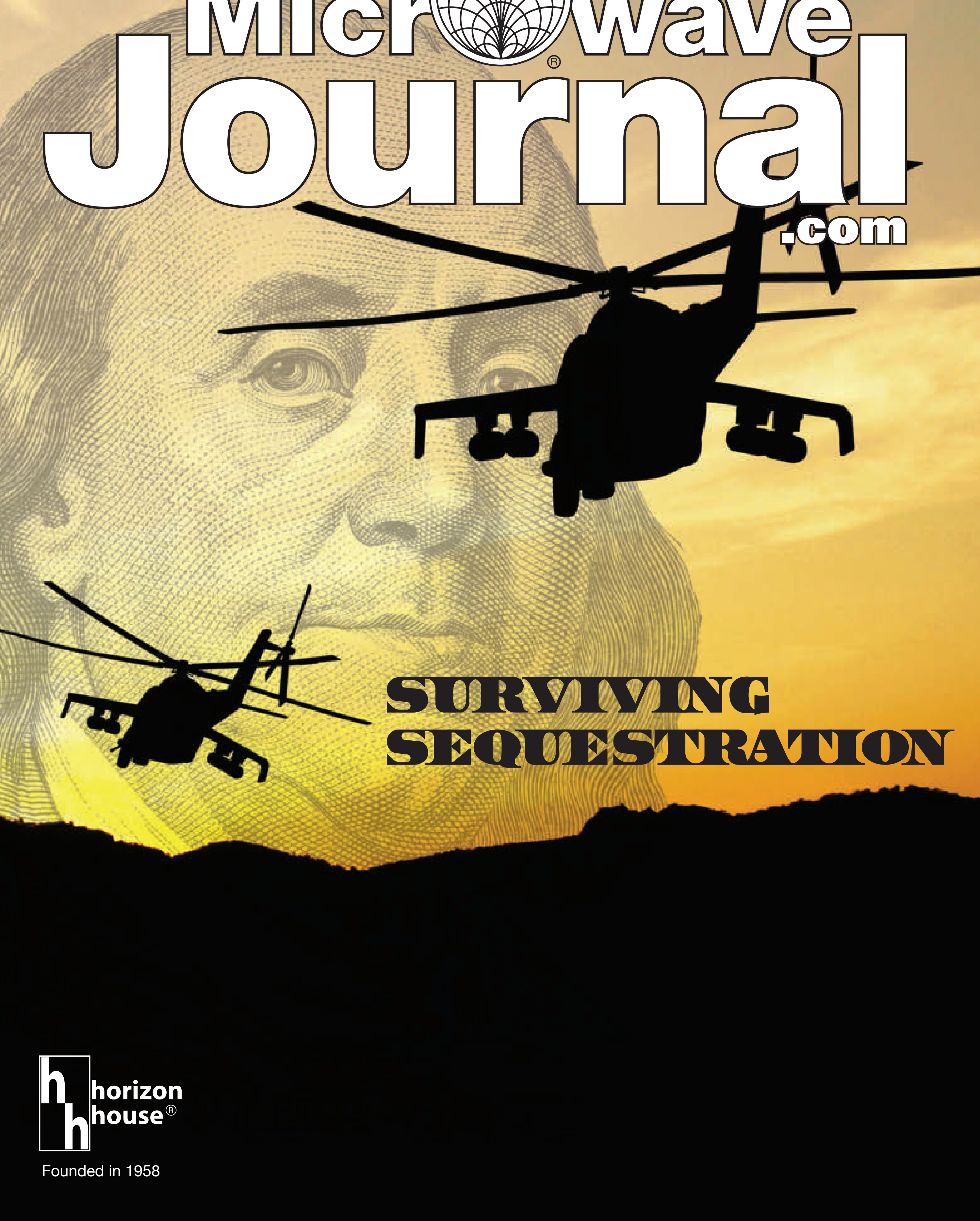
Vol. 56 • No.10

October 2013

Microwave Journal.com



SURVIVING SEQUESTRATION

horizon house®

Founded in 1958

BETTER BUILDINGS
BETTER CARE

For next-generation DAS, there's only one name for passives.

It's simple. Better signals equal better care. Today's hospitals personify the need for next-level Distributed Antenna Systems (DAS). And the engineers that are building them turn to MECA for passive components. American ingenuity and 52 years of experience have resulted in the deepest, most reliable product line of ready-to-ship and quick-turn solutions, such as:

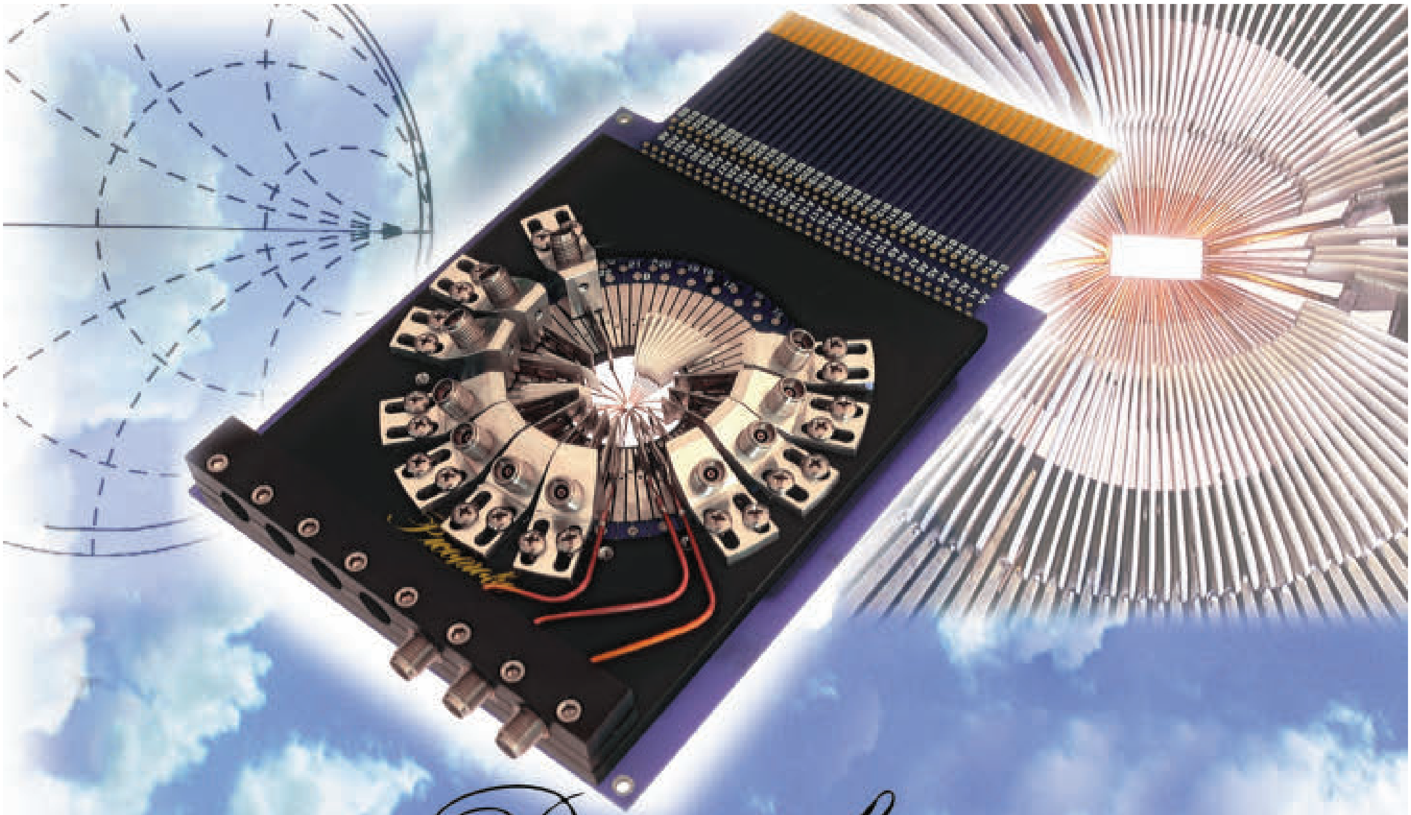
Power Dividers Up to 16 way and 18 GHz
Attenuators Up to 60 dB and 500W
Terminations Up to 500W
Couplers Up to 40 dB and 1kW
Integrated Rack Units Delivered in 3-6 weeks

They come with an industry leading 3 year guarantee and true MECA pride.

Ready to build a better DAS? Start with a visit to **www.e-MECA.com**.

iBwave
Look for the expanding lineup of MECA products in your iBwave library.

Microwave Electronic Components of America
The Professional's Choice for RF/Microwave Passive Components
MECA



Picoprobe®

Picoprobe elevates probe cards to a higher level…

(…110 GHz to be exact.)

Since 1981, GGB Industries, Inc., has blazed the on-chip measurement trail with innovative designs, quality craftsmanship, and highly reliable products. Our line of custom microwave probe cards continues our tradition of manufacturing exceptional testing instruments.

Through unique modular design techniques, hundreds of low frequency probe needles and a variety of microwave probes with operating frequencies from DC to 40, 67, or even 110 GHz can be custom configured to your layout.

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

Our proven probe card design technology allows full visibility with inking capability and ensures reliable contacts, even when probing non-planar structures.

Not only do you get all the attractive features mentioned, but you get personal, professional service, rapid response, and continuous product support--all at an affordable price so your project can be completed on time and within budget.

Typical Specs	10GHz	20GHz	40GHz
Insertion Loss	0.6 dB	0.8 dB	1.3 dB
Return Loss	22 dB	18 dB	15 dB

For technical assistance, custom product designs, or off-the-shelf delivery,call GGB Industries, Inc., at (239) 643-4400.

GGB INDUSTRIES, INC. • P.O. BOX 10958 • NAPLES, FL 34101

Telephone (239) 643-4400 • Fax (239) 643-4403 • E-mail email@ggb.com • www.picoprobe.com


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, and 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 35166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

448 rev L


Yeah, we do that.
TX
RX
Repeater Dilemma
that must be resolved.
Trying to send and
receive a small signal
among big interferers on
your repeater platform?
We should talk.
513.870.4087
POLE ZERO
CMP
A DOVER COMPANY
www.polezero.com


Mars Rover Artwork Courtesy of NASA/JPL-Caltech
Supporting Space Exploration through the Development of Innovative Technology.
SPACE HERITAGE
K&L Microwave has contributed to the aerospace industry for forty years and has been part of the following programs:
Apollo 17
Mars Science Lab
Mars Opportunity Rover
Mars Spirit Rover
Iridium Satellite Constellation
CHIRP
GPS-3
GPS-R
V-Sensor
Thuraya
MSV
OCEANSAT 2
COSMO
SKYNET 5
K&L
SPACE QUALIFIED
UHF DIPLEXER
7CZSP-397.5/442.5
Voltronics, the Trimmer Capacitor Company, is now located at the K&L Microwave facility in Maryland. An experienced manufacturing and engineering staff is available to offer the same well-respected and extensive line of products.
Voltronics
www.voltronicscorp.com
K&L MICROWAVE
A DOVER COMPANY
CERAMIC & MICROWAVE PRODUCTS
Electronic Components & Microwave Solutions
A DOVER COMPANY
BSC FILTERS • DOW-KEY MICROWAVE • NOVACAP • SYFER TECHNOLOGY
DIELECTRIC LABORATORIES • K&L MICROWAVE • POLE/ZERO • VOLTRONICS
www.klmicrowave.com
AS 9100
ISO 14001


If it's gonna fly, it has to be...
Small
K-band LNA
• 100˚K
• 2 GHz Bandwidth
• 35-50 dB Gain
Light
SSPAs – C, X, Ku and Ka-band
• 4 watts to 150 watts
• 15 watts @ Ku-band = 8 oz.
And Fast
Q-Lite High-Speed Modem
• IP Processing to 60Mbps
• Small Form Factor 255 x 184 x 18mm
• 30 Watt Typical Power Consumption
Airborne Products from Teledyne Microwave Solutions
See us at:
AOC International Symposium & Convention
Oct. 27-30 - Booth #232
MILCOM 2013
Nov. 18-20 - Booth #1303
TELEDYNE
MICROWAVE SOLUTIONS
Everywhereyoulook™
800.832.6869 or +1.650.962.6944
teledynemicrowave.com
microwave@teledyne.com

Under powered and over budget? Problem solved.

If you're in need of driving up the power handling and driving out cost in your next switch design, Aeroflex / Metelics' MSW series surface mount PIN diode switches and supercharged (+125 V, -200 V) MPD drivers are the perfect combination. It only takes a single driver to drive several of our high power (100 W CW or 500 W peak input power) switches—even symmetrical and asymmetrical T-R switches at the same time—saving you precious real estate and overhead. MPD drivers are TTL input compatible (single or double control) and offer a typical switching speed of 2 µs. Covered with a high performance RF shield they're also worry free. Get your hands on an evaluation board today and put the perfect switch in your control.

Visit our website or call **888-641-7364**.

www.aeroflex.com/metelics

PIN Diode Switch and Driver Combinations

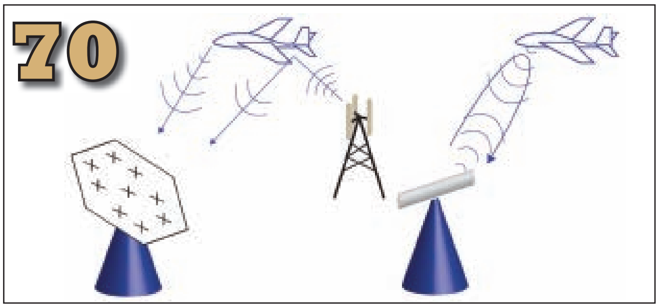
Part Number	Configuration	Drive Voltage*	Recommended Switch Driver	Frequency Band (MHz)
MSW2000–200	T-R Switch, TX Left	+V Only	MPD2T28125-700	10 to 1,000
MSW2001–200	T-R Switch, TX Left	+V Only	MPD2T28125-700	400 to 4,000
MSW2002–200	T-R Switch, TX Left	+V Only	MPD2T28125-700	2,000 to 6,000
MSW2022-200	T-R Switch, TX Right	+V & -V	MPD2T5N200-702	2,000 to 6,000
MSW2050–205	T-R Switch, TX Left	+V Only	MPD2T28125-700	20 to 1,000
MSW2051–205	T-R Switch, TX Left	+V Only	MPD2T28125-700	400 to 4,000
MSW2030–203	Symmetrical SP2T	+V Only	MPD2T28125-700	10 to 1,000
MSW2031–203	Symmetrical SP2T	+V Only	MPD2T28125-700	400 to 4,000
MSW2032–203	Symmetrical SP2T	+V Only	MPD2T28125-700	2,000 to 6,000
MSW2040–204	Symmetrical SP2T	+V Only	MPD2T28125-700	50 to 1,000
MSW2041–204	Symmetrical SP2T	+V Only	MPD2T28125-700	400 to 4,000
MSW2060-206	Symmetrical SP2T	+V & -V	MPD2T5N200-702	10 to 1,000
MSW2061-206	Symmetrical SP2T	+V & -V	MPD2T5N200-702	400 to 4,000
MSW2062-206	Symmetrical SP2T	+V & -V	MPD2T5N200-702	2,000 to 6,000
MSW3100–310	Symmetrical SP3T	+V Only	MPD3T28125-701	10 to 1,000
MSW3101–310	Symmetrical SP3T	+V Only	MPD3T28125-701	400 to 4,000
MSW3200-320	Symmetrical SP3T	+V & -V	MPD3T5N200-703	10 to 1,000
MSW3201-320	Symmetrical SP3T	+V & -V	MPD3T5N200-703	400 to 4,000
MSW4102-410	Symmetrical SP4T	+V Only	MPD2T28125-700 (2 each)	4,000 to 6,000
MSW5000-500	Symmetrical SP5T	+V Only	MPD2T28125-700 & MPD3T28125-702 (1 each)	30 to 512
MSW6000-600	Symmetrical SP6T	+V Only	MPD3T28125-702 (2 each)	30 to 512
MSWLM2420-242	Asymmetric T-R with Rx limiter	+V Only	MPD2T28125-700	2,000 to 4,000

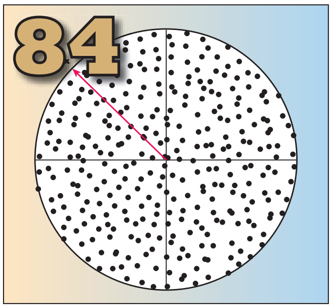
+V Only = +5 V and +28 V to +125 V
+V & -V = +5 V and -28 V to -200 V

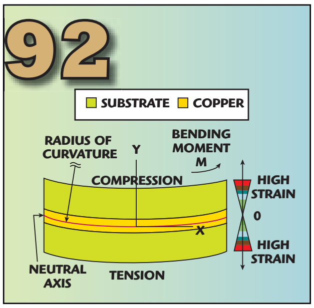
AEROFLEX
A passion for performance.

Microwave Journal CONTENTS

October 2013
Vol. 56 • No. 10
Government and
Military Electronics
mwjournal.com

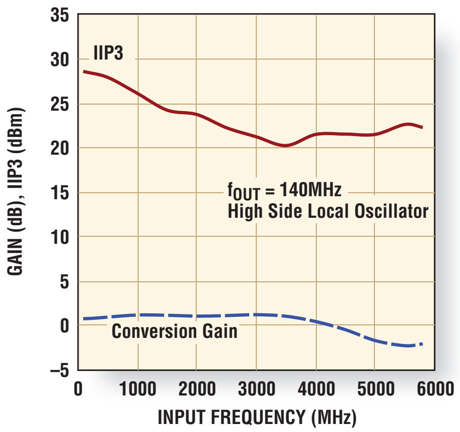


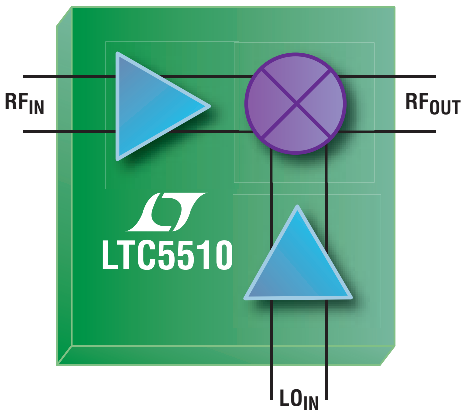




56 YEARS OF PUBLISHING EXCELLENCE

50Ω Matched Input 30MHz to 6GHz Mixer





Excellent Dynamic Range, High Port-to-Port Isolation

The LTC®5510's continuous 50Ω matched inputs and high IIP3 from 30MHz to 6GHz set a new level of performance for ultra-wideband scanning receivers, broadcast radios, VHF and white-space receivers, wireless microphone receivers, public safety radios, cable infrastructure receivers and RF test instrumentation. The device's up or downconversion capability provides flexibility while its excellent isolation performance simplifies your design.

Signal Chain Components

	LTC5567	+26.9dBm IIP3, 1.9dB Gain Mixer	Detector	LTC5582	10GHz, 57dB Dynamic Range RMS Detector
	LTC5569	Dual +26.8dBm IIP3, Low Power Mixer		LTC5587	6GHz 40dB Dynamic Range RMS Detector + ADC
	LTC6430-15	+50dBm OIP3 @240MHz, 15dB Gain Differential Amplifier		LTC6412	31dB Gain Control, Analog VGA with +35dBm OIP3
	LTC6431-15	+47dBm OIP3 @240MHz, 15dB Gain Single-Ended Amplifier		LT®5554	16dB Gain Control, 0.125dB/Step Digital VGA
ADC	LTC2158-14	Dual 14-Bit, 310Msps ADC		LTC6946	Low Phase Noise Integer-N PLL + VCO
	LTC2209	16-Bit, 160Msps ADC		LTC6945	Low Phase Noise Integer-N PLL

Info & Free Samples

www.linear.com/product/LTC5510

1-800-4-LINEAR

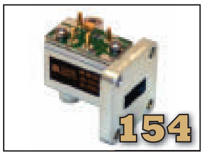
LT, LTC, LTM, Linear Technology and the Linear logo are registered trademarks of Linear Technology Corporation. All other trademarks are the property of their respective owners.

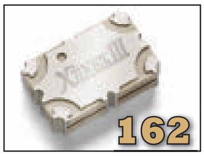
LINEAR TECHNOLOGY

Microwave Journal

CONTENTS

mwjournal.com





Product Features

Tech Briefs

Departments

Microwave Journal (USPS 396-250) (ISSN 0192-6225) is published monthly by Horizon House Publications Inc., 685 Canton St., Norwood, MA 02062. Periodicals postage paid at Norwood, MA 02062 and additional mailing offices.

Photocopy Rights: Permission to photocopy for internal or personal use, or the internal or personal use of specific clients, is granted by *Microwave Journal* for users through Copyright Clearance Center provided that the base fee of $5.00 per copy of the article, plus $1.00 per page, is paid directly to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923 USA (978) 750-8400. For government and/or educational classroom use, the Copyright Clearance Center should be contacted. The rate for this use is 0.03 cents per page. Please specify ISSN 0192-6225 *Microwave Journal* International. *Microwave Journal* can also be purchased on 35 mm film from University Microfilms, Periodic Entry Department, 300 N. Zeeb Rd., Ann Arbor, MI 48106 (313) 761-4700. Reprints: For requests of 100 or more reprints, contact Barbara Walsh at (781) 769-9750.

POSTMASTER: Send address corrections to *Microwave Journal*, PO Box 3256, Northbrook, IL 60065-3256 or e-mail mwj@omeda.com. Subscription information: (847) 291-5216. This journal is issued without charge upon written request to qualified persons working in the RF & microwave industry. Other subscriptions are: domestic, $120.00 per year, two-year subscriptions, $185.00; foreign, $200.00 per year, two-year subscriptions, $370.00; back issues (if available) and single copies, $10.00 domestic and $20.00 foreign. Claims for missing issues must be filed within 90 days of date of issue for complimentary replacement.

©2013 by Horizon House Publications Inc.
Posted under Canadian international publications mail agreement #PM40612608

STAFF

PUBLISHER: CARL SHEFFRES
EDITOR: DAVID VYE
MANAGING EDITOR: JENNIFER DIMARCO
TECHNICAL EDITOR: PATRICK HINDLE
ASSOCIATE TECHNICAL EDITOR: CLIFF DRUBIN
STAFF EDITOR: LAURA GLAZER
EDITORIAL ASSISTANT: BARBARA WALSH
CONSULTING EDITOR: HARLAN HOWE, JR.
CONSULTING EDITOR: FRANK BASHORE
CONSULTING EDITOR: PETER STAECKER
CONSULTING EDITOR: DAN SWANSON
CONSULTING EDITOR: RAYMOND PENGELLY
WEB EDITOR: CHRIS STANFA
AUDIENCE DEVELOPMENT MANAGER: CAROL SPACH
TRAFFIC MANAGER: EDWARD KIESSLING
MARKETING AND EVENT COORDINATOR: KRISTEN ANDERSON
DIRECTOR OF PRODUCTION & DISTRIBUTION: ROBERT BASS
ART DIRECTOR: JANICE LEVENSON
GRAPHIC DESIGNER: SACHIKO STIGLITZ

EUROPE

INTERNATIONAL EDITOR: RICHARD MUMFORD
OFFICE MANAGER: NINA PLESU

CORPORATE STAFF

CEO: WILLIAM M. BAZZY
PRESIDENT: IVAR BAZZY
VICE PRESIDENT: JARED BAZZY

EDITORIAL REVIEW BOARD

Dr. I.J. Bahl
F.M. Bashore
Dr. C.R. Boyd
M. Goldfarb
J.L. Heaton
Dr. G. Heiter
H. Howe, Jr.
Dr. T. Itoh
Dr. J. Lasker
Dr. S. Maas
Dr. G.L. Matthaei
Dr. D.N. McQuiddy
Dr. J.M. Osepchuk
Dr. J. Rautio
Dr. U. Rohde
M. Schindler
Dr. P. Staecker
F. Sullivan
D. Swanson
Dr. R.J. Trew
G.D. Vendelin
Prof. K. Wu

EXECUTIVE EDITORIAL OFFICE:
685 Canton Street, Norwood, MA 02062
Tel: (781) 769-9750
FAX: (781) 769-5037
e-mail: mwj@mwjournal.com

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

www.mwjournal.com

Printed in the USA

Anticipate ___*Accelerate* ___*Achieve*

Agilent Technologies

Microwave Journal Online

Visit us @ mwjournal.com

Free Webinars

RF/Microwave Training
RF and Microwave Filters
Sponsored by: AWR and Rohde & Schwarz — On Demand

Innovations in EDA
Designing with 4G Modulated Signals for Optimized Multi-Standard Transceiver ICs
Presented by: Agilent Technologies — On Demand

Technical Education Training
VCO Fundamentals
Sponsored by: Mini-Circuits — 10/15

Market Research Series
Technology Trends for Land-Based Electronic Warfare Systems
Sponsored by: Rohde & Schwarz — 10/17

Technical Education Training
Novel Very-Near-Field Measurement Technique to Test Large Directional Antennas in Minutes
Presented by: EMSCAN — 10/30

CST Webinars
High-Speed Serial Link: Full-Wave Modeling Methodology and Measurement Correlation — On Demand

Simulation and Measurement: Complementary Design Tools — 10/17

MIMO Antenna Systems for Advanced Communication — 10/24

Electromagnetic Simulation of Composite Materials and Cable Harnesses in Aircraft — 10/31

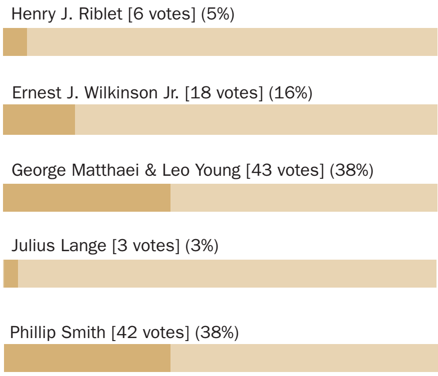
Web Survey

How do I love thee: What do you like best about being a microwave engineer?

