifications and other aspects to be considered in the design and selection of an antenna tuner include:

**Total radiated power (TRP)** is a measure of how much power is transmitted by an antenna, and **total isotropic sensitivity (TIS)** is a measure of an antenna system's receive sensitivity.

**Aperture tuning** changes the electrical length of an antenna to shift its resonance to the desired frequency band. Antenna aperture tuners improve the TRP and TIS by increasing the effective size of an antenna or by altering its radiation pattern. **Impedance tuning** aims to match the impedance

of the antenna to the impedance of the RF front-end to optimize the power transfer to the antenna. Successful matching improves TRP and TIS.

$V_{\text{peak}}$  specifies the maximum voltage the antenna tuner can withstand and still deliver acceptable harmonic performance.  $C_{\text{off}}$  is the capacitance presented by the antenna tuner while the tuner's switches are in the "off" state. Lower  $C_{\text{off}}$  increases the Q of the tuner and affects antenna efficiency and effective tuning range.  $R_{\text{on}}$  is the resistance presented by the antenna tuner while the antenna tuner switches are "on." Lower  $R_{\text{on}}$  typically results in higher antenna efficiency, as well as improved TRP and TIS. High linearity switches are required to prevent degradation of TRP, TIS and carrier aggregation performance.

## WHY IS $V_{\text{PEAK}}$ IMPORTANT?

An antenna tuner may be thought of as a resonant circuit. The peak voltage inside a matching or resonant circuit can be much higher than at its input or output. This occurs because the internal impedance can be higher than 50  $\Omega$ , even if the input and output of the matching circuit are matched to 50  $\Omega$ . An aperture tuner is typically placed near the antenna, where the impedance

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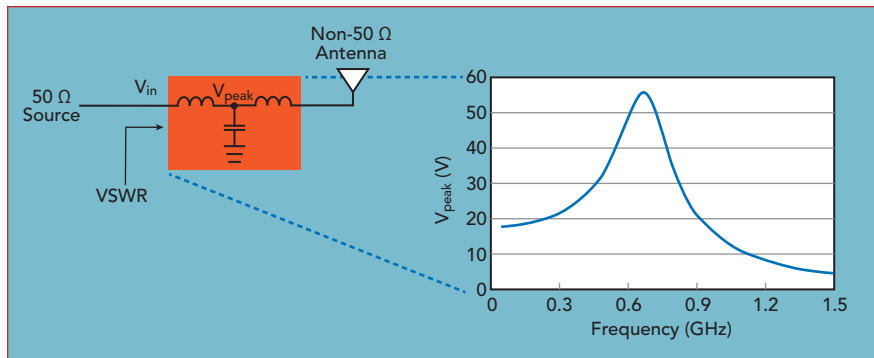
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**Fig. 1** Simplified aperture antenna (tuner installed directly on antenna radiating arm).

TABLE 1				
Power (dBm)	V <sub>in</sub> (V)			
	VSWR 1:1	VSWR 2:1	VSWR 5:1	VSWR 10:1
35	18	24	25	32

is generally higher than 50 Ω. The peak voltage on a tuning component depends on the input power level, the antenna or matching circuit topology and the loaded Q of the circuit. For example, at P<sub>in</sub> = +35 dBm, the peak voltage across a shunt capacitor inside a matching circuit can be as high as 32 V (see **Figure 1**) and depends on the VSWR (see **Table 1**).

Aperture tuning consists of placing a tuning element in an appropriate location of the radiating structure, a location not directly connected to the matching circuit of the antenna feed. This guarantees the highest antenna radiated efficiency and prevents the feed

point impedance from changing during operation over the frequency spectrum. The V<sub>peak</sub> required of an antenna tuner is determined by where the tuner is placed along the antenna and its proximity to the antenna's shorting pin (see **Figure 2**); V<sub>peak</sub> is lower closer to the shorting pin and higher further from the shorting pin. Aperture tunability is most effective when the tuning element is placed in a location with the highest voltage distribution. Due to these factors, the maximum voltage present across an aperture tuner may be much higher than the voltage present at the antenna feed point.

The peak voltage of the antenna tuner is set by the division of RF voltage across the stack of FET switches in the antenna tuner design. Using an antenna tuner with insufficient V<sub>peak</sub> for the application can result in permanent, catastrophic damage. Even if the tuner is not damaged, selecting a tuner with insuffi-

cient V<sub>peak</sub> can significantly degrade TRP and TIS and lead to excessive harmonics, causing the phone to fail certification and delay product release.

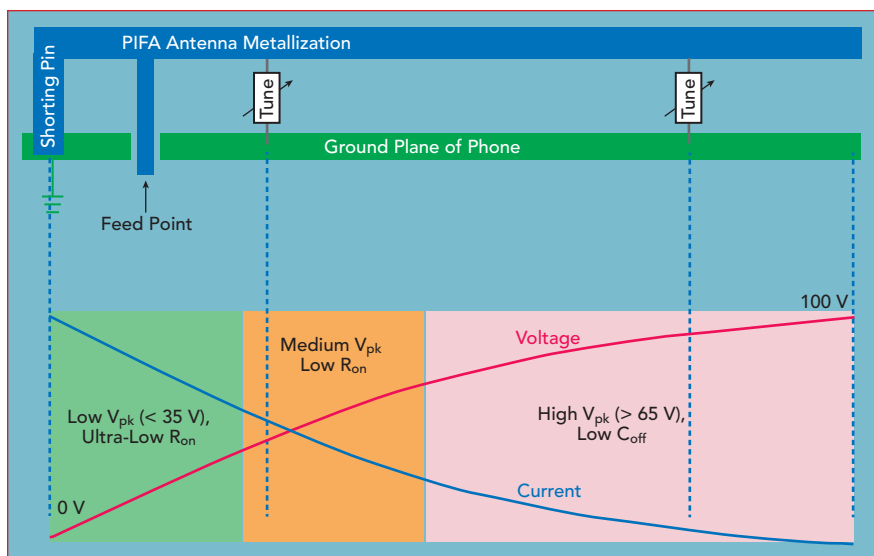
## DETERMINING THE APPROPRIATE TUNER

There are several considerations when selecting the appropriate aperture tuner. While R<sub>on</sub>, C<sub>off</sub> and V<sub>peak</sub> are all critical parameters, the first step is determining the V<sub>peak</sub> requirement. Tuning devices are used to set the resonant frequency and, as such, typically experience the highest voltage or highest current in the circuit. When V<sub>peak</sub> is exceeded, the tuner begins a breakdown cycle, linearity deteriorates and the tuning switch emits potentially harmful harmonics. Selecting a tuner with insufficient V<sub>peak</sub> will likely result in poor TRP and a failed radiated spurious emissions (RSE) certification.

V<sub>peak</sub> cannot be measured on an antenna, because the act of measuring and touching the antenna changes its RF characteristics. The V<sub>peak</sub> expected across the antenna tuner must, therefore, be simulated. Once defined, R<sub>on</sub> and C<sub>off</sub> are selected to achieve the TRP goal. This is also done through simulation. Depending on the specific antenna design and tuning bands, either R<sub>on</sub> or C<sub>off</sub> may have more influence on antenna efficiency.

## DATA SHEET V<sub>PEAK</sub>

The RF semiconductor industry has not converged on a common method for testing and specifying V<sub>peak</sub>. Some suppliers simply specify a value in the absolute maximum ratings table of the data sheet. This is sufficient for describing the voltage beyond which the part may be damaged, but it does not guarantee that the part will perform adequately and not fail system-level RSE testing. Other suppliers may include a V<sub>peak</sub> value in the electrical specifications table but do not indicate what level of performance is guaranteed. Designers must be certain sufficient performance is guaranteed when using a tuning device anywhere up to its V<sub>peak</sub> level. The consequence of using a tuner above V<sub>peak</sub> is that harmonics are injected into the system, which



**Fig. 2** Effect of the tuning element location on V<sub>peak</sub>.

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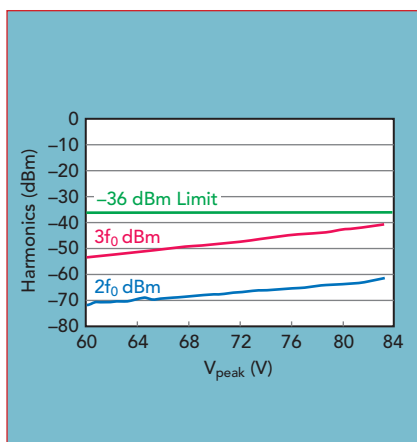


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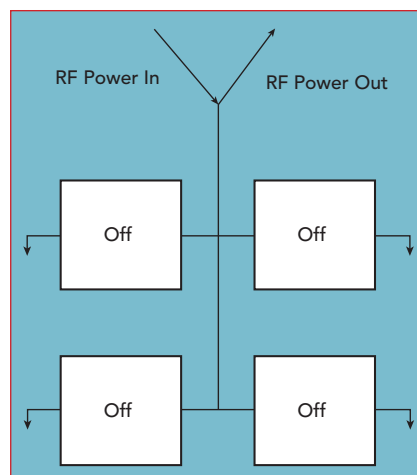
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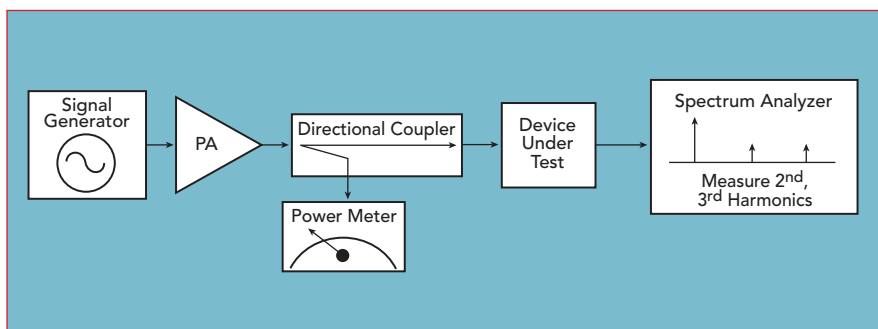
## Application Note



▲ Fig. 3 Skyworks' SPST antenna tuning  $V_{peak}$ .



▲ Fig. 5  $V_{peak}$  is measured in the shunt configuration with all arms off.



▲ Fig. 4  $V_{peak}$  measurement setup.

could result in excessive RSE and/or antenna efficiency to be lower than expected.

Skyworks uses harmonic performance to specify  $V_{peak}$ . Input power is swept and the second and third harmonics are measured.  $V_{peak}$  on a Skyworks data sheet identifies the point where harmonics exceed -36 dBm, a level chosen to comply with the "3GPP Spurious Emissions Requirement" (Section 9.2). Spurious emissions are caused by unwanted transmitter effects such as harmonics, parasitics, intermodulation and frequency conversion, but they exclude out-of-band emissions. As one example, Skyworks' SKY19250 is a SPST antenna tuner with a rated  $V_{peak}$  of 80 V. Characterization test results are shown in **Figure 3**. Harmonic performance is better than -36 dBm beyond 80 V.

