ALSO PUBLISHED ONLINE:
www.highfrequencyelectronics.com

FEBRUARY 2015

HIGH FREQUENCY ELECTRONICS

RF SEMICONDUCTOR MARKET OVERVIEW

IN THIS ISSUE:

RF Circuit Design References

Tom Perkins Editorial: The Value of Sales Reps

Featured Products

New Products

Product Highlights

Ideas for today's engineers: Analog · Digital · RF · Microwave · mm-wave · Lightwave

Distribution and Manufacturer's Representatives

C.W. SWIFT & Associates, Inc.

C.W. SWIFT & Associates distributes our extensive inventory of SGMC Microwave's quality products ... OFF THE SHELF!

SGMC MICROWAVE

ADAPTERS • CABLE CONNECTORS • RECEPTACLES • CUSTOM DESIGNS

Including These Connector Series					
1.85mm	DC-65 GHz	2.92mm	DC-40 GHz	7mm	DC-18 GHZ
2.4mm	DC-50 GHz	3.5mm	DC-34 GHz	SSMA	DC-40 GHz

ISO 9001:2008

SGMC Microwave Components are in Stock — Call Today for a Quote!

C.W. SWIFT & Associates, Inc.
15216 Burbank Blvd., Van Nuys, CA 91411
Tel: 800-642-7692 or 818-989-1133 or Fax: 818-989-4784
sales@cwswift.com •www.cwswift.com

Visit Us In Phoenix!

IMS Booth # 2229

Closed Every St. Patrick's Day!

COBHAM

Meet the magic number for two-watt temperature-variable attenuators.

The most important thing we build is trust

Push the limits of frequency without sacrificing performance. Cobham Inmet's new Powerfilm surface-mount attenuators vary with temperature and are the perfect balance of price, power, and dependability. They offer the flattest broadband performance of their kind and allow you to create automatic- and passive-link margin compensation on a wider variety of transmit and receive chain circuit applications.

- **Operation: DC to 12 GHz**
- **Superior RF attenuation vs. temperature**
- **Excellent return loss vs. frequency**
- **Great pricing**

Save money and space by throwing out your complicated gain-control circuitry and required bias and control voltages. Visit our website for complete details and request a sample today.

Cobham Inmet
888-244-6638
www.cobham.com/Inmet

powerfilm™

See our datasheets for full characterization data.

Cobham Inmet formerly Aeroflex / Inmet

TALENT • TECHNOLOGY • TRUST • 80 YEARS • COBHAM 1934 - 2014

USB & ETHERNET RF SWITCH MATRIX

DC to 18 GHz from $385 ea.

We're adding more models and more functionality to our line of RF switch matrices. All models now feature switch cycle counting with automatic calibration interval alerts based on actual usage, an industry first! This function improves test reliability and saves you money. Our new RC-series models feature both USB and Ethernet control, so you can run your test setup from anywhere in the world! Rugged aluminum cases on all models house our patented mechanical switches with extra-long life of 10 years/100 million cycles of guaranteed performance!*

Our easy-to-install, easy-to-use GUI will have you up and running in minutes for step-by-step control, full automation, or remote operation. They're fully compatible with most third-party lab software,† adding capabilities and efficiency to existing setups with ease! Visit minicircuits.com today for technical specifications, performance data, quantity pricing, and real time availability – or call us to discuss your custom programming needs – and think how much time and money you can save!

USB Control Switch Matrices

Model	# Switches (SPDT)	IL (dB)	VSWR (:1)	Isolation (dB)	RF P_{MAX} (W)	Price $ (Qty. 1-9)
NEW USB-1SP4T-A18	1 (SP4T)	0.25	1.2	85	2	795.00
USB-1SPDT-A18	1	0.25	1.2	85	10	385.00
USB-2SPDT-A18	2	0.25	1.2	85	10	685.00
USB-3SPDT-A18	3	0.25	1.2	85	10	980.00
USB-4SPDT-A18	4	0.25	1.2	85	10	1180.00
USB-8SPDT-A18	8	0.25	1.2	85	10	2495.00

NEW USB and Ethernet Control Switch Matrices

Model	# Switches (SPDT)	IL (dB)	VSWR (:1)	Isolation (dB)	RF P_{MAX} (W)	Price $ (Qty. 1-9)
RC-1SP4T-A18	1 (SP4T)	0.25	1.2	85	2	895.00
RC-2SP4T-A18	2 (SP4T)	0.25	1.2	85	2	2195.00
RC-1SPDT-A18	1	0.25	1.2	85	10	485.00
RC-2SPDT-A18	2	0.25	1.2	85	10	785.00
RC-3SPDT-A18	3	0.25	1.2	85	10	1080.00
RC-4SPDT-A18	4	0.25	1.2	85	10	1280.00
RC-8SPDT-A18	8	0.25	1.2	85	10	2595.00

*The mechanical switches within each model are offered with an optional 10 year extended warranty. Agreement required. See data sheets on our website for terms and conditions. Switches protected by US patents 5,272,458; 6,650,210; 6,414,577; 7,633,361; 7,843,289; and additional patents pending.

†See data sheet for a full list of compatible software.

NEW FEATURE
SWITCH CYCLE COUNTING

Mini-Circuits®

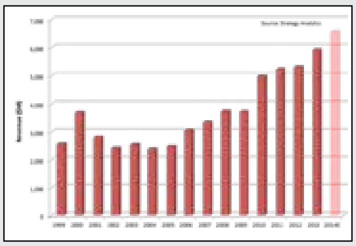
www.minicircuits.com P.O. Box 350166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

ALSO PUBLISHED ONLINE AT:
www.highfrequencyelectronics.com

FEBRUARY 2015
Vol. 14 No. 2

HIGH FREQUENCY ELECTRONICS

22
Feature Article

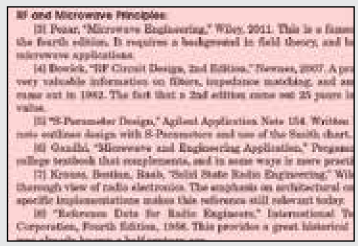


A Retrospective and Forecast for the RF Semiconductor Industry

By Eric Higham

The industry has become a vibrant segment of the broader electronics market.

34
Feature Article

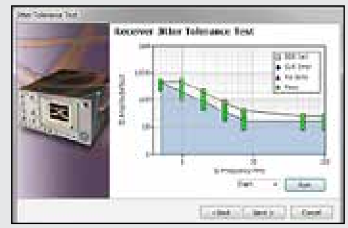

RF and Microwave Principles:
[3] Pozar, "Microwave Engineering," Wiley, 2011. This is a famou…
the fourth edition. It requires a background in field theory, and …
microwave applications.
[4] Bowick, "RF Circuit Design, 2nd Edition," Newnes, 2007. A gr…
very valuable information on filters, impedance matching, and …
came out in 1982. The fact that a 2nd edition came out 25 years l…
value.
[5] "S-Parameter Design," Agilent Application Note 154. Written …
note outlines design with S-Parameters and use of the Smith chart.
[6] Gandhi, "Microwave and Engineering Application," Pergam…
college textbook that complements, and in some ways is more practi…
[7] Krauss, Bostian, Raab, "Solid State Radio Engineering," Wil…
thorough view of radio electronics. The emphasis on architectural …
specific implementations makes this reference still relevant today.
[8] "Reference Data for Radio Engineers," International Te…
Corporation, Fourth Edition, 1956. This provides a great historical …

RF Circuit Design References

By Peter Delos

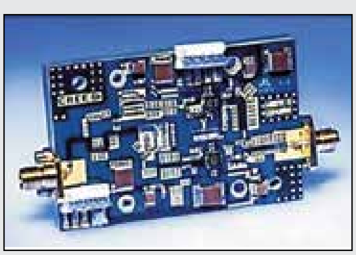
Outlining some of the important learning resources, with comments on their contributions.

16
Featured Products



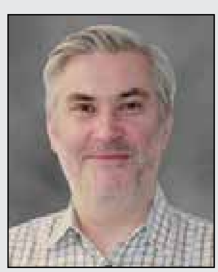
Including Tektronix, Richardson RFPD, Pulse Electronics, Link Microtek, In-Phase Technologies, Vaunix, Micro Lambda Wireless, RFMW, Gore, SGMC Microwave.

42
New Products



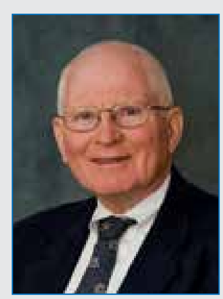
Featuring Cree, SAGE Millimeter, Quonset Microwave, Mouser Electronics, Keysight Technologies.

12
In The News



Highlighting Dr. Ian Gresham, Fairview Microwave, Analog Devices, Molex, Anritsu Company, and more.

6
Editorial

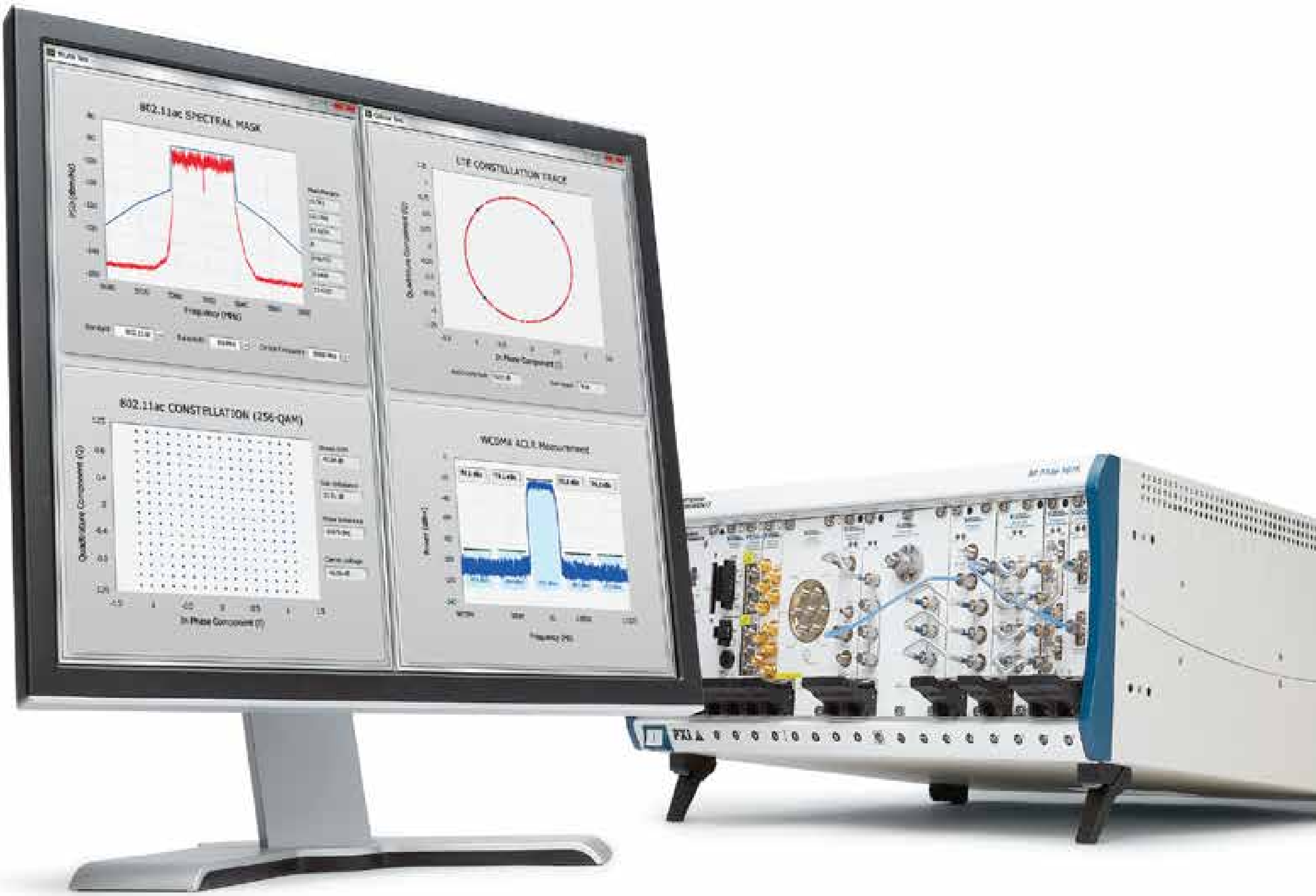


Tom Perkins comments on the value of sales representatives.

6 Editorial	**12 In the News**	**16 Featured Products**
8 Meetings & Events	**42 New Products**	**64 Advertiser Index**

Redefining RF and Microwave Instrumentation

with open software and modular hardware



Achieve speed, accuracy, and flexibility in your RF and microwave test applications by combining National Instruments open software and modular hardware. Unlike rigid traditional instruments that quickly become obsolete by advancing technology, the system design software of NI LabVIEW coupled with NI PXI hardware puts the latest advances in PC buses, processors, and FPGAs at your fingertips.

WIRELESS TECHNOLOGIES

National Instruments supports a broad range of wireless standards including:

802.11a/b/g/n/ac	LTE
CDMA2000/EV-DO	GSM/EDGE
WCDMA/HSPA/HSPA+	Bluetooth

>> Learn more at ni.com/redefine

800 813 5078

NATIONAL INSTRUMENTS™

HIGH FREQUENCY ELECTRONICS

Vol. 14 No. 2 February 2015

Publisher
Scott Spencer
scott@highfrequencyelectronics.com
Tel: 603-472-8261

Associate Publisher/Managing Editor
Tim Burkhard
tim@highfrequencyelectronics.com
Tel: 707-544-9977

Senior Technical Editor
Tom Perkins
tom@highfrequencyelectronics.com
Tel: 603-472-8261

Vice President, Sales
Gary Rhodes
grhodes@highfrequencyelectronics.com
Tel: 631-274-9530

Business Office
Summit Technical Media, LLC
One Hardy Road, Ste. 203
PO Box 10621
Bedford, NH 03110

Also Published Online at
www.highfrequencyelectronics.com

Subscription Services
Sue Ackerman
Tel: 651-292-0629
circulation@highfrequencyelectronics.com

Send subscription inquiries and address changes to the above contact person. You can send them by mail to the Business Office address above.

BPA WORLDWIDE

Our Environmental Commitment

High Frequency Electronics is printed on paper produced using sustainable forestry practices, certified by the Program for the Endorsement of Forest Certification (PEFC™), www.pefc.org

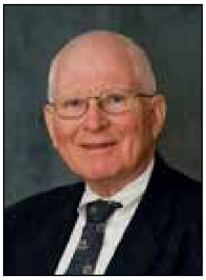
PEFC PEFC/29-31-130

SUMMIT Technical Media LLC

Editorial

The Value of Sales Representatives

Tom Perkins
Senior Tech Editor



During a recent lunch meeting with a New England-based microwave sales representative, the discussion turned to ways in which the role of reps is changing in the 21st century. Many factors affect this paradigm.

Background

The job of sales rep has never been easy. The demands placed on these individuals can be numerous and chaotic, especially at events such as shows and symposia. In some hotel, not the one at which the rep is staying, in some city often far from home, all principal companies on the rep firm's line list expect the undivided attention of their representatives at early-morning sales meetings, followed by booth duty support and evening social events.

To make a successful sale and get a purchase order by a certain date—such as an end of the month booking—can often be daunting. Sometimes lobby visits are untimely and out of sync with a program's scheduled parts-selection phase. Some companies frown on having engineers meet with reps and their principals, unless accompanied by a duly authorized customer buyer, purchasing or procurement agent. Timing of these meetings can be difficult and folks to be visited often cancel meetings at the last minute, thinking that internal matters of any kind have higher priority. Some engineers are shy, or maybe lazy about taking a walk to the lobby, or view sales reps as unnecessary "peddlers." While sales reps are often degreed engineers and are polite and well trained, a few might pretend to know more about your program than you do and will claim to have the only solution to a problem. Occasionally someone will say: tell me what it will take to get your business. Be very careful here.

The Value of Reps

Our business has always been unique in that there are many niche items and *one size almost never fits all,* so sales reps for hardware, equipment, and services have always been valuable. Software sales, (e.g. circuit design, simulation), could be debated, because of the high degree of "hands-on" knowledge needed. But even with that commodity, the rep's job is to make the initial contacts, develop rapport and provide a convenient and comfortable opening for vendor visits from the "factory." And speaking of factory visits: I used to encourage technical talks from the principals which seemed to work well and attract a reasonably sized audience. Smaller meetings addressing specific needs often immediately followed.

Final Thoughts

With web access to information for many commodities almost instantaneous, some might postulate that the role of the sales rep may be trending towards obsolescence. But my representative friend gave me pause to contemplate the possible consequences. He and others suggest that loss of personal contact with sales personnel would make for a very sterile environment. And it would diminish the suppliers' ability to service the unique needs of the RF/microwave community. Something to consider the next time a sales rep attempts to make an appointment with you.