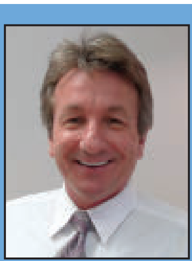
Look for our multiple choice survey online at mwjournal.com

August Survey

Who is your favorite "microwave hero?"



Executive Interview



Mario Narduzzi, **Agilent** software & modular solutions division marketing manager, discusses the trend toward modular test and measurement solutions based on flexible, scalable architectures such as PXI and AXIe.

White Papers

VNA's High-Speed Architecture Advances Radar Pulse Measurement Timing Resolution and Accuracy
Anritsu

AR's Complete Product Catalog for EMC, Wireless and RF Testing
AR RF/Microwave Instrumentation

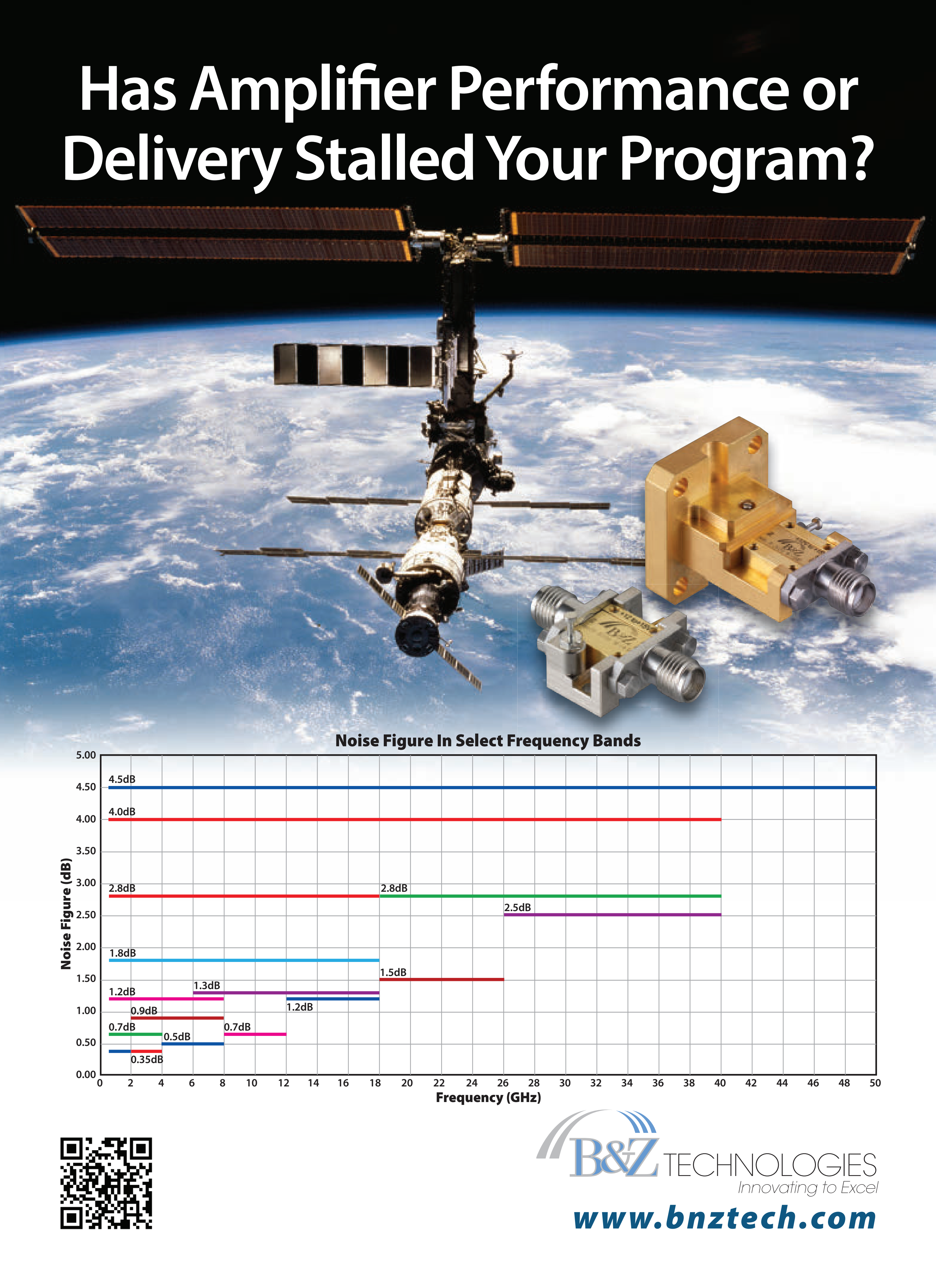
Laser Cutting Epoxy Film
Bonding Source

Normalized Phase Noise in Devices Powered by the UltraCMOS® Devices
Richardson RFPD
Presented by: Peregrine Semiconductor

A New Coaxial Flow Calorimeter for Accurate RF Power Measurements up to 100 Watts and 1 GHz
Tegam

Check Out This Channel

COM


Has Amplifier Performance or
Delivery Stalled Your Program?
Noise Figure In Select Frequency Bands
Noise Figure (dB)
Frequency (GHz)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
4.5dB
4.0dB
2.8dB
2.8dB
2.5dB
1.8dB
1.5dB
1.3dB
1.2dB
1.2dB
0.9dB
0.7dB
0.7dB
0.5dB
0.35dB
B&Z TECHNOLOGIES
Innovating to Excel
www.bnztech.com

Programmable *0–30, 60, or 90 dB*

ATTENUATORS

1 MHz to 6 GHz *from* $395

Mini-Circuits RUDAT-6000 series **USB controlled** digital step attenuators support frequencies from 1 MHz to 6 GHz in versions with maximum attenuation of **30, 60, and 90 dB with 0.25 dB attenuation steps**, providing precise level control for a wide range of test applications. All models achieve accurate, repeatable performance in a miniature, shielded metal case (2.0 x 3.0 x 0.6"). Our unique design maintains linear attenuation change per dB, over the entire range of attenuation settings. Controlled conveniently via USB or RS232 ports, all versions are supplied with easy-to-use GUI control software and everything you need for immediate use out-of-the-box! Visit minicircuits.com for detailed performance specs, great prices, and off-the-shelf availability! *RoHS compliant*

Mini-Circuits®

www.minicircuits.com P.O. Box 35166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

513 rev org

NOVEMBER 2013

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
27	28	29	30	31	1	2
3	4	5	6 APMC 2013 (Nov. 5–8) Seoul, Korea **Webinar:** RF and Microwave Amplifier Power Added Efficiency, Fact and Fiction Sponsored by AWR, CREE	7 **Webinar:** CST Wireless Power Transfer and Microwave Energy Harvesting	8	9
10	11 LAPC (Nov. 11–12) Loughborough, UK	12 **Webinar** Sponsored by Peregrine Semiconductor	13	14 **Webinar:** CST EMC Simulation in the Design Flow of Modern Electronics	15	16
17	18 MILCOM'13 (Nov. 18–20) San Diego, CA	19 **Webinar:** Passive Components: Dividers, Couplers, Combiners Sponsored by Mini-Circuits	20	21 **Webinar:** CST Traveling Wave Tube Design with Simulation	22	23
24	25	26 **Webinar:** CST Simulating Dielectric and Conductor Loss Components	27	28	29	30

Go to: mwjournal.com/events

Coming Events

CALL FOR PAPERS

RFIC 2014
December 9, 2013

IMS 2014
December 9, 2013

NEMO 2014
December 31, 2013

mwjournal.com

OCTOBER

Phased Array 2013
IEEE International Symposium on Phased Array Systems & Technology
October 15–18, 2013 • Boston, MA
www.array2013.org

Microwave Update 2013
October 18–19, 2013 • Morehead, KY
www.microwaveupdate.org

IEEE COMCAS 2013
International Conference on Microwaves, Communications, Antennas and Electronic Systems
October 21–23, 2013 • Tel Aviv, Israel
www.comcas.org

IME/China 2013
8th International Conference and Exhibition on Microwave and Antenna
October 23–25, 2013 • Shanghai, China
www.imwexpo.com

4G World 2013
October 28–30, 2013 • Dallas, TX
www.4gworld.com

MWP 2013
IEEE International Topical Meeting on Microwave Photonics
October 28–31, 2013 • Alexandria, VA
www.mwp2013.org

NOVEMBER

APMC 2013
Asia-Pacific Microwave Conference
November 5–8, 2013 • Seoul, Korea
www.apmc2013.org

2013 Loughborough Antennas & Propagation Conference
November 11–12, 2013 • Loughborough, UK
www.lapconf.co.uk

MILCOM 2013
Military Communications Conference
November 18–20, 2013 • San Diego, CA
www.milcom.org

DECEMBER

IMaRC 2013
IEEE International Microwave and RF Conference
December 14–16, 2013 • New Delhi, India
www.imarc-ieee.org

AEMC
4th Applied Electromagnetics Conference
December 18–20, 2013 • Bhubaneswar, India
www.ieee-aemc.org

JANUARY

IEEE RWW 2014
Radio Wireless Week
January 19–22, 2014 • Newport Beach, CA
www.radiowirelessweek.org

FEBRUARY

MWC 2014
Mobile World Congress
February 24–27, 2014 • Barcelona, Spain
www.mobileworldcongress.com

MARCH

SATELLITE 2014
March 10–13, 2014 • Washington D.C.
www.satellite2014.com

TAEECE2014
2nd International Conference on Technological Advances in Electrical, Electronics and Computer Engineering
March 18–20, 2014 • Kuala Lumpur, Malaysia
www.sdiwc.net/conferences/2014/taeece2014

APRIL

EDI CON 2014
Electronic Design Innovation Conference
April 8–10, 2014 • Beijing, China
www.ediconchina.com

MAY

NEMO 2014
International Conference on Numerical Electromagnetic Modeling and Optimization for RF, Microwave and Terahertz Applications
May 14–16, 2014 • Pavia, Italy
www.nemo-ieee.org

JUNE

RFIC 2014
IEEE Radio Frequency Circuits Symposium
June 1–3, 2014 • Tampa, FL
www.rfic-ieee.org

IMS 2014
IEEE International Microwave Symposium
June 1–6, 2014 • Tampa, FL
www.ims2014.org

83rd ARFTG Microwave Measurement Symposium Topic
June 6, 2014 • Tampa, FL
www.arftg.org

WAMICON 2014
IEEE Wireless and Microwave Technology Conference
June 6, 2014 • Tampa, FL
www.wamicon.org

your design advisor

REACH OUT TO US

Wish you had your own design advisor for NXP RF MOSFET Replacements?

life.augmented

www.st.com/rf

www.richardsonrfpd.com/st

See the complete lineup of ST pin-for-pin NXP replacements.

Making your job easier

As some companies move away from RF MOSFETs, STMicroelectronics continues to offer legacy products alongside their newer products that address evolving high performance designs. So if you're looking for pin-for-pin replacements for discontinued products from NXP, STMicroelectronics and Richardson RFPD have you covered.

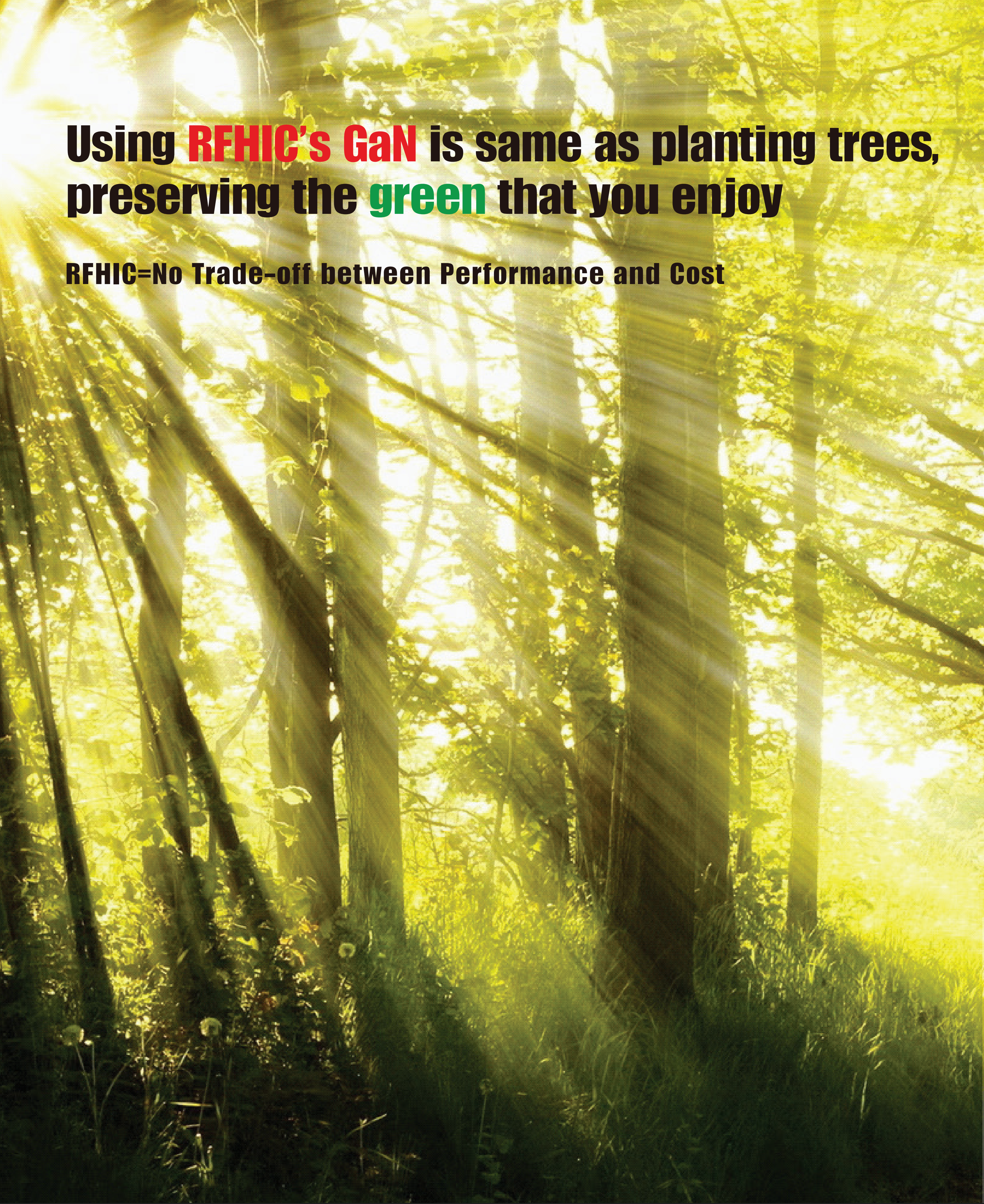
VISION REALIZED.

Your Global Source for RF, Wireless & Energy Technologies

RichardsonRFPD
An Arrow Company

www.richardsonrfpd.com | 800.737.6937 | 630.208.2700

©2013 Richardson RFPD. All rights reserved. All brands and trademarks are property of their respective owners. Specifications subject to change without notice. MK130252. Printed in the USA.



Send your inquires to rfsales@rfhic.com

RF & MW is our business & passion
Korean Facilities
Tel : 82-31-250-5078 / E-mail : rfsales@rfhic.com
US Facility
Tel : 919-677-8780 / E-mail : sales@rfhicusa.com

RFHIC
www.rfhic.com

COVER FEATURE

Surviving Sequestration

Editor's note: In this special report,* Microwave Journal *looks at the recent economic and political events that led to the budget cutting program known as sequestration, how the cuts are implemented with regard to defense spending, the projected and realized impact on the economic fortunes of defense contractors six months into sequestration and how forward-thinking contractors are adjusting their business plans to succeed in a shifting landscape of tightening government budgets.

It was five years ago this fall that the financial crisis responsible for the great recession set off a chain reaction of Federal Reserve monetary actions and government stimulus programs which, along with plummeting tax revenues, led to unprecedented U.S. budget deficits, alarm among deficit-conscious fiscal conservatives and the birth of a political movement known as the Tea Party. In the 2011 fight over raising the debt ceiling – the amount the government can borrow in order to meet its existing fiscal obligations – Tea Party activists emboldened by their wins in the 2010 congressional elections forced the Republican majority in the House to reject a compromise with Democrats to raise the debt ceiling unless acceptable cuts in spending could be met.

At the time, the imminent failure to raise the borrowing limit threatened to shut down the government and would have resulted in a default of its fiscal obligations, presumably creating new panic among financial markets as the world's largest debtor stopped making payments on existing loans. Despite negotiations between the White House and the congressional leadership to impose deep targeted cuts to the federal budget's largest items (entitlements and defense spending), individual members of Congress, fearing a backlash from their constituents and the resulting political fallout, could not muster up the will to accept draconian cuts to specific programs.

As a result of the impasse, the credit rating agency Moodys downgraded the U.S. Government credit rating from AAA to AA, citing increased lending risk due to the lack of political leadership in dealing with the pending crisis. The rating downgrade conceptually would make it more expensive for the government to borrow money. In actuality, investors continued to pour money into U.S. bonds, a sign of how the global economy remained at considerable risk of falling back into recession or worse.

To resolve the immediate crisis, lawmakers needed to devise an acceptable plan that would satisfy a highly divided and partisan Congress. In general, Democrats would fiercely protect entitlement programs, Republicans would do the same for defense programs and the Tea Party caucus would not compromise on reduc-

DAVID VYE
Microwave Journal *Editor*

RF & MICROWAVE FILTERS

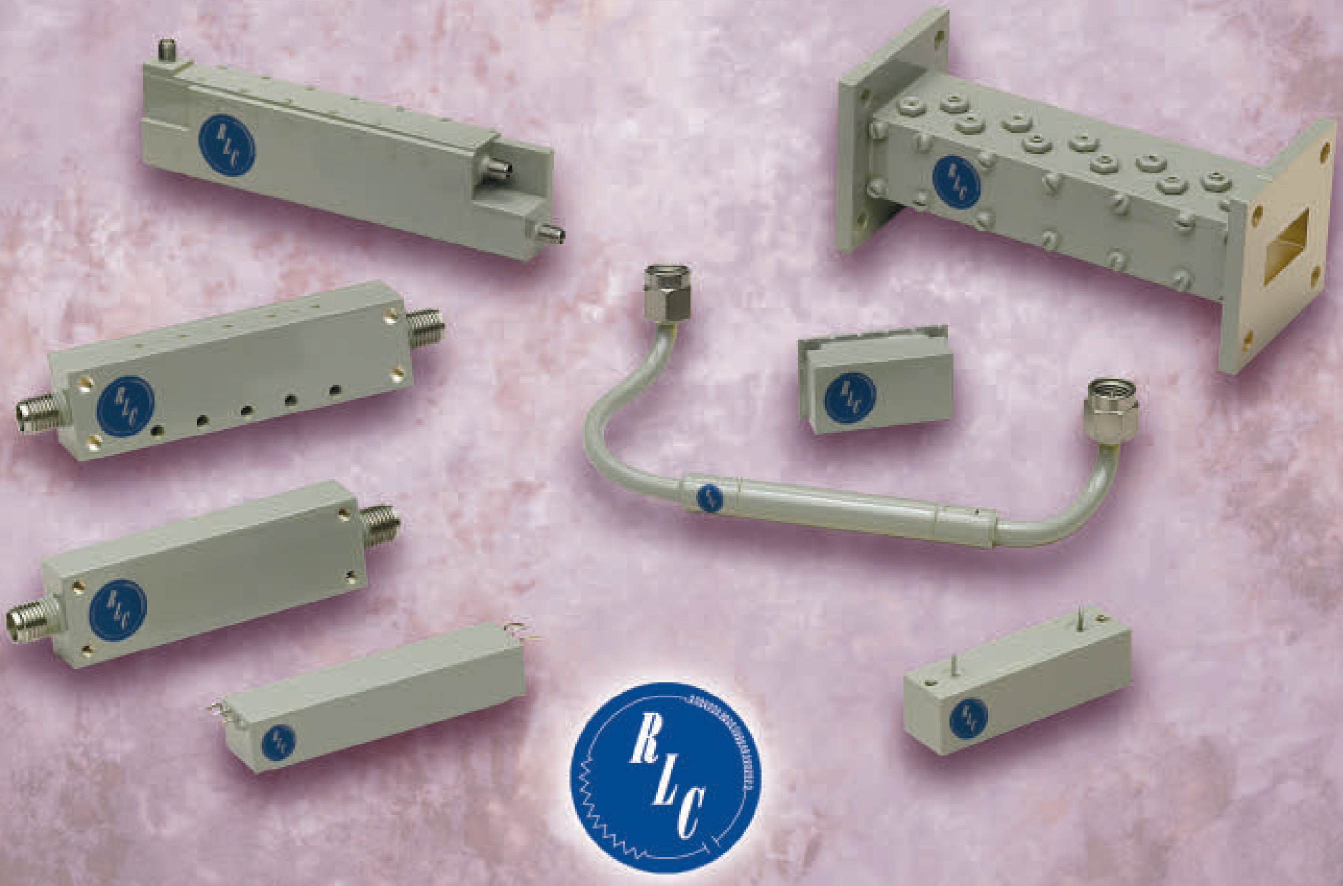
RLC has the customized filter solutions you need.

RLC manufactures a complete line of RF and Microwave filters covering nearly every application in the DC to 50 GHz frequency range. We offer different filter types, each covering a specific engineering need.

In addition, our large engineering staff and high volume production facility give RLC the ability to develop and deliver both standard and custom designed filters at competitive costs, within days or a few weeks of order placement.

- Band Pass, Low Pass, High Pass & Band Reject
- Connectorized, Surface Mount, PCB Mount or Cable Filters
- Wave Guide Bandpass and Band Reject
- 4th Order Bessel Filters
- Spurious Free, DC to 50 GHz, Low Loss, High Rejection
- Custom Designs

*For more detailed information, or to access **RLC's exclusive Filter Selection Software**, visit our web site.*



RLC ELECTRONICS, INC.

83 Radio Circle, Mount Kisco, New York 10549 • Tel: 914.241.1334 • Fax: 914.241.1753

E-mail: sales@rlcelectronics.com • www.rlcelectronics.com

ISO 9001:2000 CERTIFIED

RLC is your complete microwave component source...
Switches, Filters, Power Dividers, Terminations, Attenuators, DC Blocks, Bias Tees & Detectors.

ing the size of the cuts they hoped would shrink the deficit. In addition, the “kick-the-can-down-the-road” approach of deferring problems through legislative wizardry was unacceptable to these new hard-line congressional members who had been elected on the platform of ending business as usual in Washington. And so the Budget Control Act of 2011 was devised to allow the president to raise the debt ceiling in exchange for debt reduction levels (budget cuts) acceptable to Tea Party members of Congress.

The remaining issue of how to reduce the budget would be handled by a legislatively-engineered “fiscal cliff.” The fiscal cliff, which many felt would plunge the country back into recession, called for simultaneous increases in tax rates and decreases in government spending starting on January 1, 2013. Under the fiscal cliff scenario, select programs such as Social Security, Medicaid, federal pay (including military pay and pensions) and veterans’ benefits would be exempt from spending cuts. Discretionary spending for federal agencies and cabinet departments would be reduced through broad cuts referred to as budget sequestration. Reductions in defense spending would make up half of the spending cuts called for under sequestration.

Before reaching that cliff, the Budget Control Act called for the creation of a Joint Select Committee on Deficit Reduction, known as the super committee, which was tasked with developing a deficit reduction plan to cut at least $1.5 trillion over the coming 10 years. The super committee recommendation would be subject to a simple vote by the full legislative bodies without amendment in order to bypass congressional debate and pass a bill by the December 23, 2011 deadline. However, in late November the committee issued a statement that it would be unable to make any bipartisan agreement before the deadline and the committee was disbanded on January 31, 2012.

With 2012 being an election year and the fiscal cliff set to occur shortly thereafter, politicians held off resolving the budget issue and focused on campaigning for office based on their positions on how to address revenue (what to do about expiring Bush tax cuts) and spending. The selection of the president and members of the House of Representatives and Senate would serve as a referendum on the country’s priorities, although the meaning of the results would still be open to interpretation.

After the November election, intensive debate and media coverage over the looming fiscal cliff and its projected short-term fiscal and economic impact drew widespread public attention. The Washington interpretation of the election results swayed lawmakers to enact the American Taxpayer Relief Act in the final weeks of 2012, making the lower tax rates for the lower and middle class established under the Bush tax cuts permanent, while retaining the higher tax rate and eliminating various deductions for upper income levels. The act did not tackle the spending cuts issue, but did delay sequestration for two months (March 1^{st}).

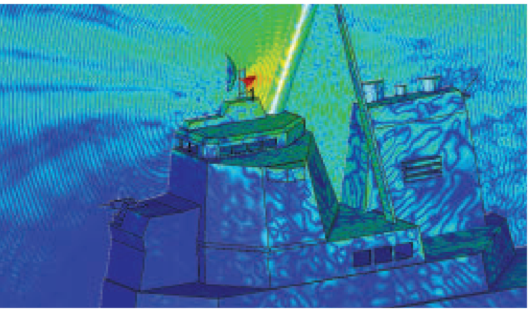
WHAT ACTUALLY IS “SEQUESTRATION?”