Skyworks uses a standardized  $V_{peak}$  measurement system (see **Figure 4**) for characterizing tuners. Peak voltage is verified by a high-power measurement in a 50 Ω en-

vironment and involves high-power levels that could destroy the device under test. To nondestructively measure  $V_{peak}$ , the antenna tuner is configured in a shunt configuration with all arms safely in the "off" state (see **Figure 5**).

### SUMMARY

It is important to choose the correct aperture tuner component that meets  $R_{on}$ ,  $C_{off}$  and  $V_{peak}$  criteria to match the antenna design. Antenna tuner  $V_{peak}$  is critical to the performance of the RF system. Using an antenna tuner with inadequate  $V_{peak}$  may result in poor TRP, TIS and certification failure. Simply relying on the  $V_{peak}$  in the absolute maximum ratings table of a data sheet is not sufficient. Harmonics are the best indicator of true  $V_{peak}$  performance and should be defined in the data sheet electrical specifications for  $V_{peak}$ . A well-calibrated  $V_{peak}$  measurement system must be used in order to safely and reliably test and select appropriate antenna tuner components. ■

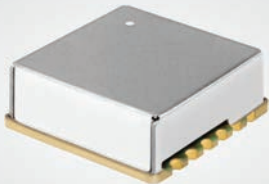
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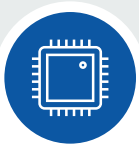
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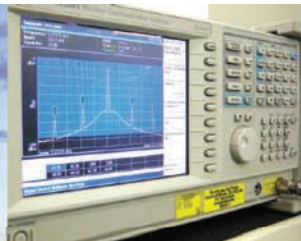
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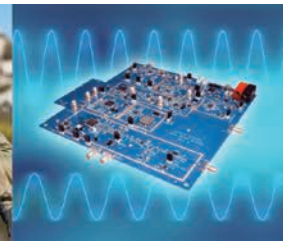
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# Type 2.2-5 Coax Connector Fits in Tight Spaces

Telegärtner Karl Gärtner GmbH  
Steinenbronn, Germany

**M**odern mobile networks are becoming increasingly powerful. More and more data is being transferred faster and more reliably, because today's mobile society has no tolerance for slow connections to the internet or the loss of voice, images or video. Everything has to travel fast and, indeed, everywhere—any service, anywhere, anytime. Taking advantage of any service, anywhere and anytime has become a matter of course. 5G will make applications possible only dreamed of a few years ago.

With more and more demanding services, the requirements on the networks that transfer all this data inevitably increase. Never has the bandwidth requirement been as great as it is today. MIMO antennas, small cell concepts and innovative distributed antenna systems (DAS) play an important role. As a result, space restrictions are increasingly noticeable, not only on antenna masts and mobile radio equipment, but also in distribution and cabling.

## PERFORMANCE IN CONFINED SPACES

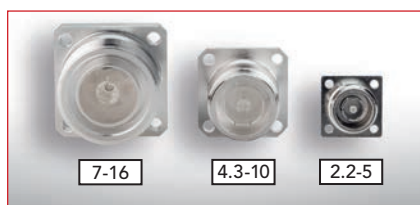
The new connector generation 2.2-5 solves this problem elegantly and reliably. Building on the success of the pioneering 4.3-10 connector, Telegärtner has developed the compact, high performance 2.2-5 connector in close collaboration with SPINNER and with the support of Amphenol, CommScope, Molex, JMA Wireless and Gigalane. Developed for the mobile networks of today and tomorrow, the 2.2-5 has had extensive field installations using mobile communications equipment from Kathrein.

The innovative connector offers performance that, until recently, was not possible in such compact dimensions. A typical 2.2-5 flange saves up to 53 percent in space compared to the 4.3-10 and 70 percent versus the 7-16 connector (see **Figure 1**). From the tried and tested 4.3-10, the 2.2-5 uses the same designed plugs with three different locking types (see **Figure 2**), all of which can be used on the same jack:

- Screw, with external hexagon for extreme environmental conditions, popular in practice.
- Hand screw with knurled nut, for easy installation indoors and outdoors.
- Push-pull, a self-locking fast connection.

The standard version supports applications to 6 GHz, and a high performance version extends the frequency range to 20 GHz. Reliable signal transmission is ensured by a very low passive intermodulation (PIM) of -166 dBc with two 43 dBm signals, as shown in **Figure 3**. Despite its small size, the 2.2-5 transmits considerable power, up to 250 W at 2 GHz. The connectors are designed for over 100 mating cycles, with the contact zones of the connectors protected against damage, thanks to the practical design—even when not plugged in.

This performance is possible using the concept of decoupling mechanical locking and electrical contacting from the 4.3-10 series. Unlike conventional connectors of this form factor, such as the TNC series, the contact force of the outer conductor is not applied by screwing the coupling nut, which makes the contact pressure dependent on factors such as torque, thread quality and surface quality. Rather, the contact principle is based on precisely-defined spring forces, which leads to precise, reproducible results.



**Fig. 1** The 2.2-5 connector is up to 53 percent smaller than the 4.3-10 and 70 percent smaller than the 7-16.



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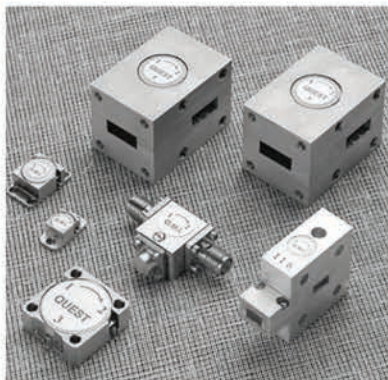
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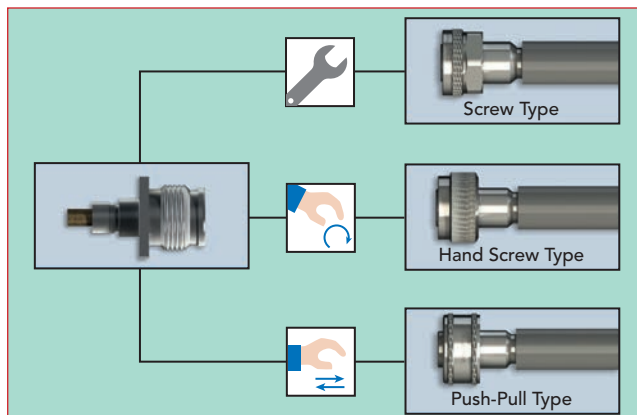
Whether screw, hand screw or push-pull, all three connector types offer IP68 protection and are suitable for applications in harsh indoor and outdoor environments. With the extended temperature range from -40°C to +85°C and handling up to 1.5 kV at 50 Hz, the small robust connector is suitable for a variety of applications such as mobile networks, small cells, low power remote radio units, in-building wireless and DAS, all of which benefit from the compact dimensions of the 2.2-5 connector, available in straight and angled versions.

Equipment installers will appreciate the screw, hand screw and push-pull versions, allowing them to choose the optimum connector lock for the project and application, which significantly aids installation in demanding and harsh conditions such as wind, weather, altitude, limited space and chronic time pressure.

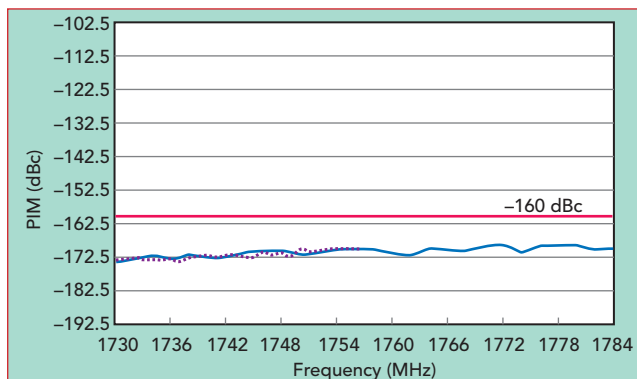
Despite its compact design, the 2.2-5 is designed for low attenuation cables up to 1/2 in., suitable for both sockets (e.g., Semiflex cable UT85, UT141, UT250) and connectors (e.g., corrugated cable 1/4 in., 3/8 in. and 1/2 in.). In addition to individual plugs and jacks, cable assemblies ready to connect in standard and customized lengths are available for convenient and time-saving installations.

### THE PATH TO A WORLDWIDE STANDARD

For decades, the connector series 7-16 dominated the RF signal transmission between base stations and antennas. The technological change away from the long distance transmission of high frequency signals by thick feeder cables up to 1 5/8 in.



▲ Fig. 2 The 2.2-5 offers three locking types, with options to best suit the application.



▲ Fig. 3 PIM with two 43 dBm signals measures well below -160 dBc.

diameter to fiber-optic fed remote radio units, where the RF signal is transmitted only a few meters with thinner 1/2 in. cables makes the series 7-16 look like a dinosaur. The IEC standardization of the 4.3-10 series was like a meteor impact, allowing the replacement of the 7-16 series with breathtaking speed by connector standards. The submission of the 2.2-5 series to the IEC at the end of 2017 paves the way for the next evolution to meet the requirements of future 5G networks.

The new 2.2-5 connector is designed for applications where high transmission quality is required, especially passive intermodulation, and where limited space is available for cabling and installation. With the three types of locking, the 2.2-5 enables trouble-free installation where other connectors can no longer be used. The ongoing IEC standardization will ensure future reliability and guarantee worldwide compatibility.

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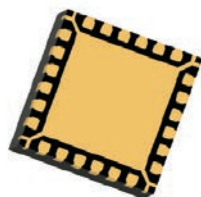
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The QPM1002 is fabricated on Qorvo's 0.25  $\mu\text{m}$  GaN on SiC process and encapsulated in a 5 mm  $\times$  5 mm plastic overmolded QFN, which minimizes cost, maximizes moisture robustness and simplifies next-level assembly. The compact size supports the tight lattice spacing of X-Band phased array radars and is also advantageous for electronic

warfare and communication systems.

In receive (Rx), the FEM provides 25 dB gain with a low noise figure of 2.2 dB (see **Figure 2**), with the typical input and output return loss around 13 and 12 dB, respectively. In transmit (Tx), the FEM has 33 dB small-signal gain and delivers 3 W saturated output power, 32 percent pow-

er-added efficiency and 25 dB large-signal gain (see **Figure 3**), with the typical input and output return loss 15 dB. The Rx and Tx performance include the losses and mismatch associated with the T/R switch. The MMIC includes an on-chip output power detector with a 0 to 0.3 V output proportional to transmit power. The FEM is robust and will handle up to 2 W power applied to the antenna port, eliminating the need for a limiter to protect the LNA in most systems. A photograph of the QPM1002 mounted on an evaluation board is shown in **Figure 4**.

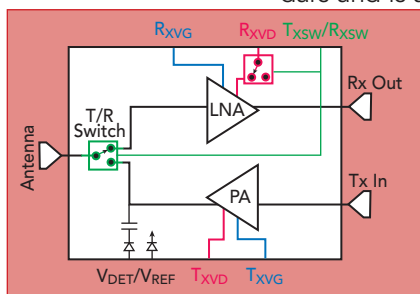
The QPM1002 is classified as EAR99 for export, meaning it can be exported to qualified international customers.

## GaN ADVANTAGES

An all-GaN MMIC solution offers several advantages:

- GaN is robust, with an operating temperature range of  $-55^{\circ}\text{C}$  to  $+100^{\circ}\text{C}$ .
- GaN LNAs can survive high incident RF power, eliminating the need for an Rx limiter in front of the LNA.
- The all-GaN solution minimizes size and simplifies system integration.