Welcome, Dr. Jeff Pawlan

We are pleased to announce that Jeffrey Pawlan, Ph.D, has been named an Editorial Advisor to *HFE*. Jeff brings with him a wealth of experience in much of the subject matter we feature.

He has been a consultant as owner of Pawlan Communications for more than 25 years. Prior to that, he worked for various companies, in diverse areas of analog, RF, and microwave design. He has been an engineer for 40 years. His work for NASA included the very successful design of the SARSAT/COSPAS search and rescue satellite ground stations. He also taught engineering part-time. Born and raised in the Los Angeles area, he attended UCLA and several other universities.

Jeff has worked on projects for consumer, industrial, and military applications covering a wide range of the spectrum from LF to 50 GHz. In addition to his primary involvement with the MTT Society, he is also a member of the Ultrasonics, Ferroelectrics, and Frequency Control group concentrating on low phase noise oscillators and phase noise measurements; a member of the AP-S; and a member of the Communications Society. He has published several papers and holds two patents. He is a member of two MTT technical committees, MTT-9 and MTT-20. He has been designing RF and microwave hardware for Software Defined Radio uses within instrumentation and military satellite communications since 1984. For the past nine years he has been concentrating on Software Defined Radio technology with his own radio designs. He has presented talks in a workshop at the 2010, 2011, and 2012 IMS chapter meetings and a short course. Jeff holds an FCC Amateur Extra Class license: WA6KBL.

HFE

Meetings and Events

Conferences & Meetings

2015 IEEE International Wireless Symposium (IWS 2015)
30 March-1 April 2015
Shenzhen, China
http://iws-ieee.org/

2015 IEEE Wireless and Microwave Technology Conference (WAMICON 2015)
13-15 April 2015
Cocoa Beach, Florida, USA
http://www.wamicon.org/
Paper Submission Deadline: 5 January 2015

2015 IEEE MTT-S International Conference on Microwaves for Intelligent Mobility (ICMIM 2015)
27-29 April 2015
Heidelberg, Germany
http://www.icmim-ieee.org
Paper Submission Deadline: 20 December 2014

2015 IEEE MTT-S International Wireless Power Transfer (WPTC 2015)
13-15 May 2015
Boulder, Colorado, USA
http://www.wptc2015.org/
Paper Submission Deadline: 16 January 2015

2015 IEEE International Microwave Symposium (IMS2015)
17-22 May 2015
Phoenix, Arizona, USA
http://ims2015.org/
Paper Submission Deadline: 8 December 2014

2015 IEEE Radio Frequency Circuits Symposium (RFIC 2015)
17-19 May 2015
Phoenix, Arizona, USA
http://rfic-ieee.org/
Paper Submission Deadline: 12 January 2015

85rd ARFTG Microwave Measurement Symposium
22 May 2015
Phoenix, AZ, USA
http://www.arftg.org/

2015 IEEE MTT-S International Conference on Numerical Electromagnetic Modeling and Optimization for RF, Microwave and Terahertz Applications (NEMO 2015)
11-14 August 2015
Ottawa, Canada
http://nemo-ieee.org
Paper Submission Deadline: 16 February 2015

2015 40th International Conference on Infrared, Millimeter, and Terahertz waves (IRMMW-THz)
23 – 28 August 2015
Hong Kong
www.irmmw-thz2015.org

2015 IEEE International Symposium on Radio-Frequency Integration Technology (RFIT)
26 – 28 August 2015
Sendai, Japan
www.ieee-jp.org/japancouncil/chapter/MTT-17/rfit2015/

2015 IEEE MTT-S 2015 International Microwave Workshop Series on RF and Wireless Technologies for Biomedical and Healthcare Applications (IMWS-BIO)
21 – 23 September 2015
Taiwan
www.ieee-jp.org/japancouncil/chapter/MTT-17/rfit2015/

2015 IEEE International Conference on Ubiquitous Wireless Broadband (ICUWB)
4 – 7 October 2015
Montreal
www.icuwb2015.org

Company-Sponsored Training & Tools

Analog Devices
Training, tutorials and seminars.
http://www.analog.com/en/training-tutorials-seminars/resources/index.html

NI AWR
On-site and online training, and open training courses on design software.
http://web.awrcorp.com/Usa/News--Events/Events/Training/

National Instruments
LabVIEW Core 1
Online
http://sine.ni.com/tacs/app/fp/p/ap/ov/pg/1/
LabVIEW Core 2
Online
http://sine.ni.com/tacs/app/fp/p/ap/ov/pg/1/
Object-Oriented Design and Programming in LabVIEW
Online
http://sine.ni.com/tacs/app/fp/p/ap/ov/pg/1/
Free, online LabVIEW training for students and teachers.
http://sine.ni.com/nievents/app/results/p/country/us/type/webcasts/

Market Reports

IoT Analytics to Reach $5.7 Billion in 2015

A new market analysis finds that the revenues from integrating, storing, analyzing, and presenting **Internet of Things (IoT) data will reach $5.7 billion in 2015.** In the next five years, the market will expand dramatically, to an extent that in 2020 it is estimated to account for nearly one-third of all big data and analytics revenues.

ABI Research principal analyst Aapo Markkanen said, "About 60% of this year's revenues come from three key areas: **energy management, security management, as well as monitoring and status applications.** Within these segments, we can generally find analytic applications that reduce the cost base of asset-intensive operations (condition-based maintenance), automate routine workflows (surveillance), or even enable new business models (usage-based insurance). These early growth drivers also have in common the fact that the economics of IoT connectivity align easily enough with the requirements of analytic modelling."

Making sense of IoT-kind data from machines and sensors data comes often with its unique challenges, such as the need for time-series databases in storage, and for relatively deep domain expertise in analysis. These kinds of factors create a certain mismatch with many leading technologies that have been designed for more traditional, "digital-first" analytic environments. This, in turn, is attracting a flurry of startup-level activity aimed at filling the gaps.

According to ABI's Dan Shey, "What is remarkable about this market is how much of the innovation actually comes from startups. Take, for instance, **ParStream's** geo-distributed architecture, **Cyberlightning's** 3D visualization technology, or **Peaxy's** work on software-defined data access. All three address some of the problems that usually come up in discussions with end-users. Meanwhile, of the more incumbent vendors likes of Datawatch, Informatica, Software AG, and Splunk seem well-positioned to seize the IoT opportunity."

—ABI Research
abiresearch.com

sUAS Market Will Surpass $8.4 Billion by 2018

The **Small Unmanned Aerial Systems (sUAS) market** will surpass $8.4 billion by 2018 according to new research published by ABI Research. By 2019 the commercial sector will dominate the overall sUAS market with revenues exceeding $5.1 billion (51% 2014 to 2019 CAGR), roughly five times larger than the prosumer/hobby market, and 2.3 times greater than the military/civil market segment. Moreover, **it is application services—industry-specific applications, as well as data, operator and modeling services—and not platforms and other hardware technologies, that will be the key driver for the growth of the commercial sector.**

Ongoing research advancements, technological developments, and rapidly dropping prices for increasingly capable enabling technologies have combined to remove barriers to innovation and commercialization, and spur the development of new sUAS and increase the ways they can be applied. For this study, the sUAS market was not defined by, or limited to, the unmanned aerial system platforms and airframes alone, but also includes other technologies, products and services that are ancillary to, and often necessary for, the use of small unmanned vehicles, along with the many applications enabled by them.

According to Dan Kara at ABI Research, **"The commercial sector is the sweet spot for the sUAS market, a fact recognized by both traditional defense industry suppliers such as Elbit Technologies, AeroVironment, and Aeryon Labs, as well as providers to the prosumer/hobbyist marketplace including DJI, Parrot, SenseFly, 3D Robotics, and others."**

—ABI Research
abiresearch.com

Security Threats Sustain Expenditures on Naval Platforms

Deteriorating international relations across the world have caused countries to sanction extensive naval **modernization and re-armament programs in Asia-Pacific, the Middle East and Russia.** The Ukraine crisis, territorial disputes on the South China Sea, and growing tensions in the Middle East have ensured that the market growth remains stable, although low.

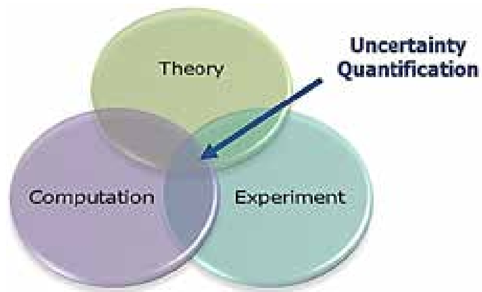
New analysis finds that the cumulative naval vessels new platforms segment's expenditure is expected to reach $376.07 billion by 2023, at a compound annual growth rate (CAGR) of 1.0 percent. **The military vessels modernization/upgrade segment, estimated to be worth $59.26 billion from 2014 to 2023, is likely to generate the highest CAGR of 2.6 percent.**

The market gained the most revenues from the procurement of multi-role frigates. The frigate is a very versatile warship, which merges together high speed, anti-ship missiles, air defense, and anti-submarine warfare capabilities with moderate operation and maintenance costs. Therefore, the frigate is becoming a primary vessel in most of the navy fleets.

"Military vessels based on the multi-mission modular **vessel (MMMV) design** will be more common and affordable for end users," said Frost & Sullivan's Dominik Kimla. "Additionally, Frost & Sullivan expects more standardization among various MMMV designs across naval companies."

—Frost & Sullivan
frost.com

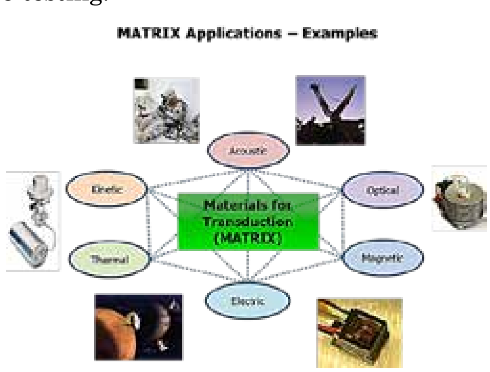
In the News



Uncertainty is sometimes unavoidable. But in the world of **scientific computing and engineering**, at least, what's worse than uncertainty is being uncertain about how uncertain one is.

Understanding with confidence the level of uncertainty in computational models used for designing complex military systems—such as new aerospace vehicles and engines, for example—can be enormously beneficial, reducing costs and development times. But achieving a useful degree of such confidence is a difficult mathematical challenge, given the large number of variables typically involved. As a result, engineers have come to rely on extensive testing to verify their modeling results—a repetitive process of design, test, verify, re-design, re-test, re-verify that can add years to the development process.

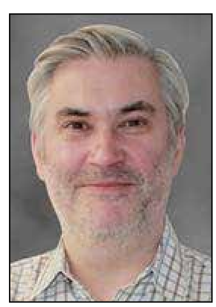
DARPA's **Enabling Quantification of Uncertainty in Physical Systems (EQUiPS) program** aims to solve this problem by developing the mathematical tools and methods to efficiently quantify, propagate and manage multiple sources of uncertainty. The goal is to create a computationally effective and mathematically rigorous framework for engineering that will accurately predict, on the basis of complex design specifications, the functional operation of complex defense-related physical and engineering systems. For example, one might want to predict the performance of an airfoil (or even design an airfoil from first principles) given known uncertainties in angle of attack, air speed, environmental conditions and design imperfections – without having to resort to extensive and repetitive testing.



Transduction involving the conversion of energy from one form into another is common in many military and space devices, such as communications antennas (radio waves to electrical signals), thermoelectric generators (heat to electricity) and electric motors (electromagnetic to kinetic energy). Research efforts to develop new transductional materials, however, have largely been limited to laboratory demonstrations and haven't always resulted in new capabilities or significant size, weight, and power (SWAP) reduction for military devices and systems.

To address this problem, DARPA announced the **Materials for Transduction (MATRIX) program.**

"Advances in materials have been key to achieving a wide range of critical, defense-related capabilities, but the development of novel, energy-transducing materials has been challenging, particularly in translating materials advances to the device and systems level," said Jim Gimlett, DARPA program manager. "We aim to develop new classes of transductional materials that can be demonstrated directly in applications, and to advance innovative modeling and simulation tools that engineers can use to design systems that take advantage of these new materials. The goal is not just to design materials for use in devices; we envision developing materials that, because of their energy-transforming properties, are effectively devices themselves."



Dr. Ian Gresham, Anokiwave Distinguished Fellow of Technology has been named a **fellow of the Institute of Electrical and Electronics Engineers (IEEE) for technical leadership in commercial automotive radar sensors**. The IEEE Grade of Fellow is conferred on those with an outstanding record of accomplishments in any of the IEEE fields of interest. It is the highest grade of membership and is recognized by the technical community as a prestigious honor and an important career achievement.

Link Microtek appointed **Rob Wilkins** MIET MIEEE as **senior microwave design engineer**. He joins the company following the closure of his previous employer, Cobham Microwave of Chichester (formerly Credowan), where he held the position of microwave design engineer for seven years. During that time, he led the design of an innovative microwave heating apparatus for recycling car tire rubber, as well as designing waveguide-based products such as triplexers, couplers, water-cooled loads and rotary joints.


sign up for our newsletter online too!
18 TO 140 GHz
SPDT Switch
SAGE
Millimeter, Inc.
3043 Kashiwa Street, Torrance, CA 90505
Tel (424) 757-0168 | Fax (424) 757-0188
www.sagemillimeter.com
sales@sagemillimeter.com
VISA
MasterCard
ONLINE STORE
SAGE Millimeter, Inc.
Open
WWW.SAGEMILLIMETER.COM

In the News

Pasternack Enterprises named **Tim Galla** as the company's Product Manager for **Active RF Components.**

Galla brings 25+ years of product development, applications engineering and business development expertise to Pasternack from many of the RF/microwave industry's most recognized names. He has a successful track record of developing and introducing market-differentiating products and creating new market opportunities. He will focus his expertise on expanding Pasternack's growing lines of active components including RF amplifiers, limiters, mixers, oscillators, circulators, isolators, switches and many more.

Fairview Microwave named **Lorie Slay** its Sales and Service Manager, a newly created position aimed to accelerate customer engagement and provide leadership to the company's inside sales team. Slay brings more than 15 years of sales and service management experience and a passion for product quality and customer engagement.

Focus Microwaves announced the acquisition of Cardiff, UK-based **Mesuro**, a developer of RF/microwave and high-speed-digital device modeling, characterization, and optimization solutions. Mesuro brings a wide range of sophisticated measurement and modeling products and technologies.

L-3 Communications acquired the assets of **MITEQ** for $41 million, subject to customary adjustments. The business will be combined with L-3's Narda Microwave-East business located in Hauppauge, N.Y., and the new organization will be called **L-3 Narda-Miteq.**

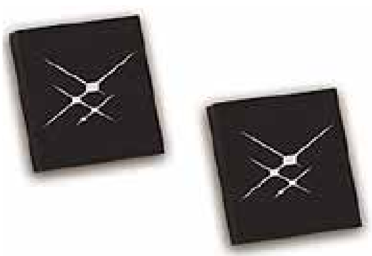
Analog Devices is celebrating its 50th anniversary by expanding support of ***FIRST***® (For Inspiration and Recognition of Science and Technology), a not-for-profit organization founded by inventor **Dean Kamen** to inspire young people's interest and participation in science and technology. ADI has contributed to the *FIRST* mission since 2004 through employees volunteering as mentors and judges, donations of converters, sensors and other products, as well as monetary donations and support of *FIRST* competition teams.

Molex announced that it and certain of its affiliates have acquired **SDP Telecom**. Headquartered in Montreal, Canada, SDP designs and manufactures RF/microwave solutions for the wireless communications industry.

Anritsu Company launched free e-Learning courses based on its **Rapid Test Designer** (RTD) that have been created to help mobile device engineers more effectively test cellular modem chipsets and devices under development. Featuring a curriculum that includes a modular series of professional product training videos, RTD e-Learning is a program instituted by Anritsu to help customers validate their designs, shorten time-to-market, and improve test procedures for greater productivity.

San-tron appointed two new sales representatives. **Sea-Port Technical Sales** will handle the Pacific Northwest region, covering Idaho, Montana, Oregon, Washington, and British Columbia. **Coastal RF Systems** will cover Southern California.

Featured Products



Power Amps

Richardson RFPD announced availability and support for five new power amplifiers for small cell applications from Skyworks Solutions. The surface mount, +20 dBm linear output power amplifiers meet spectral requirements for small cell PAs with high power-added efficiency. These fully-integrated devices offer high gain, low power current consumption, low bill-of-materials count, and more.