The word sequester comes from the Late Latin word sequestro, meaning to set aside or to take something away until a debt has been repaid. In the context of funding federal programs, sequestration is intended to implement broad automatic spending cuts in “particular categories of federal outlays” as mandated by the Budget Control Act (2011), thereby lowering government spending by approximately $1.2 trillion over a 10-year period. The $1.2 trillion reduction in spending (from 2013 to 2021) would come from $984 billion dollars in sequester split evenly over nine years ($109 billion/year) and $216 billion dollars in saved debt servicing (interest payments).[1]

The total annual spending cut of $109 billion would be divided equally between defense and nondefense spending, roughly $55 billion. Generally speaking, these cuts are divided proportionately between the discretionary and nonexempt direct spending within each broad category. Since much of direct spending is exempt, sequestration would primarily affect discretionary spending ($813 billion of the $984 billion in non-interest sav-

Make the Connection

Find the simple way through complex EM systems with CST STUDIO SUITE



Components don't exist in electromagnetic isolation. They influence their neighbors' performance. They are affected by the enclosure or structure around them. They are susceptible to outside influences. With System Assembly and Modeling, CST STUDIO SUITE helps optimize component and system performance.

Involved in defense, aerospace or maring applications? You can read about how CST technology was used to simulate installed antenna performance at www.cst.com/defense.

If you're more interested in filters, couplers, planar and multilayer structures, we've a wide variety of worked application examples live on our website at www.cst.com/apps.

Get the big picture of what's really going on. Ensure your product and components perform in the toughest of environments.

Choose CST STUDIO SUITE – Complete Technology for 3D EM.

CST

CST – COMPUTER SIMULATION TECHNOLOGY | www.cst.com | info@cst.com

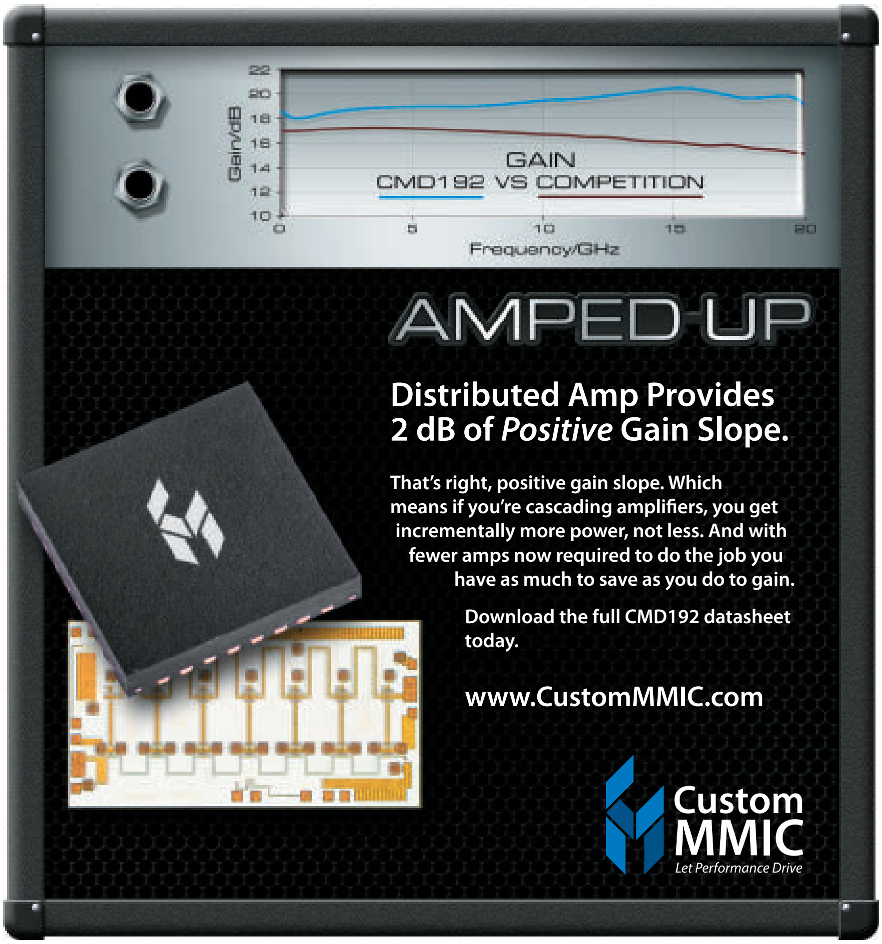
ings).[2] Defense spending is largely discretionary.

The mechanics of how sequestration works can be divided into two parts. The first part calculates the dollar amount of the required defense reduction ($55 billion/year). The second part of the Budget Control Act sets a cap on discretionary defense spending. For FY 2013, this cap starts at $546 billion. Funding is then reduced by $55 billion, making the effective budget for the FY 2013 discretionary national defense budget equal to $491 billion. The budget caps for future years would in turn be reduced by an identical amount of $55 billion.[3]

Budget caps apply to the amount of money appropriated by Congress in a given year. The DoD has multiple years to spend its budget authority depending on the type of funding appropriated. Defense acquisitions often take multiple years to award contract, obligate funding, and provide the vendor time to develop and produce the system/platform being acquired. When money is transferred from the U.S. Treasury to the vendor, it becomes an outlay.

Sequestration will cause overall defense outlays to drop by roughly 4.6 percent in FY 2013 in addition to a 2.5 percent reduction already associated with the decline in war-related funding.[4]

Since the yearly forced reduction of $55 billion is a fixed number and the defense budget cap will actually continue to increase yearly, the sequestered amount as a percentage of the overall defense budget will decrease. The Congressional Budget Office (CBO) estimates that sequestration will produce cuts ranging from 10 percent in 2013 to 8.5 percent in 2021. Between now and 2021, sequestration of new defense discretionary appropriations will result in a total cut in budget authority of $492 billion, which is estimated to yield $454 billion in outlay savings.[5]



IMPACT ON DEFENSE SPENDING

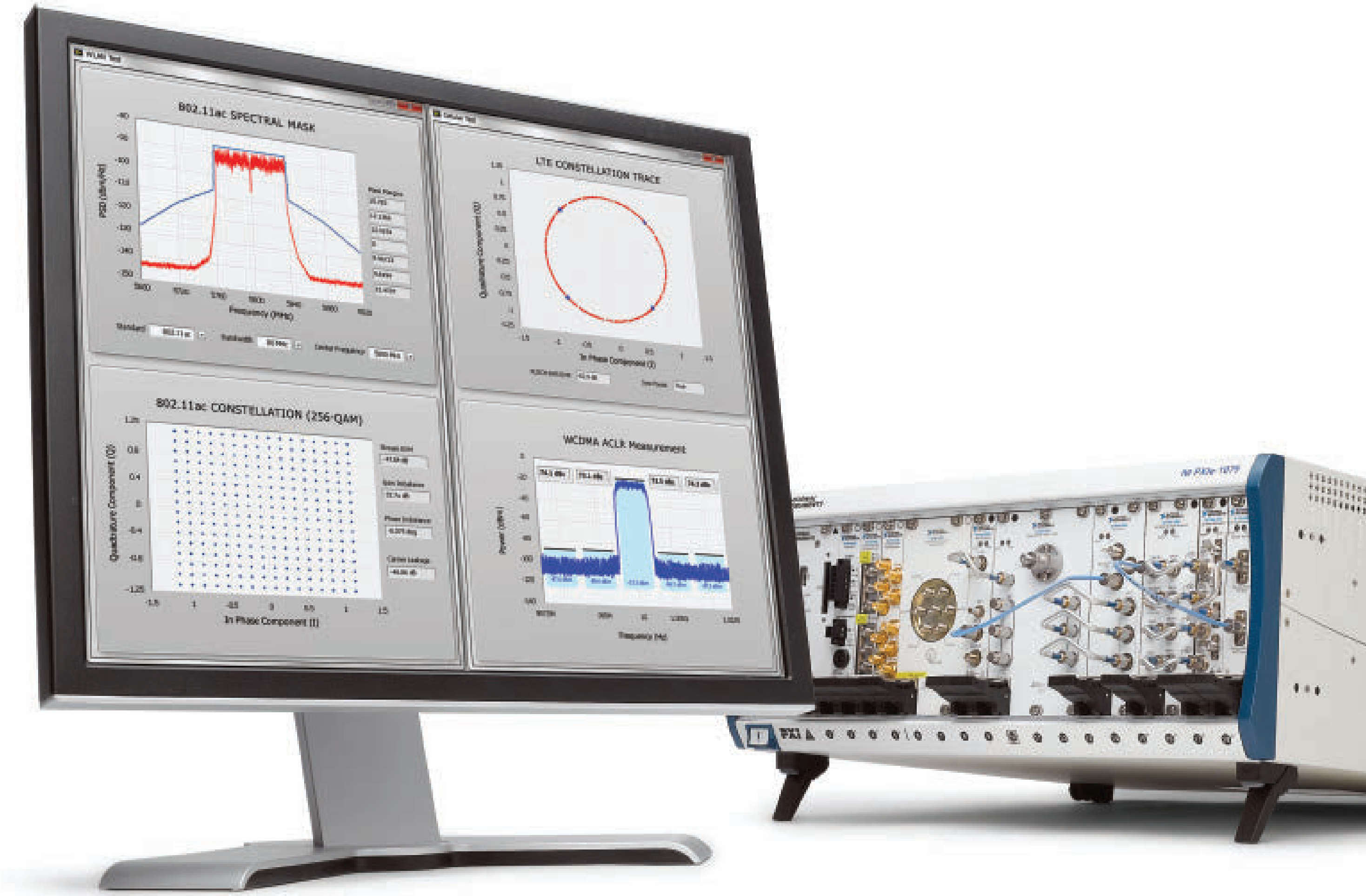
The FY 2013 DoD budget calls for $620 billion, which includes $525.4 billion in discretionary funding and $6.3 billion in mandatory funding with an additional $88.5 billion for ongoing military operations, primarily in Afghanistan. Total defense-related spending also includes $19.4 billion in discretionary and mandatory funding for defense-related atomic energy programs, $7.7 billion for defense-related activities in other agencies, and $137.7 billion for veterans' benefits and services. The Treasury must also set aside $67.2 billion to cover unfunded liabilities in the Military Retirement Trust Fund. Together these expenses total $852 billion, or 23 percent of the total federal budget.[3]

So while sequester cuts may seem daunting, they only represent a 7 percent cut of total federal spending for FY 2013, which pales in comparison to the 54 percent loss in stock market value from 2007 to 2009 and the 33 percent loss in the housing market from 2006 to 2009. Additionally, starting in 2014 and for the next seven years, discretionary limits will actually increase 1 to 2 percent per year, offsetting some of sequestration's impact. The immediate outlook for vendors is further improved by the billions of contract dollars currently obligated.

Across the DoD, allocated budget is spent at different rates. The majority of military personnel funding and more than two-thirds of Operations & Maintenance (O&M) funding is spent in the year it is appropriated. There is more of a delay between budget authority and outlays when it comes to procurement (up to three years) and Research Development Test & Evaluation (RDT&E) funding, which have a two year obligation period. Only 22 percent of procurement funding and 49 percent of RDT&E funding become outlays in the year in which they are appropriated. The delay between budget authority and outlays means that the impact of sequestration on vendors has been less immediate. Moreover, because budget authority becomes outlays at different rates in

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:

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

>> Learn more at ni.com/redefine

800 813 5078

©2012 National Instruments. All rights reserved. LabVIEW, National Instruments, NI, and ni.com are trademarks of National Instruments.
Other product and company names listed are trademarks or trade names of their respective companies.

NATIONAL INSTRUMENTS™

different accounts, the reduction in outlays will not be uniform across all parts of the budget. Due to the lag between procurement appropriations and outlays, this year's outlays should experience only a 3.5 percent reduction ($120.2 billion vs. pre-sequestration outlays of $124.5 billion), according to "Analysis of the FY 2013 Defense Budget and Sequestration" by Todd Harrison. Because more O&M funding (maintenance, logistics, and other support functions) is spent in the same year it is appropriated, the reduction in outlays for these funds will be higher at 6.9 percent.[3]

That sequestration acts on budget authority rather than outlays provides some insulation for defense companies as it allowed more time for adjustment. Because sequestration does not affect funding that has already been obligated, defense firms were able to continue working on contracts already awarded. However, sequestration is expected to affect the DoD's ability to award new contracts and exercise options on contracts. If allowed to continue long term, sequestration will result in a decline in revenues for defense firms, but it will be three or four years before defense companies feel the full impact.

This has given industry more time to adjust employment levels through natural attrition and early retirements rather than forcing immediate layoffs. In addition, RDT&E funding was only reduced by 3 percent (~$7 billion) compared to the previous year. The smaller reductions in O&M and RDT&E relative to other accounts are consistent with two of the priorities highlighted in the new strategic guidance: maintaining "a ready and capable force" even as overall force structure is reduced, and continuing investments in science and technology "to sustain key streams of innovation that may provide significant long-term payoffs."

SPECULATION, REACTIONS AND REALITY

Last fall, there was a consensus among many analysts that sequestration would have a disastrous impact on U.S. jobs and gross domestic product (GDP). The CBO initially projected that sequestration would reduce 2013 economic growth by about 0.6 percentage points (from 2.0 percent to 1.4 percent or about $90 billion) and affect the creation or retention of about 750,000 jobs through its first year.[6] The National Association of Manufacturers (NAM) and Aerospace Industry Association (AIA) painted more dour predictions in two separate reports. NAM projected that budget caps and across-the-board cuts in defense spending would result in:

- The loss of over 1 million jobs in the private sector, including 130,000 manufacturing jobs
- A 1 percent drop in GDP
- A 0.7 percent increase in the national unemployment rate
- The loss of 3.4 percent of aerospace jobs, 3.3 percent of jobs in the ship and boat industry and 9.3 percent of jobs in the search and navigation industry.

The projected loss of over a million jobs involves a "multiplier effect," according to NAM president Jay Timmons, "since the job losses, including workers in the defense manufacturing supply chain and those employed in

The Center for All Your RF Designs

RFMW Ltd. is a premier RF & Microwave specialty distributor created to support your component selection, technical design and fulfillment needs. RFMW offers a complete range of services for commercial, military, and space requirements.

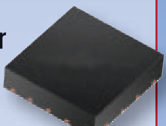
RFMW is a cut above the typical distributor.
We understand your need for on-time delivery and value because we face the same issues on a daily basis. Our focus on RF devices and technology enables us to meet your expectations with the highest service levels.

RFMW Value-Added Services.
We provide many value-added services driven by customer requirements – because we know RF and microwave.

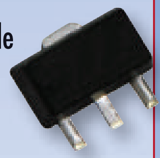
- DIE Services • Packaging • Electrical Test Capabilities
- Device Tape & Reel • Kitting • Hi-Rel Screening
- Solder Tinning • Documentation Related Services
- Obsolete Parts Replacement • Custom Product Development

From antenna to baseband, RFMW is the center for all your RF designs. Contact RFMW today or visit our website.

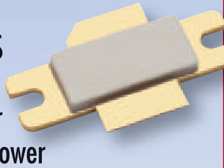
RF Switches
- SPnT
- Semiconductor
- Mechanical
- High Isolation
- High Power
- GaN • Die



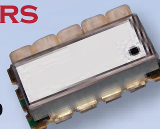
RF Amplifiers
- Gain Blocks
- Coaxial Module
- Low-Noise
- Linear Drivers
- High Power
- Variable Gain



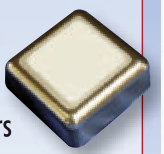
RF Transistors
- GaN
- LDMOS
- GaAs
- Bipolar
- High Power
- High Frequency



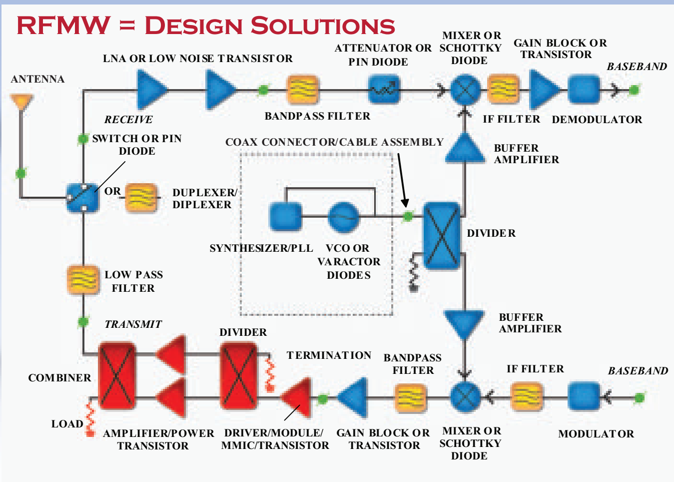
RF Filters
- Monoblock
- SAW / BAW
- HP / LP / BP
- Ceramic Resonator
- Duplexer / Diplexer
- Cavity



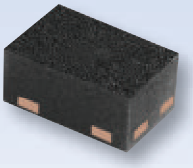
RF Oscillators
- OCXO
- VCXO
- TCXO
- PLL Synthesizers
- RF Generators



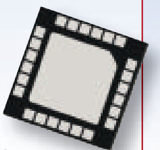
RFMW = Design Solutions



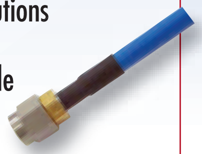
RF Diodes
- PIN
- Schottky
- Varactor
- Limiter
- Gunn



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

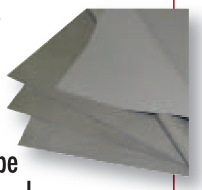


RF Cable Assemblies
- High-Performance Test
- In-Box Solutions
- Pigtails
- Conformable
- Flexible
- Semi-Rigid



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

EMI / RFI
- RF Absorber
- RF Gaskets
- Wire Mesh
- Fingerstock
- Shelding Tape
- Filtration Panels
- Shielded Windows



RFMW

ISO 9001 REGISTERED FIRM

RFMW 10 Years Since 2003

RFMW Ltd. • 188 Martinvale Lane • San Jose, CA 95119 U.S.A.
Toll Free: +1-877-367-7369 • Fax: +1-408-414-1461 • Website: www.RFMW.com

• **Canada** (Western) +1-877-367-7369 • (Eastern) +1-877-367-7369 • **RFMW Mexico** +1-408-414-1450 • **RFMW.CO.UK** +44 (0) 20 8848 4732 • **RFMW Italia** +39 0774 689994 • • **RFMW Deutschland** +49 (0) 8233 738 747 • **RFMW Europe Ltd** +44 20 8848 4732 • **RFMW France** +33 1 83 64 53 97 • **RFMW Israel Ltd.** +972 9 740 6884 •

the military and as defense contractors, will result in lower disposable income and reduced consumer demand — creating a ripple effect across the entire economy."[7]

In their study for the AIA (July 2012), Dr. Stephen S. Fuller and Dwight Schar, faculty chair and director for Regional Analysis at George Mason University, projected a loss of 2.14 million American jobs with nearly half of all sequestration job losses coming from small businesses. The report predicted that 2013 would "constitute the greatest one-year reductions in GDP, personal earning and employment" with the GDP taking a $215 billion hit and unemployment rising to above nine percent. The study went on to report that cuts in DoD procurement would lead to over 130,000 direct job losses to the professional and business sector including contractors who provide scientific, engineering and technical services.[8]

Fortunately, these predictions failed to materialize. Despite the cutbacks, the U.S. economy has not imploded. The stock market reached record highs and the housing market continues to rebound. By the end of August, the Commerce department announced that the GDP actually rose at a 2.5 percent annualized rate, up from the initial estimate of 1.7 percent. As a result, the CBO predicts the deficit will shrink this fiscal year to $642 billion, or just four percent of GDP. Thanks to sequester, coupled with higher tax revenue and improved economic growth, the deficit has been shrinking by about $42 billion a month for the past six months.[9]

Contractors have been pleasantly surprised that the automatic spending cuts were not hurting nearly as much as the industry's lobbying arm warned in the months leading up to the sequester. Defense contractors have been reporting solid earnings and dividends and their stocks are on the rise. Teledyne Technologies, Boeing, Northrop Grumman and United Technologies have hit record highs. Lockheed Martin, General Dynamics and Rockwell Collins are within 10 percent of their all-time peaks.

In late July, Lockheed Martin reported that its profit rose 10 percent to $859 million during the second quarter, despite a slight dip in revenue. According to Lockheed's chief financial officer, Bruce Tanner, the company is "seeing less impact than we had expected to see through the first half of the year, it's somewhat hard for us to imagine that the full [anticipated] impact will be realized."

So what happened? The long lead up to sequester allowed many large contractors to insulate their businesses as much as possible. Some manufacturers rushed to get contracts signed before the sequester went into effect and are in the process of fulfilling those contracts now, which means the cutbacks haven't hit their balance sheets yet. Others have diversified their portfolios by making acquisitions in areas such as unmanned aerial vehicles (UAV), computer security, health care IT, and C4ISR (command, control, communications, computers, intelligence, surveillance and reconnaissance).

"Cuts to the defense budget are part of the overall reductions in government spending necessary to ad-

Wherever you need RF, we've got you covered.

Whether you're interested in a hybrid coupler measuring .04 x .04 inches – or a sophisticated, high-complexity beamformer bound for space – Anaren is your proven, reliable, and high-integrity provider.

> **Our Space & Defense Group** offers a fast-growing range of passive and active solutions, including multichip modules and IMAs. Exciting, new substrates, high-rel PCB, and packaging choices. And a growing line up of next-gen, space-grade power combiners/dividers.

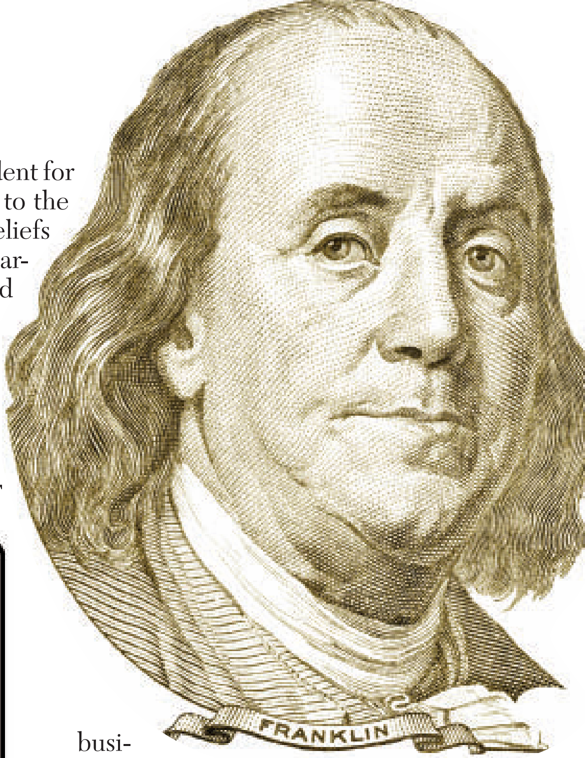
> **Our Wireless Group** continues to reinvent the passive components category. From new, Femto-sized Xinger®-brand components for today's smaller base stations. To tiny baluns, couplers, and PDs for consumer devices. To low-cost or high-powered terminations, attenuators, and resistors. To our new family of Anaren Integrated Radio (AIR) modules based on Texas Instruments low power RF chips, ideally suited to all kinds of traditionally non-RF applications that will form tomorrow's industrial, commercial, and residential "internet of things".

To learn more – visit **www.anaren.com** or email us at **sales@anaren.com** today!