Rx robustness was tested at  $95^{\circ}\text{C}$  by driving successively higher input power into the antenna port for three minutes at each power level. Based on test results, the QPM1002 has a maximum antenna port input power



**▲ Fig. 1** The QPM1002 front-end integrates an LNA, PA and T/R switch and connects to the antenna.

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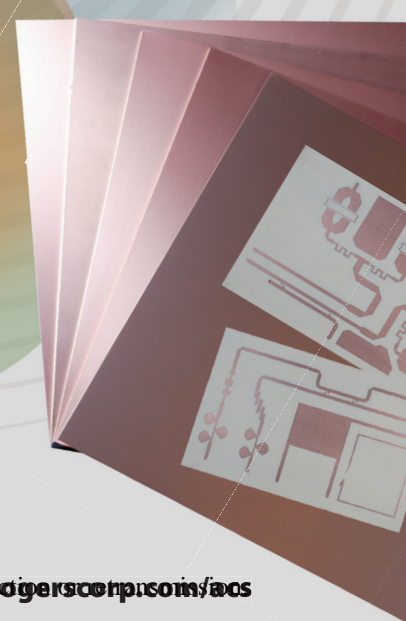
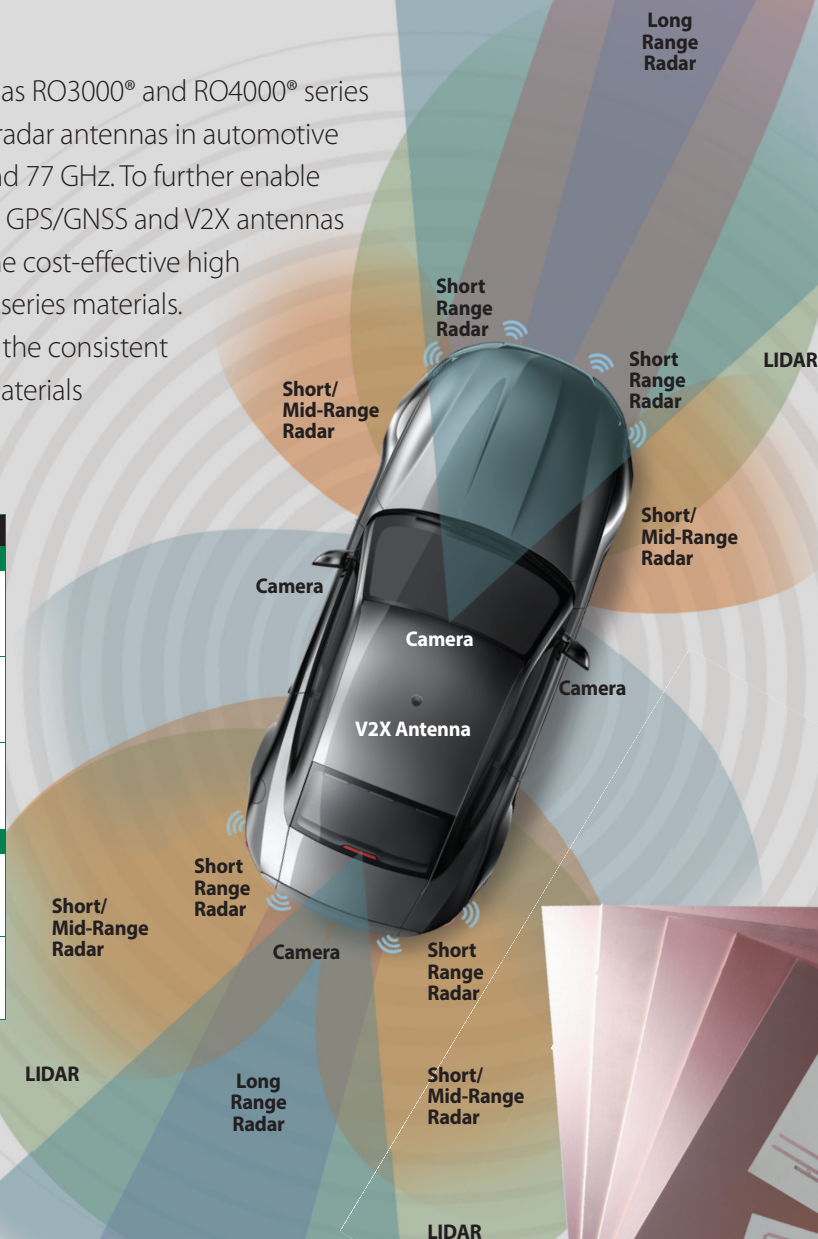


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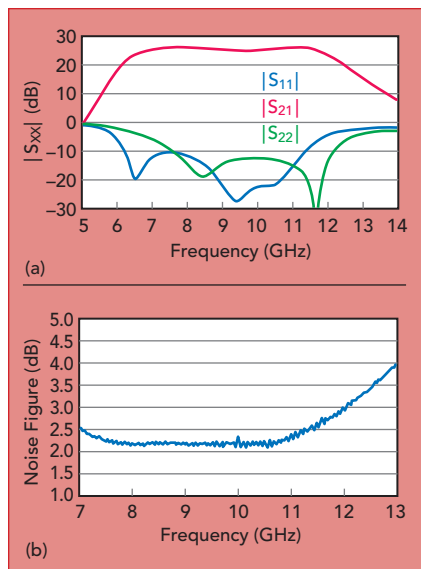
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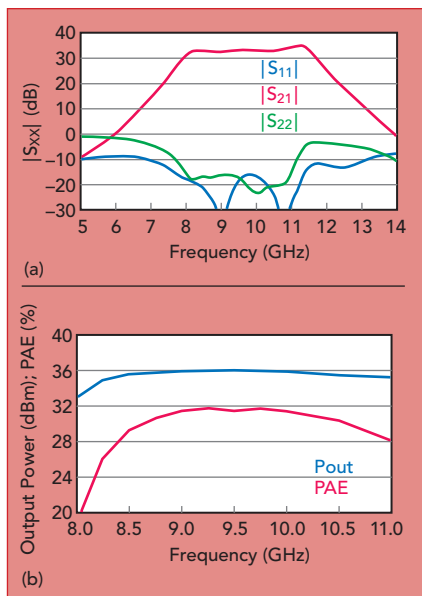




▲ Fig. 2 Gain,  $|S_{11}|$ ,  $|S_{22}|$  (a) and noise figure (b) of the LNA path at 25°C.

rating of 2 W. PA robustness was similarly tested by driving it into saturation with highly reflective loads at the antenna port. The PA withstands a 10:1 load while driven into saturation without failure or degradation.

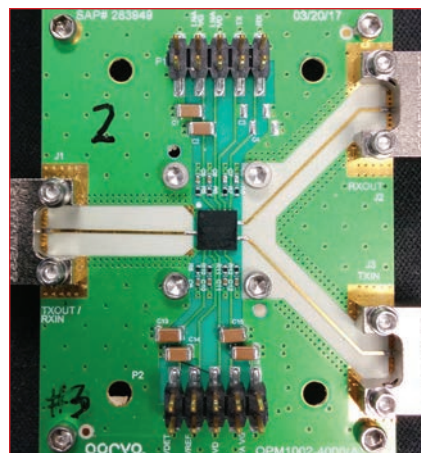
When the QPM1002 is in the Tx mode, on-chip circuitry turns off the current to the drain of the LNA using the Tx/Rx control lines (shown in Figure 1). This reduces the chance of LNA damage during Tx operation and increases the isolation of signals leaking through the LNA to the Rx output. The LNA turn-off circuitry conveniently eliminates the



▲ Fig. 3 Gain,  $|S_{11}|$ ,  $|S_{22}|$  (a) and output power and PAE (b) of the Tx path at 25°C.

need for gate/drain switching on the LNA when changing from Tx to Rx or vice-versa.

The typical output power of a GaN LNA is greater than 25 dBm, which could require attenuation or other power-limiting circuitry if downstream components are sensitive to power levels of this magnitude. To avoid this issue, the QPM1002 LNA implements a novel topology to limit the output power to 17 dBm, even when heavily saturated and at cold temperatures. This allows the LNA to directly drive sensitive SiGe beamformer ICs,



▲ Fig. 4 The QPM1002 surface-mounted to the evaluation board. A copper-filled via array underneath the module improves heat conduction from the device.

which typically have maximum input power ratings of 17 to 18 dBm.

## OPTIMIZED ANTENNA PORT SWITCH

The T/R switch topology was optimized to minimize the Rx noise figure and maximize Tx power-added efficiency; both are heavily influenced by the respective networks interfacing with the SPDT switch. The best performance was achieved by absorbing the off-state switch capacitance into the PA output and LNA input matching networks.

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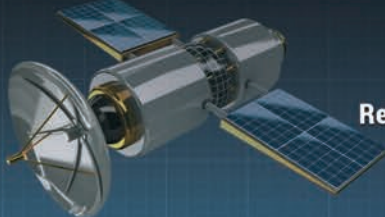
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Ontario, Calif.

**M**odern applications such as 5G, Wi-Fi and SATCOM require special attention when selecting suitable instrumentation and accessories to perform measurements for characterization, modeling, validation and design. One cannot simply use any available equipment but should select sources, analyzers and amplifiers with a high degree of linearity and sensitivity, to ensure signal fidelity and accurate, repeatable measurements. With these requirements in mind, Maury Microwave has released a line of test and measurement instrument amplifiers based on state-of-the-art, solid-state, GaN power amplifier (PA) modules to specifically address 50 and non-50  $\Omega$  measurements for modern applications, including 4G and 5G communications, advanced Wi-Fi standards, radar and SATCOM.

## PERFORMANCE

Key features include high continuous saturated output power of 1 to 50 W across the

entire bands from 0.7 to 6, 2 to 6, 2 to 18, 6 to 18, 8 to 12 and 18 to 26.5 GHz. Maury Microwave MPA-series instrument amplifiers have high gain—between 30 and 50 dB, with a typical gain flatness of  $\pm 2$  dB—to amplify the typical signal generator output power to the amplifier's rated saturated output. Users can manually adjust the gain over a range of 15 to 20 dB using the gain-adjustment knob on the front panel of the amplifier. All Maury amplifiers are unconditionally stable, and signal fidelity and accurate device-under-test measurements are ensured, due to low:

- Second harmonic output contribution of -35 to -15 dBc.
- Spurious signal contribution of -65 dBc at rated saturated output power.
- Third-order intermodulation products (IM3) of -48 to -33 dBc at 13 dB back-off with 10 MHz signal spacing.
- ACPR values of -50 to -40 dBc at 13 dB back-off typical, using an LTE signal with 20 MHz bandwidth and 9 dB peak-to-average ratio.

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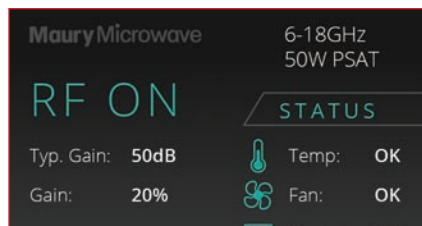
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▲ **Fig. 1** The LCD display shows operating status, gain level and faults.