Richardson RFPD
richardsonrfpd.com

Engineering Library

Engineers often have specific requirements that may not be available in the standard range of products. AtlanTecRF recognises this by demonstrating how they are able to optimize, customize or design a specific solution depending on customer needs with the release of over 120 drawings across 19 component categories into an online Engineering Library on its website.

AtlanTecRF
atlantecrf.com

Transformers

Pulse Electronics introduced a series of high isolation switch mode transformers that come in a standard SMT package. The PH9185 series provides a reinforced insulation power supply that's compatible with the MAXIM™ MAX253 to power RS-485/RS-232 transceivers. They operate in a fixed duty cycle push-pull topology that delivers lower power (up to 3W) from a low voltage source.

Pulse Electronics
pulseelectronics.com

VCO

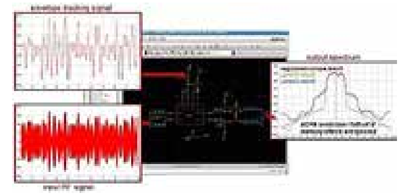
Crystek's CVCO55CC-1690-1690 VCO operates at 1690 MHz with a control voltage range of 0.3V~4.7V This VCO features a typical phase noise of -120 dBc/Hz @ 10 KHz offset and has excellent linearity. Output power is typically +2.5 dBm. Engineered and manufactured in the USA.

Crystek
crystek.com

Rotary Joint

The new AM28RJD dual-channel rotary joint provides an effective means of reducing component count and saving space and weight in the compact antennas that are used for Ka-band high-data-rate SOTM (satellite-on-the-move) communication systems. It is particularly suitable for military or commercial airborne systems such as satcom uplinks in unmanned aerial vehicles.

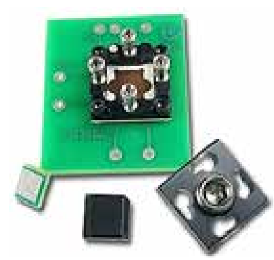
Link Microtek
linkmicrotek.com



Design Software

Keysight Technologies announced the latest release of GoldenGate software, the simulation, analysis and verification solution for large-scale RFIC circuit design. Keysight EEsof EDA's GoldenGate 2015.01 offers new and enhanced capabilities designed to improve productivity and efficiency for silicon RFIC designers.

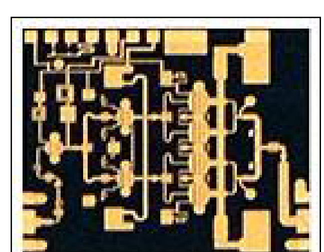
Keysight Technologies
keysight.com



Socket

Ironwood Electronics introduced a high performance elastomer socket for 0.4mm pitch QFN package. The SG-MLF-7084 socket is designed for a 6 mm x 4.5 mm package size and operates at bandwidths up to 30 GHz with less than 1dB of insertion loss (GSSG configuration). The contact resistance is typically 20 milliohms per pin.

Ironwood Electronics
ironwoodelectronics.com



Amplifier

RFMW announced design and sales support for a 1W (30.5dBm) Psat amplifier covering radar and satcom applications from 16 – 18 GHz. The TGA2621 is fabricated using Qorvo's TQPHT15 GaAs technol-

ogy. The TGA2621 can be used as a general purpose amplifier drawing 400mA from a 6V supply. PAE is 28% while small signal gain is 26.5 dB.

RFMW
rfmw.com

Test System

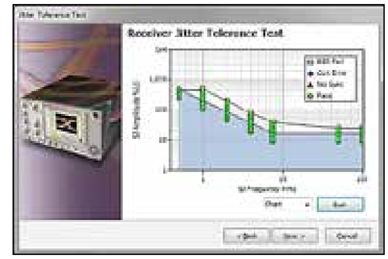
The PCT306 Microwave Vector Test System is a computer-controlled measurement system for testing RF and microwave passive devices in helicopters, aircraft, ships, submarines and militarized vehicles. Covering 30 KHz to 26.5 GHz, it measures S parameters, scalar insertion loss, VSWR and distance to fault (DTF) of RF and microwave cable assemblies under harsh environments.

In-Phase Technologies
in-phasetech.com

Attenuator

Vaunix added a new 75 Ohm model to its family of LDA Series Digital Attenuators. This family offers attenuators with up to 120 dB of programmable attenuation through 6,000 MHz. The LDA-102-75F has input power of up to 1 W, attenuation range to 95 dB, and offers frequency coverage of 10 – 1000 MHz. It is powered and controlled by connection to a PC or self-powered USB hub.

Vaunix
vaunix.com



Test Software

A new set of USB 3.1 compliance test solutions allows designers to quickly verify designs against the latest USB specs and achieve fast time to market while minimizing costs. The new release expands Tektronix's USB 3.1 and USB 2.0 test capabilities to include a new USB 3.1 receiver test solution supporting the 10 Gb/s data rate, a new USB Power Delivery test solution and a new USB Type-C cable test solution.

Tektronix
tektronix.com

Synthesizers

Micro Lambda Wireless has completed development of three YIG based synthesizer product lines. These small size (2.5" x 2.5" x 1.0") and low power consumption (< 8 Watts) units are specifically designed for high data rate (>100 Mbps) QAM digital radios. Telecom and satcom applications and wide-band low -noise synthesizers for test and measurement.

Micro Lamba Wireless
microlambdawireless.com

Crimp Plug

RFMW announced design and sales support for the Delta Electronics Manufacturing N Crimp Type Plug 1103018A00E-000. Produced for commercial and military applications including flight requirements, the Delta 1103018A00E-000 meets Mil Spec

Featured Products

M39012/01-0503 specifications for use on RG142, 223 and 400 cables.

RFMW
rfmw.com

Online Calculator

A new online tool enables fast, easy microwave/RF cable assembly selection. The GORE™ Microwave/RF Assembly Calculator is used to calculate insertion loss, VSWR and other parameters of GORE® Microwave/RF Assemblies for different cable types. It is particularly useful when the initial cable type is unknown and needs to be specified independent of the connector.

Gore
gore.com

Adapters

SGMC Size #8 to SMA Adapters are Precision Between-Series Adapters that feature: DC - 18 GHz; VSWR: 1.15:1 Max; Body & Contact: Heat Treated Beryllium Copper/Gold Plated; Dielectric: PTFE (Teflon); O-Rings: Fluorosilicone Rubber; Epoxy Captivated. SGMC Microwave's hallmarks are always: Quality, Performance, & Reliability.

SGMC Microwave
sgmcmicrowave.com

Mixer

Model SFS-10450314-1015SF-N1 is a W-Band, subharmonically pumped mixer with an external frequency diplexer. It employs high performance GaAs Schottky beam-lead diodes and balanced configuration to produce superior RF performance. The conversion loss is 12 dB typical and 14 dB maximum in the RF frequency range of 75 to 110 GHz with local oscillator frequency at 50 GHz and power at +15 dBm.

SAGE Millimeter
sagemillimeter.com

A Retrospective and a Forecast for the RF Semiconductor Industry

By Eric Higham

The industry has become a vibrant segment of the broader electronics market.

Shortly after the conclusion of World War II, research began on a solid-state replacement for vacuum tube-based devices. The goal was to develop devices that would be more robust and more reliable than the tube devices in use at the time. Bell Labs started a group, led by William Shockley, to develop this solid-state alternative for amplification purposes. In the late 1940s, this group announced the invention of a point-contact transistor with gold contacts to a sliver of germanium (1). This was a start, but this device was also very fragile, relying on a spring to ensure contact of the gold probes to the germanium surface. Shockley was not satisfied with this solution and pushed on in his research. This work culminated in the theory of p-n junctions and minority carrier injection and what Shockley called the junction transistor (2). In 1951, Bell Labs fabricated a working germanium transistor (3).

The size, portability, performance and reliability of the germanium-based transistor fueled the growth of both military and commercial applications. Computers became one of the biggest early users of the germanium transistor, but the material had issues with temperature range and most notably, reverse leakage. The temperature range was a problem for military applications and the reverse leakage created serious issues for computer manufacturers. In 1954, the chemist who was instrumental in the germanium transistor fabrication process at Bell Labs announced that a team he was running at Texas Instruments had fabricated a silicon-based transistor (4).

DoD Funding

Silicon technology has become the preeminent high-volume process technology, but the US Department of Defense started funding efforts to develop the capabilities of III-V semiconductor technologies in the 1980s. These efforts started with the GaAs Pilot Line Program that sought to develop GaAs digital integrated circuits to compete with silicon (5). The program was successful, but the advantages of silicon were undeniable and the government shifted their funding to refining GaAs MESFET technology and developing high frequency GaAs amplifiers with the Microwave/Millimeter Wave Monolithic Integrated Circuits (MIMIC) program. (6)

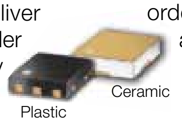
While the initial focus of the MIMIC program was on defense applications, the funding also helped develop ancillary developments in test and measurement, assembly and manufacturing applications. Because of this and other funding, GaAs devices have seen performance, reliability, manufacturability and market share increase appreciably. From the groundbreaking transistor work in the 1940s, the RF semiconductor industry has grown to become a large, vibrant segment of the broader electronics market.

Ultra Small 2x2mm

2W ATTENUATORS DC-20 GHz from $1.99 ea. (qty. 1000)

Save PC board space with our new tiny 2W fixed value absorptive attenuators, available in molded plastic or high-rel hermetic nitrogen-filled ceramic packages. They are perfect building blocks, reducing effects of mismatches, harmonics, and intermodulation, improving isolation, and meeting other circuit level requirements. These units will deliver the precise attenuation you need, and are stocked in 1-dB steps from 0 to 10 dB, and 12, 15, 20 and 30 dB.

The ceramic hermetic ***RCAT*** family is built to deliver reliable, repeatable performance from DC-20GHz under the harshest conditions. With prices starting at only $4.95 ea. (qty. 20), these units are qualified to meet MIL requirements including vibration, PIND, thermal shock, gross and fine leak and more, at up to 125°C!



The molded plastic ***YAT*** family uses an industry proven, high thermal conductivity case and has excellent electrical performance over the frequency range of DC to 18 GHz, for prices starting at $2.99 ea. (qty. 20).

For more details, just go to minicircuits.com – place your order today, and you can have these products in your hands as soon as tomorrow!

RoHS compliant

FREE Simulation Models! Modelithics®

http://www.modelithics.com/mvp/Mini-Circuits/

Mini-Circuits®

www.minicircuits.com P.O. Box 350166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

515 rev E

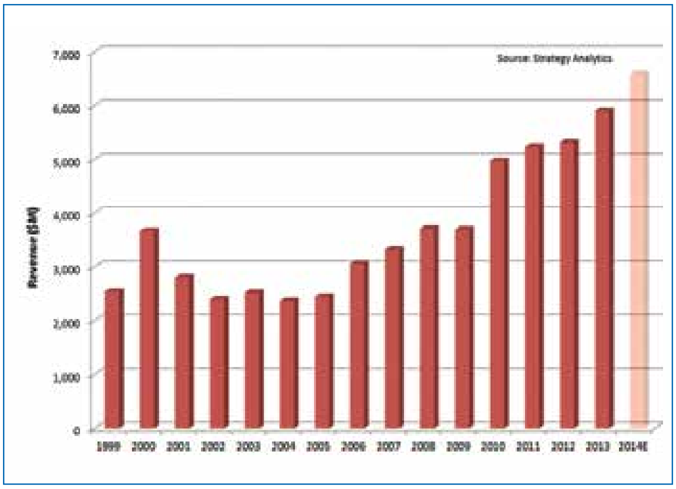


Figure 1 • Historical Performance of GaAs RF Device Revenue.

Market Drivers

To predict where the compound semiconductor market will head in 2015 and beyond, it is useful to review the historical performance and the factors that have influenced the growth profile to date. Germanium transistors quickly transitioned to silicon and this technology has enjoyed a tremendous ramp in volume, first with discrete transistors and now with integrated circuits going to process nodes below 20nm. The performance of compound semiconductor-based devices has been superior to silicon and GaAs has become a very mature, high volume technology. Even though other competitive technologies will factor into the prospects for the future of the RF semiconductor market, GaAs is currently the dominant technology.

Figure 1 shows the historical performance of GaAs device revenue from 1999 to a forecast for 2014. It tells an interesting story and illustrates market drivers. There was fast growth in the 1999/2000 timeframe as the .com era hit full stride. The working theory was "build it and they will come", but the unfortunate reality was there was very little demand for the increased capacity and speed of the new networks. The .com bubble burst; companies built networks, but no one came! As a result, GaAs revenue dropped as quickly as it rose and floundered around at this level for several years.

In 2004, the effects of the "wireless revolution" and mobile communications become apparent on GaAs revenue and the revenue trajectory has been steadily upward. The initial attraction of mobile communications was the "anywhere, anytime" aspect of staying in touch. As analog communications evolved into digital and data rates started to increase, the clunky bag phone evolved into a much more sophisticated terminal that is fueling the tidal wave of data consumption. Smartphone usage has grown dramatically and Strategy Analytics esti-

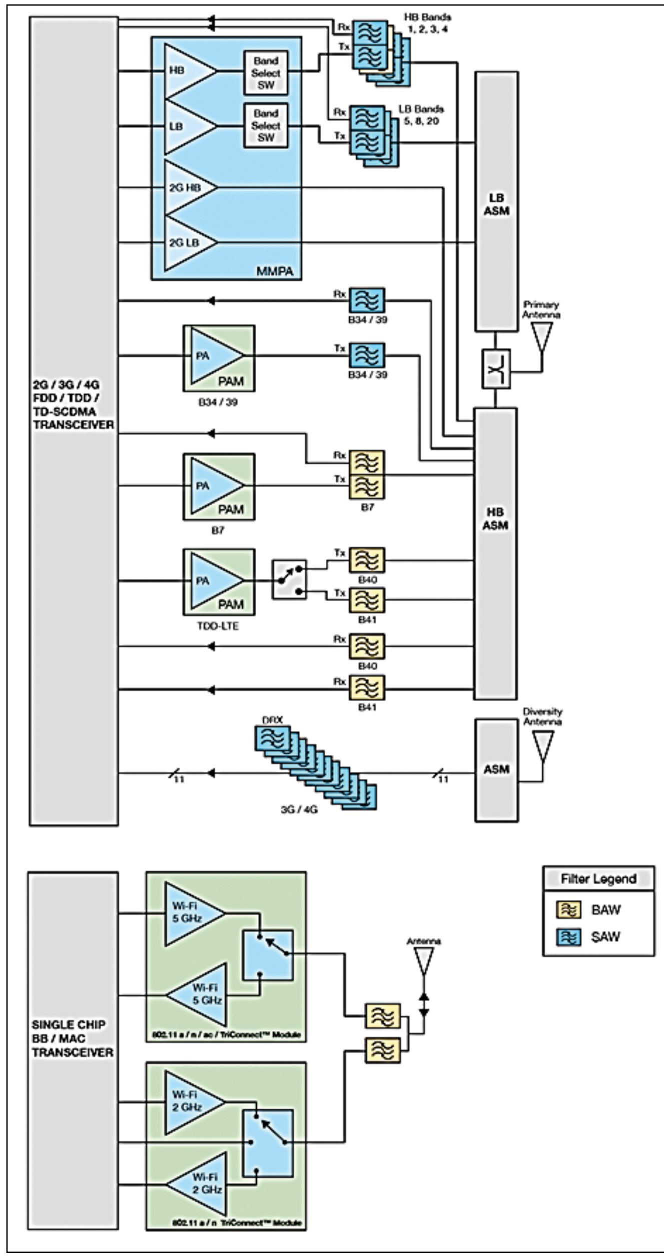


Figure 2 • Smartphone Block Diagram.

mates that nearly two-thirds of all phones sold in 2014 will be smartphones. The CAGR for GaAs device revenue since 2004 has been almost 11% and this will push 2014 results to an estimated $6.6B.