Anaren®
What'll we think of next?®
800-411-6596 > www.anaren.com

dress the nation's debt issue," said Steve Brecken, a spokesman for Honeywell's aerospace division. "We have been anticipating and planning for sequestration for over a year, and to date, the impacts have been largely as we expected. We do not anticipate any changes in our financial outlook nor any layoffs or furloughs due to sequestration, mainly due to our thoughtful planning and our large commercial aerospace businesses."[10]

David Herr, executive vice president for services at BAE Systems, speaking to the *National Journal Daily*, shared his beliefs that big firms such as Lockheed Martin, Northrop Grumman, BAE and General Dynamics would do some "portfolio-shaping" to strengthen their ability to go after new business. In the service business, Herr is predicting a lot of consolidation that will probably create some very big players interested in the IT



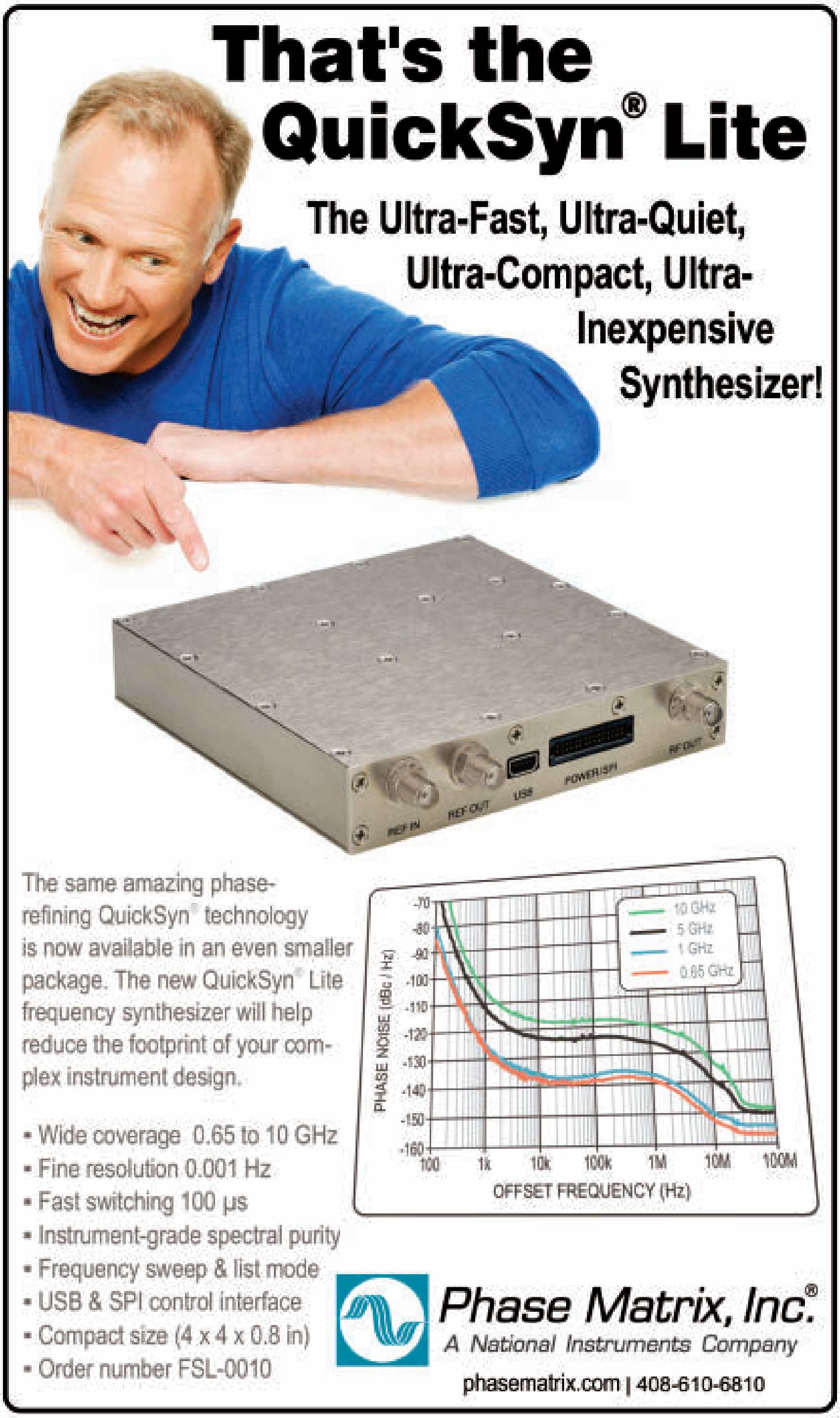
business, maintaining hardware and space systems. According to Herr, "If you look at the history, in the last downturn those companies that sat back and did nothing fared the worst. There will be consolidators and those that will be consolidated. BAE would like to be one of the consolidators."

The company is also diversifying into more commercial markets and opportunities outside the U.S. BAE is developing next-generation cabin electronics for commercial aircraft. It is not alone in pursuing opportunities in commercial and international markets. Earlier this year, General Dynamics announced a partnership with Samsung to deliver enhanced security to that company's mobile devices.

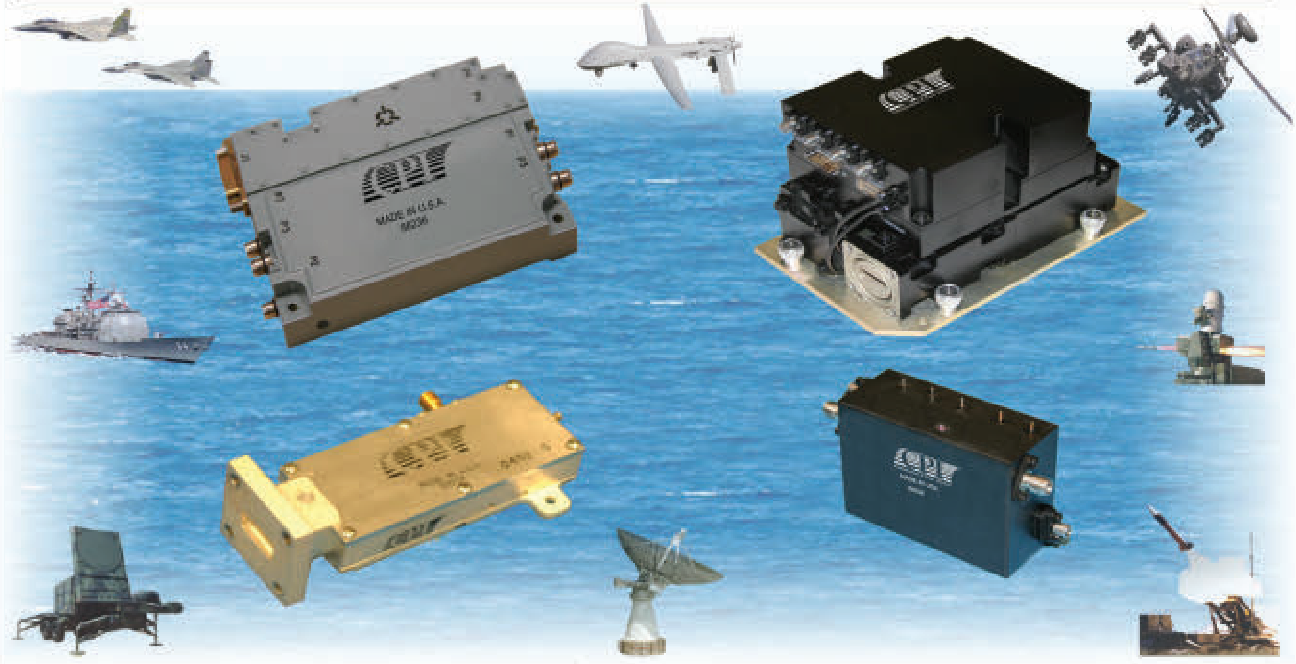
WHAT ABOUT THE SMALL COMPANIES?

Dan Stohr, a spokesman for the Aerospace Industries Association (AIA), told lawmakers that his association was concerned that smaller suppliers might feel the pain more acutely than large contractors, despite the minimal impact on their bottom lines. One concern is that small firms do not have access to the kind of capital and credit the larger firms do, and they are far less likely to be diversified. Many of these smaller companies rely on large DoD contractors for 25 to 50 percent or more of their business. On the other hand, small companies have the advantage of agility and willingness to innovate.

According to the Small Business Administration (SBA), 20 percent of



Integrated Microwave Assemblies



Advanced Technology - Extensive Experience - Superior Performance

Communications & Power Industries

Communications & Power Industries' Beverly Microwave Division (BMD) offers product technology that includes Integrated Microwave Assemblies and Control Components. BMD's broad experience and extensive capabilities in the areas of high power microwave component design for military and non-military radar, satellite, communications, and EW systems makes it uniquely suited to design and manufacture a wide range of components and multi-function assemblies in small, lightweight packages. Coupling that with our experience in other transmission lines and technologies gives us a technical capability that is unparalleled in the microwave industry.

* Multi-function components
* RF front ends
* Switches & attenuators
* High level assemblies & modules
* Design capability up to 40 GHz
* Power handling to 1 MW+ peak
* Integral driver & associated electronics
* The industry's most extensive high power test facility

Communications & Power Industries
Beverly Microwave Division

150 Sohier Road
Beverly, MA 01915
Phone: (978) 922-6000
Fax: (978) 922-2736

marketing@bmd.cpii.com
www.cpii.com/bmd

Defense Department prime contracts and 35 percent of DoD subcontracts in 2011 were awarded to small firms. In 2011, 18 percent of NASA prime contracts went to small businesses and 38 percent of its subcontracts to small companies. Additionally, between two-thirds and three-quarters of defense industrial purchases are directed to small suppliers, many of which are the only source of specialty parts and technologies for the U.S. military.

The SBA says that small firms employ half of all private sector employees. According to the U.S. Census Bureau, small businesses create 90 percent of all new jobs on an annual basis. "From a national security perspective, letting the avoidable occurrence of sequestration force small businesses to exit the defense industry or go out of business altogether would not only hurt our economy but taxpayers," said Mackenzie Eaglen, resident fellow at the Marilyn Ware Center for Security Studies.

In turn, hits to small companies may eventually trickle upward and be felt on a national scale, resulting in layoffs, mergers and further industry consolidation among aerospace companies. According to Herr, BAE has brought some smaller subcontractors to visit policy makers and discuss concerns over losing certain skills and preserving capabilities within the supply chain. One fear among prime defense contractors is that they will muscle through this sequestration and budget downturn, and when they put out a request for bids, there won't be anyone there to fill them. This is a network of thousands of small and midsize businesses spread across all 50 states.

Several lawmakers in Congress are concerned for the plight of small businesses under sequester, among them U.S. Senator Mary Landrieu (R-La.), chairwoman of the Small Business and Entrepreneurship Committee. "Small businesses are going to be the ones that feel the most immediate effects as these government budget cuts come down, because contrary to popular notion, government spending does affect private-sector jobs," Senator Landrieu told *Politico* this past April.

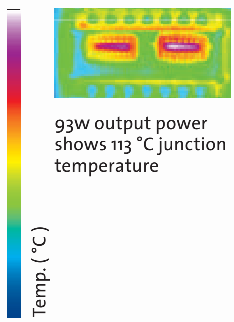
Landrieu held a roundtable event entitled, "Sequestration: Small Business Contractors Weathering the Storm in a Climate of Fiscal Uncertainty," to urge federal agencies to maintain their small business contracting goals. While the senator's efforts may help small businesses that contract directly with the U.S. government, it will not directly provide support to companies far down the supply chain from the largest defense contractors. As budget tightening trickles down from top defense contractors, small companies will need to adapt.

So how are these companies weathering sequestration? Some small defense suppliers say sequestration already cut into their businesses, reporting that the Pentagon has been slow to place orders because of budget indecision, compounded by furloughs of civilian defense employees. Still, the Pentagon has worked hard to shield big weapons programs such as the F-35 jet, the military's most expensive weapons system, from the mandatory cuts. According to Lockheed's Bruce Tanner, "The Pentagon has done a fairly masterful job kind of deflecting" cuts to weapons programs.

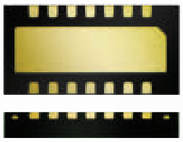
High-power **GaN in** Space-saving **Plastic**

90w, 50w, 15w Transistors in 3 x 6 mm Packages for Military/ATC Radar, IFF & Satcom Applications

Experience transistors that combine the power of GaN with the size, weight and cost savings only true SMT packaging delivers. Using decades of pulsed power experience our engineers have designed these devices to be rugged, highly reliable and with excellent thermal performance for demanding pulsed applications.



93w output power shows 113 °C junction temperature



3 x 6 mm dual flat no-leads (DFN) package

Fully tested and ready to ship, GaN in Plastic transistors arm your applications with dramatic size and weight advantages compared to ceramic packaging. Yet, they are designed to achieve similar moisture resistance and operating temperatures for applications up to 3.5 GHz.

Only MACOM gives you the highest power of GaN in elegantly simple, yet extremely reliable plastic packaging.

Order samples and get more information at www.macomtech.com/gan

MACOM™

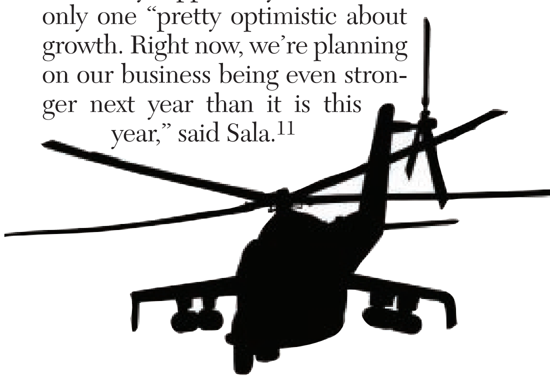
Partners in RF & Microwave

As a result, much of the doomsday predictions have yet to materialize for small- to mid-size contractors. Sequestration may have cut some spending, but it may be an improvement over the budget uncertainty recurring since 2011. Sequestration has also changed priorities for a Pentagon looking to maintain its objectives to meet future threats with a more efficient use of its procurement and R&D money. As a result of these new priorities, contractors are finding new opportunities among its government and prime contractor customers.

Wall Street has taken notice. According to Bloomberg, investors are returning to many of the smaller government suppliers whose shares slumped during months of budget uncertainty leading up to sequestration. A Bloomberg index providing a sample of 17 small and mid-sized contractors, including API Technologies, Anaren and CPI Aerostructures, has gained 20 percent since March 1. It fell 14 percent in the five months before sequestration kicked in, partly reflecting concerns they would be more vulnerable to budget cuts. The surge comes as second-quarter profits and raised outlooks for the full year were reported from defense contractors such as Lockheed Martin, Raytheon and Northrop Grumman.[11]

There has been a nice bit of bounce back for small defense stocks, "because the sky is not falling and companies are not going out of business," said Mark Jordan, a St. Louis-based analyst at Noble Financial Capital Markets. For example, the shares of API Technologies, which makes RF/microwave components and integrated microwave assemblies for defense and medical applications, have risen 16 percent since March 1 after falling four percent during the previous five months. API Technology, with a market capitalization of $167 million, hasn't been "affected by any programs that were either eliminated or are to be eliminated," commented Bel Lazar, API's chief executive officer, during a conference call in July. According to Lazar, the Pentagon is now "more careful in terms of what they're procuring and how much they're paying."

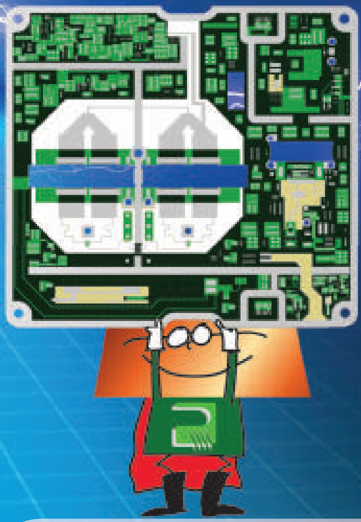
Executives at Anaren, a leading manufacturer of microwave passive components, assemblies and subsystems for telecommunications and military radar systems, "assumed the cuts would prevent sales from increasing more than roughly five percent. Instead, the company now projects a 10 percent boost in revenue from its defense and space businesses this year," according to president Larry Sala. Anaren's stock has jumped 19 percent since March 1, which Sala attributed mostly to a buyout offer from a private equity firm, which the company rejected in May. Apparently, Anaren isn't the only one "pretty optimistic about growth. Right now, we're planning on our business being even stronger next year than it is this year," said Sala.[11]



Give your next amp a boost with

RO4360G2™

6.15 Dk High Frequency Laminates



When amplifier designers asked, Rogers listened and developed RO4360G2™ high-frequency laminates. These thermoset materials feature a powerful balance of high performance, low cost and ease of processing in a laminate with a dielectric constant of 6.15.

RO4360G2 laminates deliver the low loss and high thermal conductivity sought by amplifier designers. Suitable for a variety of commercial and industrial applications, RO4360G2 laminates can be processed similar to FR-4 & support lead-free, RoHS-compliant manufacturing practices.

Features

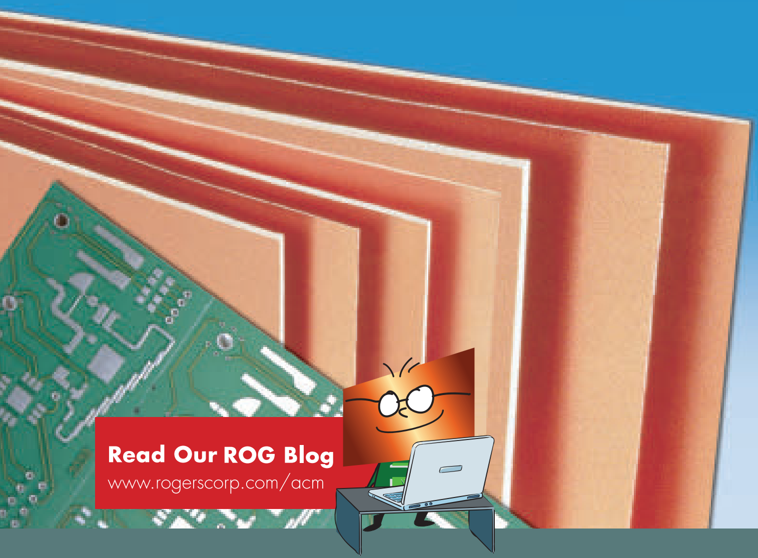
- High dielectric constant
- Low loss
- High thermal conductivity
- Low Z-axis CTE (30 PPM/°C) for reliable PTHs

Total Cost Solution

- Priced better than alternatives
- Low fabrication cost

Ease of Fabrication

- Ideal for multilayer circuits
- Suitable for automated assembly lines
- Processes similar to FR-4
- Lead free, RoHS compliant



The world runs better with Rogers.®

ROGERS CORPORATION

Advanced Circuit Materials

Visit www.rogerscorp.com/acm to learn more about our full line of High Frequency Laminates

USA - AZ, tel. +1 480-961-1382 • EUROPE - BELGIUM, tel. +32 9 235 3611 • www.rogerscorp.com

STRATEGIES FOR SURVIVING SEQUESTRATION

Defense contractors large and small need to utilize their core strengths to navigate the evolving nature of government spending and provide solutions that meet the DoD's long-term objectives. These companies need to consider how to protect existing business, diversify into new markets, and look for ways to cut costs internally and for their customer. Now more than ever, it is important to maintain high visibility with existing and potential customers.

Jim Assurian, director of business development at Reactel, a leading manufacturer of RF/microwave filters, believes companies will react in a variety of ways. "For the larger guys [defense contractors], their best defense may be to let people go. On a much smaller scale (say for companies 100 employees and less), I think they are (or should be) redoubling their marketing and sales efforts. While they may lay off a few folks, I think there are opportunities out there to at least remain even in sales. We are mainly talking about companies with sales of $10 million or less, so it does not take much to replace the small share of programs they were on. These are really Business 101 type things, and should not be a revelation to anyone. However, with so many small companies in our industry, the thought of increasing spending to add sales guys and increase advertising in a down economy is counter-intuitive."

To protect and serve the government, business consultants to the defense industry make the following suggestions:[12]

- Know your existing contracts: Take the time to do a full inventory and determine what types they are – indefinite delivery/indefinite quantity are increasingly common, time-and-materials less so. Understand what accounts are funding the contracts and how they will be cut, if at all.
- Know your contract/program lifecycle: When does it expire, what are the option periods? Contracts later in their lifecycle may be less flexible. Determine which are severable and which are non-severable: some will have to be carried over beyond the current fiscal year, but others may allow spending in fiscal 2013 for services carried out later. Also know the termination provisions and option expirations for their contracts and subcontracts.
- Strengthen ongoing performance: "Nothing will succeed in this area like a well-performing program." Take preemptive measures to protect contracts from cancellation by working with clients on proactive approaches to reduce scope/cost of contracts and don't give the government an excuse to cancel a contract by addressing any performance deficiencies immediately. Also, maintain relevant records – such as past performance – ensuring they are as accurate and favorable as possible.
- Engage customers, both at the contracting officer and end-user levels, to understand the importance of the work, the status, the performance, their plans and strategies going forward.

▶ Network Analyzers

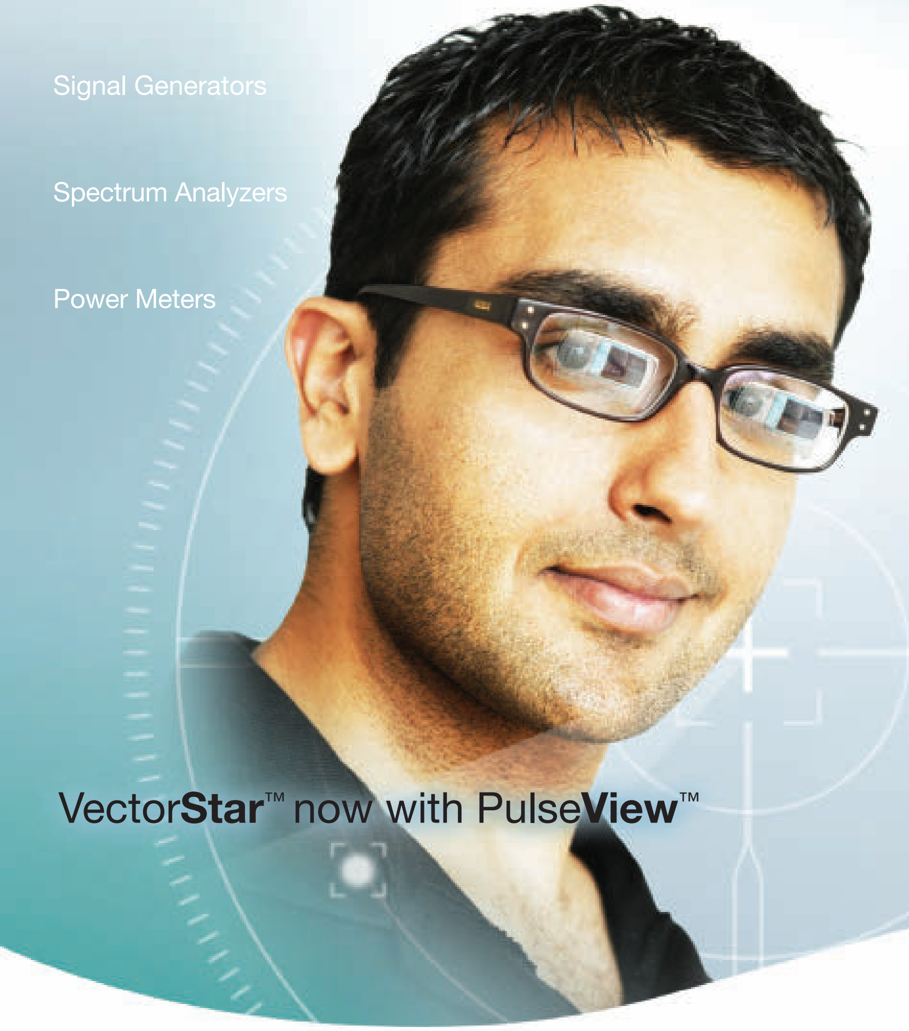
Signal Generators

Spectrum Analyzers

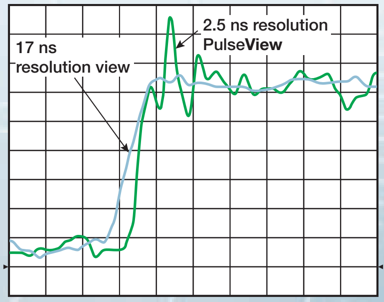
Power Meters

Anritsu | Since 1895

You can't solve your RADAR pulse distortion problem until you get a clear view of it.



VectorStar™ now with PulseView™

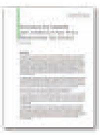


Time Resolution

Bring your vision into resolution with the **NEW** Vector**Star** MS4640B.

With Vector**Star** and Pulse**View**, you get the tools and performance to confidently characterize RADAR components and subsystems. With pulse profile, point-in-pulse, and pulse-to-pulse measurements based on the latest architecture, Pulse**View** delivers **industry-leading 2.5 ns VNA pulse measurement resolution**. Plus real-time set-up/display capability offers confidence that both set-up conditions and measurement results are consistent.

Confidence on the Cutting Edge



Get the true view. Download our complimentary white paper, ***VNA's High-Speed Architecture Advances Radar Pulse Measurements Timing Resolution and Accuracy***

Designed and Manufactured in U.S.A.

Visit us online at: **www.anritsu.com/en-us/VectorStarMWJ**

Anritsu

Discover What's Possible™

USA/Canada 1-800-ANRITSU Europe 44 1582-433433 Japan 81 (46) 296-1208
Asia-Pacific (852) 2301-4980 Singapore-South Asia (65) 6282-2400
South America 55 (11) 3283-2511 ©2013 Anritsu Company

- Evaluate agency funding and spending priorities for both existing and new work. What must be saved, deferred or deleted? Perform an inventory of contracts based on their importance to fulfilling federal customers' missions to assess areas most at risk for cuts.
- Agencies will be eager to use fixed-price contracts to shift cost risk to contractors. Companies should mature their processes quickly to improve their bottom line.

To find growth opportunities, contractors should look to utilize their current areas of expertise applied to the commercial sector and/or foreign markets. As an example, Anthony Sweeney, general manager of Mercury Systems RF and Microwave Component Group, points out, "While a significant portion of our revenue is aimed at the EW and radar markets, we also have a strong presence in the commercial telecom marketplace via base station power amplifiers, point to point digital microwave radio through our ferrite lines, and test and instrumentation through our control components line, as well as low noise and CNG test equipment lines. We also see several opportunities to leverage our technology into homeland security applications."[13]

As in the Mercury System example, the commercial sector can actually help win new government business, especially when the Pentagon is looking for off-the-shelf commercial components to lower their costs. In addition, the Pentagon is working to maintain military readiness with existing defense assets, technology and operational support. With several major contracts in limbo, the electronics industry is the beneficiary of an increasing need for replacement parts or enhanced technology to improve current systems that are being kept operational longer.

"With sequestration lingering earlier this year, we saw a significant reduction in the bid solicitation from government sources," says Julian Andrews, operations manager of Coaxial Components Corp., which manufactures RF connectors, attenuators, terminations and other microwave components. "With cuts now in place, we're seeing a growing focus on maintaining or upgrading existing communication and defense systems."