▲ **Fig. 2** An MPA-series amplifier used in a vector-receiver load-pull system.



▲ **Fig. 3** The MPA-series amplifiers are tested extensively, including harmonics, intermodulation and ACPR.

MPA-series amplifiers include an integrated LCD display indicating amplifier operating status, gain level and any faults recorded by the internal protection circuitry (see **Figure 1**). Fault protection includes automatic shut-off due to elevated temperature, fan failure and PA module over-current.

### APPLICATIONS EXPERTISE AND RELIABILITY

MPA-series amplifiers have been created, in part, by leveraging Maury's 60+ year history in the RF/microwave industry and 30+ years of direct experience with transistor characterization, modeling, validation and PA

design. As application experts, Maury has manufactured, trained and supported turnkey measurement and modeling systems for 4G, 5G, Wi-Fi, radar and SATCOM applications, experiencing the pitfalls of using non-ideal instruments and accessories and, conversely, the benefits of using ideal components. Using this experience, Maury specified and designed application-specific instrument amplifiers to act as the backbone of each measurement and modeling system (see **Figure 2**). Maury's unique insight from the application and user perspective enables its engineers to support the customer's entire test bench, not only the amplifier.

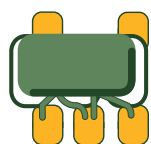
Maury MPA-series test and measurement instrument amplifiers are incredibly reliable, in part because of the advanced burn-in and aging procedures performed prior to final electrical test. The process includes exposing the amplifiers to extreme temperature conditions for prolonged duration, to identify premature component failure and mounting deficiencies. In addition, extended operation at the maximum saturated output power over the entire rated temperature range under CW and pulsed-CW operating conditions helps identify MMIC and PA module deficiencies or failures. After burn-in and aging, each instrument amplifier is tested using a state-of-the-art vector-receiver measurement system (see **Figure 3**). This system independently measures power at the fundamental, harmonic and intermodulation frequencies using single- and two-tone input signals, as well as true ACPR using modulated wideband signals.

### CUSTOM AND SEMI-CUSTOM

In addition to the standard offering, semi-custom models with variations on frequency range, power and gain are offered. Fully-custom amplifiers can also be developed, based on an extensive customer questionnaire covering frequency, output power, gain, harmonic power, spurious signals, intermodulation power, noise floor, mechanical dimensions, cooling requirements, etc.

Maury will release additional PAs during 2018 and 2019: 100 and 200 W between 0.7 and 2.7 GHz, higher power 18 to 26.5 and 26.5 to 40 GHz models.

**Maury Microwave Corp.**  
Ontario, Calif.  
[www.maurymw.com](http://www.maurymw.com)



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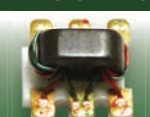
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# High-Power Silicon Switches for Massive MIMO Front-Ends

Analog Devices Inc.  
Norwood, Mass.

**M**IMO transceiver architectures are becoming widely used in the design of high-power RF wireless communication systems. As a step into the 5G era, massive MIMO (mMIMO) system covering the cellular bands are now being deployed in urban areas to meet the emerging demand for high data throughput and new services. The availability of highly integrated, single chip, baseband transceiver solutions, such as ADI's new ADRV9008/9 family of products, made this achievement possible. Similar integration is needed at the RF front-end of these systems to reduce power consumption for thermal management, shrink size, reduce cost and accommodate more MIMO channels.

MIMO architectures allow the RF output power and power handling requirements for amplifiers and switches to be relaxed. However, as the number of parallel transceiver channels increases, the complexity of peripheral circuits and total power consumption scales accordingly. ADI's new high-power switches, fabricated in silicon, are designed

to simplify the RF front-end design, eliminating the need for peripheral circuits and reducing power consumption to a negligible level. ADI's high-power silicon switches offer RF designers and system architects the flexibility to increase system complexity without the RF front-end becoming a bottleneck in the design.

In time-division duplex (TDD) systems, a switch function is used at the antenna interface to isolate and protect the receiver input from the power of the transmitted signal. This switch can either be used directly at the antenna interface in relatively lower power systems (see **Figure 1**) or placed on the receive path for higher power applications, to ensure proper termination to the duplexer (see **Figure 2**). In both architectures, having a shunt arm on one of the switch outputs helps improve isolation.

PIN diode switches have been the preferred solution, offering low insertion loss and high-power handling. However, they need high bias voltages, to reverse bias for isolation, and high current, to forward bias for low insertion loss, which are shortcom-

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We're excited! European Microwave Week is coming to Spain for the first time ever! Being held in the effervescent and wildly exciting city of Madrid.

Bringing industry and academia together, European Microwave Week 2018 is a SIX day event, including THREE cutting edge conferences and ONE exciting trade and technology exhibition featuring leading players from across the globe. EuMW 2018 provides access to the very latest products, research and initiatives in the microwave sector. It also offers you the opportunity for face-to-face interaction with those driving the future of microwave technology.

EuMW 2018 will see an estimated 1,500 conference delegates, over 4,000 attendees and in excess of 300 international exhibitors (inc. Asia & US).

## REGISTRATION TO THE EXHIBITION IS FREE!

- **Over 300 International Companies** - meet the industry's biggest names and network on a global scale
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- **Industrial Workshops** - get first hand technical advice and guidance from some of the industry's leading innovators
- **MicroApps** - attend our annual European Microwave Week Microwave Application Seminars (MicroApps)

### BE THERE

#### Exhibition Dates

Tuesday 25th September

Wednesday 26th September

Thursday 27th September

#### Opening Times

09:30 - 18:00

09:30 - 17:30

09:30 - 16:30

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- Alternatively, you can register onsite at the self service terminals during the Exhibition

**Please note NO visitor badges will be mailed out prior to the Exhibition.**



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- European Microwave Conference (EuMC) 25th - 27th September 2018
- European Radar Conference (EuRAD) 26th - 28th September 2018
- Plus Workshops and Short Courses (From 23rd September 2018)
- In addition, EuMW 2018 will include, for the 9th year, the Defence, Security and Space Forum on 26th September 2018

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

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**There are TWO different rates available for the EuMW conferences:**

- **ADVANCE DISCOUNTED RATE** – for all registrations up to and including 23rd August 2018
- **STANDARD RATE** – for all registrations made after 23rd August 2018

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

**Online registration is open now, up to and during the event until 28th September 2018**

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- Alternatively, you can register onsite at the self service terminals during the registration opening times below:
  - Saturday 22nd September (16:00 - 19:00)
  - Monday 24th September (08:00 - 17:00)
  - Wednesday 26th September (08:00 - 17:00)
  - Friday 28th September (08:00 - 10:00)
  - Sunday 23rd September (08:00 - 17:00)
  - Tuesday 25th September (08:00 - 17:00)
  - Thursday 27th September (08:00 - 17:00)

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



# CONFERENCE REGISTRATION INFORMATION

## EUROPEAN MICROWAVE WEEK 2018, 23rd - 28th September, Madrid, Spain

### Register Online at [www.eumweek.com](http://www.eumweek.com)

**ONLINE registration is open from 28th May 2018 up to and during the event until 28th September 2018.**

**ONSITE registration is open from 16:00 on 22nd September 2018.**

**ADVANCE DISCOUNTED RATE (up to and including 23rd August) STANDARD RATE (from 24th August & Onsite).**

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

EuMA membership fees: Professional €25/year, Student €15/year.

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

Reduced Rates for the conferences are also offered if you are a Student/Senior (Full-time students 30 years or younger and Seniors 65 or older as of 28th September 2018).

The fees shown below are invoiced in the name and on behalf of the European Microwave Association. EuMA's supplies of attendance fees in respect of the European Microwave Week 2018 are exempted from Spanish VAT.

#### ADVANCE REGISTRATION CONFERENCE FEES (UP TO AND INCLUDING 23RD AUG.)

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

#### STANDARD REGISTRATION CONFERENCE FEES (FROM 24TH AUG. AND ONSITE)

CONFERENCE FEES	ADVANCE DISCOUNTED RATE			
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	Standard	Student/Sr.	Standard	Student/Sr.
<i>1 Conference</i>				
EuMC	€ 660	€ 190	€ 930	€ 270
EuMIC	€ 510	€ 170	€ 720	€ 240
EuRAD	€ 450	€ 160	€ 630	€ 230
<i>2 Conferences</i>				
EuMC + EuMIC	€ 940	€ 360	€ 1320	€ 510
EuMC + EuRAD	€ 890	€ 350	€ 1250	€ 500
EuMIC + EuRAD	€ 770	€ 330	€ 1080	€ 470
<i>3 Conferences</i>				
EuMC + EuMIC + EuRAD	€ 1140	€ 520	€ 1600	€ 740

#### WORKSHOP AND SHORT COURSE FEES (ONE STANDARD RATE THROUGHOUT)

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

#### Other Items

##### PRIVATE VISIT TO THE THYSSEN-BORNESMIZA MUSEUM & COCKTAIL DINNER - 26TH SEPTEMBER 2018

Tickets for the private visit and cocktail dinner at the Thyssen-Bornesmiza Museum are offered at the price of € 45. Tickets are limited and available on a first-come, first-served basis.

##### DELEGATE LUNCHBOXES

Subsidised lunchboxes for delegates, WS/SC, doctoral and student school attendees are being offered by EuMW at the reduced cost of € 5 per lunchbox (one per day).

##### Proceedings on USB Stick

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

##### International Journal of Microwave and Wireless Technologies (8 issues per year)

International Journal combined with EuMA membership: € 67 for Professionals or € 57 for Students.