Cellular Segment

The evidence for how much the GaAs and the RF compound semiconductor industries rely on the cellular segment should be clear in Figure 2. This block diagram, courtesy of TriQuint, shows the front end for a representative smartphone. It includes eleven amplification functions, many of them accommodating multiple trans-


CEL
INTRODUCING
TOKYO KEIKI
CUSTOM RF PRODUCTS
Delivering High Quality & Performance
5 CLEANROOMS
JIS-Q9100 CERTIFIED FACTORY
AS9100 U.S. EQUIVALENT
Bring us your challenging specs
X-Band
100 W
GaN Power AMP
Best in Class
High Power Amplifier
Lumped Element Filter
Directional Coupler
Monitor
Broadband Amplifier
PIN Diode Switch
VCO/Synthesizer
Divider
Filter
Amp
Mixer
HPA
Power Divider
Cavity Filter/Duplexer
Low Noise Amplifier
Balanced Mixer
TX32ZSDA
002
KEIKI
CEL
TOKYO KEIKI
Scan code to learn more or visit:
www.cel.com/TK-HFE

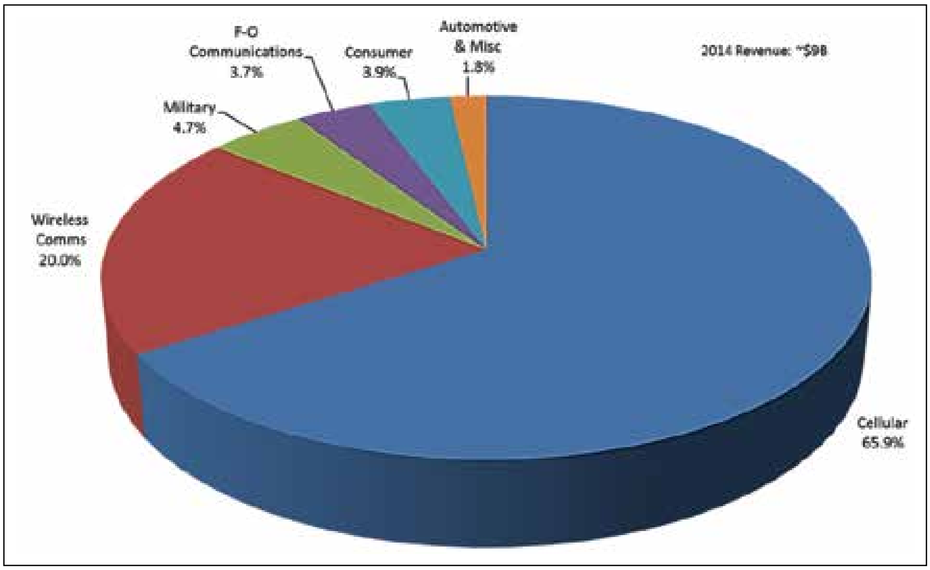


Figure 3 • Segmentation of RF Semiconductor Market Revenue.

mission bands and eight switching functions, with most of them being multi-throw.

The complication in the front-end is rooted in technical and business considerations. A simplistic analysis shows that data capacity increases as the spectral efficiency increases (more bits/sec/Hz) or the amount of bandwidth increases (more Hz). Wireless operators use both of these techniques by purchasing additional spectrum and developing more sophisticated modulation schemes that allow for wider channel bandwidths. The term "4G" has really become synonymous with faster data speeds. To support higher data rates, network operators have embraced the W-CDMA/UMTS standard that serves as an evolution path for GSM and the newly developed LTE standard. Both use linear modulation schemes that increase spectral efficiency and incorporate flatter network architectures to reduce cost.

The second part of the technical consideration is spectrum and that is a thornier issue. Spectrum is a scarce resource. Since more spectrum cannot be created, the best option is to repurpose it. Governments around the globe are doing this with auctions of reclaimed or underutilized spectrum. This creates some additional challenges for wireless operators, because this additional spectrum may not be close to existing frequency bands, it may not exist over a large geographical footprint, the channel bandwidth may be less than desired and it is expensive!

The final dimension addresses the operator business model. Ideally, operators would like a single handset that covers their entire service footprint and allows users to roam on different networks. This is currently not possible, but operators are pushing to minimize the number of phones they must maintain. To enable this, manufacturers use architectures that incorporate the latest generation of linear PAs, while still accommodating older standards that use saturated PAs. These architectures must accommodate frequency bands that are likely not contiguous and range from 450 MHz to 3.8 GHz. A report from Strategy Analytics identifies 45 E-UTRA WCDMA/LTE bands, with another eight that have been proposed, but not approved. In response to these divergent business requirements, cellular front-end architectures are making more use of multi-mode, multi-band PAs, along with saturated PAs shown as "2G" in the block diagram of Figure 2.

Strategy Analytics estimates that roughly 1.2 billion phones will have block diagrams similar to, or perhaps even more complicated than the one shown in Figure 2. Our research indicates these phones currently handle an average of 4.6 linear bands, in addition to four saturated bands and we expect the number of linear bands to exceed six shortly. Add in approximately 1.4 billion "other" cellular devices (feature phones, tablets, PCs, notebooks, E-readers, etc.) and it is easy to see why GaAs and compound semiconductor revenue is so high in this segment.

GaAs Competitors

In the early days of the wireless revolution, GaAs was the only technology that could provide the performance, frequency coverage, cost and reliability for high volume applications. As volumes and device complexity continue to increase, competitive technologies are beginning to capture market share from GaAs. The best example of this is with the handset switches shown in Figure 2. This application has largely shifted to a Silicon-on-Insulator (SoI) technology that makes use of the high volume processing capabilities of silicon CMOS foundries. Silicon also provides a better opportunity to integrate additional low frequency control circuitry and offers better ESD performance. These and other performance-related features have allowed SoI switches to displace GaAs devices in many of these applications.

While silicon switches stand as the largest volume RF application to capture share from GaAs, power amplifiers represent the largest revenue opportunity for competitive technologies. CMOS-based PAs have steadily been capturing share in entry level, lower tier handsets. Since these applications represent a slowly shrinking opportunity, GaAs PA manufacturers have been willing to cede some market share. The big shock to the

Make RF smarter with Freescale.

Design your next high-power RF system faster with the new Freescale RF Power Tool system.

Speed your development with:

- Quick setup
- Runs directly from PC or front panel
- 1MHz–3GHz integrated signal generator
- Flexible pulse modulation, internal, external trigger
- Real-time display: VSWR, efficiency, temperature, DC power, voltage, current and more
- Easy system validation

Use with a range of Freescale reference designs.

Introducing the world's first integrated RF power development system—only from Freescale, the leader in RF power devices.

The global leader in RF power introduces another breakthrough—the Freescale RF power tool system, the industry's first fully integrated RF power application development system-in-a-box. Get all the components needed to design leading-edge RF power applications in a modular portable unit at a fraction of the cost of a traditional bench setup. Compatible with Freescale RF power evaluation boards and used by our own engineering teams, this innovative new tool simplifies your design process, reduces development time and costs, and gets you to market faster. Next time inspiration strikes, be ready. Visit **freescale.com/RFpowertool**

make it
freescale™

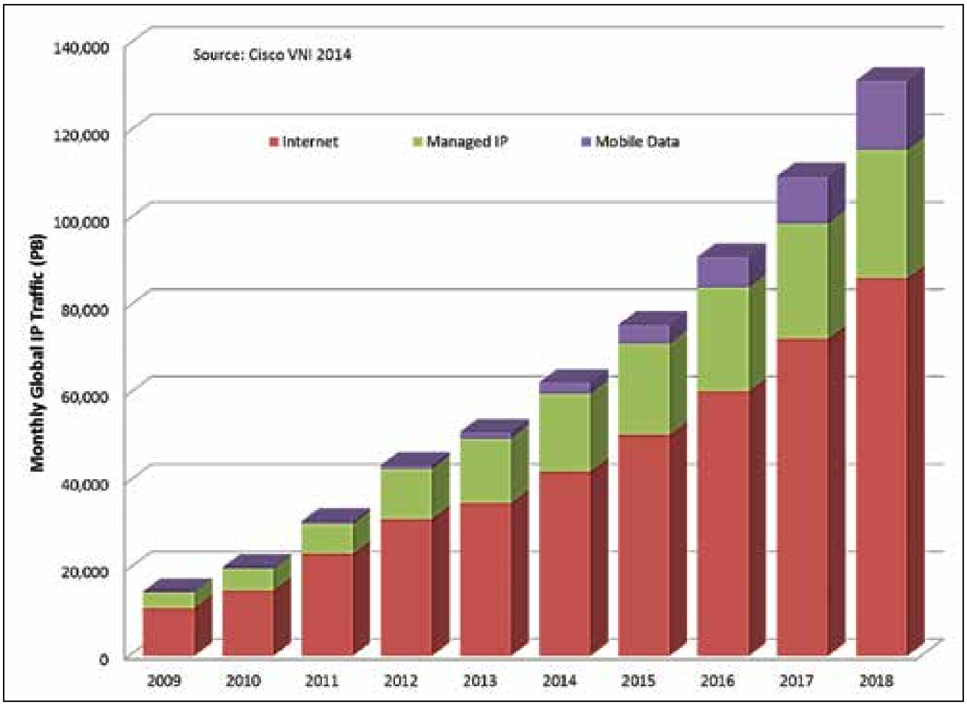


Figure 4 • IP Data Consumption.

GaAs community was the announcement of CMOS PAs that target emerging LTE opportunities. Currently, only Qualcomm and Peregrine Semiconductor have competitive offerings for these applications and they are enduring the usual growing pains, but these devices will take share away from GaAs. In addition to CMOS, SiGe for low power applications and GaN and LDMOS for power applications serve as the main competitive threats to GaAs in RF applications.

Combining these thoughts and accounting for all the technologies that address applications in the RF segment, Figure 3 shows a snapshot of the segmentation of the estimated 2014 RF market revenue.

The competitive technologies add about $2.4 billion of revenue to the GaAs portion of the market, bringing the total to about $9 billion. It should be very clear how important cellular applications are to the overall RF market, accounting for nearly 66% of the revenue. Adding in other wireless applications like Wi-Fi (the second largest revenue segment), base stations, microwave/millimeter wave backhaul, VSAT, etc. increases the wireless segment to nearly 86% of the total RF semiconductor revenue.

With this snapshot of where the RF compound semiconductor industry stands in 2014 and a good understanding of the developments and trends that got us here, where does the industry go in 2015? The overwhelming, insatiable desire to consume increasing amounts of data will influence every future development and trend. It is not hyperbole to say that every trend in the electronics market ultimately ties to data consumption. Figure 4 shows the Cisco VNI (Visual Networking Index) forecast to 2018, with actual data back to 2009. The CAGR for the data in the chart approaches 28%. To put this into perspective, a petabyte of data is equivalent to about 223,000 DVDs. In 2018, this forecast implies users will generate data equivalent to 29.3 billion DVDs…per month!

The wireless segment shows the fastest growth, with a CAGR slightly greater than 77%. Given the segmentation of the RF semiconductor industry shown in Figure 3, this is a promising trend. As impressive as mobile growth is, it will only represent 12% of the total data consumption in 2018! The rest of the data will reside on wired copper, fiber or coaxial cable networks. Increasingly, a bit of data will travel over several of these networks and there are opportunities for RF semiconductors in all these data segments. The revenue and volume associated with the cellular and Wi-Fi segments shifts the spotlight away from some of the other areas of the industry, but there are a number of interesting developments taking place in these segment.

I think the discussion of the history, trends, drivers and present state of the RF semiconductor industry focuses the view of 2015 and beyond. The last section includes my thoughts on some of the important topics in the industry. Some are obvious, but some will require a bit of faith:

Data Consumption: This engine drives the entire semiconductor market. Any substantial changes to the trajectory presented in Figure 4 would have catastrophic repercussions for the semiconductor industry. Even though the last couple of data forecasts have shown declining growth forecasts, the numbers remain large. There are developments like 4K or UHD TV, the Internet of Things (IoT), increasing HD and UHD video uploading to social networking sites and the ongoing arms race between fiber and coax to provide the highest data rates that will sustain and probably increase data consumption rates.

RF CMOS: This is an easy trend to call. CMOS-based amplifiers and switches will continue to capture market share from GaAs. The trendy discussion in the industry has been “the death of GaAs”. This is unlikely to happen anytime soon. CMOS has undeniable perfor-

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".

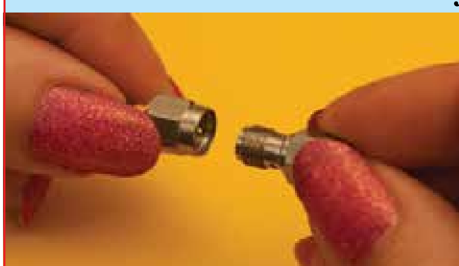
3. Push "Lock Nut" forward and engage the Push-On end of the Adapter with the mating female. Back nut must be released.

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.

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.

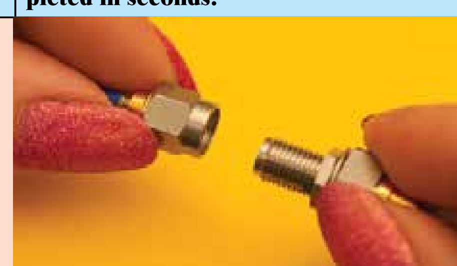
3. Just slide the Push-On SMA male Connector onto any standard SMA female. The connection is securely completed in seconds.

4. To disconnect, just pull the connector off.

Spectrum Elektrotechnik GmbH

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

Spectrum Elektrotechnik GmbH



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.

mance, integration and cost benefits, but this technology works best with high volume applications that have stable performance requirements. When volumes are lower, mask costs of CMOS affect the cost competitiveness of the technology. RF CMOS revenue will increase in 2015 and beyond, but it will not be the dominant RF technology in the foreseeable future.

MMMB PAs: To address the rise of LTE bands, carrier aggregation and increasing data consumption, multi-mode, multi-band (MMMB) PAs will continue to capture market share in handset front-end architectures. With the price sensitivity of this market, the price of the MMMB PAs cannot exceed the price of the components they replace. This would seem like a bad development for GaAs device revenue, but manufacturers seem to be making the block diagram even more complicated by including more functionality or expanding the number of bands in the phone. The net effect for the GaAs device market will be neutral to positive. The situation will be a bit different for epitaxial substrate manufacturers, because the MMMB trend will mean less production area and a reduction in the $/mm2 metric.

GaN: There has not been much discussion of GaN here, but the technology has turned the corner and it is seeing significant adoption in commercial applications. Defense applications have driven the development and adoption of GaN and the latest Strategy Analytics forecast shows this will continue with defense applications accounting for more than 50% of GaN revenue in 2018. Commercial adoption is increasing quickly with CATV adoption continuing and base station PA applications increasing quickly. VSAT and point-to-point radio applications are also starting to see growth. The vast majority of these devices will be GaN-on-SiC. There is a chorus to push GaN-on-silicon into lower power, high volume applications and functions. The argument is that the lower cost structure will allow the technology to address more applications. Unless there is a disruptive manufacturing development, the realization of this idea appears to be several years down the road, at best.

Trajectory Change

The preceding topics have addressed a shorter time horizon. The final two topics are longer term, with the potential to change the trajectory of the entire industry.

Internet of Things (IoT): This is one of the hottest discussions in the electronics industry. The premise is that deploying a large number of embedded computing sensors and interconnecting them into wide area networks with the Internet will dramatically improve society. The latest Strategy Analytics forecast anticipates more than 33 billion devices connected to the Internet in 2020. The concept involves smart sensors sending data that enables better decisions. This "intelligence" gives rise to applications involving telemedicine, "smart" cities and utilities, industrial automation, security and a whole host of others. The connected devices and networks will create a vibrant service economy, which will provide substantial revenue. This concept is a superset of M2M communications, Wi-Fi, cellular terminals and the whole host of devices already connected to the Internet, so it is clear that the IoT is already happening. The use cases currently involve low data rate, low power applications, so silicon-based semiconductors manufactured in high volume seem the most likely choice. With the breadth of devices and applications included in the IoT concept, there is little doubt that there will be growth. The challenge will be determining applications for RF compound semiconductors.

5G: If IoT is the most discussed topic, then 5G is running a close second. This concept assumes that existing network architectures will not be able to keep up with the anticipated data consumption increases. This effort will revolutionize the RF industry, because the goal is to increase user data rates, capacity, battery life and network devices by orders of magnitude over existing capabilities. Network deployments may not be until 2020, but development work streams are currently underway, under the auspices of Alcatel-Lucent, Fujitsu, NEC,

Ericsson, Samsung and Nokia. This is a disruptive opportunity for the RF semiconductor industry because several of the activities involve developing networks at frequency bands of 5 GHz to 86 GHz, with more available bandwidth. Other concepts under development involve the use of antenna beamforming, beam tracking and massive MIMO. These all play into the strengths of compound semiconductor devices and 5G represents an exciting opportunity for the entire RF semiconductor supply chain.

This is a very exciting time for the RF semiconductor industry. High volume applications are growing, new technologies are gaining traction and new applications are in development to handle the tidal wave of data consumption. There will undoubtedly be twists and turns, along with a surprise or two along the way, but the future for the industry looks rosy.

About the Author:

Eric Higham serves as Director, Advanced Semiconductor Applications Service, Strategy Analytics. He has held various positions in engineering, applications, business development and marketing at Raytheon, MicroDynamics and M/A-COM. He received a BSEE from Cornell University with a concentration in solid-state semiconductors and an MSEE from Northeastern University with a concentration in Fields, Waves and Optics.