LOOKING AHEAD

America's future military will be defined as a globally agile force characterized by small, precision engagements that feature minimal violence applied with surgical precision. Over the coming decades, the U.S. military will look to "pivot from the past and a turn to the future." The Pentagon's new vision represents a shift from the types of missions and forces that dominated the wars in Iraq and Afghanistan, emphasizing "strategic flexibility" made possible through specialized, tailored capabilities, from cyber warfare tactics to special operations forces.

There will also be a rebalance of the global posture and presence to emphasize the Asia-Pacific region

Purity & Precision
Speed & Ease
Rohde & Schwarz FSW

Now up to 50 GHz

The most advanced signal and spectrum analyzer for aerospace and defense applications. The highest bandwidth, lowest phase noise, clearest user interface and a host of convenient new tools — all on the largest touchscreen available. The R&S®FSW is tailored to the unique requirements of A&D applications. At the press of a button, it delivers all relevant pulse parameters from radar signals. Its RF performance opens up applications far beyond the capabilities of other analyzers.

- Analyze oscillators and synthesizers with a phase noise of –137 dBc (1 Hz)
- Measure frequency-hopping and chirp signals with a bandwidth of up to 320 MHz
- Analyze in realtime with 160 MHz bandwidth and 585.938 FFT/s to obtain 100% POI for signals as short as 1.87 µs
- Measure pulses, spurious and modulation at the same time with MultiView
- See more and obtain faster results on the large touchscreen

The R&S®FSW. When performance matters.
www.rohde-schwarz.com/ad/fsw-ad

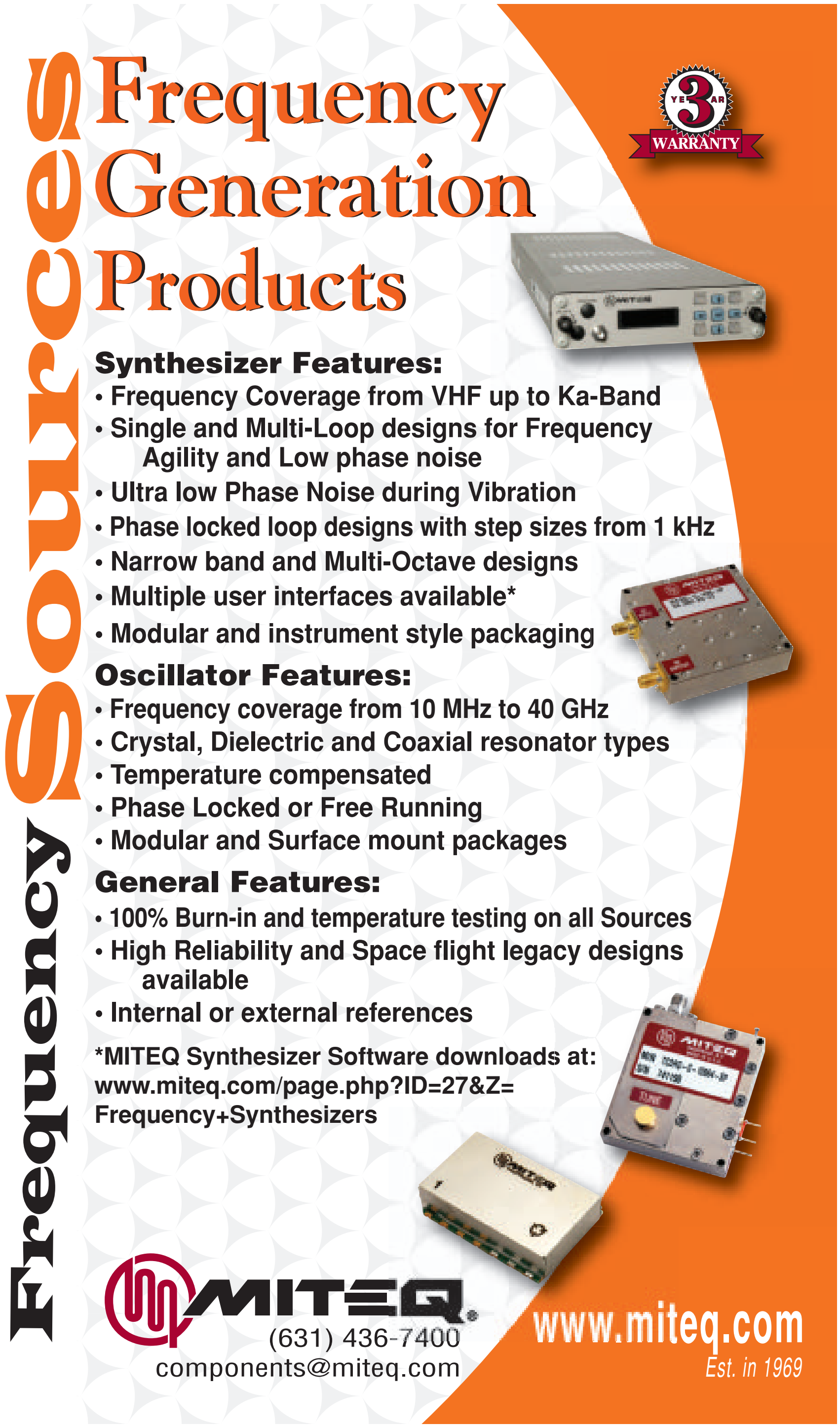
Watch the Video

ROHDE&SCHWARZ

and the Middle East, building upon key alliances in all regions. Procurement and RDT&E plans will protect investments in key technology areas and advance new capabilities, as well as the DoD's capacity to grow, adapt and mobilize as needed. These goals will lead to continued investments in intelligence, surveillance, and reconnaissance (ISR) and further developments in improved precision strike, cyberspace, and space capabilities maintained through funding for research and development (R&D) of technologically advanced capabilities.[14]

In Washington, Congress is expected to pass another stopgap bill, known as a continuing resolution, to fund government operations for fiscal year 2014, but it is unclear whether such funding will stay at current levels or shrink. Earlier this year, the House and the Senate passed spending bills for the 2014 fiscal year, which began on October 1, that were about $90 billion apart, but never settled on a final figure. The fate of the sequester, scheduled under current law to continue through 2021, is uncertain in the next round of budget and debt ceiling negotiations.

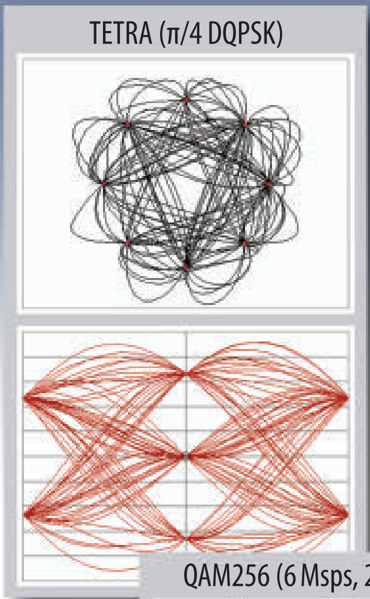
As Jim Fallon, president and CEO of Fallon and Associates LLC, advised last year in *Microwave Journal*, companies should, "keep looking for growth opportunities in defense and commercial markets by focusing on the technology trends and programs that will survive. Look for platform upgrades, electronic warfare systems, low cost SATCOM terminals, and IP based tactical radios, to name a few applications. Develop new customer relationships in emerging applications like UAV data links, autonomous vehicular guidance, and electronically scanned arrays." As the country asks lawmakers to trim waste from the budget, look for government dollars to flow to companies willing to help them get lean and mean. ■

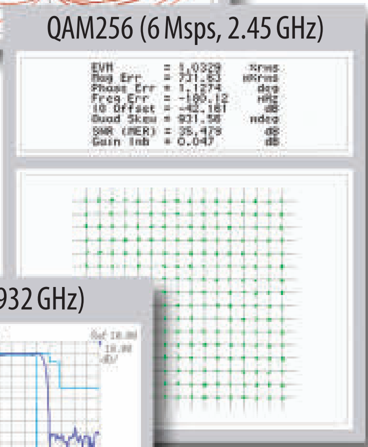


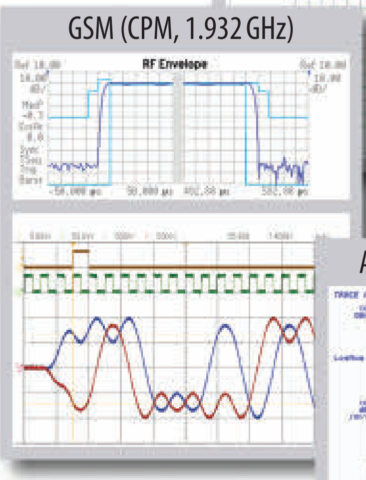
References

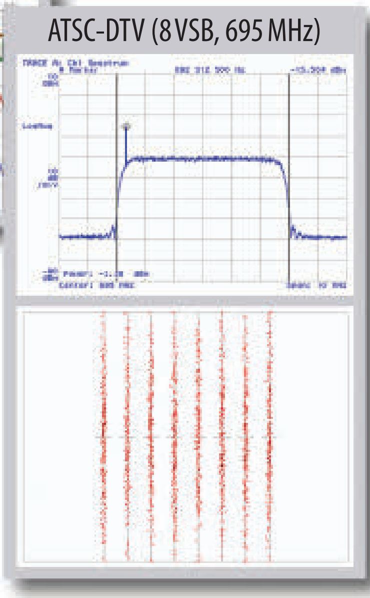
1. www.gpo.gov/fdsys/pkg/CPRT-113SPRT79796/pdf/CPRT-113SPRT79796.pdf
2. http://cbo.gov/sites/default/files/cbofiles/attachments/09-12-BudgetControlAct.pdf
3. www.csbaonline.org/publications/2012/08/analysis-of-the-fy2013-defense-budget-and-sequestration/
4. www.cbo.gov/sites/default/files/cbofiles/attachments/43907-BudgetOutlook.pdf
5. www.cbo.gov/publication/42754
6. www.cbo.gov/publication/43961
7. www.nam.org/Communications/Articles/2012/06/Defense-Cuts-Would-Cost-More-Than-1-Million-Jobs.aspx
8. http://secondtonone.org/sequestration-study-956181-small-business-jobs-at-risk#sthash.ARVMuhs4.dpbs
9. www.bea.gov/newsreleases/national/gdp/gdpnewsrelease.htm
10. http://articles.washingtonpost.com/2013-07-23/business/40861242_1_sequester-spending-cuts-big-defense-contractors
11. www.businessweek.com/news/2013-08-01/small-defense-contractors-bounce-back-as-u-dot-s-dot-cuts-concerns-fade
12. http://fedconnects.com/index.php/2012/08/knowledge-is-power-key-to-overcoming-sequestration-uncertainty/
13. www.microwavejournal.com/articles/20402-going-the-distance-with-end-to-end-ownership
14. http://comptroller.defense.gov/defbudget/fy2014/FY2014_Budget_Request_Overview_Book.pdf

Vector Signals at the touch of a button









- 2 GHz, 4 GHz & 6 GHz models
- Dual baseband arb generators
- Vector & analog modulation
- I/Q modulation inputs (300 MHz RF BW)
- ASK, FSK, MSK, PSK, QAM, VSB & custom I/Q
- Presets for GSM, EDGE, W-CDMA, APCO-25, DECT, NADC, PDC, ATSC-DTV & TETRA
- GPIB, RS-232 & Ethernet interfaces

The SG390 Series ***Vector Signal Generators*** — taking communications testing to a new level.

The SG390 series has outstanding features and performance: complete vector and analog modulation, dual baseband arb generators, I/Q inputs with 300 MHz RF bandwidth, low phase noise, and an OCXO timebase are all included.

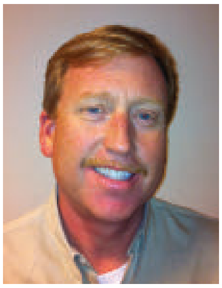
We've also made communications testing quick and easy — everything is available from the front panel of your instrument. Pulse shaping filters, TDMA gating signals, additive white noise, and event markers are all there. Use the built-in pattern or PRBS generators to create data, or upload your own symbol data. Map your symbols to any constellation and transmit at rates up to 6 Msps — it's that simple.

Pricing (U.S. list)

SG392 (2 GHz) ... $5,400
SG394 (4 GHz) ... $6,600
SG396 (6 GHz) ... $8,400

SRS Stanford Research Systems
Tel: (408)744-9040 • www.thinkSRS.com

GaN in Plastic: A Disruptive Technology



PAUL BEASLY AND DAMIAN MCCANN
MACOM, Lowell, MA

For radar and communication driven military applications, system designers are under continuous pressure to achieve the aggressive size, weight and power (SWaP) profiles that can help ensure a sustained, strategic battlefield advantage. But achieving higher power and smaller, lighter components using conventional silicon and GaAs-based power transistors is an ever mounting challenge. For these devices, limitations in component power density, breakdown voltage and thermal reliability are introducing increasingly problematic performance constraints, with significant implications for system reliability, ruggedness and functionality to meet new mission objectives.

This problem is impeding the evolution and proliferation of small form factor radar and communication systems optimized for mobile and airborne applications, particularly UAVs. In these domains, parallel advances in radar and sensor fusion innovation are driving greater operational autonomy, situational awareness and responsiveness for remote military personnel, vehicles and aircraft – which are critical advances to sustain strategic battlefield advantage.

Meanwhile, for sea-borne applications, momentum is gathering behind the development of a new generation of more versatile, multifunction radar and communication systems that consolidate large numbers of co-located antenna masts within a single streamlined, multifunction Active Electronically Scanned Array (AESA) aperture. This naturally reduces system size and complexity while enhancing battlefield performance and versatility.

Meaningful forward progress on these strategic initiatives hinges on the ability to develop and manufacture smaller, wider bandwidth, lighter and functionally more flexible power transistors that promote multifunction integration. What is needed in all of these cases is a new approach to power transistor design and packaging technology that provides greater overall power performance in a smaller form factor with the greatest possible ease of assembly.

ACHIEVING THE PROMISE OF GaN

The recent emergence of GaN-based power amplifiers is equipping radar system designers to achieve high-power operation using smaller power transistors while improving efficiency, frequency bandwidth and reliability. These new GaN-driven capabilities are yielding a new generation of more agile, ruggedized radar

Get it airborne with feature-packed hybrid switch matrices.

Is the lack of a lightweight, high power switch matrix keeping your antenna/ sensor system grounded? Aeroflex Control Components (ACC) can help.

Covering UHF through Ka band, ACC's broadband and multi-octave solutions are available in nearly limitless I/O configurations. They're housed in your choice of fully hermetic or non-hermetic packaging, and can be engineered to incorporate all your BIT, attenuation, filtering, amplification and conversion requirements.

With decades of hybrid chip and wire and SMT experience, you can count on ACC to achieve all your insertion loss, gain, signal output and size reduction goals.

Talk with an application engineer today.

732-460-0212
www.aeroflex.com/ACC

AEROFLEX
A passion for performance.

If we told you that changing your EDA environment was easy, would you do it?

Intercept offers a unified CAE/CAD design solution with RF models & simulation interfaces. Now at our lowest prices.

Take another look at our superior functionality:

REUSE BLOCK TECHNOLOGY
MULTI-BOARD, PANEL ARRAYS
ARTWORK PANELIZATION
LAYOUT DRIVEN DESIGN & PROTOTYPING
INTERFACES TO SIMULATION & ANALYSIS
BIDIRECTIONAL RF INTERFACES
AUTOMATIC DRAWING CREATION
DESIGN AUTOMATION
DFM + MANUF. RULE CHECKING
ARTWORK VERIFICATION

Contact us today at 1.800.444.9304 to learn more about our superior design solutions.

INTERCEPT
CELEBRATING 30 YEARS OF EDA SOFTWARE SOLUTIONS

www.intercept.com
Visit us at PCB Carolina, Oct. 23, Raleigh, NC

systems optimized for increasingly demanding performance and multifunction flexibility requirements.

The higher breakdown voltage performance of GaN semiconductor technology allows scaling to a higher operational voltage, which minimizes power loss, reduces power supply demand, allows for wideband impedance matching, enables system designers to use smaller energy storage capacitors and reduces current handling within the power supply system. High breakdown voltage significantly improves ruggedness under load mismatch conditions and allows for greater flexibility in signal wave-forms for multifunction roles. GaN-enabled power efficiency gains improve overall thermal performance, which provides greater flexibility in pulse and CW operational modes.

GaN semiconductor technology has clearly set a new standard in power performance for power transistors targeted at military radar and communication systems. Going forward, it is the implementation of this GaN technology – the packaging and assembly – that will require our focused innovation if we are to unlock the full benefits of GaN.

To date, most vendor approaches to applying GaN to power amplifiers have relied on packaging techniques found in earlier generation ceramic, flange-mount packaged devices like Si LDMOS and Si BJT. By replacing the silicon material in these packages with GaN, improvements in power density and efficiency have been achieved.

But GaN is not Si LDMOS or Si BJT, nor should it be thought of as a mere enhancement of a power semiconductor. GaN on SiC offers the chance to make a complete paradigm shift based on the fact it can dissipate heat better and run hotter more reliably than any other power semiconductor technology to date. The continued reliance on conventional ceramic packaging has not yielded meaningful reductions in component size or weight, or for that matter performance and cost – nor has it taken advantage of advances in commercial, surface-mount packaging technologies. Metal-ceramic based flange mount packages have a number of limitations compared to plastic, surface-mount packages, including larger size, manual assembly, higher cost, more challenging impedance matching and additional board manufacturing.

BENEFITS OF GaN IN PLASTIC PACKAGING

The landscape of the GaN power transistor market has shifted radically with the introduction of new GaN in plastic power transistors. Ideally suited for high-performance military radar applications, GaN in plastic-based power transistors defy the power, size and weight limitations of competing GaN-based offerings to enable a new generation of high-power, ultra-compact radar systems for use in mobile and/or multifunction battlefield electronics systems.

MACOM has demonstrated the benefits of GaN in plastic packaging technology with new GaN in plastic power transistors that scale up to 100 W – among the industry's highest power levels for this product category. Achieving this level of power performance requires sophisticated thermal dissipation techniques to ensure reliability that's comparable to conventional ceramic-packaged GaN-based offerings.

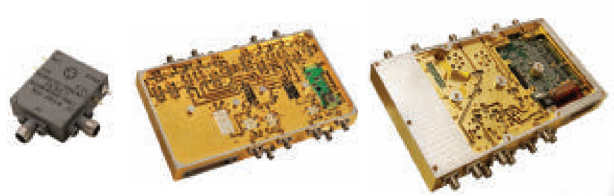
By optimizing the transistor die layout and using advanced heat sinking and die attachment methods, these GaN in plastic power transistors have demonstrated less than 115°C average junction temperature (80°C baseplate) for a pulsed power output of 93 W, using a 1 mS pulse, 10 percent duty cycle. These performance metrics have been verified using stringent thermal imaging testing methodologies.

These transistors operate at 50 V drain bias resulting in outstanding power density and performance, higher efficiency and smaller impedance matching circuits due to improved device parasitics. The high voltage operation also benefits overall system design with smaller energy storage capacitors and lower current draw.

GaN in plastic-based power transistors are also extremely lightweight compared to ceramic-packaged GaN-based offerings. Combined with significant size reduction in the external application solution and aggregated across the hundreds of power amplifiers within a typical modern military radar system, this can reduce overall system weight considerably. The resulting weight reduction ensures greater ease of movement for mobile radar systems.

Innovation **That Jams.**

Protecting our platforms and warfighters from radar-directed attack is the new front in modern warfare. And that requires flawless jamming and deception. Mercury's open architecture RF and microwave building blocks let you design these next-generation EW systems. These low-latency building blocks include Digital RF Memory (DRFM) components and Integrated Microwave Assemblies (IMAs). Best of all, they fit inside a rugged, compact enclosure to meet your specific requirements.



Visit us at Booth #124 at the AOC Annual Symposium to see our latest innovations

MERCURY SYSTEMS™

INNOVATION THAT MATTERS™

Visit mrcy.com/mwj and download our whitepaper: Leveraging DRFM Electronic Jammers for Deceptive Electronic Attack Systems

Copyright © 2013 Mercury Systems and Innovation That Matters are trademarks of Mercury Systems, Inc.

The first entries in MACOM's GaN in plastic power transistor product portfolio include 90, 50 and 15 W transistors, all of which are available in standard 3 × 6 mm DFN packaging. The devices can be mounted on PCBs via ground/thermal arrays. Internal stress buffers allow these devices to be reliably operated at up to 200°C channel temperature. All of these transistors are capable of operating at frequencies up to at least 3.5 GHz.

EASE-OF-ASSEMBLY EVOLUTION

The GaN in plastic approach also allows for ultra-small, fully matched, integrated module solutions. The next evolutionary step is to develop high gain power modules based upon the GaN in plastic power transistors for the L- and S-Band radar markets. These modules can be fully matched with two stages of high gain and are realized using surface-mount technology (SMT) assembly on a compact RF board. The GaN power transistors are assembled using standard reflow techniques and the module can be easily integrated into a radar system front end.

The ability to offer a full SMT solution using GaN combines the best of advanced military power technologies and high volume commercial manufacturing expertise. With this combination, it is possible to break through the current boundaries of SWaP and realize a new level of performance and capability in future radar systems.

FROM MILITARY TO THE MAINSTREAM

As mass production and deployment of GaN in plastic power transistors accelerates, we can expect this class of product to follow a commoditization trajectory that aligns with most other plastic-packaged products, both military and commercial. Manufacturing efficiency gains and cost of material reductions drive reduced production and product costs, which drive volume demand – a historical trend followed by many product types after they translate to lead-frame based plastic packaging.

This naturally leads to penetration into other markets. With the advent of low-cost GaN in plastic power transistors, we can envision this technology being deployed in government and commercial applications including centralized and remotely-based weather and early-warning radar systems, and even radar-driven automotive applications such as advanced driver assistance.

AESA technology itself has already extended beyond the military domain into commercial communication link equipment, and it will find its way into other non-military applications in the years ahead. The accelerating proliferation of AESA systems, which can integrate hundreds to tens of thousands of active RF elements, will contribute to the growing ubiquity of low-cost GaN in plastic power transistors – and vice versa.

Of course, the military domain is more sensitive to dual-sourcing requirements than the commercial domain, and dual-sourced GaN-based components have been hard to come by to date. But this too is changing. Dual-source supply chains for high-performance GaN devices are now a reality with the recent partnership between MACOM and Global Communications Semiconductors (GCS). This dual-source agreement – an industry first – unlocks one of the key remaining barriers to mainstream GaN market adoption by providing a secure supply chain.

NEW GENERATION OF HIGH-PERFORMANCE MILITARY RADAR SYSTEMS

Continued innovation in high-power GaN in space-saving plastic is enabling radar system designers to take full advantage of GaN technology and achieve new levels of power density while significantly reducing system size and weight. Utilizing sophisticated packaging and thermal management techniques, GaN in plastic power transistors, accompanied by industry small application solutions, are helping designers overcome challenging development hurdles and pioneer a new generation of high-performance, rugged radar systems for mobile and multifunction military radar applications that transcend the capabilities of systems based on conventional power transistors. ■

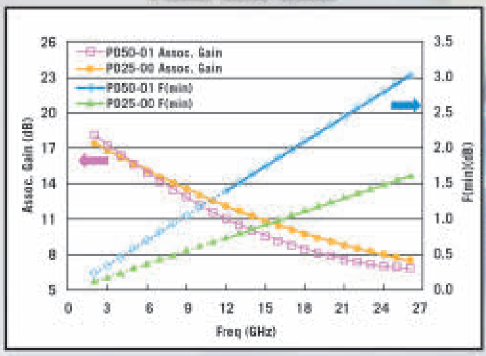
win SEMICONDUCTORS

Leading Global Communications

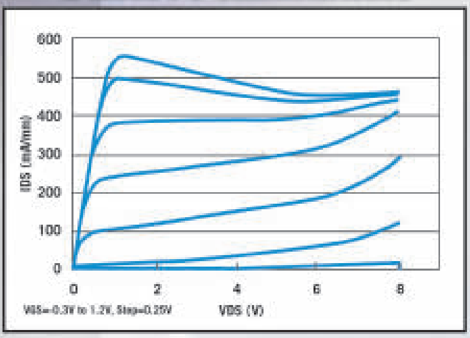
PD25-00 0.25μm E / D pHEMT

- 4th generation E/D PHEMT Technology
- High performance 0.25μm E-mode combined with latest generation 0.5μm D-mode switch
- E-mode device: Ultra low noise and high gain
- D-mode device: Compact layout and low Ron-Coff product

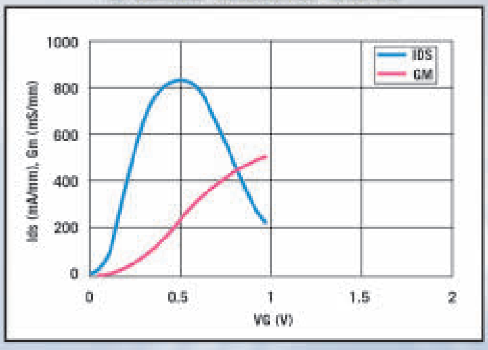
Fmin and Gain



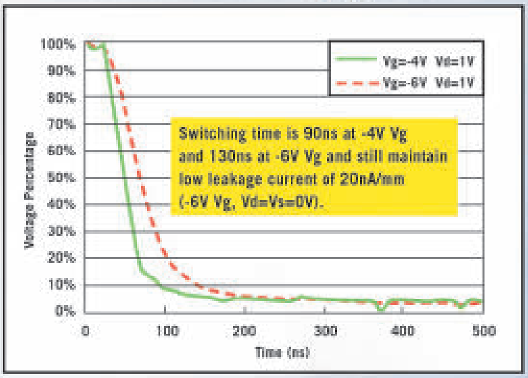
E-mode I-V Characteristics



E-mode Transfer Curve



D-mode Switching Speed



D-mode Device Performance

	PD50-01		PD25-00	
	Single	Triple	Single	Triple
Ron (ohm.mm)	1.9	3.7	1.3	2.2
Coff (fF/mm)	168	83	163	92
RonxCoff(ohm.fF)	316	310	209	198

DUT: NOF x UGW= 5 x 12μm

WIN SEMICONDUCTORS CORP.