#### EUMW 2018 WORKSHOPS & SHORT COURSES

SUNDAY 23rd September			TUESDAY 25th September		
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Half Day AM	WS-02	EuMC/EuMIC			
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Full Day	SS-02	EuMC/EuMIC			
Full Day	SS-03	EuMC/EuMIC			
MONDAY 24th September			FRIDAY 28th September		
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Full Day	WM-02	EuMC	Full Day	WF-02	EuMC
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Full Day	WM-04	EuMC	Half Day AM	WF-04	EuRAD
Full Day	SM-01	EuMC	Full Day	WF-05	EuMC
Full Day	SM-02	EuMC	Full Day	WF-06	EuMC
Full Day	SM-03	EuMC	Full Day	WF-07	EuMC
Full Day	SM-04	EuMC	Half Day AM	SF-01	EuMC/EuRAD

#### SPECIAL FORUMS & SESSIONS

Date	Time	Title	Location	No. of Days	Fee	
Wednesday 26th September	10:50 - 17:50	Defence, Security & Space Forum	N101 + N102	1	€ 20 for delegates (those registered for EuMC, EuMIC or EuRAD)	€ 60 for all others (those not registered for a conference)
Monday 24th - Wednesday 26th September	08:30 - 17:50	European Microwave Student School	N107	One full day and two half-days	€ 40	
Monday 24th - Wednesday 26th September	08:30 - 17:50	European Microwave Doctoral School	N108	One full day and two half-days	€ 80	

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- Plus Workshops and Short Courses (From 23rd September 2018)
  - In addition, EuMW 2018 will include for the 9th year, the Defence, Security and Space Forum on 26th September 2018

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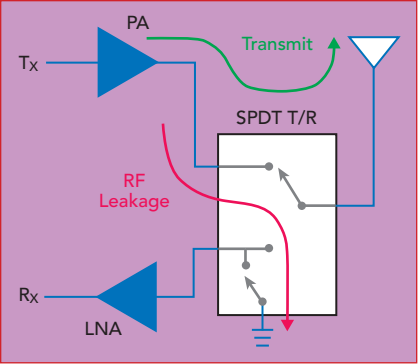


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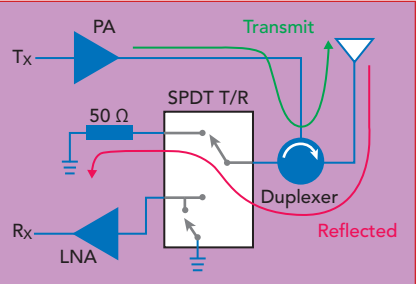
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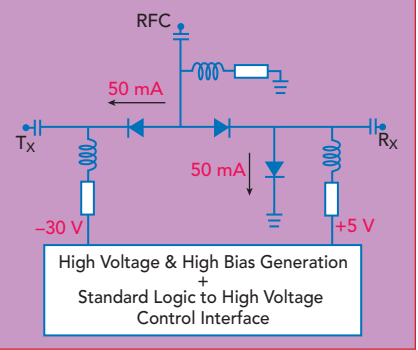




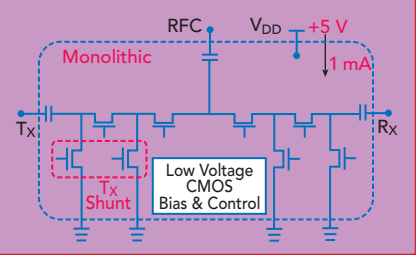
▲ Fig. 1 Antenna switch.



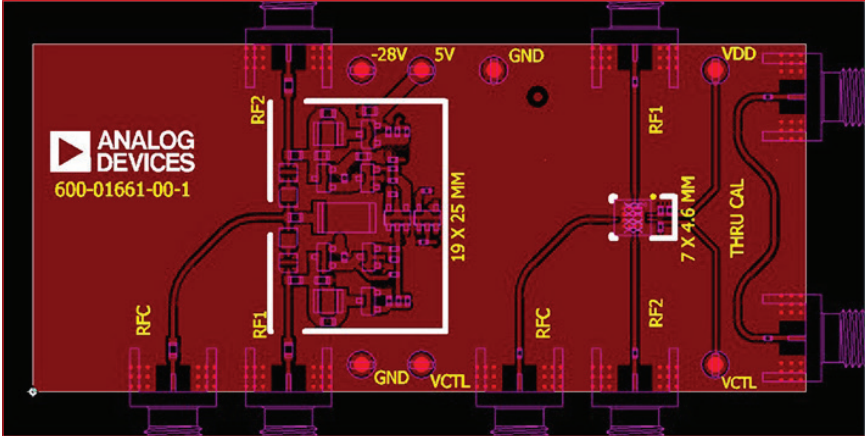
▲ Fig. 2 LNA protection switch.



▲ Fig. 3 PIN diode switch.



▲ Fig. 4 Silicon switch.



▲ Fig. 5 PCB footprint comparison: PIN diode vs. silicon switch.

ings in mMIMO systems. **Figure 3** shows a typical application circuit for a PIN diode switch, including the peripheral circuitry, where three discrete PIN diodes are biased through bias-tees and controlled with a high voltage interface circuit.

ADI's new high-power silicon switches are better suited to mMIMO designs. They are biased with a single 5 V supply, draw less than 1 mA current and do not need external components or interface circuits. The FET circuit architecture (see **Figure 4**) operates on low supply voltages and draws low bias currents, making the power consumption negligible and aiding system thermal management. Additionally, the FET architecture yields better isolation, as more shunt arms are incorporated on the RF signal path. ADI's silicon switches handle RF peak power up to 80 W, adequate margin to cover the peak-to-average power requirements for mMIMO systems.

**Figure 5** shows a side-by-side comparison of the PCB artwork on a single-layer design for a PIN diode switch and ADI's new silicon switch. The footprint of the silicon switch is

more than 10× smaller than the PIN diode switch footprint.

**Table 1** shows ADI's family of high-power silicon switches, which are optimized for various power levels and package options. These devices reflect the intrinsic advantages of silicon technology: better ESD robustness and less part-to-part variation compared to alternative solutions.

As mMIMO systems evolve, they will need even higher levels of integration. ADI's new high-power silicon switch technology is well-suited for multi-chip module designs, enabling integration with LNAs to offer a complete single chip solution for TDD receiver front-ends. ADI plans to scale new designs to cover higher frequencies, leading to similar solutions for 5G mmWave systems. Other applications such as phased array radars will benefit from the advantages of the silicon switch architecture as ADI expands its product portfolio to X-Band and higher.

**VENDORVIEW**  
**Analog Devices Inc.**  
**Norwood, Mass.**  
**www.analog.com**

TABLE 1						
HIGH-POWER SILICON SWITCH FAMILY						
Part Number	Frequency (GHz)	Insertion Loss (dB)	Isolation (dB)	Average Power (W)	Peak Power (W)	Package Size (mm)
ADRF5130	0.7 to 3.5	0.6 at 2.7 GHz 0.7 at 3.8 GHz	45 at 3.8 GHz	20	44	4 × 4
ADRF5132	0.7 to 5.0	0.60 at 2.7 GHz 0.65 at 3.8 GHz 0.90 at 5.0 GHz	45 at 3.8 GHz 45 at 5.0 GHz	3.2	20 at 3.8 GHz 10 at 5.0 GHz	3 × 3
ADRF5160	0.7 to 4.0	0.8 at 2.7 GHz 0.9 at 3.8 GHz	48 at 3.8 GHz	40	88	5 × 5

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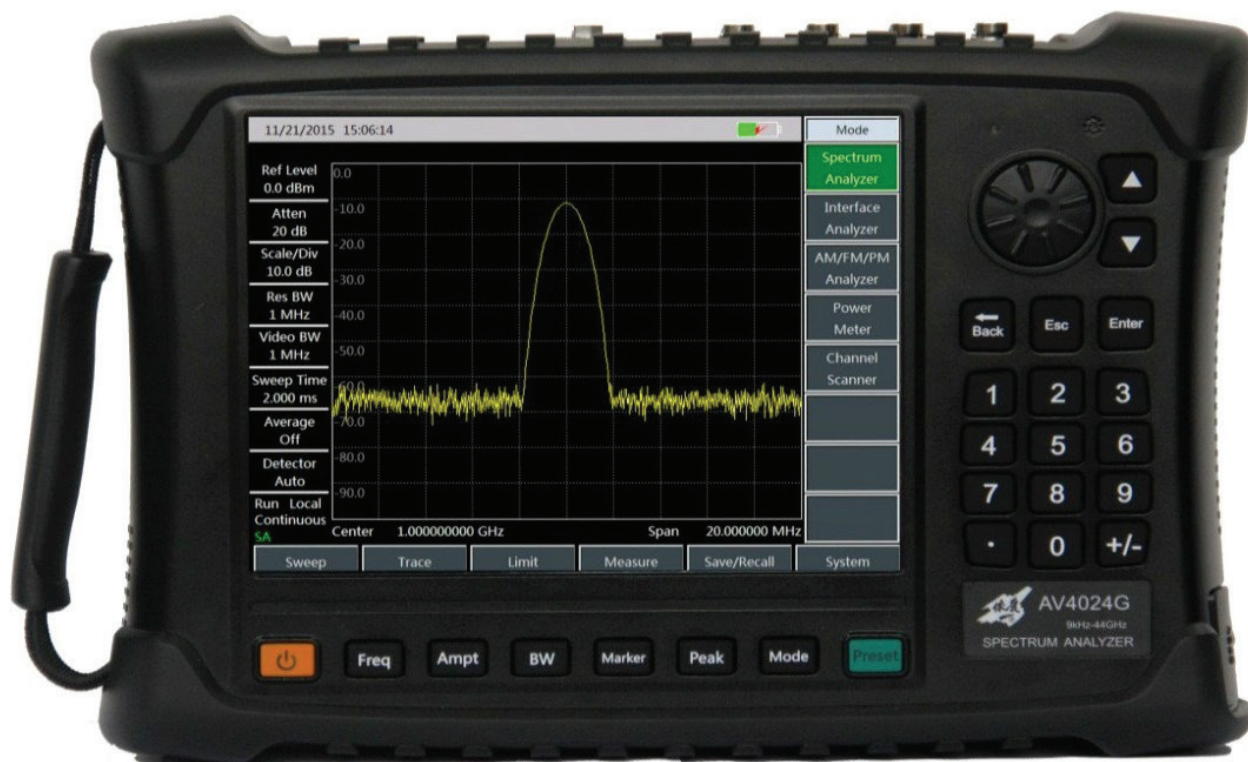
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- Various intelligent measurement functions: field strength, channel power, occupied bandwidth, adjacent-channel power ratio, tune & listen, carrier-to-noise ratio, emission mask.
- Various auxiliary test interfaces: 10MHz reference I/O, GPS antenna, zero span IF output, external triggering input, etc.
- Various measurement functions: spectrum analyzer, interference analyzer (spectrogram, RSSI), AM/FM/PM analyzer, channel scanner, high accuracy power meter etc.



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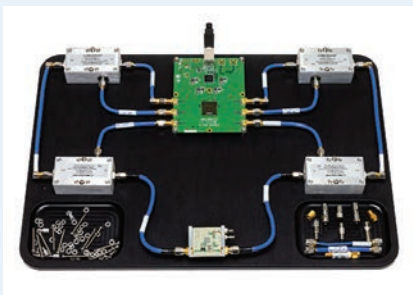
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**M**ini-Circuits and Vayyar Imaging, a 3D imaging sensor company, have partnered to offer transceiver project kits for students, university programs and hobbyists. The kits are developed to enable students to explore electromagnetic theory, RF/microwave engineering and applications such as radar. They address a significant gap in most university's RF/microwave programs, between textbook theory and the lab measurements to confirm the theory or evaluate the "real world" performance of RF/microwave components and systems.

The first kit, UVNA-63, enables students to build a fully functioning

# DIY Vector Network Analyzer for Universities and Hobbyists

vector network analyzer (VNA), develop S-parameter algorithms and perform real-time measurements of two-port RF devices from 500 MHz to 6 GHz. The kit comprises Vayyar's high performance transceiver IC with RF components from Mini-Circuits and includes calibration standards, control software and a development environment for Python and MATLAB®.

The UVNA-63 VNA kit can be pre-ordered now from Mini-Circuits and will be delivered in September, coinciding with the fall semester at most schools.

Attendees at the upcoming EDI CON conference in Santa Clara will have the opportunity to play

with the DIY VNA at a workshop on Thursday morning, October 18. The hands-on "Build Your Own VNA" session, one of several EDI CON courses eligible for IEEE continuing education credits, will cover transmission line theory, the basics of S-parameter measurements and construction of a VNA. Participants will use the UVNA-63 kit to build a VNA, load the scripts, understand the math behind the measurements, make measurements and evaluate accuracy.