References:

(1) Bardeen, J. and Brattain, W. “Three-Electrode Circuit Element Utilizing Semiconductor Materials,” U. S. Patent 2,524,035 (Filed June 17, 1948, issued Oct. 3, 1950).

(2) Shockley, W. “Circuit Element Utilizing Semiconductive Material,” U. S. Patent 2,569,347 (Filed June 26, 1948. Issued September 25, 1951)

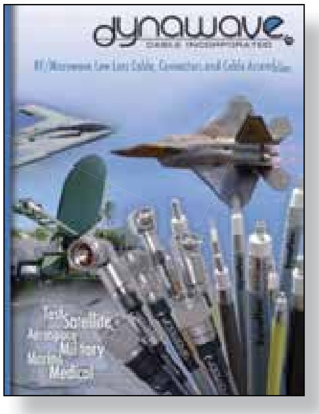
(3) Teal, Gordon K. “Methods of Producing Semiconductive Bodies,” U. S. Patent 2,727,840 (Filed June 15, 1950. Issued December 20, 1955)

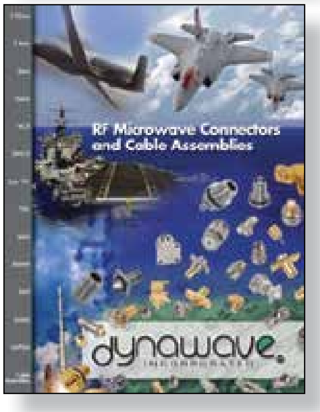
(4) Teal, G. K. “Some recent developments in silicon and germanium materials and devices,” Presented at the National Conference on Airborne Electronics Dayton, Ohio (May 10, 1954)

(5) Zolper, John Z. “A DARPA Perspective on the Future of Electronics”, CSMantech Presentation, 2003.

(6) Cohen, Eliot D. “MIMIC from the Department of Defense Perspective”, IEEE Trans. Microwave Theory and Technique, vol. 38, no. 9, 1171 (1990).

Microwave Components is now stocking Dynawave Cable Inc.
High Performance Low Loss Bulk Cables !!





DynaFlex® Cable Series easily handles the most challenging interconnect design specifications where size, weight, power, loss, phase stability, flexure or other requirements are critical. This is accomplished by employing the **DynaCore™** and **FiberLite™** technologies along with the latest manufacturing equipment and controlled processes.

DynaFlex® Series DF 100 (DC - 65 GHz) is the **"Best in All Around Performance"**

DynaFlex® Series DF 200 (DC - 40 GHz) is the **"Best in Electrical Performance"**

DynaFlex® Series DF 300 (DC - 40 GHz) is the **"Best in Weight Performance"**

DynaFlex® Series DF 400 (DC - 65 GHz) is the **"Best in Flexure Performance"**

D-Flex™ Cable Series replaces semi rigid cable applications with a flexible equivalent and the **D-Flex™** Microporous Cable Series offers extended operational frequencies and temperature ranges through utilization of microporous cores
.

D-Flex™ Series (DC – 18 GHz), DX 086, DX 141

D-Flex™ Microporous Series (DC – 40 GHz), DXM 047, DXM 086, DXM 141

Call us today and put our experience to work for you….

MICROWAVE COMPONENTS

AS9120
ISO 9001:2000
CERTIFIED

Phone: (888) 591-4455 or (772) 286-4455 Fax:(772) 286-4496
E-Mail: admin@microwavecomponentsinc.com
Web Site: www.microwavecomponentsinc.com

RF Circuit Design References

By Peter Delos

Proficiency in the RF circuit design profession requires significant awareness of many areas of electrical engineering. Acquiring foundational material and digesting the engineering principles involved is a lifelong undertaking. For engineers entering the RF profession it is not always clear where to begin. Fortunately, many well written references have been published over the last few decades. The purpose of this note is to outline some of the important references with comments on their contributions. The intention is to provide a starting point for working engineers entering the RF arena, as well as a useful reference list for seasoned RF engineers.

Outlining some of the important learning resources, with comments on their contributions.

Effort was placed on providing references that provide a comprehensive foundation through books, some IEEE papers, and many working-level application notes. As a disclaimer to the compiled reference list, there is no way to include every possible reference book or famous paper. Any detailed design or study in a particular topic will lead to additional material not cited here.

Introductory Material:

If you are brand new to RF, these books can provide a practical foundation with easy to read descriptions.

[1] American Radio Relay League, “2015 ARRL Handbook for Radio Communications,” October 2014. This is the 92nd edition. It is written as a training manual at a practical level and highly recommended.

[2] Hagen, “Radio Frequency Electronics, Circuits and Applications,” Cambridge University Press, 1996. This book provides short summaries of many topics routinely encountered.

RF and Microwave Principles:

[3] Pozar, “Microwave Engineering,” Wiley, 2011. This is a famous reference and is up to the fourth edition. It requires a background in field theory, and brings EM principles into microwave applications.

[4] Bowick, “RF Circuit Design, 2nd Edition,” Newnes, 2007. A practical read that provides very valuable information on filters, impedance matching, and amplifiers. The 1st edition came out in 1982. The fact that a 2nd edition came out 25 years later is an indicator of its value.

[5] “S-Parameter Design,” Agilent Application Note 154. Written by Hewlett-Packard, this note outlines design with S-Parameters and use of the Smith chart.

[6] Gandhi, “Microwave and Engineering Application,” Pergamon Press, 1981. This is a college textbook that complements, and in some ways is more practical, than Pozar.

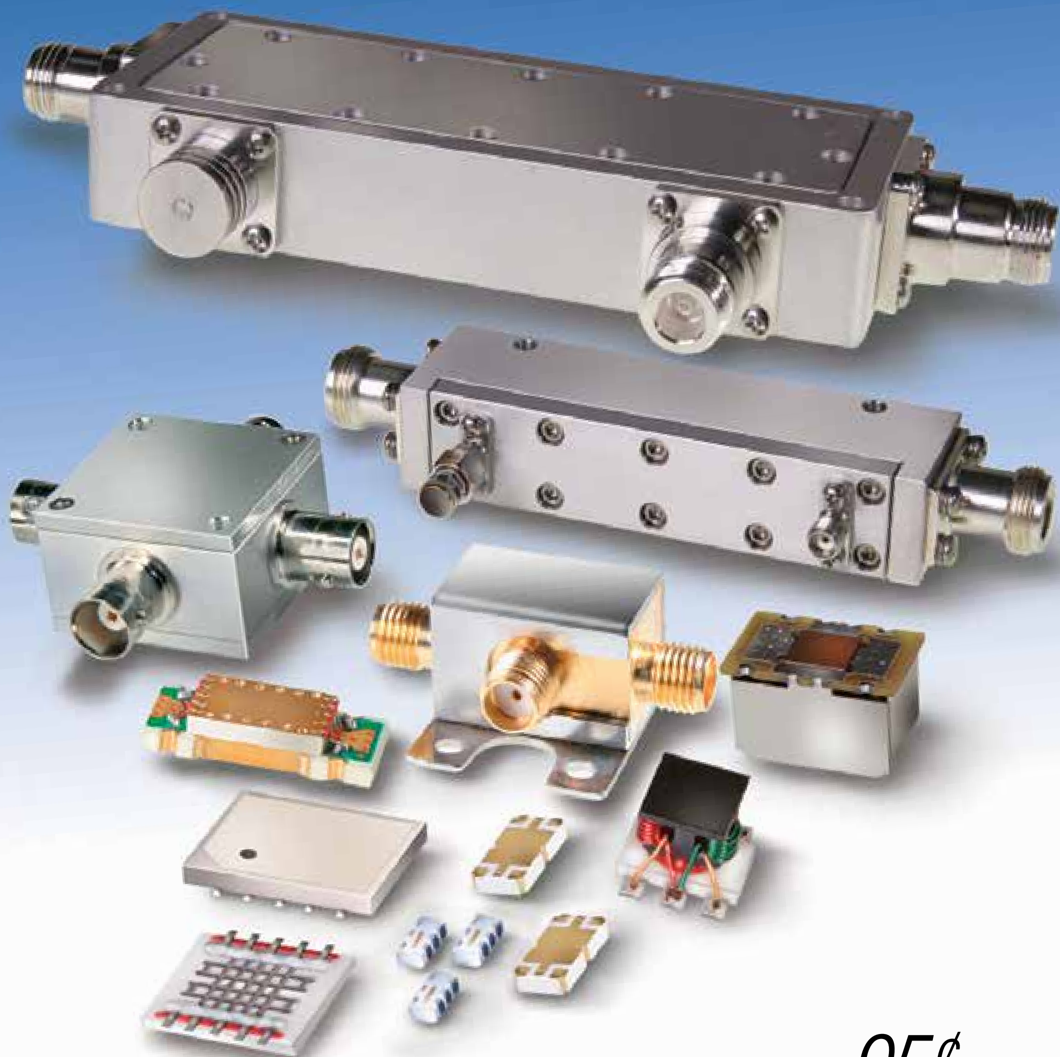
[7] Krauss, Bostian, Raab, “Solid State Radio Engineering,” Wiley, 1980. A practical and thorough view of radio electronics. The emphasis on architectural considerations rather than specific implementations makes this reference still relevant today.

[8] “Reference Data for Radio Engineers,” International Telephone and Telegraph Corporation, Fourth Edition, 1956. This provides a great historical perspective of how much was already known a half century ago.

Signal and Communication Theory: These first two books are college level textbooks, heavy in math, but provide some of the fundamental theory taught at the university level.

Directional / Bi-Directional

COUPLERS



5 kHz to 18 GHz up to 250 W from 95¢ ea. (qty.1000)

Now! 326 ~~279~~ models in stock, and we're adding even more! Looking for couplers or power taps? Mini-Circuits has 326 ~~279~~ models in stock, and we're adding even more! Our versatile, low-cost solutions include surface-mount models down to 1 MHz, and highly evolved LTCC designs as small as 0.12 x 0.06", with minimal insertion loss and high directivity. Other SMT models are designed for up to 100W RF power, and selected core-and-wire models feature our exclusive Top Hat™, for faster, more accurate pick-and-place.

At the other end of the scale, our new connectorized air-line couplers can handle up to 250W RF input power, with low insertion loss and exceptional coupling flatness! All of our couplers are RoHS compliant. So if you need a 50 or 75Ω, directional or bi-directional, DC pass or DC block coupler, for military, industrial, or commercial applications, you can probably find it at minicircuits.com, and have it shipped today!

Mini-Circuits®

www.minicircuits.com P.O. Box 350166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

495 rev D

[9] Oppenheim, Willsky, and Nawab, “Signals and Systems, 2nd Edition,” Prentice Hall, 1997.

[10] Proakis, Salehi, “Communcation Systems Engineering,” Prentice Hall, 1994. A second edition was published in 2001.

These references break down the basics of modulation and are well written:

[11] Hewlett-Packard, “Amplitude and Frequency Modulation,” Application Note 150-1, 1989

[12] Mccune, “Practical Digital Wireless Signals,” Cambridge Press, 2013

Receiver Architectures

[13] McClaning, Vito, “Radio Receiver Design,”New York, Noble Publishing, 2000. A sequential walk-through of receiver concepts and considerations.

[14] Abidi, “Direct-Conversion Radio Transceivers for Digital Communications,” IEEE, 1995

[15] Razavi, “Design Considerations for Direct-Conversion Receivers,” IEEE, 1997

[16] Murphy et al, “A Blocker-Tolerant, Noise-Cancelling Receiver Suitable for Wideband Wireless Applications,” JSSC, 2012. This received Best Paper Award at the time. Murphy outlines and includes many references for noise-cancelling receiver architectures. These methods may change how receivers are done in the future.

Waveform Generation

[17] “A Technical Tutorial on Digital Signal Synthesis,” Analog Devices, 1999

Modern waveform generation begins in the Direct Digital Synthesizer (DDS). Next it is followed by an up-conversion stage. The up-converter is conceptually a mirror of the receiver, but with different considerations. Much has been written on receiver design; less literature exists on the upconverter aspects of waveform generation. For this, the designer can refer to the mixer, filter, and amplifier references.

Phase Locked Loops

[18] Gardner, “Phaselock Techniques,”3rd Edition, Wiley, 2005

[19] Banerjee, “PLL Performance, Simulation, and Design,”4th edition, 2006

[20] Wolaver, “Phase Locked Loop Circuit Design,” Prentice Hall, 1991

[21] Brillant, “Understanding Phase Locked DRO Design Aspects,” Microwave Journal, 1999

Oscillators

[22] Rhode, Poddar, Bock, “The Design of Modern Microwave Oscillators for Wireless Applications,” Wiley, 2005. Rhode and Poddar are prolific writers with hundreds of published articles and several books.

[23] Rhea, “Oscillator Design and Computer Simulation,” Noble Publishing, 2000

[24] Kurzenknabe, “Practical Considerations in Specifications of High Stability Crystal Oscillators,” Piezo Crystal Company (Now Vectron), exact date unknown, probably ~1990. This is a great reference for anyone buying crystal oscillators.

[25] McNeilage, Searls, Ivanov, et al, “A Review of Sapphire Whispering Gallery-Mode Oscillators including technical progress and future potential of technology,” UFFC, 2004. An outline of methods used for the lowest phase noise high frequency oscillators available at the time of writing.

[26] Everard, “Fundamentals of RF Circuit Design with Low Noise Oscillators,” Wiley, 2001. A good RF book with an extended section on oscillator design.

[27] Hegazi, Eldin, Abidi, “The Designers Guide to High Purity Oscillators,” 2005. A specialized book that details integrated circuit CMOS oscillators.

Noise

[28] “Fundamentals of RF and Microwave Noise Figure Measurements,”Agilent Application Note AN57-1. This originated as a Hewlett-Packard note and is the place to start on noise figure. The fundamental theory is described along with measurement techniques.

[29] Ott, “Noise Reduction Techniques in Electronic Systems,” Wiley, 1988. A practical book written for the working engineer. This work broke new ground at its time and is still relevant today.

[30] Maas, “Noise in Linear and Nonlinear Circuits,” Artech House, 2005

Phase Noise: Although this could be considered a subset of noise, it is so important in RF it that is given its own section.

[31] “Phase Noise Characterization of Microwave Oscillators, Phase Detector Method,”Agilent Product Note 11729B-1. Another note originated by Hewlett-Packard and is the place to start on phase noise. It is online along with several other phase noise application notes.

[32] Rubiola, “Phase Noise and Frequency Stability in Oscillators,” Cambridge University Press, 2008. One of the few textbooks on the subject, a lengthy set of references are cited and online lecture notes are also available.

Some famous phase noise papers:

[33] Leeson, “A simple Model of Feedback Oscillator Noise Spectrum,” IEEE, 1966

[34] Lee, Hajimiri, “Oscillator Phase Noise: A Tutorial,” IEEE, 2000

Design References

Mixers

Frequency translation is a fundamental to RF. The methods, limitations, and additional filtering required should be understood.

[35] Henderson, "Mixers in Microwave Systems," WJ Tech-Note, 1990. A two part application note that describes spurious charts and most of the essentials for consideration in frequency planning.

[36] Maas, "Microwave Mixers," Artech House, 1993. A well-known reference on mixer design.

Harmonic Rejection Mixers may become a fundamental building block in the future. The concept of minimizing mixing spurious through emulating LO signals with reduced harmonics can become practical with highly integrated RFIC design. One recent paper is cited, and other also exist.

[37] Forbes, Ho, Gharpurey, "Design and Analysis of Harmonic Rejection Mixers With Programmable LO Frequency," JSSC 2013.

Filters

Three famous books provide the foundation for much of the modern filter theory in use today.

[38] Matthaei, Young, Jones, "Microwave Filters, Impedance-Matching Networks and Coupling Structures," Artech House, 1980

[39] Zverev, "Handbook of Filter Synthesis," Wiley, 1967

For Active Filter Design:

[40] Valkenburg, "Analog Filter Design," Saunders, 1982

OpAmps

A working knowledge of operational amplifiers is fundamental to electrical engineering. Several references from major semiconductor companies are cited.

[41] Jung, "Op Amp Applications," Analog Devices, 2002

[42] Mancini, "Op Amps For Everyone," Texas Instruments, 2001

[43] National Semiconductor, "Linear Applications Handbook," 1994

Audio Amplifier Design

With the exception of parasitic impact, discrete circuit design techniques applied in audio are closely related to RF and IC design. The Self and Cordell books outline the essentials of discrete solid state audio design, and the O'Conner book provides a detailed design guide to tube based guitar amplifier design.

[44] Self, "Audio Power Amplifier Design 5th Edition," Focal Press, 2013

[45] Cordell, "Designing Audio Power Amplifiers," McGraw-Hill, 2011

[46] Self, "Small Signal Audio Design," Focal Press, 2010

[47] O'Conner, "The Ultimate Tone," Power Press, 1995

RF Amplifiers

[48] Gonzales, "Microwave Transistor Amplifiers," Prentice Hall, 1997. A thorough textbook on amplifier design through S-Parameters.