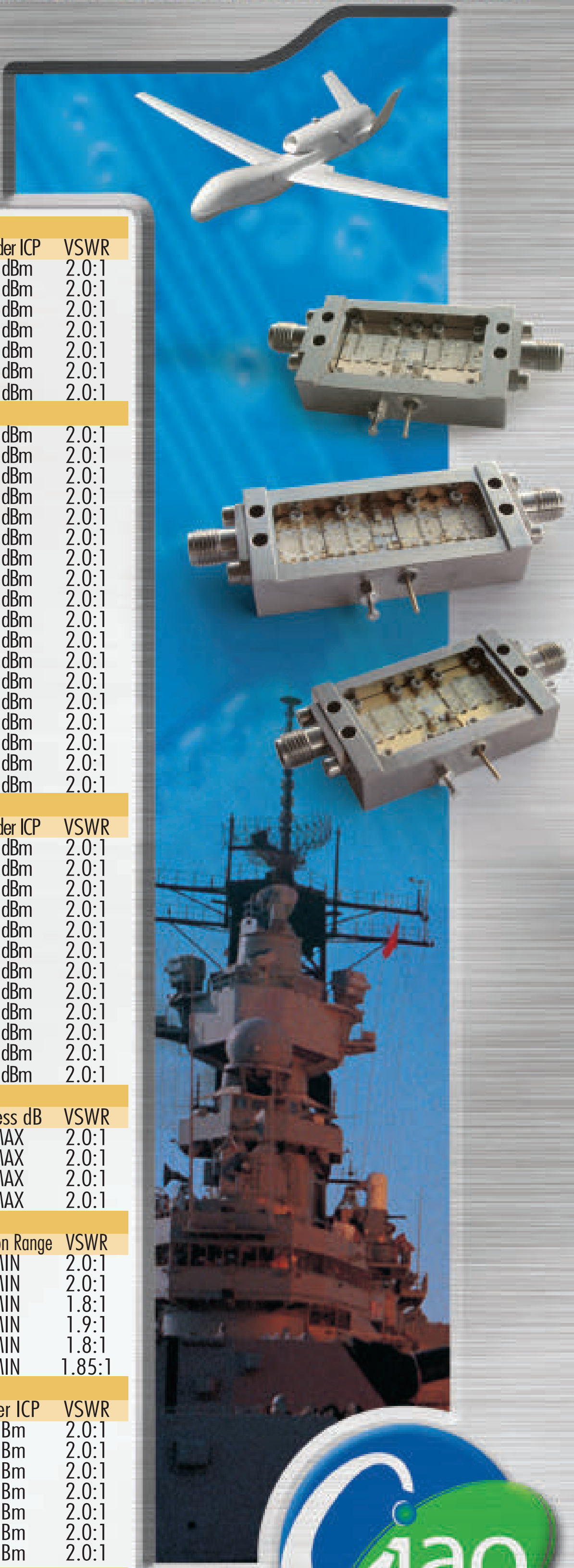
Tel:+886-3-397-5999 Fax:+886-3-397-5069 http://www.winfoundry.com

RF Amplifiers and Sub-Assemblies for Every Application

Delivery from Stock to 2 Weeks ARO from the catalog or built to your specifications!

- Competitive Pricing & Fast Delivery
- Military Reliability & Qualification
- Various Options: Temperature Compensation, Input Limiter Protection, Detectors/TTL & More
- Unconditionally Stable (100% tested)

ISO 9001:2000 and AS9100B CERTIFIED



OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

CIAO Wireless can easily modify any of its standard models to meet your "exact" requirements at the Catalog Pricing.

Visit our web site at **www.ciaowireless.com** for our complete product offering.

Ciao wireless

Ciao Wireless, Inc. 4000 Via Pescador, Camarillo, CA 93012

Tel (805) 389-3224 Fax (805) 389-3629 sales@ciaowireless.com

Boeing Advanced Super Hornet Demos Significant Stealth

During three weeks of flight testing the Advanced Super Hornet, Boeing and partner Northrop Grumman demonstrated that the fighter can outperform threats for decades to come with improvements that make the jet much harder for radar to detect and give it significantly more combat range.

Through 21 flights in St. Louis and Patuxent River, MD, that began August 5, the team tested conformal fuel tanks (CFT), an enclosed weapons pod (EWP), and signature enhancements, each of which can be affordably retrofitted on an existing Block II Super Hornet aircraft or included on a new jet.

"We continually insert new capabilities into today's highly capable, already stealthy Super Hornet, and the Advanced Super Hornet is the next phase of this technology evolution," said Debbie Rub, Boeing Global Strike vice president and general manager. "Boeing and our industry partners are investing in next-generation capabilities so warfighters have what they need when they need it, and so the customer can acquire it in a cost-effective manner."

Improvements to the aircraft's radar signature, including the enclosed pod, resulted in a 50 percent reduction compared with the U.S. Navy's stealth requirement for the current Super Hornet variant. The tests also showed that the CFTs increase the jet's combat radius by up to 130 nautical miles, for a total combat radius of more than 700 nautical miles.

Source: U.S. Navy photo by Mass Communication Specialist 3rd Class Nathan R. McDonald/Released

"Even though we added components to the aircraft, their stealthy, low-drag design will enhance the combat capability and survivability of the Super Hornet on an aircraft that has a combat-proven history launching and recovering from aircraft carriers," said Mike Wallace, the Boeing F/A-18 test pilot who flew the Advanced Super Hornet configuration.

The improvements will ensure that the Advanced Super Hornet outpaces enemy aircraft and defenses through 2030 and beyond, especially when that enemy tries to deny access to a specific area, such as skies over international waters near its assets.

Lockheed Martin's Latest Aegis Combat System Demonstrates Extended Line of Sight Capability

The latest Naval Integrated Fire Control-Counter Air (NIFC-CA) test marks the first test at sea, and the second consecutive time this year, where Aegis used remote data to successfully intercept a target. Using the Cooperative Engagement Capability (CEC) to interpret data from remote sources, Aegis launched a Standard Missile-6 (SM-6) missile from the USS Chancellorsville (CG-62) to intercept the target.

"The latest NIFC-CA test demonstrated how the Aegis Combat System has taken a significant step forward in increasing interoperability with remote systems to extend the distance that we can detect, analyze and intercept targets," said Jim Sheridan, director of U.S. Navy Aegis programs for Lockheed Martin. "We continue to use our advanced solutions to provide the Navy with the robust and reliable capabilities needed to defend our nation from sophisticated threats."

As a result of the successful NIFC-CA test, Aegis proved once again that it can transform and adapt to threats and address a changing defense landscape. The U.S. Navy and Lockheed Martin are committed to modernization programs for the Aegis Combat System on cruisers and destroyers to extend service life and provide new technologies to the ships and their crews. Ships receiving Aegis system upgrades will field Open Architecture and Commercial Off-the-Shelf technologies that will reduce total ownership costs and ensure military readiness for ongoing missile defense needs.

U.S. Army, Raytheon Achieve First Inflight Intercept of Low Quadrant Elevation Rocket

Raytheon Co. successfully intercepted and destroyed a low quadrant elevation (QE) 107mm rocket as part of the second series of guided test vehicle (GTV) flight tests of the Accelerated Improved Intercept Initiative (AI3) program. The intercept is a major test milestone before the U.S. Army live-fire engagements begin in September.

"Beginning only 18 months and one week ago, and with firm cost requirements, the AI3 interceptor project successfully engaged and destroyed an inflight rocket on a challenging, high-speed flight profile greatly enhancing the range of existing capabilities," said Michael Van Rassen, the U.S. Army's project director for Counter Rockets, Artillery and Mortars (C-RAM) and AI3. "The project used a system of systems approach that lowered risk and enabled an accelerated schedule by leveraging existing government components and off the shelf subsystems to expand the footprint of the protected area for our warfighters."

The AI3 Battle Element system includes: a Raytheon Ku Radio Frequency System (KRFS) Fire Control Radar, an Avenger-

Go to mwjournal.com for more defense news items

based AI3 launcher, a C-RAM command and control, Technical Fire Control, and the Raytheon AI3 interceptor missile.

After launch, the AI3 interceptor initially guided on inflight radio frequency (RF) data link updates from the Ku RF Sensor radar, which was tracking an inbound rocket target threat. The interceptor then transitioned to terminal guidance using the interceptor's onboard seeker and the illumination from the radar to guide the missile to within lethal range. The target was then detected using an active RF proximity fuze that determined the optimal detonation time for the warhead. With these measurements, the missile calculated the appropriate warhead burst time and defeated the incoming threat.

"This is a significant technical and performance milestone for the program and our team that met the Army's tight schedule and costs objectives," said Steve Bennett, Raytheon Missile Systems AI3 program director. "This second GTV demonstrated full integration of the AI3 Battle Element with the C-RAM command and control architecture against the threat target."

U.S. Army Awards Lockheed Martin $206M

The U.S. Army awarded Lockheed Martin $206 million in additional orders for the AN/TPQ-53 (Q-53), a long-range counterfire radar that provides soldiers with enhanced 360-degree protection from indirect fire.

This contract is for 19 Q-53 systems, formerly designated as EQ-36. To date Lockheed Martin has delivered 32 initial production systems to the U.S. Army and is currently producing an additional 33 systems, which were awarded in March 2012. This latest contract builds on those 33 systems currently in production.

"The Q-53 radar is helping to save the lives of U.S. forces through its exceptional performance in theater" said Lee Flake, program director for counterfire target acquisition radar programs at Lockheed Martin's Mission Systems & Training business. "Deployed since 2010, we have listened to feedback from our soldiers to ensure the system meets operational demands and is evolving to stay ahead of global threats."

Mounted on a five-ton truck, the Q-53 can be rapidly deployed, automatically leveled and remotely operated with a laptop computer or from a fully equipped climate-controlled command vehicle.

Lockheed Martin won the competitive development contract for the Q-53 radar – then known as EQ-36 – in 2007. Responding to urgent need statements from theater and following early program successes, the Army awarded the company an accelerated contract for 12 initial production systems in July 2008 and a contract with options for an additional 20 systems in April 2010. The Army began deploying Q-53 systems to combat in Iraq and Afghanistan in fall 2010. The March 2012 contract for 33 systems was a combination of low-rate initial production orders one and two.

THE EFFICIENT RF ALL-ROUNDER –

NSG 4070 – MORE THAN A GENERATOR

The NSG 4070 is a multi-functional device for carrying out tests to accompany development and conformity testing in accordance to IEC/EN 61000-4-6 and several automotive standards. Anyone who spends a considerable amount of time on test station calibration, connecting EUT monitors or documentation can now carry out immunity testing in a much more efficient manner with the 3rd generation of NSG 4070. Additional highlights: EUT monitoring results can be annotated during testing with the output incorporated into the report.

NSG 4070 at a glance:

- **Solution for IEC/EN 61000-4-6 and automotive BCI**
- **Frequency range 9 kHz to 1 GHz**
- **Easy to operate via front panel or Windows Software**
- **Calibration data displayed in graphical or table form**
- **Amplifier-saturation-check**

Teseq Inc. Edison, NJ USA
T+1 732 417 0501 www.tesequsa.com

a TESEQ Company

MILMEGA
a TESEQ Company

TESEQ
Advanced Test Solutions for EMC

Reactel, Incorporated

Reacting First to All Your Filter Needs.

GPS FILTERS

AIRBORNE

Since 1979, Reactel has been a global leader in the design and manufacture of filters for military and commercial applications.

Our versatility and expertise is reflected in the variety of units we are providing for GPS systems.

Small and lightweight, rugged for high power or anything in between; let our engineers design a unit which is the right fit for your application.

- Bandpass
- Notch
- Multiplexers
- Dual Filters
- L1, L2, L5 Bands

PORTABLE

MOBILE

COMMERCIAL

Download a copy of our new full line catalog today!

8031 Cessna Avenue • Gaithersburg, Maryland 20879 • Phone: (301) 519-3660 • Fax: (301) 519-2447
For general inquiries, please email reactel@reactel.com • http://twitter.com/reacteljim • Go online to www.reactel.com to download your Reactel catalog today.

EDI CON 2014
Electronic Design Innovation Conference
电子设计创新会议

April 8-10, 2014
Beijing International Convention Center
Beijing, China

Where the Experts Speak...

The leading technical conference and exhibition developed by and for the RF, microwave, EMC/EMI and high speed electronics industry returns to Beijing. Share your expertise with fellow technologists as a speaker in the EDI CON technical program.

DEADLINE EXTENDED: NOVEMBER 15TH

CALL FOR PAPERS

Topics

- Design
- Measurement & Modeling
- Systems Engineering
- Commercial Applications

Submit your paper online
For details go to:
www.ediconchina.com/CallForPapers.asp

Host Sponsor:
Agilent Technologies

Diamond Sponsor:
ROHDE&SCHWARZ

Corporate Sponsor:
AWR
NATIONAL INSTRUMENTS

Gold Sponsors:
Anritsu
CST
Mini-Circuits
RichardsonRFPD An Arrow Company
SPIRENT

Organized by:
horizon house
ACT
Microwave Journal

www.EDICONCHINA.com

ESiP Research Enables Miniaturization of Microelectronic Systems

The largest research project in Europe for researching and developing highly integrated system-in-package solutions has been successfully completed. The Efficient Silicon Multi-Chip System-in-Package Integration (ESiP) project partners have worked out future system-in-package solutions that are more compact and reliable. They have also developed methods for simplifying analyses and tests.

Under management of Infineon Technologies, 40 research partners – microelectronics companies and research institutions – from a total of nine European countries worked together. ESiP was funded by public authorities of all nine countries and the ENIAC Joint Undertaking.

Technologies for combining chips in SiP packages and manufacturing them were developed and procedures for measuring reliability and methods, as well as equipment for failure analysis and testing. Basic technologies were developed that enable the integration of various types of chips in the smallest volume of an SiP package – for example, customer-specific processors with the latest CMOS technologies, light-emitting diodes and DC-DC converters, MEMS and sensor components and passive components such as miniaturized capacitors and inductors. These compact SiP solutions will find application in, for example, electric vehicles, industrial applications, medical equipment and communications technology.

"…ESiP research enhances Europe's position…"

"The successful ESiP research enhances Europe's position in the development and manufacture of miniaturized microelectronics systems," said Dr. Klaus Pressel, ESiP project head. "With the ESiP findings we will be able to further miniaturize and improve microelectronic systems. We have developed new manufacturing processes and materials for SiP solutions along with methods for testing them, running a failure analysis on them and evaluating their reliability."

New Collaboration Between Plextek and Hethel

Product innovation and design consultancy Plextek Consulting has formalised a partnership with Hethel Innovation to stimulate a collaborative innovation process and champion the cross-pollination of technology ideas. Rather than waiting for light-bulb moments, true innovators today look at other sectors and apply existing technologies in unexpected ways. By working together, Plextek Consulting and Hethel Innovation hope to nurture an ecosystem that creates opportunities for cross-sector research and engagement that deliver a competitive advantage to both organisations' customer base and the wider UK technology industry.

"The best ideas require information, not just inspiration…"

Multi-sector product design and development consultancies like Plextek are 'innovation hubs' where the transfer of sector skills happens under a single roof. Hethel Innovation and its innovation hub Hethel Engineering Centre are dedicated to supporting the growth and success of high performance engineering and manufacturing companies. Its remit involves developing new ways to exploit the innovation potential in businesses and harness the innovation power of the private and public sectors.

"Using existing technology and applying it differently can be a cheaper and easier way to market than 're-inventing the wheel.' However a lack of recognition and awareness of these processes means that many entrepreneurs are looking for innovation in the wrong places and pursuing new product design ineffectively," commented Dr. Jon Lewis, chief innovation officer at Plextek Consulting.

"The best ideas require information, not just inspiration, and this information should be drawn from a much wider pool of sector experience. Partnering with Hethel Innovation creates a fantastic collaborative platform to engage with other public and private business and inspire true innovation, breakthrough technologies and ideas for our customers."

QinetiQ Expands UK UAS Environment

QinetiQ and Llanbedr Airfield Estates (LAE) have signed an agreement to further develop the Wales Unmanned Aircraft System (UAS) Environment, incorporating Llanbedr Airfield in North West Wales as an operating centre which further enhances the UK's reputation in facility and capability provision for UAS operations.

The QinetiQ and LAE 'Teaming Agreement,' supported by Welsh Government, is the catalyst to delivering extended UK UAS operating capability in early 2014 and enables UAS programme development in support of both civil and defence related opportunities. The regeneration of Llanbedr Airfield as an operational centre for unmanned aviation complements the existing infrastructure and services currently being delivered by QinetiQ's West Wales UAV Centre (WWUAVC) and affirms the Wales UAS Environment as a unique capability dedicated to accelerating the growth of the UAS industry in the UK and beyond.

Building on the existing capability developed and delivered by the QinetiQ WWUAVC, Llanbedr will provide enhanced airfield services and access to the dedicated infrastructure and airspace already in place through recent regional government investment. Combining the Llanbedr

Go to mwjournal.com for more international news items

Airfield infrastructure with the experience, knowledge and facilities already available through the QinetiQ WWUAVC presents access to world leading test and evaluation, demonstration and training capabilities, as well as increased options for permanent operations for future civil UAS opportunities.

Paul Hearn, air division strategy director, at QinetiQ, said, "We are delighted to sign this agreement and be at the forefront of UAS growth in the UK. With QinetiQ's UAS operations and facility provision expertise, alongside LAE and the support of the Welsh Government, we look forward to further expanding UK UAS capability and consolidating the UK's ability to remain at the forefront of UAS development."

Cassidian's TRSS Naval Radar Thinks Small

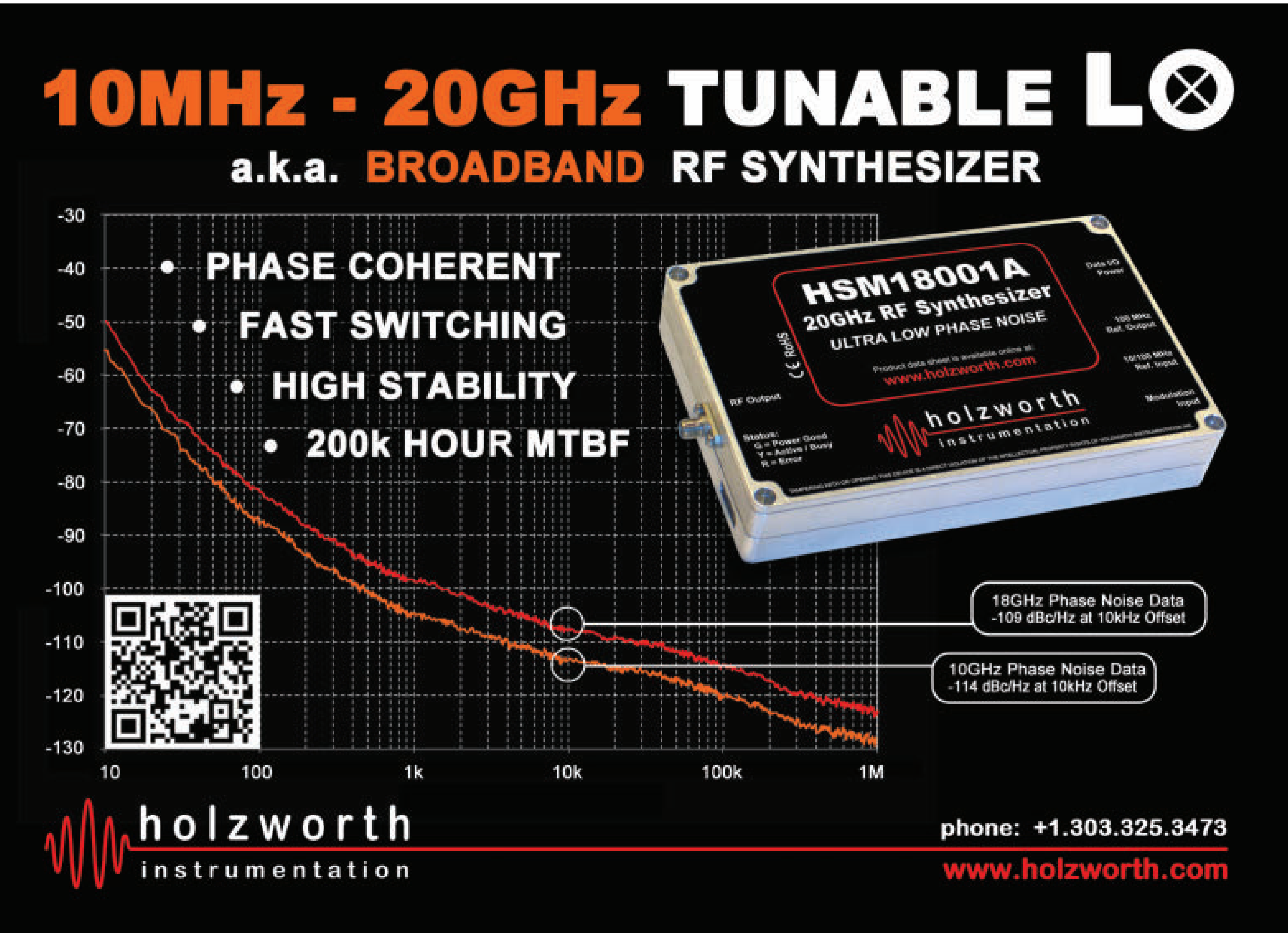
Cassidian, the defence division of EADS, has introduced a new naval X-Band radar optimized for the detection of extremely small objects and countering asymmetric threats. Based upon the latest Active Electronically Scanning Array (AESA) radar technology, the new Tactical Radar for Surface Surveillance (TRSS) substantially increases the detection capabilities, and thus the protection level, of navy ships and coastguard vessels.

"Our new radar constitutes a quantum leap in terms of detection capabilities," said Elmar Compans, head of sensors & electronic warfare at Cassidian. "It provides high-performance surveillance not only at sea but also over land which makes it unique in the market."

TRSS with its low weight, power consumption and space requirements makes the AESA technology now affordable for small and medium-sized vessels. This is beneficial particularly to ships operating in littoral waters which previously could not accommodate radars at all or had to use conventional mechanically rotating models. TRSS is able to detect and distinguish small objects precisely at close ranges, e.g., individual swimmers. These features allow operators an optimal overview of the situation, e.g., against terrorist attacks, and additionally enable operators to monitor movements on land.

> *"…a quantum leap in terms of detection capabilities…"*

AESA technology and electronic beam steering enables the radar to fulfil several tasks at the same time while increasing detection capability substantially. This detection performance derives from a multitude of Cassidian's transmit and receive modules, based on state-of-the-art technology. The technology applied holds unique electronic characteristics such as high power added efficiency and allows for very efficient industrial production processes.



TINY TOUGHEST MIXERS UNDER THE SUN

Rugged, tiny ceramic SIM mixers *from* $4.95 *ea. qty. 1000* offer unprecedented wide band, high frequency performance while maintaining low conversion loss, high isolation, and high IP3.


0.2" x 0.18"

Over 21 models IN STOCK are available to operate from an LO level of your choice, +7, +10, +13, and +17 dBm. So regardless of the specific frequency band of your applications, narrow or wide band, there is a tiny SIM *RoHS* compliant mixer to select from 100 kHz to 20 GHz. Built to operate in tough environments, including high ESD levels, the SIM mixers are competitively priced for military, industrial, and commercial applications. Visit our website to view comprehensive performance data, performance curves, data sheets, pcb layouts, and environmental specifications. And, you can even order direct from our web store and have it in your hands as early as tomorrow!

Mini-Circuits...we're redefining what VALUE is all about!

U.S. Patent # 7,027,795 *RoHS compliant*

Mini-Circuits®

www.minicircuits.com P.O. Box 35166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

428 rev J

FLAT GAIN WIDEBAND *amplifiers*

flatness from ±0.7dB across 0.1-6 GHz IP3 up to 38 dBm

NEW!

***Free X-Parameters* are now included with our GVA-62+ and GVA 63+ MMIC amplifiers.** These MMICs are right-on for high performance base stations, portable wireless, LTE and cellular, CATV/DBS systems, MMDS, and wireless LANs. They make excellent gain blocks for almost any 50Ω circuit. DC power as low as 5V/69 mA delivers a typical output power of 18 dBm, unconditional stability, and built-in ESD protection, all with no external matching components required.

Visit minicircuits.com for detailed technical specifications and performance data, **free X-Parameters models**, export info, additional pricing, real-time availability, and everything else you need to make your selection today – for delivery as soon as tomorrow!