**VENDORVIEW**

**Mini-Circuits  
Brooklyn, N.Y.**

**[www.minicircuits.com](http://www.minicircuits.com)**



**K**P Performance Antennas has developed a new series of dual sector antennas designed to reduce tower rental and installation costs by housing two or more antennas in a single radome. KP's new line comprises seven models, each consisting of two or more sector antennas inside a single, rugged radome. The antennas are offered with four or eight ports and support 2 x 2, 4 x 4 and 8 x 8 MIMO, depending on the model. The single mounting point reduces inches on the tower, lowers wind resistance and halves tower rental. The antennas also provide a rapid upgrade path to add frequency bands without installing more infrastructure.

# Dual Sector Antennas Cover Bands from 2 through 6 GHz

The straight-on models in this line provide two forward-facing, high gain, 65 or 90 degree sector antennas in a single radome, one for each frequency band, and come in frequency combinations of 2 and 3 GHz, 2 and 5 GHz, 3 and 5 GHz and 5 and 5 GHz. They feature clean patterns and provide complete 360 degree coverage while minimizing interference. They also have mounting space for two ePMP radios, have four Type N female connectors and hot-dip galvanized steel sector brackets. These antennas are ideal for point-to-multipoint applications and support many of the popular radios in the WISP/WLAN market.

The side-angle models combine two 65 degree sector antennas in a single radome and mounted 60 degrees apart, with two ports angled at -60 degrees and the other two at +60 degrees, for a total of 120 degree coverage using two, 2 x 2 MIMO radios on a single antenna. These antennas achieve complete 360 degree coverage while minimizing interference, with only three side-angle sectors connected to six, 2 x 2 MIMO radios around a tower and ABCABC frequency reuse.

**KP Performance Antennas  
Edmonton, Alberta, Canada  
[www.kpperformance.com](http://www.kpperformance.com)**



# Cowave: A Hybrid Coax-Waveguide Switch

**T**he microwave industry lacks a suitable coaxial switch for frequencies above 30 GHz. Commercially available coaxial switches fall short in performance: they prove to be very lossy at high frequencies and cannot handle high power. Addressing this shortcoming, Sector Microwave Industries developed a new innovative technique that achieves the benefits of both coaxial and waveguide switches

in a hybrid, "Cowave" switch. The Cowave switch is capable of handling high power and can be tuned by design to a wide band of waveguide frequencies up to 50 GHz.

The innovative aspect of this new switch is that it is contactless. The unit uses a miniature waveguide rotor and waveguide channels, enabling the transfer of energy inside the Cowave housing. The switch is compact and miniature compared to using coaxial-to-waveguide adapters with a typical waveguide

switch. The Cowave switch is also modular and can be configured to have different combinations of coaxial connectors and waveguide ports on both inputs and outputs to form DPDT, SPDT and more options.

Within the waveguide bandwidth, the switches typically measure 0.5 dB insertion loss, 1.25:1 VSWR and 45 dB isolation.

**Sector Microwave Industries**  
Deer Park, N.Y.  
[www.sectormicrowave.com](http://www.sectormicrowave.com)



Catch up on the latest industry news with the bi-weekly video update **Frequency Matters** from Microwave Journal @ [www.microwavejournal.com/frequencymatters](http://www.microwavejournal.com/frequencymatters)

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mmWave OTA  
Test Approaches

Spatial Multiplexing for  
5G Systems

A Highway to European  
Cooperation in Defence  
Technology Research –  
Avoiding the Tower of Babel

EuMW Show Coverage and  
Industry News



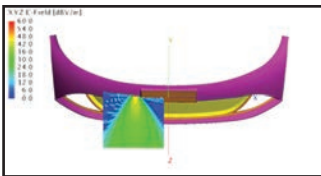
## Software and Mobile Apps

### 2018 Versions of EM Simulation Software



Altair has released the 2018 versions of electromagnetic (EM) simulation software FEKO®, WinProp®, Flux® and FluxMotor®. These EM solver tools, part of Altair's HyperWorks®, The Platform for Innovation™, are used to accelerate the global design process for the automotive, aerospace, defense, communications, consumer electronics, energy and healthcare industries. The 2018 release broadens functionality, simplifies workflows and enhances the user experience. For example, Flux 2018 brings new capabilities for CAD geometry simplification and meshing, improving workflow and increasing flexibility with the ability to solve faster in 3D using new HPC resources.

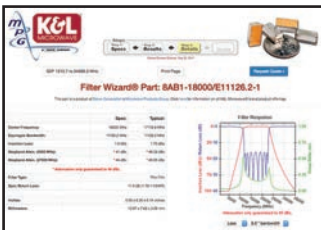
**Altair Engineering Inc.**  
<https://altairhyperworks.com/>



### Filter Wizard®

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

**K&L Microwave**  
[www.klfilterwizard.com](http://www.klfilterwizard.com)

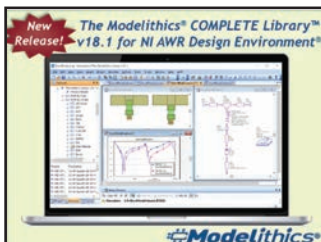


### The COMPLETE Library™ v18.1



Modelithics has released the newest version, version 18.1, of the COMPLETE Library for use with NI AWR software. With this release, the Modelithics mmWave & 5G Library, a new product introduced in 2018, is now available for the NI AWR Design Environment® platform. With the addition of 47 new models, the library now represents over 16,000 components. Four significant new features have been incorporated into the v18.1 release as well. The release also includes the Modelithics mmWave & 5G library, with all models validated to at least 30 GHz, with some validated as high as 125 GHz.

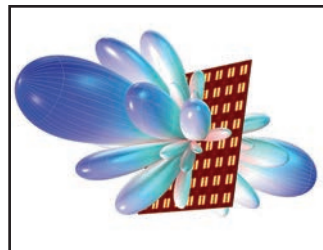
**Modelithics Inc.**  
[www.modelithics.com](http://www.modelithics.com)



### Multiphysics® Software

COMSOL is a global provider of simulation software for product design and research. Its COMSOL Multiphysics® product is an integrated software environment for creating physics-based models and simulation apps. A particular strength is its ability to model multiphysics systems. COMSOL users can convert their models into easy-to-use apps for their colleagues and customers worldwide. Apps are deployed and accessed online through the COMSOL Server™ product. Interfacing tools enable the integration with all major technical computing and CAD tools.

**COMSOL Inc.**  
[www.comsol.com](http://www.comsol.com)



### MegaPhase Connect App

Download MegaPhase's free iOS app, MegaPhase Connect, to help assist with daily calculations including wavelength, cable loss, insertion loss and time delay. All test and measurement, RF cables and connector and adapters datasheets are accessible within the app, created specifically for engineers designing and building RF/microwave systems and components. Select the "MegaPhase Cable Builder" feature, which allows you to enter your specifications and render instant product offerings. The "My Products" feature allows you to save items of interest for future reference. Browse the updated brochure now available through the app.

**MegaPhase LLC**  
<https://itunes.apple.com/us/app/megaphase-connect/id976835614?mt=8>

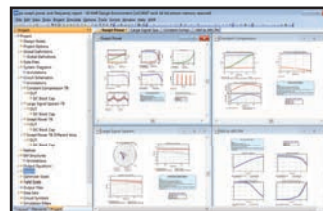


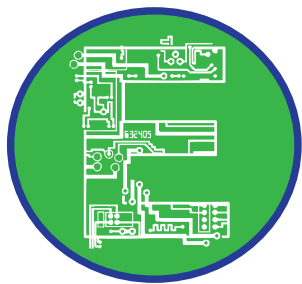
### New Design Environment V14



NI AWR Design Environment V14 focuses on all stages of RF/microwave design with an emphasis on accelerating design starts to address today's most challenging communications and aerospace/defense applications. Capabilities include powerful network synthesis for multi-band impedance matching circuits, advanced layout editing capabilities for PCB/module EM verification, design support for phased-array antenna configuration/optimization and enhanced analysis, automation and report/measurement management.

**NI AWR**  
[www.ni.com/awr](http://www.ni.com/awr)





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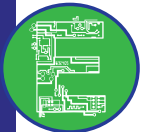
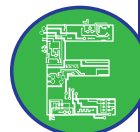
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**Presented by:** Dr. Eli Brookner

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### Distributed Wi-Fi (Wi-Fi Mesh): A Key to Smarter Homes

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**Presented by:** Cees Links, General Manager of Qorvo's Wireless Connectivity Business Unit

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# NEW PRODUCTS

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## Centric RF

### 1.85 mm F/F 67 GHz Flanged Adapter



Centric RF announced a 4-hole flanged adapter covering the full IEEE P287 bandwidth of 0 to 67 GHz. The C8064 is a 1.85 mm female to female adapter with a

4-hole flange featuring a stainless steel body and BeCu female contacts. Maximum VSWR is 1.25 from 0 to 67 GHz. The 67 GHz performance allows usage in some of the new Wi-Fi bands which can extend to 66 GHz. Availability is from stock, pricing is \$355 for 1-9.

[www.centricrf.com](http://www.centricrf.com)

## Ceyear



### Solid-State Amplifiers



Ceyear announced their new line of solid-state amplifiers. These amplifiers are highly accurate in banded solutions from 9 kHz to 110

GHz and power levels reaching as high as 200 W. These amplifiers are highly accurate using internal RF power monitoring and superior cooling. This new amplifier line offers top level quality at an affordable price to all RF designers. Prices start at \$22,500.

[www.topdogtest.com/ceyear](http://www.topdogtest.com/ceyear)

## Custom MMIC



### GaAs Low Noise Amplifier



Custom MMIC now offers a new GaAs Low Noise Amplifier (LNA) MMIC with broadband noise figure performance previously only achievable with

discrete FET designs. The CMD283C3, with 0.6 dB noise figure, is the first in a family of new ultra-low noise amplifiers. The CMD283C3 LNA covers 2 to 6 GHz with high midband gain of 27 dB and output P1dB of 16 dBm.

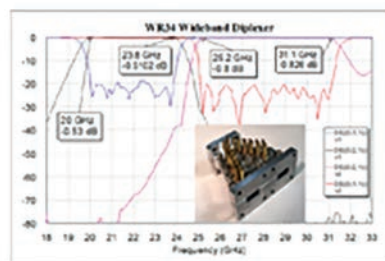
[www.custommmic.com/cmd283c3-low-noise-amplifier/](http://www.custommmic.com/cmd283c3-low-noise-amplifier/)

## Exceed Microwave



### Wideband Waveguide Diplexer

Exceed Microwave's WC-Series waveguide diplexers can provide very wide passbands and also comes in small sizes. DPX-WC-22-28-34 is a WR34 diplexer cover-



ing nearly the entire waveguide operating frequency band. Each channel bandwidth of DPX-WC-22-28-34 is roughly 20 percent while maintaining very good return loss at all ports. The size is only 1.5 in. x 1.8 in. x 0.9 in., which allows waveguide assemblies to be compact. WC-Series diplexers are available in different waveguide sizes. Exceed Microwave designs and manufactures high performance waveguide and coaxial filters.