[49] Ladbrooke, "MMIC Design: GaAs FETs and HEMTs," Artech House, 1989. Old but still relevant.

RF Power Amplifiers

[50] Cripps, "Advanced Techniques in Power Amplifier Design," Artech House, 2002. This is Cripps' newer book. Another book listed as 2006 is a second edition of an older book.

[51] Walker (editor), "High Power GaAs FET Amplifiers," Artech House, 1993. This is a good collection of material from multiple important authors.

[52] Kenington, "High Linearity RF Amplifier Design," Artech House, 2000. As the title suggests, the subject of all-important linearity.

Data Converters

[53] Kester, "Analog-Digital Conversion," Analog Devices, 2004. This is a weighty book that includes a historical perspective, architectures, sampling theory, specifications, and user considerations. The information from many other application notes is included in this reference.

IC Design

[54] Gray et al, "Analysis and Design of Analog Integrated Circuits," Wiley, 2009. This book is referenced routinely in many IEEE papers on RFIC design. It has been a valuable resource for both the university level and the working engineer for many years. It is now up to the fifth edition.

[55] Baker, "CMOS Circuit Design, Layout, and Simulation," Wiley, 2010. A wealth of information on CMOS design; from the transistor level through both analog and digital circuits. It is up to the 3rd edition.

[56] Allen, Holberg, "CMOS Analog Circuit Design," Oxford Press, 2012. Also at the 3rd edition. Complementary with the Baker book, the combined use of both references provides a solid CMOS foundation. The Allen website provides very good lecture notes and a view into the book.

[57] Sedra, Smith, "Microelectronic Circuits," Oxford Press, 2009. This has been a college textbook for several decades now and is up to the sixth edition.

[58] Razavi, "Fundamentals of Microelectronics," Wiley, 2014. Razavi is a prolific writer. He has many other books worth considering, also. This is his latest

and outlines a foundation in IC design as the title indicates.

Transistor Properties

Most circuit books have a chapter or two on transistor principles. Sometimes it is good a have a book dedicated to the topic at a practical level without going too deep into semiconductor physics.

[59] Frederiksen, "Intuitive IC Electronics: A sophisticated Primer for Engineers and Technicians," McGraw-Hill, 1982

[60] Ashburn, "SiGe Heterojunction Bipolar Transistors," Wiley, 2003. A comprehensive treatment of bipolar transistors; covering properties, modelling, and how they are made. This also provides a good historical perspective of improvements over the decades of development.

[61] Hastings, "The Art of Analog Layout,"Prentice Hall, 2001. Geared towards IC layout, and provides insight not considered in the schematic phase of the design.

[62] Anholt, "Electrical and Thermal Characterization of MESFETs, HEMTs and HBTs," Artech House, 1995. Excellent basic book on modeling.

Printed Wiring Board Layout

[63] Montrose, "Printed Circuit Board Design Techniques for EMC compliance," IEEE Press, 2000

[64] Edwards, "Foundations for Microstrip Circuit Design," Wiley, 1992, 1981. Excellent reference with a lot of very hard-to-find information.

[65] Ott, "Partitioning and Layout of a Mixed-Signal PCB," Printed Circuit Design Magazine, 2001. An important detail of grounding implementation in PWB layout is described.

Power Supplies and Regulation

Much literature exists on power supply design. For the RF designer it is more important to be versed in the topologies and concepts of linear and switching regulator design, since not typically working specifically in this area. For this reason, several application notes readily available on the internet are cited and only one book.

[66] Pressman, et al, "Switching Power Supply Design, Third Edition," McGraw-Hill, 2009. Written by a seasoned engineer for working engineers. The reference provides a thorough foundation and design guidelines for numerous switching topologies.

[67] "Basic Concepts of Linear Regulator and Switching Mode Power Supplies," Linear Technology Application Note

[68] "Basic Linear Design, Chapter 9, Power Management," Analog Devices

[69] "Switch-Mode Power Supply Reference Manual," On Semiconductor

Low noise RF performance starts with low noise DC power. Two application notes are cited:

[70] Teel, "Understanding Noise in Linear Regulators," Texas Instruments Application Note

[71] Morita, "Noise Sources in Low Dropout Regulators," Analog Devices Application Note

Digital Signal Processing: Some knowledge of signal processing after the A/D capture is very useful to aid in understanding specification requirements flowed to the RF systems.

[72] Oppenheim et al, "Discrete-Time Signal Processing," Prentice Hall, 2009. An advanced college textbook currently at the 3rd edition.

[73] Smith, "The Scientist and Engineer's Guide to Digital Signal Processing," Analog Devices, 1998. A practical, working engineer's guide to DSP concepts.

Radar: Radar is its own specialized application. However, many RF engineers will work on something related to radar at some point in their careers. These references are old, but many of the system-level approaches in use today were worked out years ago and are just being implemented with modern methods.

[74] Stimson, "Introduction to Airborne Radar," SciTech Publishing, 1998. A very concise, practical description of radar principles. The 2nd edition was 1998. The book is popular enough that a 3rd edition was published in 2014 with additional editors.

[75] Cook, Bernfeld, "Radar Signals, An Introduction to Theory and Application," Academic Press, 1967. Develops the theory for how radar waveforms are chosen. This was popular enough to be re-released in 1993.

[76] Skolnik, "Radar Handbook," McGraw-Hill, 1978. A 39-chapter dissertation on radar. All the principles are still valid although some of the electronic implementations are old. A 3rd edition was released in 2008.

[77] Skolnik, "Introduction to Radar Systems," McGraw-Hill, 1980, 1962. This is an important classic radar book.

[78] "MIT Radiation Lab Series," 1947-1951. Although old, this series documents the volume of development work made during the World War II time period advancing radar and related technologies. These developments and technical descriptions laid the foundation for radar development through the rest of the 20th century and on to today.

Antennas: Antenna theory is fundamental to RF. The above references are geared toward RF electronics and signal processing. A completely separate list could be compiled on antennas.

[79] Balanis, "Antenna Theory, Analysis and Design," Wiley, 1982, 1997, 2005. This is the "bible" for antenna design, currently on its 3rd edition.

[80] John L. Volakis, ”Antenna Engineering Handbook,” Fourth Edition, McGraw-Hill, 2007. This is another well-known and well-respected antenna reference.

[81] Mailloux, “Phase Array Antenna Handbook,” Artech house, 1994. The study of phased arrays is an important subject on its own, once you get past individual antennas.

Tutorial Websites

The volume of information online is incredible. Learning through this method is encouraged and a good balance to written books or papers. Many great application notes are available from semiconductor companies, RF component companies, and test equipment companies, and research institutions. A few websites are listed which bring a unique contribution to the volume of available online material.

[82] http://www.rfcafe.com/

[83] http://www.microwaves101.com/

[84] http://www.circuitsage.com/

[85] http://www.rfwireless-world.com/

[86] http://www.rf-mw.org/

[87] http://hyperphysics.phy-astr.gsu.edu/hbase/hph.html

[88] http://ecee.colorado.edu/~bart/book/contents.htm

[89] http://www.tubebooks.org/technical_books_online.htm

Areas Not Covered

The following areas are not referenced specifically but are also an important aspect of the RF engineering profession. These include:

1) Programming: Every engineer needs some programming fluency. Programming should be an aid, not a hindrance.

2) CAD Tools: CAD tools have progressed to an amazing level in our lifetimes. Circuit simulators, EM modelling, PWB and IC layout tools have made things possible that otherwise wouldn’t exist. Learn the CAD tools in use at your facilities and help bring the latest tools into your departments.

3) Mathematics: While electrical engineering college curriculum is heavy in math, later, as working engineers, it is easy to forget. Keep some old college books around, and review the basics periodically.

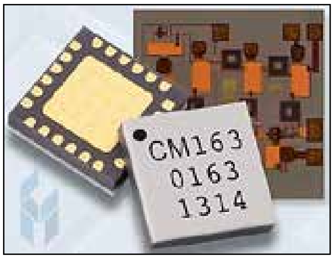
Acknowledgement & Final Comment

The author would like to thank the engineers who reviewed this compilation and contributed to the list of titles provided. The above list is by no means complete. It is geared towards providing a foundation and a starting point. If this can provide some help for others, then it was worth the time to compile.

About the Author:

Peter Delos is a lead RFIC Engineer in the Lockheed Martin Microwave Center at the Moorestown, NJ, facility. He received his BSEE from Va Tech in 1990 and MSEE from NJIT in 2004. He began his career as an electrical field engineer gaining experience in many types of systems, electrical problems, and a foundation in the electrical engineering profession. In 1997, he accepted a position with Lockheed Martin in Moorestown, NJ, and began Receiver/Exciter/Synthesizer design. Mr. Delos has both worked in and led many design teams on highly integrated RF and mixed signal designs. The quest for high performance in reduced footprints led to detailed RFIC designs, and in 2012 he was transferred to the Lockheed Martin RFIC Design Center.


GREAT SERVICE ISN'T EXPENSIVE...
...IT'S PRICELESS.
EXCELLENT SERVICE
EXCELLENT DELIVERY
EXCELLENT QUALITY
RF COAXIAL RELAYS
SMA, N AND PCB LAUNCH
STANDARD AND CUSTOM DESIGNS
RELCOMM TECHNOLOGIES, INC.
• Mission Critical Communications:
- Security, Safety and Intelligence
- Commercial Telecom Infrastructure
- Military Defense Fixed, Mobile & Shipboard
• Instrumentation:
-Test and Measurement
RF Relay Store.com is the answer to your urgent small quantity needs.
RF Coaxial Relays available from Stock at www.rfrelaystore.com
sales@relcommtech.com • www.relcommtech.com • 410-749-4488
EXCELLENCE BY DESIGN



LNA

The CMD163 is a 17 to 27 GHz low noise amplifier in die form. It has a gain of +24 dB, a noise figure of less than 1.3 dB, and an output 1 dB compression point of +19 dBm across the 17 to 27 GHz bandwidth. It utilizes an all-positive bias scheme, eliminating the need for negative voltages and expensive sequencing circuitry.

Custom MMIC
custommmic.com

Test Set

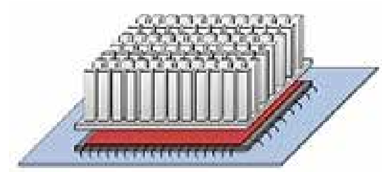
Keysight expanded capabilities for the E7515A UXM wireless test set. The new features address the rapidly evolving 3GPP LTE-Advanced carrier aggregation advancements. The UXM wireless test set is highly integrated, and created for functional and RF design validation in the 4G era and beyond.

Keysight Technologies
keysight.com

Mixer

Model SFB-83310410-1010KF-N3 is a W-band, low distortion and high performance balanced mixer. It exhibits 7 dB +/- 1 dB conversion loss in the RF frequency range of 65 to 102 GHz while LO is set at 102 GHz/+12 dBm. The 2RF-LO and 2LO-2RF products are -40 dBc typical relative to its fundamental LO-RF product typically. In addition, the mixer also shows excellent port to port isolation.

SAGE Millimeter
sagemillimeter.com



Pad Material

RFMW announced sales support for MAST Technologies' line of dual use RF Absorber + Thermally Conductive pad material. Trademarked Suppress-n-Sink, the target application is reducing harmful reflections from heat-sinks and heat-spreaders used on packaged components. Large OEMs have adopted the solution as a thermal conductor and EMI suppressor for on-board microprocessors.

RFMW
rfmw.com

Upconverter

The QM1002-2-18-2 Dual Channel 1U 19-inch Rack 2-18 GHz RF upconverter provides two channels of RF upconversion with an RF output frequency range of 2 to 18 GHz. The IF input is centered at 1 GHz with a 500 MHz bandwidth (750-1250 MHz), with an option to shift the IF input to be centered at 300 MHz (50-550 MHz).

Quonset Microwave
quonsetmicrowave.com

Mixer

Model SFH-12SFSF-A1 is an E-Band balanced harmonic mixer especially designed for Keysight's spectrum analyzer series. The mixer employs high performance GaAs Schottky flip chip diodes, balanced configuration to produce superior RF performance. The required LO frequency range is 3 to 6.1 GHz and power is +16 dBm, which translates the harmonic number 18 and resultants IF frequency around 1 GHz.

SAGE Millimeter
sagemillimeter.com

BERT

Keysight Technologies introduced adjustable and integrated intersymbol interference (ISI) capability for the J-BERT M8020A high-performance BERT. When engineers characterize and test high-speed digital receivers for compliance, they often need to emulate a certain channel loss. The new adjustable and programmable ISI function allows engineers to emulate channel loss.

Keysight Technologies
keysight.com

Attenuator

Mini-Circuits' 50Ω, 0 to 31 dB, 1.0 dB Step, DC to 4.0 GHz, DAT-31A+ Series Surface mount Digital Step Attenuator provides adjustable attenuation from 0 to 31 dB in 1.0 dB steps. The control is a 5-bit serial/parallel interface, and the attenuators operate with either single posi-

tive or dual (positive and negative) supply voltage.

Mini-Circuits
minicircuits.com

Connector System

TE's new ARISO Contactless Connectivity system, available from Mouser Electronics, is a hybrid interconnect system that allows for both power and data to be sent over short distances without any mechanical contact between the two couplers. This permits easy connectivity through materials such as walls, fluids, dust, and harsh atmospheric conditions.

Mouser Electronics
mouser.com

Power Divider

Link Microtek's new two-way power divider is particularly suitable for use in military mobile jamming systems to counter the threat of IEDs. Manufactured by Narda Microwave, the Model 2382-2 power divider operates over microwave frequencies from 500 MHz to 6 GHz and can handle an input power of up to 250W CW or 2kW peak.

Link Microtek
linkmicrotek.com

Coupler

Mini-Circuits' 75Ω, Up to 100W, 700 to 2500 MHz, ZABDC20-25H75F+ Bi-Directional Coupler features: excellent mainline loss, 0.3 dB typ.; excellent directivity, 25 dB typ.; high power, up to 100W; rugged

shielded case; DC current through input to output 2.0A Max. at 50 watt RF input power.

Mini-Circuits
minicircuits.com

Cable Analyzers

Keysight introduced two cable test options for its FieldFox handheld analyzers. The new Time Domain Reflectometry (TDR) cable measurement option enables TDR measurements for the cable and antenna analyzer. The Extended Range Transmission Analysis option addresses one of the major challenges to measuring cables in the field; measuring in-situ, long lossy microwave cables.

Keysight Technologies
keysight.com

Coupler

KRYTAR announced a new Directional Coupler operating in the frequency range of 6.0 to 26.5 GHz and offering Nominal Coupling of 6 dB in a extremely compact package. Model 106026506 offers some of widest frequency coverage using stripline designs on the market. Stripline designs offer superior low

Quality, Performance and Reliability in Precision Coaxial Connectors

ADAPTERS · CABLE CONNECTORS · RECEPTACLES · CUSTOM DESIGNS

Including These Connector Series					
1.85mm	DC-65 GHz	2.92mm	DC-40 GHz	7mm	DC-18 GHz
2.4mm	DC-50 GHz	3.5mm	DC-34 GHz	SSMA	DC-40 GHz

ISO 9001:2008

SGMC Microwave — The name to count on for Quality, Performance and Reliability! Please contact us today by Phone, Fax or Email.

SGMC MICROWAVE

Manufacturer of Precision Coaxial Connectors
620 Atlantis Road, Melbourne, FL 32904
Phone: 321-409-0509 Fax: 321-409-0510
sales@sgmcmicrowave.com
www.sgmcmicrowave.com

Get info at www.HFeLink.com

Visit Us In Phoenix!

IMS Booth # 2129

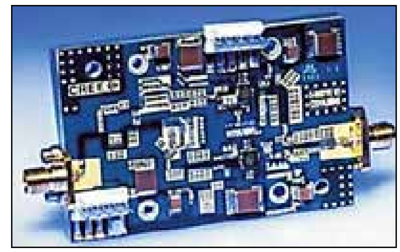
insertion loss, high directivity and tight coupling.

KRYTAR
krytar.com

Transformer

Mini-Circuits' 50Ω, 3W, Up to 18 GHz NCR2-Series RF Transformers have an impedance ratio of 1:2 and are commonly used for unbalanced to balanced applications. LTCC construction provides exceptional reliability, thermal stability, and a high degree of repeatability. A small footprint (0.08 x 0.10") offers flexibility of integration with RF integrated circuits.