Model	Freq. Range (MHz)	Gain (dB)	P_{OUT} (dBm)	Price $ ea. (Qty. 20)
GVA-62+	10-6000	15	18	0.99
GVA-63+	10-6000	20	18	0.99

Mini-Circuits®

www.minicircuits.com P.O. Box 35166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

505 rev B

Half of New Vehicles Shipping in North America to Have Driverless, Robotic Capabilities by 2032

In North America, the first driverless vehicles will appear in the beginning of the next decade, evolving to more than 10 million robotic vehicles shipping in 2032.

"While the technological feasibility of autonomous vehicles is being demonstrated by Google, Audi, Volvo, Bosch, and Continental, obstacles such as high costs and lack of legislation remain. On the other hand, the benefits of autonomous vehicles in terms of safety, cost savings, efficiency, and positive impact on the economy, are driving research and development efforts globally. With ADAS-type assistance features already being implemented on a wide scale, the next phase of autonomous Co-Pilot type vehicles will materialize in this decade. Fully autonomous, self-driving, robotic vehicles will appear 10 years from now," says VP and practice director Dominique Bonte.

> *"Fully autonomous, self-driving, robotic vehicles will appear 10 years from now…"*

The disruptive effects of autonomous driving are only just being discovered and its transformative impact on the auto industry and society as a whole will be huge with car sharing and declining vehicle ownership being two of its main exponents.

Autonomous driving technology represents a long term vision and forms a framework for automotive strategy development. The current focus on passive safety functionality, such as emergency calling, integrated smartphone-based infotainment, advanced HMI addressing driver distraction, and UBI will become less relevant as the gradual move toward active safety and automation renders driver-centric features at least partially redundant. This will require changing attitudes from governments favoring V2X mandates and autonomous driving legislation and subsidization over eCall mandates, HMI guidelines, and banning portable devices.

Hybrid Indoor Location to Dominate Billion Unit Smartphone Market

Apple's acquisition of WiFiSLAM has brought smartphone indoor location technologies to the fore. With over 1 billion new smartphones forecast to utilize indoor location technologies in 2018, there are still significant opportunities for companies with the right technologies and strategies.

In ABI Research's latest Location Technology report, "Smartphone Indoor Location Technologies," it has forecast the adoption of different indoor location technologies, and the companies best placed to be successful. "We see a significant trend towards hybridization, with Wi-Fi, BLE and sensor fusion vita," commented senior analyst, Patrick Connolly. "By 2014, hybrid solutions will have already surpassed standalone indoor location technologies on smartphones, with Wi-Fi and sensor fusion hybrid solutions reaching over 900 million units in 2018. Longer term, technologies around optical light, object recognition and LTE-direct are all forecast to offer differentiation."

Practice director Dominique Bonte added, "We are already seeing start-ups pivot out of this space, but there is still huge opportunity for partnerships/acquisitions with major Android handset vendors, carriers and large application developers. Clearly Google is developing its own Wi-Fi indoor location solution; however, it may well open up its indoor location framework, enabling the market to expand much more rapidly. For IC vendors, with access to the hardware abstraction layer, indoor location innovation is vital for future socket wins."

Interactive Security to Reach $1.6 Billion in Western Europe by 2018

Strategy Analytics' research and analysis of the market for interactive security in Western Europe and the U.S. concludes that a robust market is developing to expand home security beyond consumers who traditionally subscribe to such services. Analysis of the $6 billion market for home security in Western Europe points to a dramatic shift in spending from traditional to interactive security with its remote monitoring and control capabilities. Home security market leader Securitas Direct launched its Verisure platform and SFR, Swisscom and others introduced services to capitalize on the opportunity. Security with home automation capabilities will hit $1.6 billion and account for over 26 percent of total security revenues in the region by 2018 according to Strategy Analytics' Smart Home Strategies (SHS) advisory service report, "Interactive Security: Market Outlook and Competitive Landscape." In the U.S., interactive security will hit $10 billion and account for over 40 percent of total security revenues by 2018.

"The home security market is larger in the North America than Western Europe, but we've detected robust interest and willingness to pay for professionally monitored security, as well as remote monitoring and control in Western Europe," commented Bill Ablondi, director, Smart Home Strategies advisory service and author of the report. "However, the picture is different for remote, self-monitoring and control. The Western European market will hit $2.9 billion by 2018, higher than the $2.7 billion we project for the U.S. market."

MSS Operators Generating Revenue of $1.5 Billion in 2012

According to Euroconsult, the leading global consulting firm in the space sector, the active MSS terminal base grew at a CAGR of 10 percent over the past five

Go to mwjournal.com for more commercial market news items

years with over 2.9 million active MSS terminals deployed on a global basis in 2012. Revenues generated by the six active MSS operators stood at around $1.5 billion in 2012. The industry remains very concentrated with the leading three operators, Inmarsat, Iridium and Thuraya still accounting for close to 90 percent and Inmarsat alone having a market share of 55 percent.

"MSS wholesale service revenues grew at around 5 percent in 2012, strongly driven by MSS broadband as well as by the low-data-rate machine-to-machine (M2M) devices," said Wei Li, senior consultant at Euroconsult. "M2M devices account now for more than half of total MSS terminals, however due to their much lower APRU levels they only accounted for ~13 percent of wholesale service revenues."

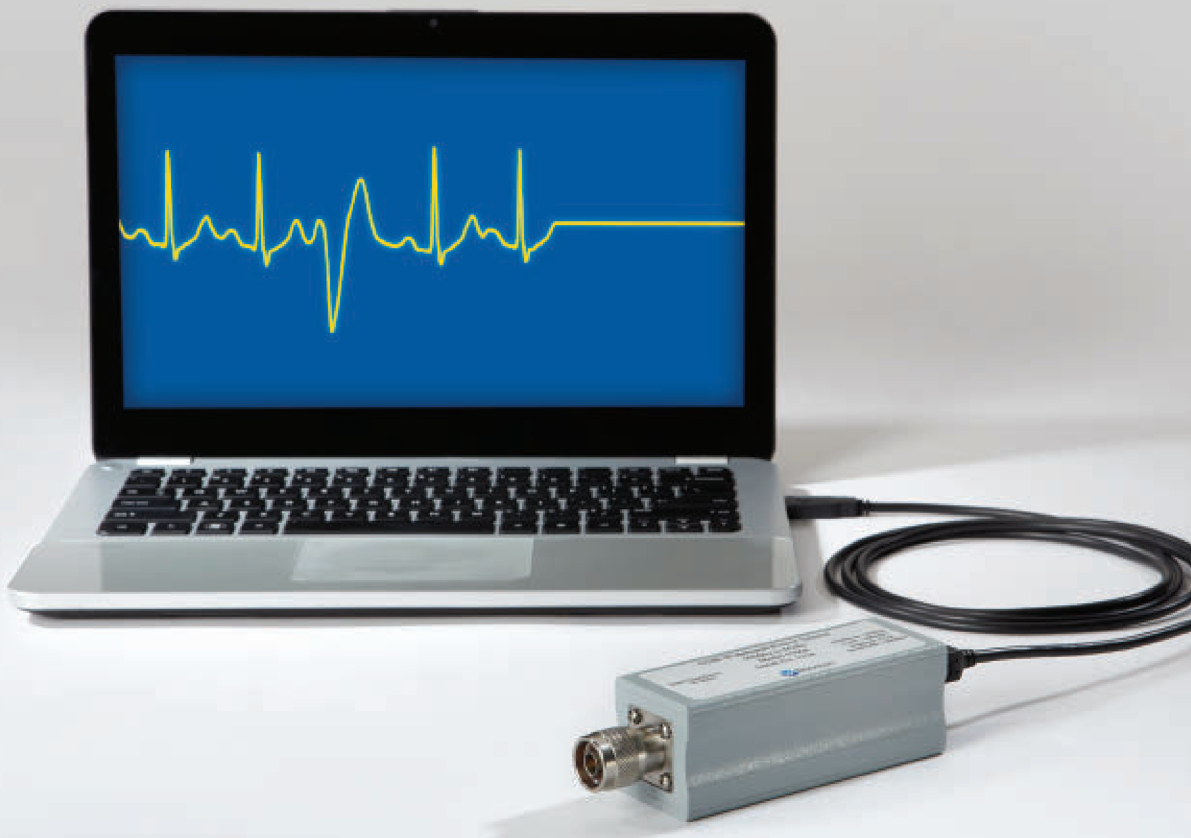
Troop withdrawal, Ku-Band VSAT competition and the anticipated migration toward new generation Global Xpress Ka-Band services will limit the revenue growth potential for the L-Band business in the next decade. Nevertheless, the bulk of MSS customers will remain satisfied with the L-Band business, and a range of emerging applications are entering into a fast growing phase for the next 10 years.

Overall the MSS sector has been strongly diversifying its product and service portfolio over the past years to reach an increasing number of addressable markets including the maritime, aeronautical and land-mobile market. More enhanced MSS products will become available once MSS operators have completed their next generation satellite systems. While Globalstar has already launched its 2nd generation satellite constellation in 2013, and after Inmarsat's launch of its Alphasat satellite in July 2013, Orbcomm is expected to launch its 2nd generation constellation in 2014 and Iridium over 2015-17.

> *"The market is likely to remain dominated by North America, but we also see strong growth in emerging markets, notably in Asia…"*

Looking forward, Euroconsult forecasts that the MSS market will grow at an annual rate of 12 percent in number of terminals from 2.9 million in 2012 to close to 9.4 million active terminals by 2022. Wholesale service revenues are projected to grow at a 10 year CAGR of 5 percent over 2012 to 2022. "The market is likely to remain dominated by North America, but we also see strong growth in emerging markets, notably in Asia," concluded Li. "Land should be the largest market segment by 2022 with over $1 billion in wholesale service revenue, while the aeronautical segment will be the fastest growing vertical market in terms of revenue, with double-digit growth in service revenue over the coming decade."

Missing a Pulse Can Be Deadly.



The Smartest, Fastest and Only Real-Time USB Peak Power Sensor.

Don't fall victim to conventional power measurement techniques that will leave you missing valuable data - we capture every pulse with no missed glitches. The new **55 Series** delivers unsurpassed speed and accuracy for the most demanding RF power measurements thanks to Boonton's **Real-Time Power Processing™** technology. With this revolutionary technique, all processing steps take place in parallel, guaranteeing gap-free signal acquisition and reliable capture of all transients, dropouts or interference.

The new Boonton **55 Series** delivers real results no one else can see.

- Real-Time Power Processing™ for gap-free analysis
- 100 MSa/sec SUSTAINED sample rate is world's fastest
- 10 GSa/sec effective rate for superb waveform fidelity
- <5 ns risetime and 70+ MHz video bandwidth
- 100 ps time resolution for enhanced trigger stability
- Triggered acquisition speeds over 40,000 sweeps/sec
- Capture and analyze data more than 100x faster than conventional power sensors

For more information visit us at boonton.com or call +1 973-386-9696.

Watch measurements come alive with **Real-Time Power Processing™**

Taking Performance to a New Peak.

Wireless Telecom Group
Boonton Microlab Noisecom

Boonton

Around the Circuit

Laura Glazer, Staff Editor

MERGERS & ACQUISITIONS

Microsoft Corp. and **Nokia Corp.** announced that the boards of directors for both companies have decided to enter into a transaction whereby Microsoft will purchase substantially all of Nokia's Devices & Services business, license Nokia's patents, and license and use Nokia's mapping services. Under the terms of the agreement, Microsoft will pay EUR 3.79 billion to purchase substantially all of Nokia's Devices & Services business, and EUR 1.65 billion to license Nokia's patents, for a total transaction price of EUR 5.44 billion in cash. Microsoft will draw upon its overseas cash resources to fund the transaction. The transaction is expected to close in the first quarter of 2014.

Verizon Communications Inc. announced that it has entered into a definitive agreement with **Vodafone Group Plc.** to acquire Vodafone's U.S. group with the principal asset of 45 percent of Verizon Wireless for $130 billion, consisting primarily of cash and stock. Verizon expects the transaction at close to be immediately accretive to the company's earnings per share (EPS) by approximately 10 percent, without any one-time adjustments. The transaction is expected to close in the first quarter of 2014.

Molex Inc. announced that it has entered into a definitive agreement to be acquired by **Koch Industries Inc.** Under the terms of the agreement, Koch Industries will acquire all of Molex's outstanding shares, including the Common Stock (MOLX), the Class A Common Stock (MOLXA) and the Class B Common Stock, for $38.50 per share in cash, for a total equity value of approximately $7.2 billion. At the close of the transaction, Molex will become a standalone subsidiary of Koch Industries and will continue to be operated by the company's current management team. Molex will retain the company name following the transaction.

TriQuint Semiconductor Inc. announced that it has acquired **CAP Wireless** (Newbury Park, CA) and its patented Spatium™ RF power combining technology that replaces traveling wave tube amplifiers (TWTA) in communications and defense systems. The acquisition leverages TriQuint's position as a GaN pioneer and CAP Wireless' high power RF solid state amplifier system expertise. The combined company now offers a wider selection of high power/high frequency products. TriQuint is continuing operation of CAP Wireless product sales and contracts while it develops new devices based on Spatium technology using TriQuint GaN and GaAs MMIC amplifiers.

Renaissance closed on a stock purchase agreement with **LEC Acquisition LLC** and **K Acquisition LLC**, both of DE. LEC Acquisition LLC owns 99 percent of Renaissance, and in turn is majority owned and controlled by Southvest Funds VI LP. Southvest Funds VI is in turn controlled by Gen Cap America, a private investment firm headquartered in TN. The company's new name is now **Renaissance Electronics & Communications LLC**. All operations, including manufacturing, will remain unchanged in its Harvard, MA facility, and it is anticipated that the change in ownership will be seamless for customers. Its subsidiary, **HXI LLC**, will also remain unchanged as part of the Harvard, MA facility.

COLLABORATIONS

SK Telecom and **Rohde & Schwarz** announced that they have signed a memorandum of understanding (MOU) on joint research and development of next-generation antenna technologies. Under the MOU, SK Telecom and Rohde & Schwarz will work together to create a test bed for AAS, a core technology in next-generation antenna systems, for performance verification. Under this agreement, the two companies will also conduct research and development for next-generation antenna system equipment. Rohde & Schwarz will provide SK Telecom with signal generators (R&S SMW200A, R&S SGS100A) and a radio network analyzer (R&S TSMW).

Peregrine Semiconductor Corp. and **LG Electronics** announced they have teamed up to develop the high-performance antenna tuning design solution in the LG Optimus G Pro smartphone that was recently introduced to the Korean market. Peregrine's DuNE™ technology optimizes the performance of the main antenna by bringing the best of what its UltraCMOS® and DuNE technologies offer — namely, optimized handset efficiency, data rate, call integrity and battery life. By enabling one antenna to more efficiently cover multiple frequency bands, the DuNE-based tuning solution enables the Optimus G Pro to support a subset of the more than 40 frequency bands available with 4G LTE.

DuPont Circuit & Packaging Materials and **IQLP LLC**, a division of Interplex Industries Inc., announced their ongoing efforts to further develop and refine liquid crystal polymer (LCP) thin-film technology for use in high-speed circuit applications. The development efforts are being conducted pursuant to a joint development agreement and a license agreement previously entered into by the parties.

The **NGMN Alliance** officially welcomes **BT**, **SingTel**, **Tele2**, **Turkcell**, **VimpelCom**, **Broadcom** and **University of Toronto**, which have all recently joined NGMN. With these new partners, the NGMN Alliance membership base now comprises 22 global mobile network operators, 33 major telecom vendors and 12 international research institutions.

To prepare for the growing number of smartphone users in Thailand, **Real Future**, a subsidiary of True Corp. Plc under the True Mobile Group, has chosen **Ericsson** as a key supplier to expand its mobile broadband network in Thailand.

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

HPXO series

High Performance Crystal Oscillators

Model	Frequency (MHz)	Output Power dBm (typ.)	Harmonics dBc (Typ.)	Frequency Stability Over Temp. (Typ.)	Bias Voltage VDC (Typ.)	Phase Noise (dBc/Hz) [Typ.]		
						@100 Hz	@1 kHz	@10 kHz
HPXO100	100	+15	-35	±0.2 ppm	+12	-140	-162	-183
HPXO125	125	+15	-35	±0.2 ppm	+12	-140	-160	-183

RoHS

FEATURES:

- *Excellent Performance*
- *Oven / Voltage Controlled*
- *Ultra Low Phase Noise*
- *High Stability*
- *Standard Compact Package*
- *Low-G-sensitivity*

Call Factory For Your Specific Requirement

SYNERGY® MICROWAVE CORPORATION

Phone: (973) 881-8800 | Fax: (973) 881-8361
E-mail: sales@synergymwave.com
Web: WWW.SYNERGYMWAVE.COM
Mail: 201 McLean Boulevard, Paterson, NJ 07504

This expansion will allow the True Mobile Group to offer their 21.5 million subscribers with improved mobile broadband experiences based on HSPA and LTE technologies.

ACHIEVEMENTS

Emerson Network Power, a business of Emerson and global leader in RF, microwave and optical connectivity solutions for the delivery of voice, video and data, announces the Occupational Health and Safety Assessment Series (OHSAS) 18001:2007 certification at their Chelmsford, UK facility.

Isola Group S.a.r.l. announced that it has become a full member of the Electronic Industry Citizenship Coalition (EICC). Isola has been an applicant member of the EICC since July 2011. The EICC is a collaboration of leading electronics companies that promotes an industry code of conduct to collectively address issues of social, ethical and environmental concerns in the industry.

AeroVironment Inc. announced that a recent outdoor test flight of a solar-powered prototype version of the company's proven Puma AE™ small unmanned aircraft system (UAS), operating with the company's newest long-endurance battery, lasted 9 hours, 11 minutes – significantly longer than the flight endurance of a small UAS being used in the field today. AeroVironment is working with Alta Devices, a Sunnyvale, CA company that provides flexible, portable power that can be embedded into any other material, in the development of the solar Puma AE.

Cassidian has developed a flexible airborne ground surveillance radar, which can be deployed on a variety of manned and unmanned platforms for the detection of ground and sea targets. As part of a major flight test series carried out from the German air base in Hohn, Cassidian's SmartRadar showed record detection performance, now including various operating modes for maritime surveillance. This success confirms Cassidian's concept of a software-defined sensor, which can be used for different surveillance tasks while only requiring minor modifications.

CONTRACTS

Harris Corp. has received authorization from the **Federal Aviation Administration** to begin work on the seven-year, $150 million Data Communications Network Services (DCNS) element of its Data Communications Integrated Services (DCIS) program. DCNS will help to transition U.S. air traffic control from primarily analog voice communications to digital data connectivity — significantly increasing the efficiency and safety of the nation's air traffic control system. Under DCNS, Harris will provide the terrestrial circuits and very high frequency data links that connect ground-based air traffic controllers and airborne flight crews.

Mercury Systems Inc. announced that its Mercury Defense Systems subsidiary has received a $2.3 million delivery order from the **U.S. Navy** for advanced Digital RF Memory (DRFM) jammers to support both U.S. Navy and U.S. Air Force requirements. The order is part of the firm-fixed-price, indefinite delivery/indefinite quantity (IDIQ) time and material contract award worth up to $44.4 million originally received by KOR Electronics (now Mercury Defense Systems) in March 2010, which has been recently extended by the U.S Navy for an additional 63 units for a total contract value of $56.7 million. All other terms and conditions remain unchanged from the original contract award.

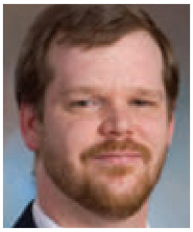
Comtech Telecommunications Corp. announced that its Santa Clara, CA-based subsidiary, **Comtech Xicom Technology Inc.**, has received an additional $1.4 million in orders to supply solid-state high-power amplifiers to a military integrator. The orders included X-Band, C-Band and Ku-Band SSPA products for use in highly mobile satellite communications (SATCOM) systems providing voice, data, video conferencing, internet and high resolution video connectivity for military forces deployed worldwide.

FIRST RF Corp. announced that it has been awarded 12 Small Business Innovative Research (SBIR) Phase I contracts from the DoD 13.1 competition. The company earned 10 Air Force and two Navy SBIR Phase 1 projects. These 12 awards bring the company's total SBIR wins to 77 Phase Is, 44 Phase IIs, several Phase 2.5 and numerous Phase IIIs since 2003. The company has also been awarded three Rapid Innovation Fund (RIF) programs in the last year intended to quickly transition innovative products to the marketplace.

DiTom Microwave has received a contract from a major U.S. satellite manufacturing company for thermal vacuum (TVAC) compatible X- and Ka-Band isolators. Under the contract agreement, DiTom will supply ferrite isolators for the Wideband Global Satcom (WGS) program. These isolators will be used in a thermal vacuum environment where low outgassing materials are critical for space ground support testing. The manufacturing work will be performed at DiTom's facility in Fresno, CA and is expected to be completed by the beginning of Q4 FY2013.

Telefónica has been selected by the **UK Department of Energy and Climate Control** as the preferred communications service provider for two out of three lots in the UK's smart meter tender, subject to contracts being agreed. Telefónica's proposed communications solution is based on its existing cellular network in the UK, supported by Connode's IPv6 based wireless mesh solution which will connect meters in areas without cellular coverage. The Smart Meter Implementation Programme is a major national infrastructure project that will involve the roll out of 53m gas and electricity meters across the UK by 2020, helping consumers to better understand and control their energy usage.

PEOPLE


▲ *Tom Callahan*

QRC Technologies (QRC) announced that its board of directors has appointed **Tom Callahan** as president of the company. Callahan has played a central role in the development of QRC's product lines. He has been QRC's general manager for two years, and prior to this, Callahan was VP of engineering since joining the company in 2006. He came to QRC from PCTEL, formerly DTI, a world leader in commercial cellular test solutions, where he was the VP of engineering overseeing the development of world class software defined scanning receivers and software solutions.

At the heart of the next generation electronic defense systems.

The next generation air and missile defense radars demand effectiveness, reliability, power efficiency and affordability. You can count on CTT's twenty-five years of experience in microwave amplification and subsystem integration to meet these demands.

CTT offers not only form, fit, function of microwave amplifier replacements for many mature systems, but also incorporates leading-edge technology components such as GaN and GaAs.

CTT has delivered production quantities of amplifiers with power levels of 10, 20, 40, 80, and 100 Watts – and higher – for a variety of radar applications.

CTT is well positioned to offer engineering and production technology solutions – including high-rel manufacturing – to infuse new technology into legacy systems for improved reliability and life cycle costs.

- AMDR-X Radar
- Shipboard Radar
- VLO/FLO Threats
- New Land Radar

More than twenty-five years ago CTT, Inc. made a strong commitment to serve the defense electronics market with a simple goal: quality, performance, reliability, service and on-time delivery of our products.

Give us a call to find out how our commitment can support your success. **It's that simple.**

Microwave Technology Leadership

- ❖ **Power Amplifiers**
  - Radar Bands up to 400W
  - Pulse and CW
  - **NEW** Rack-Mount Configurations
  - **NEW** GaN and GaAs Models
- ❖ **Low-Noise Amplifiers**
- ❖ **Up and Downconverters**
- ❖ **Subsystems**
- ❖ **Contract Manufacturing**
- ❖ **Custom Engineered Options**

nsai
ISO 9001:2000 QUALITY

USA-based thin-film microwave production facility

CTT INC.

241 East Java Drive • Sunnyvale • California 94089
Phone: 408-541-0596 • Fax: 408-541-0794 • www.cttinc.com • E-mail: sales@cttinc.com

Around the Circuit


▲ David Choi

David Choi joins **Mercury Systems** as technical director, RF power amplifiers. Choi brings over a decade of experience and a wide breadth and depth of knowledge spanning the commercial and defense industries as well as academia. During his time as Visiting Scholar at University of California, San Diego, Choi led cutting edge academic research in highly linear and efficient (envelope tracking/EER) RF transmitters. Choi earned his Ph.D. from the Department of Electrical and Computer Engineering at the University of California, Santa Barbara and a bachelor's degree in physics from the University of California, Berkeley.

OBITUARIES


▲ Michael Adlerstein

Michael Adlerstein, former consulting scientist at Raytheon Advanced Device Center and associate editor of the *IEEE Transactions on Electron Devices*, passed away on August 14th. Adlerstein served on various international conference technical committees including the High Temperature Semiconductor Committee of the National Research Council and as the Proceedings Editor of the Cornell University Conference on Advanced Concepts in High Speed Semiconductor Devices and Circuit. He received a B.S. degree in mathematics and M.S. degree in physics from Polytechnic Institute of Brooklyn, Brooklyn, NY. He received a second M.S. and the Ph.D. in applied physics from Harvard University, where he was a National Science Foundation Fellow and a Woodrow Wilson Fellow.


▲ John Aubin

John Aubin passed away on August 28, 2013 at the age of 59. Aubin was the CTO at ORBIT/FR Inc. in Horsham, PA. He received his BSEE from Virginia Tech in 1977, his MBA from Temple University in 1982, and his MSEE from Drexel University in 1988. His career began at Harris Corp. in 1977. Except for a few years in between, Aubin spent the majority of his career working for Flam & Russell (now Orbit/FR Inc.) which he joined in 1980. Aubin served as principal design engineer on a number of automated antenna and radar measurement systems ranging from VHF up to millimeter waves, including a microwave imaging system for evaluation of biological tissue, a high performance low frequency radar cross section measurement system, and a dynamic radar cross section measurement system using an integrated tracking and signature measurement radar. From its inception Aubin was a regular contributor to the Antenna Measurement Techniques Association (AMTA). He has authored over 40 papers on antennas, radar, and measurement technology and is the co-inventor on several patents.