[www.exceedmicrowave.com](http://www.exceedmicrowave.com)

## Fairview Microwave Inc.

### Gold-Plated 4-in-1 SOLT Calibration Kits



Fairview Microwave Inc. has launched a new line of 4-in-1 3.5 mm calibration kits for cable verification, antenna measurement and other field test and measurement applications. Fairview Microwave's new line of integrated, short-open-load-through (SOLT) calibration kits is made up of two models that have a 26.5 GHz calibration capability. They feature a compact, lightweight, 4-in-1 design package with gold-plated, 3.5 mm connectors and a convenient lanyard. Plus, they are available off-the-shelf with same-day shipping.

[www.fairviewmicrowave.com](http://www.fairviewmicrowave.com)

## Kaelus

### Battery Operated PIM Analyzer



The iPA Series passive intermodulation (PIM) analyzer from Kaelus is the first battery powered PIM test analyzer versatile enough to support multiple test scenarios such as testing at the top of the tower, base of tower, rooftop and in-building for DAS systems. This IEC compliant 20 W, rugged, battery operated analyzer includes a tablet computer in a ruggedized case for remote control. This allows hands-free dynamic testing that is safe and convenient.

[www.kaelus.com](http://www.kaelus.com)

## MCV Microwave



### Ultra-Low PIM Cavity Filters and Multiplexers



MCV Microwave has developed a new line of ultra-low passive intermodulation (PIM) cavity filters and

multiplexers covering the TETRA and all LTE frequency bands from 300 to 3600 MHz. The typical production PIM performance is -163 dBc, measured with two CW tones, each at 43 dBm. An even lower PIM filter line with a guaranteed -173 dBc is available for PIM test bench and more demanding testing applications.

[www.mcv-microwave.com](http://www.mcv-microwave.com)

## Mini-Circuits



### MMIC Amplifier



Mini-Circuits' PHA-23HLN+ ultra-high dynamic range MMIC amplifier sets the new industry standard for noise figure and IP3 in VHF/UHF communications.

This model is well matched to 50  $\Omega$  from 30 MHz to 2 GHz and provides 1.4 dB noise figure, +44.4 dBm IP3, making it ideal for maximizing sensitivity and dynamic range in high performance receiver applications. It delivers 21 dB typical gain with  $\pm 1.8$  dB flatness, +28.4 dBm output power at 1 dB compression. The amplifier is fabricated using E-PHEMT technology with excellent repeatability.

[www.minicircuits.com](http://www.minicircuits.com)

## MiniRF



### Transformers



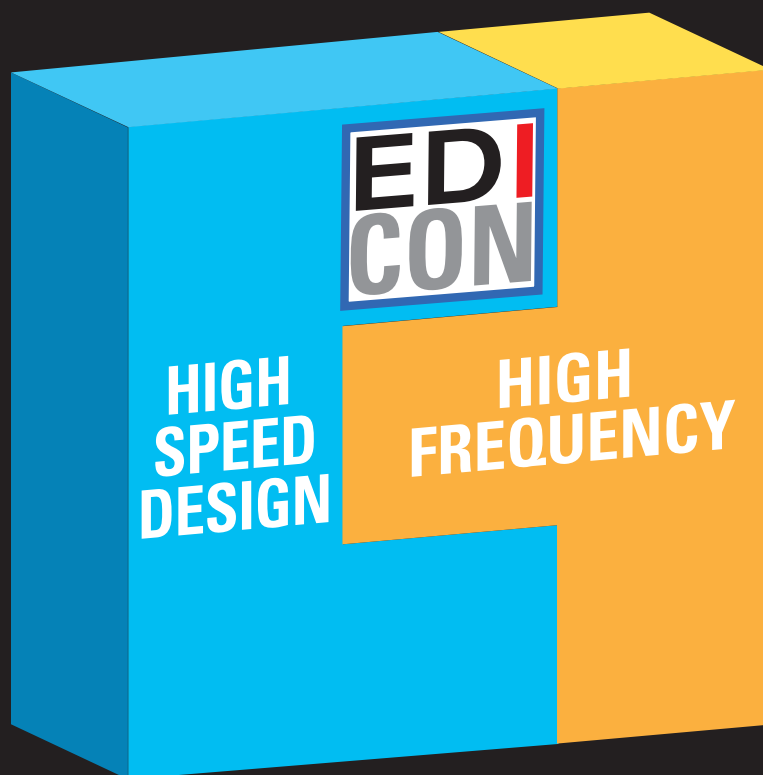
The MRFXF0024 transformer is designed for applications that require very small, low cost and highly reliable surface mount components.

Applications may be found in broadband, wireless and other communications systems. These units are built lead-free and RoHS compliant and feature welded wire construction for increased reliability. S-parameters are available on request.

[www.minirf.com](http://www.minirf.com)

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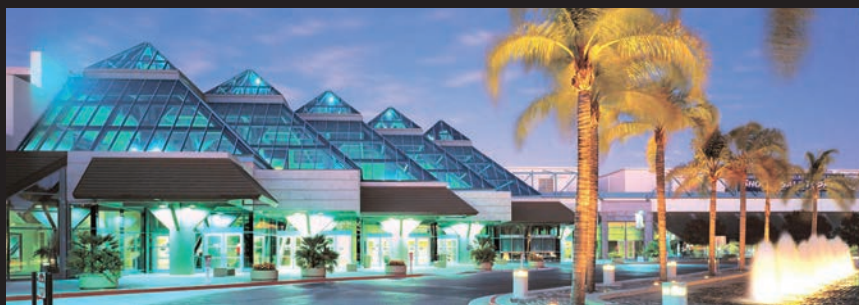


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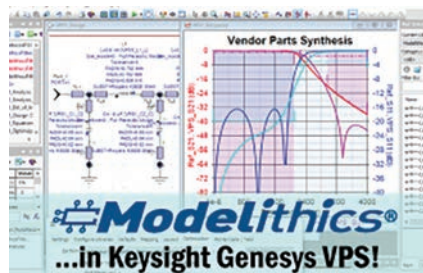


## NewProducts

### Modelithics



The Modelithics® COMPLETE Library v18.2



The 2018 version of the Modelithics COMPLETE Library for Keysight Genesys is now available. Modelithics models play a key part in the new Vendor Parts Synthesis (VPS) tool in Genesys software. VPS utilizes the scalability features of

Modelithics models to allow complete design synthesis in a simple, streamlined process. Once goals are set for a specific design, VPS incorporates Modelithics models to accurately account for parasitics and optimize the design using the over 16,000 commercially available vendor components represented in the Modelithics library.

[www.modelithics.com](http://www.modelithics.com)

### Pasternack



40 GHz Skew Matched Cable Pairs



Pasternack has launched a new line of skew matched cables for use in high speed digital tests of 10 to 28 Gbps, including differential signals, bit-error-rate testing and eye diagrams. Pasternack's new line of skew matched cables is made up of three new models that are extremely flexible and have 1

ps delay match. These cables deliver excellent VSWR of 1.4:1 and are 100 percent tested for skew match.

[www.pasternack.com](http://www.pasternack.com)

### Reactel Inc.



Filters, Multiplexers & Multifunction Assemblies



Reactel manufactures a line of filters, multiplexers and multifunction assemblies covering up to 50 GHz. From small, light-weight units suitable for flight or portable systems to high-power units capable of handling up to 25 kW, connectorized or

surface mount—the company's talented engineers can design a unit specifically for your application.

[www.reactel.com](http://www.reactel.com)

### Richardson RFPD

Wideband RF Transceiver



Analog Devices' ADRV9009 is the only transceiver with the bandwidth and RF performance to create a clear path to 5G, and the versatility to support all 2G, 3G and 4G cellular standards. Features include 75 MHz to 6 GHz, 200 MHz bandwidth dual transceiver, common platform design for 2G/3G/4G/5G, system integration replaces up to 20 components, significantly reducing SWaP, simplified digital beamforming through internal LO phase synchronization and fast frequency-hopping.

[www.richardsonrfpd.com](http://www.richardsonrfpd.com)

### RLC Electronics Inc.

Surface Mount Product Enhancements



RLC Electronics continues to invest in its surface mount technology to add to its extensive capabilities across multiple product lines. These parts are ideal for the latest aerospace and

## PicoVNA™ Vector Network Analyzer

- 300 kHz to 6 GHz
- > 5000 .s2p points/s
- To 118 dB and 0.005 dB RMS
- 8 / 12 term cal. incl. unknown thru

The PicoVNA 106 brings you full-function bidirectional vector network analysis at an unprecedented low price. Fast, professional-grade measurement and analysis that you can afford.

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## NewProducts

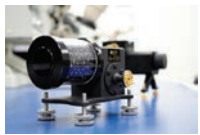
defense platforms, which utilize surface mount components to reduce size, overall footprint and integration time and, most importantly, cost. The company's surface mount electro-mechanical switch product enhancements include both SPDT and DPDT offerings, operating up to as high as 26.5 GHz.

[www.riceelectronics.com](http://www.riceelectronics.com)

### SAGE Millimeter



### Rotary Vane Attenuator



Model STA-60-12-D8 is an instrumentation grade, high precision and high attenuation range direct reading, rotary vane attenuator

for use in mmWave test sets across the standard E-Band frequency range of 60 to 90 GHz. The attenuator has a large scale calibrated dial which indicates the attenuation value directly. The attenuator is an ideal piece of equipment in waveguide systems where a broad direct reading of attenuation is required. The attenuator exhibits exceptional repeatability during frequent attenuation setting operations.

[www.sagemillimeter.com](http://www.sagemillimeter.com)

### W. L. Gore & Associates

### PHASEFLEX® Microwave/RF Test Assemblies



W. L. Gore & Associates has introduced the new GORE®PHASEFLEX® Microwave/RF Test Assemblies, Type ON for high density test/

interconnection—a lightweight assembly that ensures consistent, repeatable measurements with stable electrical performance up to 50 GHz. High-density and modular test instruments for wireless devices and aerospace systems have become increasingly complex, with a larger number of ports that can accept up to 32 test assemblies or more.

[www.gore.com](http://www.gore.com)

### SECTOR MICROWAVE INDUSTRIES, INC.



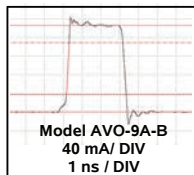
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## MICRO-ADS

### Laser Diode Drivers with Butterfly Sockets



Each of the 19 models in the Avtech AVO-9 series of pulsed laser diode drivers includes a replaceable output module with an ultra-high-speed socket suitable for use with sub-nanosecond rise time pulses. Models with maximum currents of 0.1A to 10A are available with pulse widths from 400 ps to 1 us. GPIB, RS-232, and Ethernet control available.

Avtech Electrosystems Ltd.  
<http://www.avtechpulse.com/>

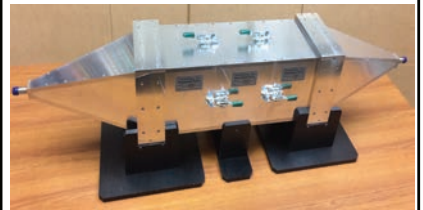


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### FREQUENCY SYNTHESIZERS to 34 GHz

#### Model SLSM5

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- Good phase noise
- Frequency control
  - RS485 (multidrop)
  - USB via converter
  - Supplied with evaluation GUI
- Reference ext 10 MHz or int ( $\pm 0.5$  PPM)
- Miniature package (2.5"x2.5"x0.63")
- DC power single 5V
- Affordable and a great value

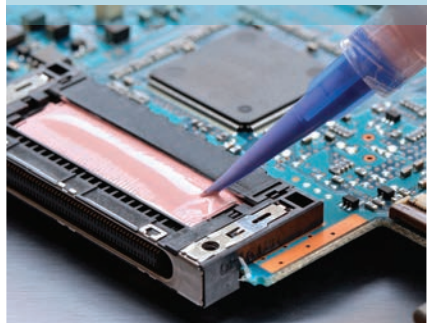


In short we build so much performance into the SLSM5 that the only surprise is its price and affordability!