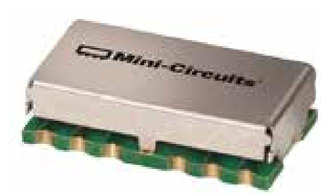
Mini-Circuits
minicircuits.com



Reference Design

Cree introduced the new CDPA35045 asymmetric Doherty power amplifier (PA) reference design for the 3.5 - 3.7 GHz band. This band is an additional spectrum space intended to complement small cell technology by providing increased wireless system capacity for both licensed wireless carrier services and unlicensed public use, such as WiFi.

Cree
cree.com



Phase Shifter

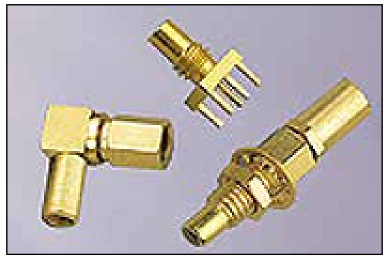
Mini-Circuits' 50Ω, 360° Voltage Variable, 1650 to 2400 MHz SPHSA-242+ Surface Mount Phase Shifter features: low insertion loss, 4.5 dB typ.; low control voltage, 10V; wide phase shift, 360°; aqueous washable. Applications: cellular; communications.

Mini-Circuits
minicircuits.com

Connectors

Delta SSMC connectors are microminiature, 50ý impedance connectors with 6-40 threaded coupling. SSMC connectors are ideal for use in limited-space applications that require the rugged design of a threaded coupling interface. They are best suited for use with semi-rigid cables or miniature flexible

New Products



cables in demanding applications up to 12.4 Ghz.

Delta Electronics
deltarf.com

VCO

Z-Communications announced a RoHS compliant VCO model V480MEM2-LF. The V480MEM2-LF operates at 445 to 480 MHz with a tuning voltage range of 0.5 to 2.5 Vdc. This high performance VCO features a spectrally clean signal of -113 dBc/Hz @ 100 kHz offset and a typical tuning sensitivity of 25 MHz/V.

Z-Communications
zcomm.com

Connectors

SGMC Microwave's 1.0 mm series are precision grade connectors designed for use with microwave applications requiring excellent performance up to 110 GHz. Optimum results are achieved with the use of a 1.0 mm outer conductor diameter and air dielectric. SGMC offers precision adapters, receptacles, and cable connectors for various semi-rigid and flexible coaxial cables. Special designs are also available upon request.

SGMC Microwave
sgmcmicrowave.com

Filter

Mini-Circuits' 50Ω, DC to 2690 MHz, LFCW-272+ Ceramic Low Pass Filter features: Low loss, 0.8 dB typ.; Small size 0603 (1.6 x 0.8 mm); Temperature stable; LTCC construction. Applications: Wireless communication; Harmonic Rejection; VHF/UHF transmitters / receivers; Lab use.

Mini-Circuits
minicircuits.com

SDR

The Signal Hound USB-SA44B is a Software Defined Radio (SDR) optimized as a spectrum analyzer. It is compact, simple to use, and an effective troubleshooting tool for general lab use, engineering students, ham radio enthusiasts, and electronics hobbyists. Using recent innovations in RF technology, the Signal Hound has the sensitivity, accuracy and dynamic range you'd expect in a unit many times its cost.

Signal Hound
signalhound.com

CST

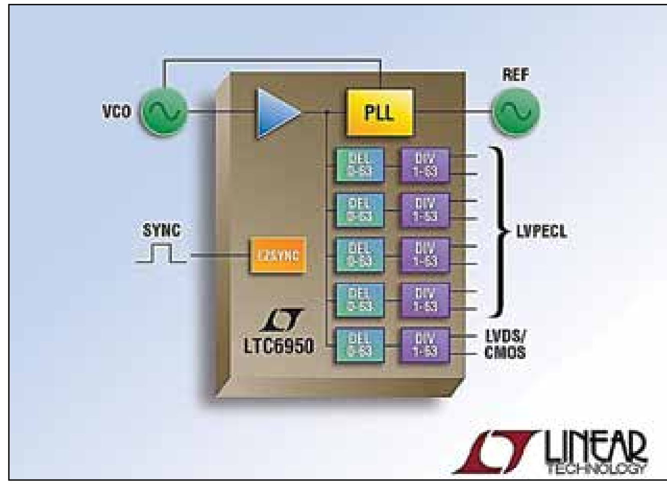
EMC Software

CST announced CST EMC STUDIO, a product for electromagnetic compatibility (EMC) and electromagnetic interference (EMI) analysis. EMC is an important consideration in product design across a wide range of industries. CST's EM solutions help identify potential compliance issues before the actual prototype is built.

CST
cst.com

Product Showcase

Product Highlights



Connector Website

SV Microwave launched a new, user-friendly website including a redesigned Product Search function that allows users to drill down to their selection from predefined categories. Created to streamline the product selection and order placement process, the new site also allows users to view product information, check availability and place orders all from one page.

SV Microwave
svmicro.com

Clock Distributor

The LTC6950 is a low phase noise integer-N synthesizer core with an ultralow jitter clock distribution output section. It is ideal for generating and distributing the low jitter signals essential to clocking data converters with a high signal-to-noise ratio (SNR). Maintaining low jitter on the data converter clock is fundamental to achieving outstanding SNR levels when digitizing or synthesizing high analog frequencies.

Linear Technology
linear.com

MCU

Mouser Electronics is stocking the MSP430i202x Mixed Signal Microcontroller Family from Texas Instruments (TI). This low power 16MHz 16-bit RISC microcontroller has up to four 24-bit sigma-delta analog to digital converters (ADCs) with differential programmable gain amplifier (PGA) Inputs. Additional features include a hardware multiplier, 75nA shutdown mode, and a temperature sensor.

Mouser Electronics
mouser.com

Product Highlights

Connectors

The 0.9 mm SuperMini product line provides the performance of Southwest's standard-size, high frequency connectors in a miniaturized footprint. With broad bandwidth and coupling nut mating, the series includes field-replaceable two and four-hole flange mount and thread-in connectors, solder-on end launch and 4-post vertical launch connectors, and direct solder cable connectors.

Southwest Microwave
southwestmicrowave.com

Power Sensor

LadyBug Technologies' updated LB480A firmware now includes both internal and external triggering as a standard feature. The sensor's flexible triggering features give users the ability to make time-gated measurements on CW or pulsed signals. External TTL triggering can be used to synchronize measurements of signals that are near the noise floor, making it possible to visualize them using the pulse profiling display.

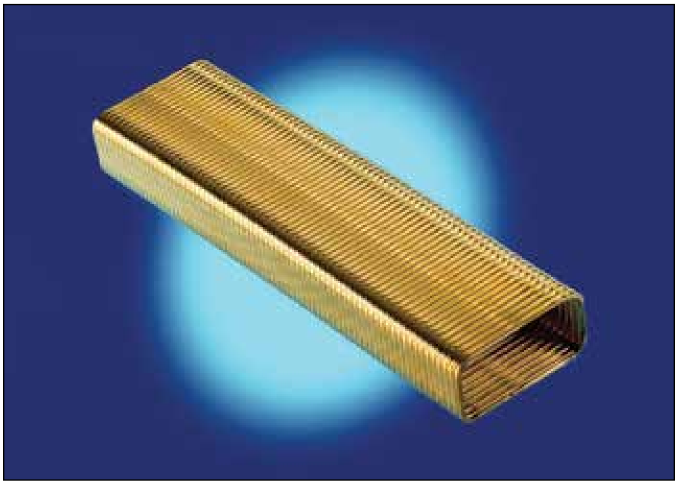
LadyBug Technologies
ladybug-tech.com

T&M Seminars

Keysight Technologies' Insight Seminar Series will help engineers hone their T&M skills. One free seminar focuses on advanced measurement theory and techniques, the other on core benchtop-instrument measurements. The Advanced Measurements Seminar tour begins Feb. 2 and the Core Bench Lab Seminar begins Feb. 24. Planned are more than 70 stops across the US and Canada.

Keysight Technologies
keysight.com

Product Highlights



Waveguide

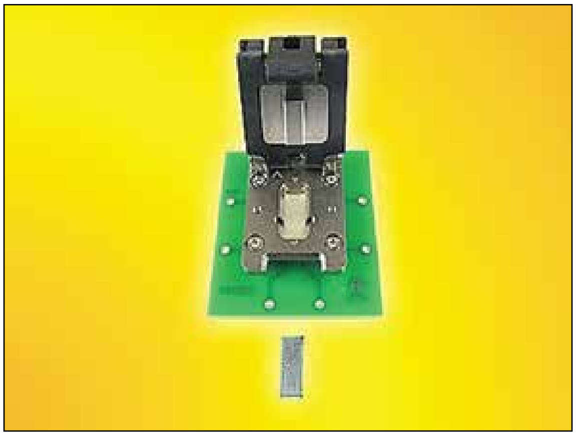
ATW Companies announced that its flexible waveguide and waveguide components are ideally suited for satellite applications and other airborne and space systems. Products include seamless flexible waveguide, flexible twistable waveguide, flexible waveguide, and semi flexible waveguide. In addition to tubing, the company offers components for all flexible waveguide types.

ATW Companies
atwcompanies.com

Adapters

TE Connectivity announced the approval of new RoHS-compliant black zinc nickel "Z" plating for AS85049 adapters /82 to /90. AS85049 is a military specification for connector accessories designed to work with military connectors like those built to MIL-DTL-38999. "This solution helps our customers reduce cadmium usage and provides enhanced performance,"said Daniel Redmon of TE Connectivity.

TE Connectivity
te.com



Socket

A new stamped spring pin socket addresses burn-in test requirements for testing 74 lead QFN - CBT-QFN-7038. The contactor used in the socket is a stamped spring pin with 15 gram actuation force per ball and cycle life of 10,000+ insertions. The self-inductance of the contactor is 0.98 nH, insertion loss < 1 dB at 10 GHz and capacitance 0.03pF.

Ironwood Electronics
ironwoodelectronics.com

Product Highlights

Oscilloscope Software

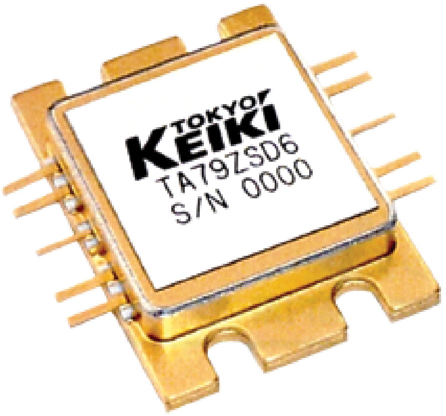
Keysight introduced measurement capability designed to help engineers quickly and accurately characterize PAM-4 (pulse amplitude modulation with four amplitude levels) signals using the Keysight 86100D DCA-X wide-bandwidth oscilloscope platform. Keysight 86100D-9FP PAM-N analysis software provides comprehensive analysis of optical and electrical PAM-4 signals.

Keysight Technologies
keysight.com

Connector

The MPX50 multicoax connector solution combines the highest density, lowest loss and highest performance characteristics for cutting edge data rate testing in one solution. It is based on a triplex approach that includes the MXP PCB connector, the MULTIFLEX 53-02 break-out assembly and the SUCOFLEX 100 cable assembly, designed to connect measurement equipment with lowest loss.

HUBER+SUHNER
hubersuhner.com



Power Amp

The TA79ZSD6 is a new X-Band 100W Solid State GaN Power Amplifier. It uses a compact and lightweight 17.4 mm x 24 mm x 4.1 mm package. It has greater than 36% Drain efficiency and 11dB of gain. It requires a +30V supply voltage. All bias, input and output matching circuitry are included. For more information, visit cel.com.

CEL
cel.com

Product Highlights

Spectrum Analyzers

Anritsu introduced a Capture and Playback function for its MS2830A and MS269xA Spectrum/Signal Analyzer families. The new function gives engineers confidence when validating the performance of devices used in cellular, Land Mobile Radio (LMR), Machine to Machine (M2M), Internet of Things (IoT), automotive, and satellite applications.

Anritsu
anritsu.com

Capacitors

Passive Plus, Inc. now offers extended-values for the Traditional NP0, Hi-Q 0505 (.055” x .055”) -- now available up to 1,000pF; and 1111 (.110” x .110”) -- now available up to 10,000pF (.01uF). These parts exhibit Low ESR/ESL, Low Noise, High Self-Resonance as well as ultra-stable performance over temperature.

Passive Plus
passiveplus.com

Test Software

Keysight’s N1930B Physical Layer Test System (PLTS) 2015 is the latest release of its signal integrity test software for designing and validating high-speed digital interconnect. A key software enhancement includes an N-port automatic fixture removal (AFR). This removes the effects of multiple test fixtures with a single step – reducing the error-correction time by 75 percent.

Keysight Technologies
keysight.com

Product Highlights

Extension Module

The S12MS offers a solution to connect to the RF of your existing signal generator to extend microwave outputs to millimeter and sub-millimeter frequencies of 60 to 90 GHz. With a typical output power of +6 dBm, the S12MS offers options for variable attenuation (S12MS-A) and electronic attenuation (S12MS-EA) which offers 60 dB of electronic controlled attenuation.

OML
omlinc.com

Synthesizer

MLBS-Series bench test synthesizers are ideal for production test sets, laboratory tests and test equipment racks where generation of microwave signals is essential. Frequency coverage is 2 to 20 GHz. Each synthesizer consists of a frequency synthesizer, heat sink, power supply, cooling fans, keyboard, display, USB interface, Ethernet interface and a manual tuning knob.

Micro Lambda Wireless
microlambdawireless.com

Filter

Microwave Filter Company offers this medium power lowpass RF filter from 50 MHz to 500 MHz. The model 19141 is designed for use in any medium power application (100 Watts or less) that requires harmonic band rejection of up to 6 times the fundamental cut-off frequency (Fc). Filters and components offered from stock or custom designed to meet specific applications.

Microwave Filter Company
microwavefilter.com

Product Highlights

Diplexer

Model SWY-63315310-VM-C1 is a V-Band diplexer specially designed for harmonic mixer applications. The LO port frequency range is from 45 to 75 GHz and IF port from DC to 30 GHz. The diplexer exhibits a typical 1.0 dB insertion loss from the common port to LO port and the common port to IF port. The isolation from LO port to IF port is 10 dB minimum and 15 dB typical.

SAGE Millimeter
sagemillimeter.com

Switch

Richardson RFPD announced availability and design support for a new reflective, single-pole double-throw (SPDT) RF switch from Peregrine Semiconductor. The PE42722 is designed for use in customer premises equipment (CPE) cable applications, including DOCSIS 3.0/1 cable modems and set-top boxes. The new switch delivers high linearity and excellent harmonics performance in the 5–1794 MHz band.

Richardson RFPD
richardsonrfpd.com

Adapters

HASCO Components introduced a line of "Low PIM" Low Passive Intermodulation Distortion 7/16 DIN In-series and Between-Series adapters. HASCO's 7/16 DIN In-Series and 7/16 DIN to Type N adapters measure -168 dBc @ 1800 MHz, 43 dBm per two tone. 7/16 DIN to SMA measure -155 dBc @ 1800 MHz, 43 dBm per two tone.

HASCO Components
hasco-inc.com

Product Highlights

Switches

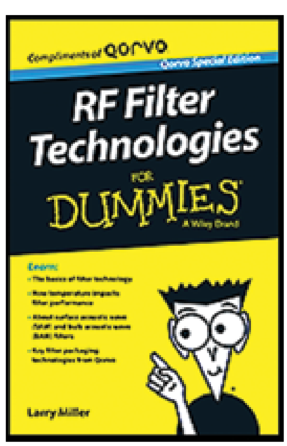
Pasternack introduced a family of in-stock high-rel electromechanical relay switches with designs that range from 2 to 10 million life cycles, making them uniquely qualified for applications including defense and commercial aviation, semiconductor manufacturing, communications, radar, SATCOM, test instrumentation, medical devices and many others.

Pasternack
pasternack.com

Amplifier

Aethercomm Model Number SSPA 0.125-0.500-125 is a high power, RF amplifier module that operates from 125 MHz to 500 MHz minimum and is packaged in a rugged and robust enclosure. The bandwidth of this module can be extended to 50 MHz on the low side and several hundred MHz on the high side. This PA is employed in systems that require high levels of RF energy with high power added efficiency.

Aethercomm
aethercomm.com

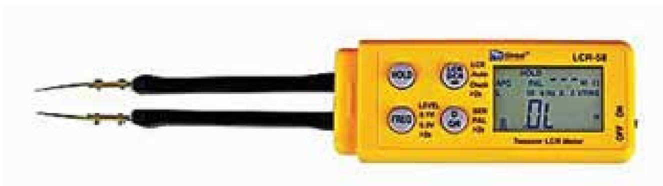


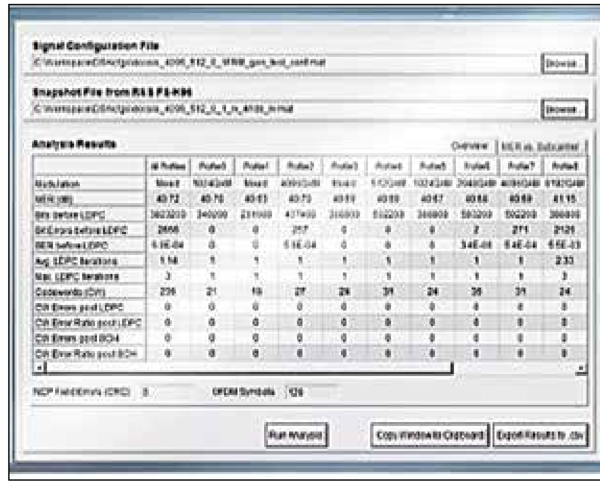
RF Filter Resources

Qorvo's two new free e-books – RF Filter Technologies For Dummies® and RF Filter Applications For Dummies® – help you learn more about RF filters and their special applications in mobile devices and network infrastructure. They explain how various filtering technologies, including Qorvo's LowDrift™ and NoDrift™ filters, address unique challenges in the 4G LTE environment and solve some of the industry's toughest coexistence challenges.

Qorvo
qorvo.com

Product Highlights





Handheld Meter

Global Specialties' Tweezer Meters are highly versatile, economically priced, hand-held meters designed to be small enough for one-hand operation on Surface Mount Devices (SMD). Perfect for use by engineers, technicians, electricians and students, they have exceptional features and functions not offered by any similarly priced products on the market today.

Global Specialties
globalspecialties.com

Analysis Software

Rohde & Schwarz offers a solution for analyzing DOCSIS 3.1 signals. Cable TV network operators and manufacturers of cable TV network components can use the R&S DSA DOCSIS snapshot analysis software and the R&S FSW high-end spectrum analyzer to carry out performance measurements. The software makes it possible to quickly and reliably characterize downstream signals of up to 192 MHz.

Rohde & Schwarz
rohde-schwarz.com

Waveguide Adapters

RLC Electronics offers coaxial to waveguide adapters in a variety of configurations. They offer both broadband adapters (whose excellent electrical specs are maintained over the entire adapter bandwidth) and also narrow band adapters (whose enhanced performance are provided over a specific band of the adapters' bandwidth).

RLC Electronics
rlcelectronics.com

Product Highlights

Assemblies

GORE-FLIGHT™ Microwave Assemblies 6 Series are lightweight cable solutions that deliver the lowest insertion loss before and after installation, ensuring reliable performance for the life of the system. Their robust construction reduces total costs by withstanding the challenges of installation, reducing costly production delays, field service frequency, and the need for purchasing replacement assemblies.

W. L. Gore & Associates
gore.com

Waveguide Interface

OML's patented boss and jack precision waveguide interface provides an advantage for those seeking the best waveguide flange interface solutions ranging from 50 GHz to 1.0 THz. Fully compatible with MIL DTL-3922/67D (UG 387); it offers the ultimate precision interface for your millimeter wave needs.

OML
omlinc.com

IEEE

Advancing Technology for Humanity

IEEE COMCAS 2015

The 2015 IEEE International Conference on Microwaves, Communications, Antennas, and Electronic Systems

2–4 November 2015, David Intercontinental Hotel, Tel Aviv, Israel

Call for Papers

IEEE COMCAS2015 continues the COMCAS tradition as a multidisciplinary forum for the exchange of ideas, research results, and industry experience in the areas of microwave/RF/mm-wave engineering, communications, antennas, solid state circuits, electromagnetic compatibility, engineering in medicine, electron devices, radar and electronic systems. It includes a technical program, industry exhibits, and invited talks by international experts in key topical areas.

CONFERENCE DATES: 2–4 November 2015.
CONFERENCE LOCATION: Tel Aviv, Israel at the David Intercontinental Hotel on the Mediterranean Sea.

Papers are solicited in a wide range of topics, including:

- Aeronautical and space applications and challenges Analog/digital RF circuits and systems
- Antennas (components, modeling, micro & macro scale)
- Automotive and transportation radar and communications
- Biomedical applications (body area systems, scanning devices, telemedicine)
- CAD techniques for microwave and communications devices
- Circuit theory, modeling and applications
- Cognitive radio and spectral sharing technologies Electromagnetic compatibility
- Fifth generation mobile communication
- Filters and Multiplexers
- First responder and military communication, sensing and information retrieval systems
- Environmentally sensitive design ("green" communications, electromagnetic, and antenna systems)
- MEMS modeling, devices and applications
- Microcell, picocell and femtocell devices, systems and applications
- Microwave and millimeter wave circuits and technologies
- Microwave imaging and tomography
- MIMO (multiple antenna systems for communications and radar)
- Modulation and signal processing technologies
- Nanotechnologies and applications
- Optical/wireless convergence and integration; radio over fiber
- Radar signal processing
- Radar techniques, systems and applications
- RFID devices, technologies, systems and applications
- RF power amplifiers and devices
- Sensor networks and technologies
- Software-defined radio and multiple air interface devices
- Solid-state devices, RFICs
- Spatial coding
- Terahertz technologies and systems

Submission of Abstracts

Regular oral presentations will be 20 min. in length; there will also be Poster sessions. All submitted papers will be peer reviewed and assessed on key accomplishments, technical contribution, and advancement of the state-of-the-art, originality and interest to the attendees. Accepted papers will be published in the COMCAS2015 Proceedings, which will be submitted for publication in IEEE Xplore® after the conference. For further information, see www.comcas.org.

Important Deadlines

Submission of abstract:	30 May 2015
Notification of acceptance/rejection:	15 July 2015
Submission of final camera-ready paper:	20 September 2015
Early bird (lower cost) registration:	30 August 2015

Technical Exhibition

The technical program will be complemented with a technical exhibition, which will be held on 2–3 November 2015, offering companies and agencies a unique opportunity to visit Israel and present related products and services in display and printed advertisement. For further details please contact the Conference Secretariat.

Co-sponsors

Organizing Committee

Conference Chair and Co-Chair
Shmuel Auster
Elta Systems Ltd, Israel
IEEE AP/MTT Chapter Chair
Simon Litsyn
Tel-Aviv Univeristy, Israel
IEEE Israel Section Chair

Technical Program Chair
Amir Boag
Tel-Aviv Univeristy, Israel

TPC Co-Chairs
Stephen B. Weinstein
CCTC, USA
Caleb Fulton
OU, USA
Peter de Maagt
European Space Agency, The Netherlands
Lance M. Kaplan
US Army ARL, USA

Publications Chair
Benjamin Epstein
OpCoast LLC, USA

Electronic Submissions Chair and Co-Chairs
Jeffrey M. Pond
NRL, USA
Benjamin Epstein
OpCoast LLC, USA
Matthias Rudolph
BTU Cottbus, Germany

Treasurer
Itzhak Shapir
Elta Systems Ltd, Israel

Exhibition Chair
Oren Hagal
Interlligent, Israel

Local Arrangements Chair
Ital Voller
AEAI, Israel

Social Functions and Hospitality
Meira Auster

Global Administration
James Rautio
Sonnet Software, USA

Publicity Chair and Co-Chairs
Carl Sheffres
Microwave Journal, USA
Pat Hindle
Microwave Journal, USA
Gary Lerude
Microwave Journal, USA
Sherry Hess
NI/AWR, USA
Antti Lautanen
NI/AWR, Finland

Members at Large
Barry S. Perlman
US Army CERDEC, USA (ret.)
Douglas N. Zuckerman
IEEE Communications Society
Elya Joffe
IEEE PSA and EMC Societies

Advisors
Richard Sparks
George Heiter
IEEE MTT Society

www.comcas.org
comcas@ieee.org

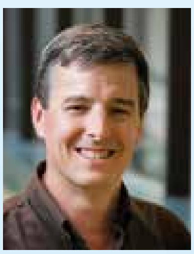
International Microwave Symposium
IEEE 17-22 May 2015 · Phoenix, Arizona, USA MTT-S

IMS

2015 PLENARY SPEAKER

SOFT ASSEMBLIES OF RADIOS, SENSORS AND CIRCUITS FOR THE SKIN

- Dr. John Rogers
Swanlund Chair, Professor of Materials Science and Engineering, Professor of Chemistry
University of Illinois, Urbana-Champaign

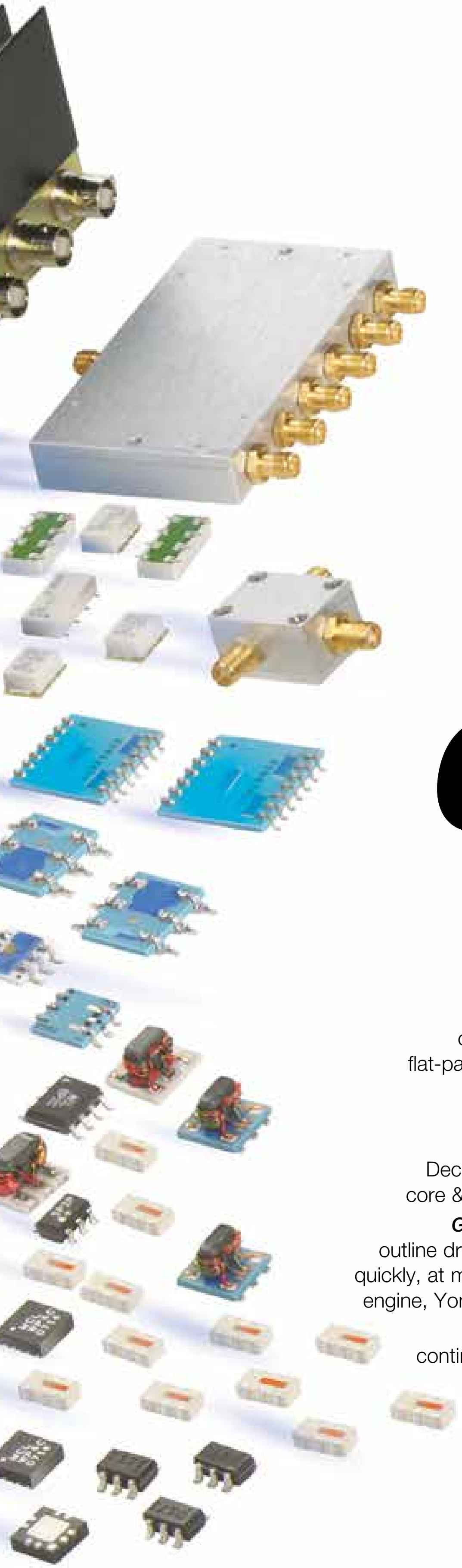


Professor John A. Rogers obtained BA and BS degrees in chemistry and in physics from the University of Texas, Austin, in 1989. From MIT, he received SM degrees in physics and in chemistry in 1992 and the PhD degree in physical chemistry in 1995. From 1995 to 1997, Rogers was a Junior Fellow in the Harvard University Society of Fellows. He joined Bell Laboratories as a Member of Technical Staff in the Condensed Matter Physics Research Department in 1997, and served as Director of this department from the end of 2000 to 2002.

He is currently Swanlund Chair Professor at the University of Illinois at Urbana/Champaign, with a primary appointment in the Department of Materials Science and Engineering, and joint appointments in several other departments, including Chemistry. He is Director of the Seitz Materials Research Laboratory.

Rogers' research includes fundamental and applied aspects of materials for unusual electronic and photonic devices, with an emphasis on bio-integrated and bio-inspired systems. He has published more than 450 papers and is inventor on over 80 patents, more than 50 of which are licensed or in active use. Rogers is a Fellow of the IEEE, APS, MRS and the AAAS, and he is a member of the National Academy of Engineering and the American Academy of Arts and Sciences. His research has been recognized with many awards, including a MacArthur Fellowship in 2009, the Lemelson-MIT Prize in 2011, the MRS Mid-Career Researcher Award and the Robert Henry Thurston Award (American Society of Mechanical Engineers) in 2013, and the 2013 Smithsonian Award for Ingenuity in the Physical Sciences.


MCL B 744
ADP-2-10



POWER SPLITTERS/ COMBINERS

NOW! from **2 kHz to 18 GHz** as low as **79¢**

The Industry's Largest Selection includes THOUSANDS of models, from 2 kHz to 18 GHz, at up to 300 watts power, in coaxial, flat-pack, surface-mount and rack-mount housings for 50 and 75 Ω systems.

From 2-way through 48-way designs, with 0°, 90°, or 180° phase configurations, Mini-Circuits power splitters/combiners offer outstanding performance for insertion loss, isolation, and VSWR. Decades of experience with multiple technologies make it all possible, from core & wire, microstrip, and stripline, to semiconductors and LTCC ceramics.

Get easy-to-find, detailed data and performance curves, S-parameters, outline drawings, PCB layouts, and everything else you need to make a decision quickly, at minicircuits.com. Just enter your requirements, and our patented search engine, Yoni2, searches *actual test data* to find the models that meet your needs.

All Mini-Circuits catalog models are in stock, continuously replenished, and backed by our 1-year guarantee. We even list *current stock quantities and real-time availability*, as well as pricing, to help our customers plan ahead and make quick decisions. So why wait? Take a look at minicircuits.com today!

RoHS Compliant
Product availability is listed on our website.

Mini-Circuits®

www.minicircuits.com P.O. Box 350166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

448 rev N

Advertiser Index

Company	Page
Advanced Switch Technology	49
AMCOM	30
Avtech	49
CEL	25
Cernex	18
Coilcraft	11
Cobham Inmet	1
C. W. Swift & Associates	C2
C. W. Swift/SRI Connector Gage	31
Delta Electronics	19
dBm	7
Fairview Microwave	15
Freescale	27
Herotek	14
IEEE COMCAS	60
IMS 2015	61
Keysight Technologies	17
Krytar	46
Micro Lambda Wireless	9
Microwave Components	33
Microwave Filter Company	47
Mini-Circuits	2, 3
Mini-Circuits	21
Mini-Circuits	23
Mini-Circuits	35
Mini-Circuits	43
Mini-Circuits	62, 63
Molex	C3
National Instruments	5
Passive Plus	44
Pulsar Microwave	20
RelComm Technologies	41
RF Bay	49
Richardson RFPD	C4
SAGE Millimeter	13
Satellink	49
Sector Microwave	49
SGMC Microwave	45
Spectrum Elektrotechnik	29
Times Microwave	37
VIDA Products	48
VidaRF	32
WAMICON	59
Wenteq Microwave	49

The ad index is provided as an additional service by the publisher, who assumes no responsibility for errors or omissions.

Find Our Advertisers' Web Sites using HFeLink™

1. Go to our company information Web site: www.HFeLink.com, or
2. From www.highfrequencyelectronics.com, click on the HFeLink reminder on the home page
3. Companies in our current issue are listed, or you can choose one of our recent issues
4. Find the company you want ... and just click!
5. Or ... view our Online Edition and simply click on any ad!

HIGH FREQUENCY ELECTRONICS

PUBLISHER
Scott Spencer
Tel: 603-472-8261
Fax: 631-667-2871
scott@highfrequencyelectronics.com

ADVERTISING SALES — EAST
Gary Rhodes
Vice President, Sales
Tel: 631-274-9530
Fax: 631-667-2871
grhodes@highfrequencyelectronics.com

ADVERTISING SALES — WEST
Tim Burkhard
Associate Publisher
Tel: 707-544-9977
Fax: 707-544-9375
tim@highfrequencyelectronics.com

ADVERTISING SALES—WEST—NEW ACCOUNTS
Jeff Victor
Tel: 224-436-8044
Fax: 509-472-1888
jeff@highfrequencyelectronics.com

ADVERTISING SALES — CENTRAL
Keith Neighbour
Tel: 773-275-4020
Fax: 773-275-3438
keith@highfrequencyelectronics.com

ADVERTISING SALES — NEW ACCOUNTS & PRODUCT SHOWCASE
Joanne Frangides
Tel: 201-666-6698
Fax: 201-666-6698
joanne@highfrequencyelectronics.com

U.K. AND EUROPE
Sam Baird
Tel: +44 1883 715 697
Fax: +44 1883 715 697
sam@highfrequencyelectronics.com

U.K. AND EUROPE
Zena Coupé
Tel: +44 1923 852 537
Fax: +44 1923 852 261
zena@highfrequencyelectronics.com

High Frequency Electronics (USPS 024-316) is published monthly by Summit Technical Media, LLC, 3 Hawk Dr., Bedford, NH 03110.
Vol. 14 No. 2 February 2015. Periodicals Postage Paid at Manchester, NH and at additional mailing offices.
POSTMASTER: Send address corrections to High Frequency Electronics, PO Box 10621, Bedford, NH 03110-0621.
Subscriptions are free to qualified technical and management personnel involved in the design, manufacture and distribution of electronic equipment and systems at high frequencies.