[www.luffresearch.com](http://www.luffresearch.com)

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### TECHPLUS MICROWAVE Inc.

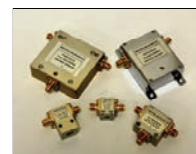
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Wenteq Microwave Corporation

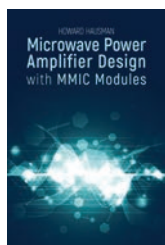
138 W Pomona Ave, Monrovia, CA 91016

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Email: [sales@wenteq.com](mailto:sales@wenteq.com), Website: [www.wenteq.com](http://www.wenteq.com)

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## Microwave Power Amplifier Design with MMIC Modules

Howard Hausman

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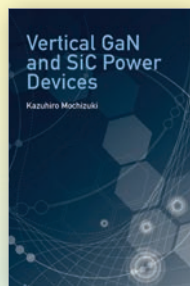
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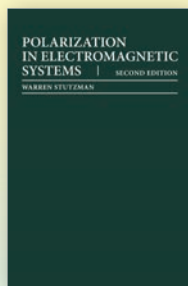
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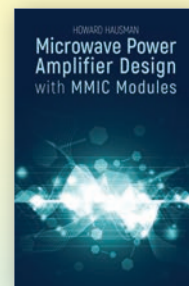
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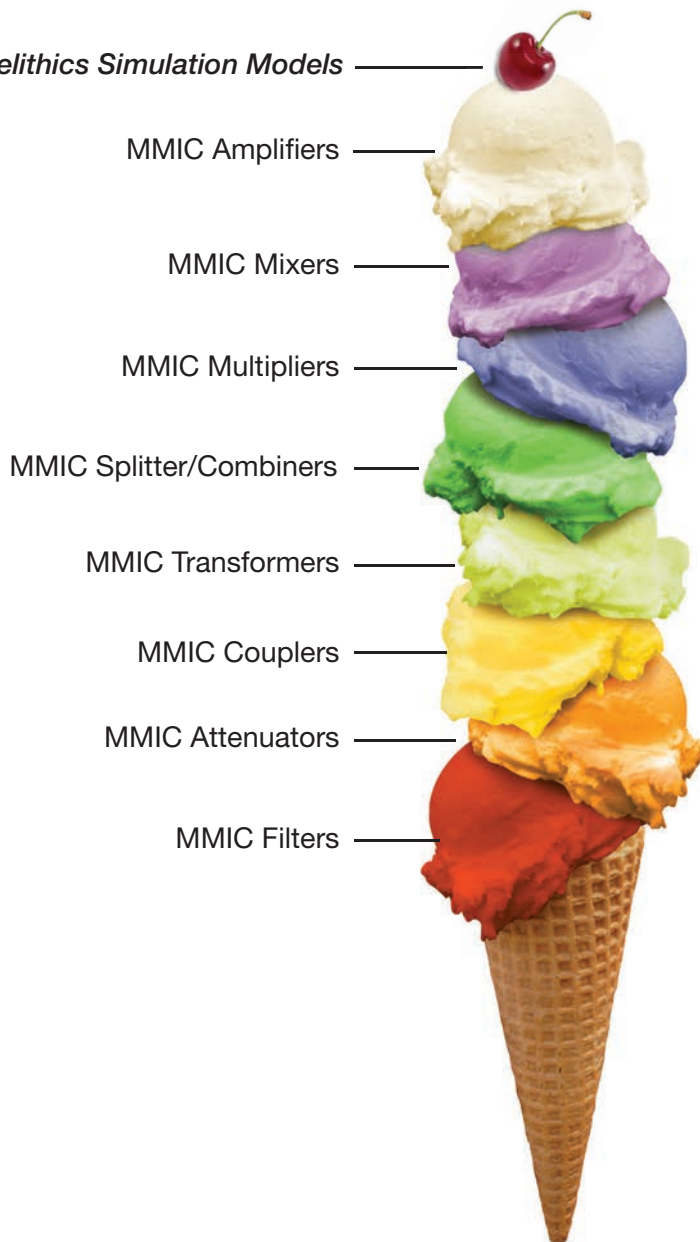
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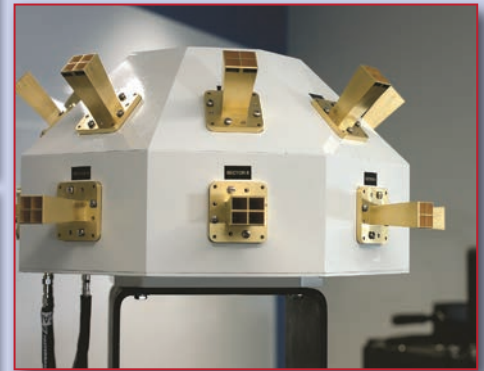
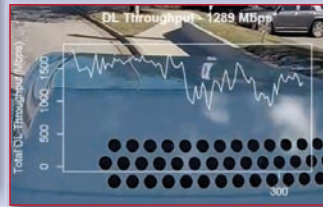


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# FAB\$ and LABS

## AT&T's 5G Lab Lays the Foundation for 5G



Following the approval of the 5G New Radio (NR) non-standalone specification in December and the standalone specification in June, 5G is quickly, although quietly, being deployed, moving from modest lab and field trials to what will become highly visible commercial offerings to paying customers in often non-ideal environments: cities, towns and rural stretches with leaves, rain and snow, energy-efficient glass, moving vehicles and non-line-of-sight links. Turning the academic theory of 5G into the promises we read about—multi-Gbps broadband, connected and autonomous vehicles, nearly every object sending data to the cloud—offers both potential and challenge, causing mobile operators to invest billions in this next-generation network.

AT&T, serving some 90 million U.S. subscribers, has declared it will be the first to deploy mobile 5G by the end of 2018, fully conforming to the 3GPP standard, operating at mmWave frequencies and initially in 12 U.S. cities. As 5G smartphones will not yet be available, early adopters will use 5G “pucks” tethered via Wi-Fi to their existing phones or computers. The infrastructure hardware is frozen and now being deployed, although the software will be updated as the 5G standard evolves.

This commercial 5G launch will take the efforts of thousands of AT&T employees, following hundreds doing the R&D to establish feasibility and define the network architecture. One core team behind this effort has been a dozen or so engineers in Austin, led by David Wolter. Known as the 5G Lab, the team's mission was to evaluate the architectural trade-offs to optimize the system-level performance of AT&T's 5G network. The first step: understanding the propagation characteristics of the new frequency bands. The team combined simulation using internally-developed tools with measured data to model link performance. The

next step: extending the analysis to assess and optimize network performance.

Key to making 5G robust—and much of the fun and gratification from the role—comes from conducting measurements in the field. To help characterize propagation, the 5G Lab developed the “Porcupine,” a channel sounder that acquires and processes data in real-time, which the lab uses to develop channel models for office, outdoor and arena environments. From their nine-story office building, the team tests links to beta 5G users at nearby businesses, apartments and a church, as well as performing drive testing along a mile-long route around the building. Data collected from these nearby tests has been supplemented with field trials in Kalamazoo, South Bend and Waco. To acquire more real world data, AT&T is building a larger test site at another location, with more telephone poles for mounting small cells and a longer road for testing V2X and autonomous vehicles.

Among its duties, the 5G Lab provides data and recommendations to support AT&T's standardization efforts with the 3GPP, other bodies and industry groups such as the NYU Wireless 5G Summit. The team has contributed more than 330 technical papers and been granted 15 essential patents.

The Lab maintains close relationships with network equipment manufacturers such as Ericsson and Nokia, to keep abreast of and steer their developments. The team also devotes time to the component companies developing the building blocks for 5G, as it's vital to understand the capabilities of the underlying technologies—particularly considering the nascent maturity of mmWave.

While the world awaits 5G, much of the 5G Lab's work is complete. Confident that the technology will work, the team is looking to the next challenge. Is it too soon to say 6G?

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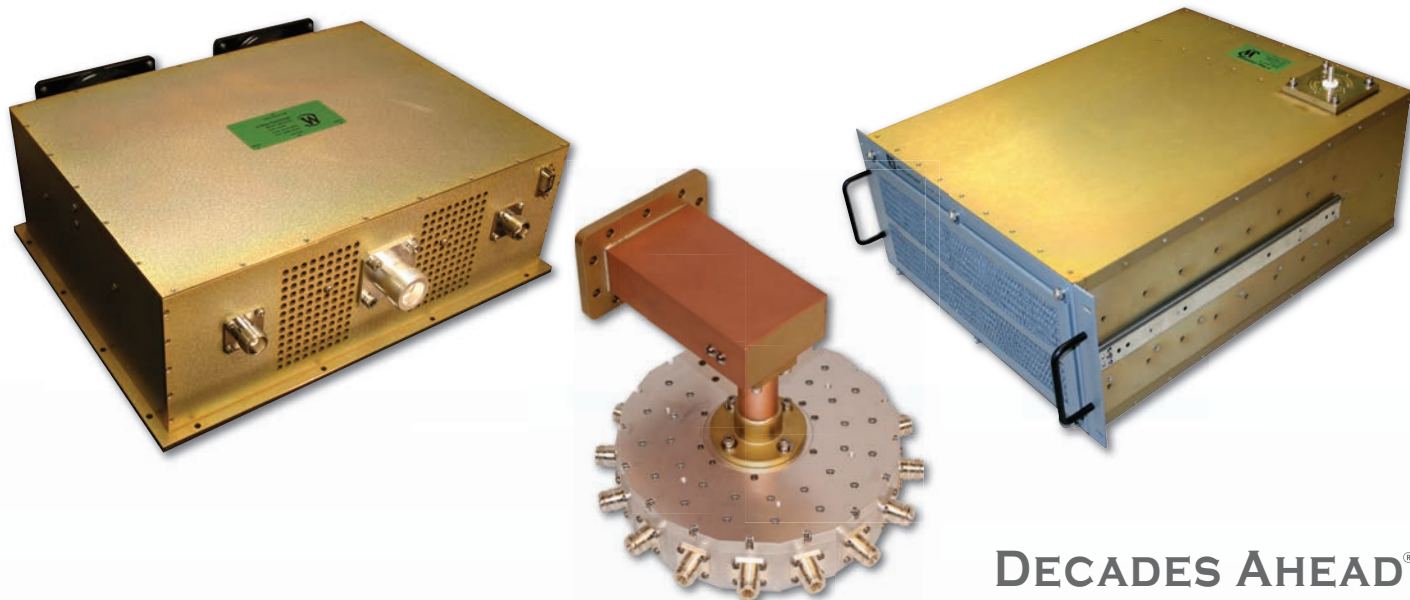


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