Tabor's WaveXciter Series
High-Speed Arbitrary Waveform Generators

- 1.25GS/s and 2.3GS/s, 14 bit, 16M/32M waveform generators
- Single, dual or four channel, separate or synchronized (10ps resolution)
- 1GHz sine and 500MHz square waves
- Up to 4Vp-p into 50
- Extensive modulation capabilities with up to 1GHz CW
- Powerful pattern composer for analog, digital and mixed signals
- Advanced sequencer allows, stepping, looping, nesting and jumps
- Built-in fast dynamic segments and sequences hop control
- Optional 32 digital bits with up to 32M independent memory
- Two instrument synchronization to form a 8-channel system

Tabor's all-new WaveXciter series offers unrivaled performance, even when compared to instruments designed to generate fewer types of signals or higher sampling rates. The WaveXciter can generate literally any waveform, at frequencies up to 1GHz with 8 digits of resolution and 1 point granularity, resulting in the highest precision signal creation and regeneration. Aside from its natural ability to generate arbitrary waveforms, the WaveXciter can also be used as a full-featured standard, modulation or pulse generator to solve various applications. Its affordable footprint saves space and cost without compromising bandwidth and signal integrity.

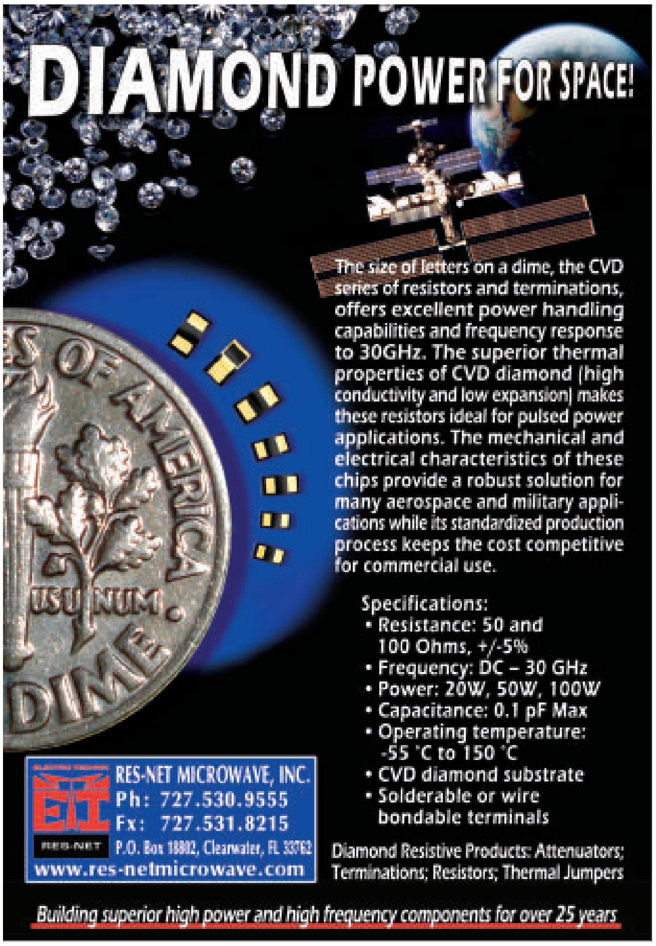
EADS
NORTH AMERICA

EADS North America Test and Services is the exclusive distributor of Tabor products in the United States. For more information, visit **www.ts.eads-na.com.**

www.taborelec.com

Leading the Way In Waveform Generation

TABOR ELECTRONICS Ltd.
Since 1971



CALL FOR BOOK AUTHORS

You can enhance your professional prestige and earn substantial royalties by writing a book. With over 1,500 titles published, Artech House is a leading publisher of professional-level books in microwave, radar, communications and related subjects. We are seeking to publish new microwave engineering books and software in areas such as microwave and RF device design, wireless communications, advanced radar and antenna design, electromagnetic analysis, RF MEMS, sensors, and more.

We are currently seeking potential authors among engineers and managers who believe that they can make a contribution to the literature in their areas of expertise. If you have published technical papers, conducted professional seminars or solved important real-world problems, then you are an excellent candidate for authorship.

We invite you to submit your manuscript or software proposal for review. For a complete publications catalog and Author's Questionnaire please contact:

Mark Walsh, Senior Editor
1-800-225-9977
mwalsh@artechhouse.com

Artech House, Inc.
685 Canton St.
Norwood, MA 02062

ARTECH HOUSE
www.artechhouse.com

Around the Circuit

REP APPOINTMENTS

Hirose Electric signed a North American distribution agreement with **Sager Electronics** to expand its product availability and customer support. The new agreement authorizes Sager to distribute Hirose's full product portfolio to its customers across North America.

Intercept Technology Inc. announces its newest authorized reseller, **Fusion CADSoft LLC**. As an experienced EDA software reseller in the eastern U.S., Fusion CADSoft aims to supply Intercept's PCB, RF, and Hybrid design and engineering software in the regions from ME to FL and MN to NJ. Post-sales support will remain Intercept's responsibility.

Maury Microwave Corp. announces its European stocking distribution program with **BSW** (BeNeLux, Germany), **EMCO** (Germany) and **MB Electronique** (France). Holding European stock of Maury's ColorConnect™, Test Essentials™ and Stability™ lines will allow worldwide customers access to next-day delivery.

MITEQ Inc. announced the appointment of **Disman Bakner Northwest Inc.** as the company's exclusive sales representative in WA, OR, ID and British Columbia. Disman Bakner Northwest will represent MITEQ's component division of products.

Spacek Labs has appointed **APC Novacom** of Nettleham, Lincoln, UK, to represent Spacek Labs in the United Kingdom. APC Novacom has over 22 years experience as sales representatives.

PLACES

Hesse Mechatronics Inc. recently opened its newest training and applications lab in Tempe, AZ. The company has appointed Allan Camp, who joined the company as technical support manager in June 2012, responsibility for the new lab. Camp's role and the new lab are additional steps in Hesse Mechatronics' strategy to improve customers experience and convenience in qualifying and learning about the company's wedge bonding equipment and taking advantage of support services.

On July 16, **National Instruments** (NI) held a ribbon-cutting event to mark the opening of its new Santa Clara, CA site. NI relocated three of its existing Silicon Valley groups (Phase Matrix Inc., Ettus Research, and NI's field sales engineering team) under one roof to reinforce its commitment to driving growth in the RF market while also boosting efficiency.

Ultra-Low Phase Noise Microwave Oscillators AND Phase Noise Test Measurement System

Compact Opto-Electronic Oscillator

Micro-Opto-Electronic Oscillator

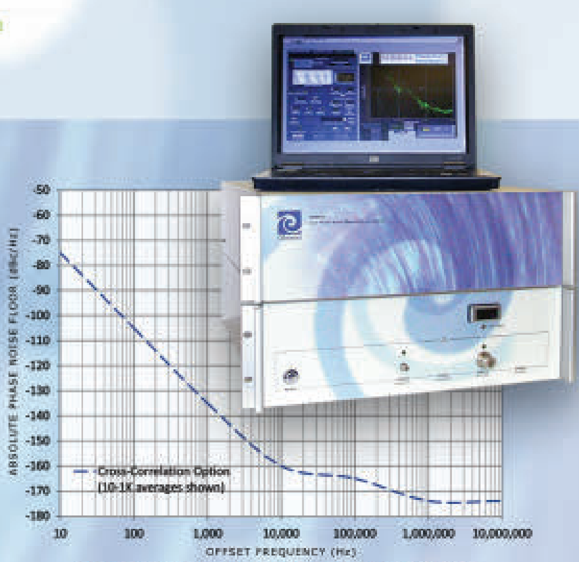
	Advanced OEO	Compact OEO	Micro OEO
Output Frequency	10 GHz	10 GHz	35 GHz
Offset Frequency	SSB Phase Noise (dBc/Hz) – Free Running		
10Hz	-75	-60	-30
100Hz	-115	-90	-55
1kHz	-145	-120	-85
10kHz	-163	-140	-108
100kHz	-165	-150	-120
1MHz	-170	-160	-130
10MHz	-170	-170	-135
Size	19" Rack Mount	25in³	0.06in³

FEATURES

- EMI tolerant
- High stability
- Low vibration/acceleration sensitivity
- Low spurious content

Microwave and Millimeter Wave Phase Noise Test Measurement System

- Complete automated connect & click microwave phase noise/jitter measurement system
- -174 dBc/Hz absolute phase noise measurement capability
- **No** reference source required
- **No** microwave down-converter required



Absolute Phase Noise Floor at 10 GHz

VISIT OUR WEBSITE FOR MORE INFORMATION

OEwaves

626.351.4200
www.oewaves.com

Invent. Develop. Deliver.

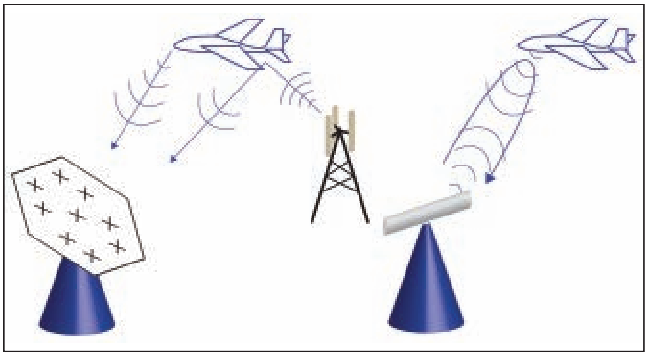
These products are designated as defense articles under Category XI(c) of the USML and are subject to ITAR licensing requirements.
This product line is covered by one or more of the following U.S. patents: 5,204,640; 5,723,856; 5,777,778; 5,929,430; 6,389,197; 6,488,861; 6,594,061; 6,762,869; 6,795,481; 6,798,947; 7,173,749; 7,248,763; 7,356,214; 7,440,651; 8,155,913; 8,155,914. Other patents pending.

Design, System Integration and Testing of Radar Systems

This article discusses some of the fundamental research and development challenges in both the digital and RF/millimeter wave domains (such as waveform generation, receiver algorithms and transmit/receive front ends) and addresses current and future directions in design, system integration and test.

Radar applications are becoming more diverse and commercialization is accelerating due to significant advances in digital and RF/microwave technologies. Today, there are numerous radar applications from traditional defense and surveillance[1] to automotive radar for driver assistance[2] to biomedical radar for imaging, monitoring and treatment.[3] For all of these applications, the competitive environment demands rapid cycles of design, system integration, prototyping and testing.

An emerging area of development in cellular communication systems, for example, is focused on the issue of localization for handsets. Due to the FCC's E911 initiative in 2004, accurate localization techniques for use in emergency calls and mobile applications have been researched extensively. One of the techniques employs time difference of arrival (TDoA) from multiple nearby base stations to obtain accurate location information. Many of the principles used in passive radar systems are applied to this application as well. The challenge is that the localization algorithms must work with RF front ends designed with requirements and capabilities that are very different from radar systems. An LTE standard compliant front end has limited resources for signal processing and variations in operating environment such as indoor and outdoor environments.[4]



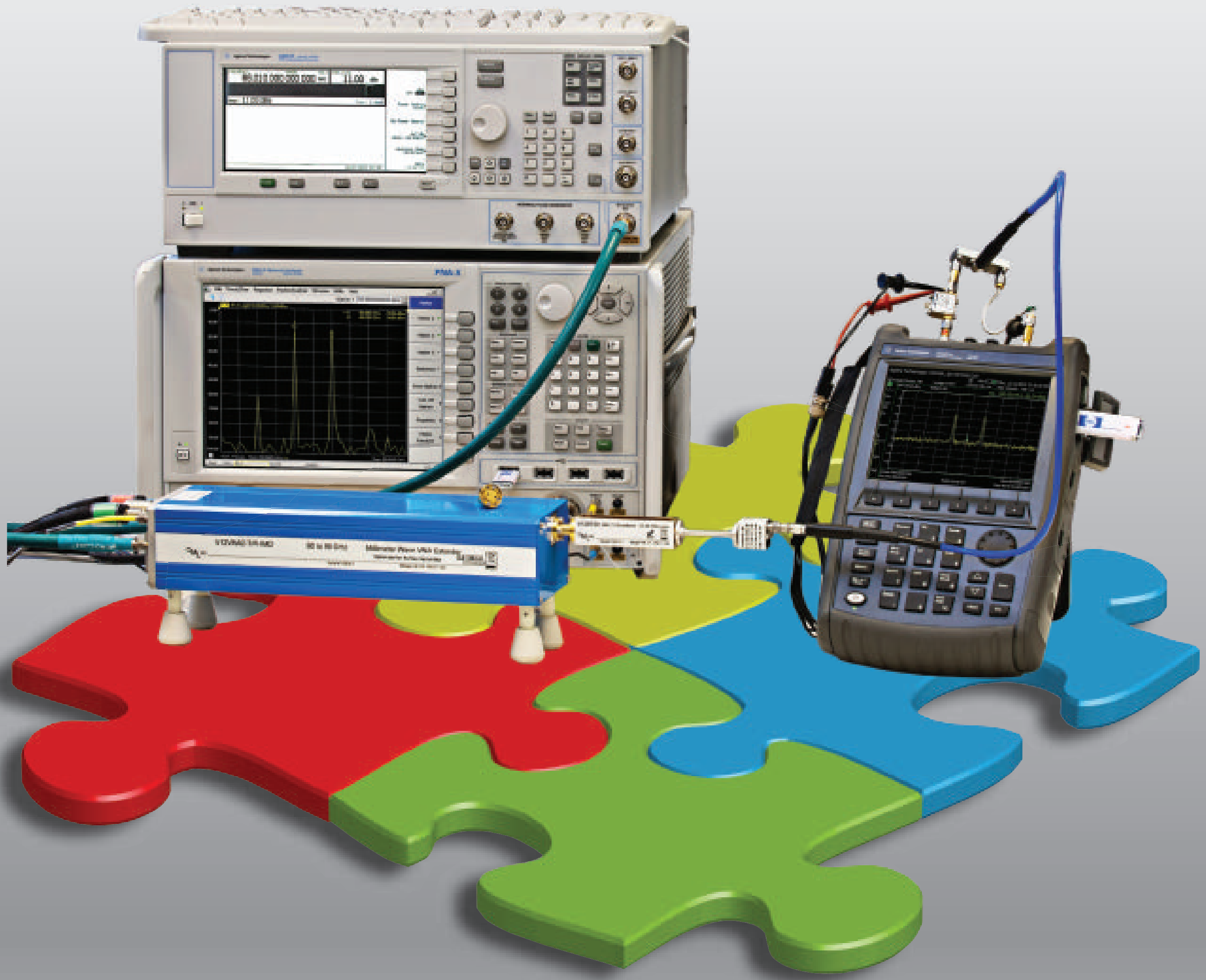
▲ *Fig. 1 Passive radar (left) and active radar (right).*

BACKGROUND

Radar is used to detect and/or track target objects and their attributes such as range, speed and other information obtained through signals at RF and microwave frequencies. The broad classes of radar systems are active and passive (see ***Figure 1***). Passive radar systems use non-cooperative source(s) of illumination, such as a target's emitted signals, broadcast signals or cellular communication signals, to obtain information about the target. Since radar performance relies on the sensing capabilities of the receiver, significant innovations have been made in areas such as phased array antennas, digital beamforming, detection algorithms

Takao Inoue
National Instruments, Austin, TX

Millimeter Wave Intermodulation Distortion (IMD) for Amplifier Test (50 to 110 GHz)

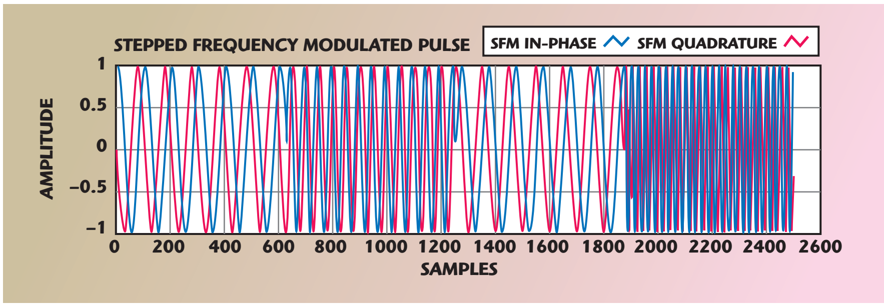


With a single connection, measure S-parameters, Gain Compression and Intermodulation Distortion (IMD).

Learn more at www.omlinc.com/find/imd

Innovation in Millimeter Wave Measurements
www.omlinc.com
(408) 779-2698

OML



▲ *Fig. 2 Example SFM waveform where a pulse sweeps through four different frequencies.*

and source separation algorithms. Active radar uses cooperative sources of illumination by generating its own signal(s) to illuminate the target. Within the class of active radar, there is monostatic radar where the signal source is collocated with the receiver and multistatic radar where there are two or more receiver locations.

Among the class of active radar systems, there are several common signal types. The most basic is continuous wave (CW) radar where a constant frequency sinusoidal signal is transmitted. The CW signal allows the receiver to detect phase/frequency variations (Doppler shift) from the target reflection. Unless a special provision for absolute time marker is used, however, range detection is not possible. A modified CW signal using a stepped frequency modulated (SFM) signal obtains a better range estimate by hopping over multiple discrete frequencies (see ***Figures 2*** and ***3***). A further modification of the CW signal to linearly ramp up and down a range of frequencies is called linear frequency modulation (LFM) or frequency modulated CW (see ***Figures 4*** and ***5***). An LFM radar allows detection of Doppler as well as range by observing the frequency difference of the time delayed received signal from the transmitted signal. If a stationary object is detected, a constant beat frequency (transmit to receive frequency difference) is observed.

Pulsed signals of CW, SFM and LFM are also widely used. An extreme example, the ultra-wideband (UWB) pulse signal radar is receiving renewed interest due to its low interference characteristics resulting from low spectral power density. UWB pulse radar is characterized by a pulse width that is typically on the order of a nanosecond or less.

The magnetron has been one of the popular components for higher power signal generation in applications such as aviation and marine radar. Since the early development of radar magnetron by Henry A. H. Boot, John T. Randall and their associates in late 1939, the resonant cavity tube structure continues to evolve to serve a variety of radar applications to this day. Over the last few decades, however, rapid advancements in solid state devices have had a significant impact on the radar's capability and system design.

Gallium Nitride (GaN) Military Radio Power Amplifiers

by Aethercomm

Aethercomm®
We make hardware that saves lives.™

QUALITY SYSTEM CERTIFICATION AS/EN/JISQ 9100:2009 DNV

Quick facts:

- 14 years in business
- >200,000 amplifiers fielded
- AS9100 Rev.C certified
- 50,000 square foot state of the art facility
- Communications, EW, RADAR and medical
- Power amplifiers, subsystems, systems & high power switches
- MIC lab and build-to-print services

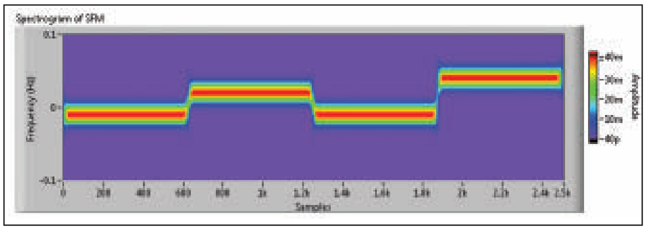
Radio Power Amplifier Specifications:

- Two broadband amplifiers per assembly
- VHF, UHF and L band coverage (30 MHz-2 GHz)
- 125 Watts peak or 100 Watts CW power with EVM (<3%)
- Transmits SRW, WNW and all legacy waveforms
- Fourth generation GaN devices (high efficiency, linearity & ruggedness)
- ALC ensures flat power across each sub band
- Internal Rx bypass with low insertion loss
- Full digital control with power on self test and BIT
- Field firmware upgradeable
- Width 2.520” x height 6.850” x depth 9.225”

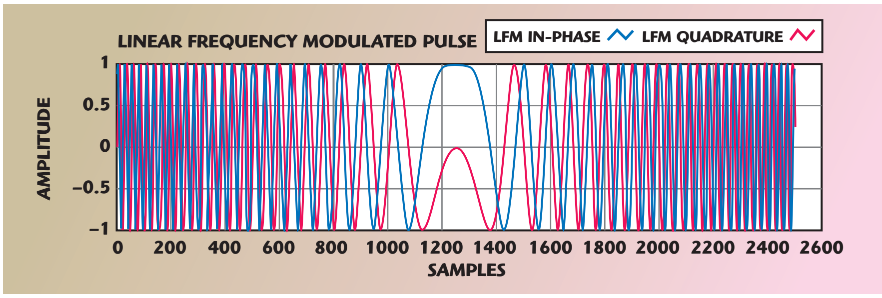
Tel 760.208.6002
sales@aethercomm.com

14 YEARS IN BUSINESS 14 1999-2013

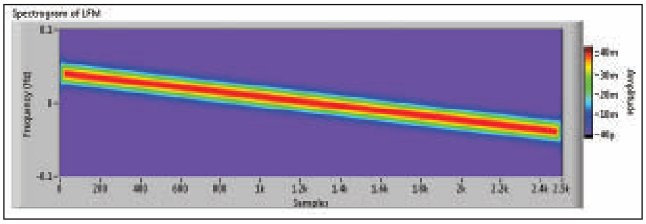
www.aethercomm.com



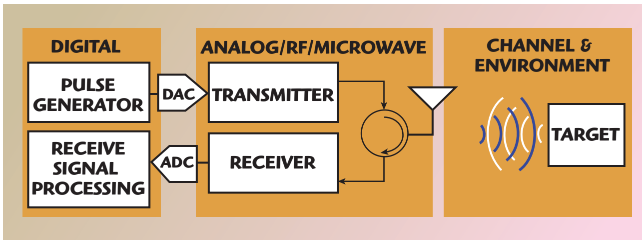
▲ *Fig. 3 Spectrogram of a SFM waveform showing the instantaneous frequency over time.*



▲ *Fig. 4 Example LFM waveform where a pulse ramps from high frequency to low and back again.*



▲ *Fig. 5 Spectrogram of LFM showing the instantaneous frequency across time.*



▲ *Fig. 6 General radar block diagram.*

Some of the high impact advancements include higher density digital circuits and faster analog-to-digital converters, RF and microwave circuit integration techniques (MMIC and CMOS), and advances in device technologies (GaN, GaAs, SiGe and high electron mobility transistor variations).

DESIGN, INTEGRATION AND TESTING

Without loss of generality, today's active radar system design can be broken into two major components: the baseband signal processing and the RF/microwave front end (including the antenna). ***Figure 6*** shows a high level block diagram of an active radar system.

Digital Signal Processing

Thanks to widely available commercial processors, embedded processors, field programmable gate arrays (FPGA), digital signal processors (DSP) and, more recently, graphics processing units (GPU), radar signal processing engineers now have a breadth of platforms to choose from. The choice largely depends on the type of signal processing that is needed and the cost of implementation. General purpose, personal computer, type hardware may be sufficient for radar systems with relatively low throughput and simple signal processing requirements. An FPGA or GPU based processor might be needed if large parallel processing is needed. In this case, however, the cost of the hardware increases substantially. In most platforms, pulse generation and receiver algorithms can be implemented with appropriate software bringing benefits such as programmability and reuse of intellectual property. At the same time, radar signal processing engineers are faced with the challenge of incorporating more and more sophisticated algorithms, consuming longer simulation times within the system and exhausting the available computational resources.

Pulse compression is a technique used to improve range resolution and

SMP & **SMPM** connectors from Delta Electronics Mfg. The smart choice for board to board or module to module microwave interconnects. Whether you're increasing package density, reducing weight or improving performance at higher frequencies, Delta has a solution engineered for your critical application.

Download Catalog Here

Engineered:

- ☑ Robust
- ☑ Reliable
- ☑ Cost Effective

DELTA
ELECTRONICS MFG. CORP.
Connect Here.

Get your copy of our **NEW SMP/SMPM** catalog, contact Delta today!

AS9100/ISO 9001 REGISTERED · RoHS COMPLIANT · SOMWBA Woman-Owned CERTIFIED

(978) 927-1060 • www.deltarf.com

signal to noise ratio. Range resolution depends on the signal bandwidth:

$$\text{Range Resolution} = \frac{c}{2B}$$

where c is the speed of light and B is the bandwidth. Therefore, better range resolution (or lower range granularity) is obtained when the bandwidth of the signal is high. Unfortunately, the bandwidth of the time-gated sinusoid is inversely related to the pulse duration. Thus a very short pulse is desired for higher range resolution. A very short pulse, however, imposes more stringent radar front end requirements. It is also more difficult to concentrate the energy of a short pulse waveform, limiting the radar's range. Pulse compression overcomes this problem by computing the cross correlation of the transmit signal and the receive signal. An LFM signal can be expressed as

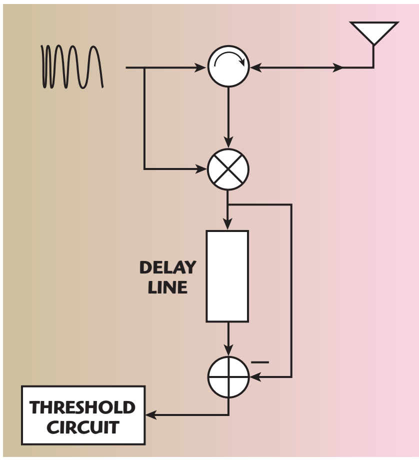
$$x(t) = A\,\text{rect}\left(\frac{t}{T}\right)\cos\left(2\pi f_0 t + \pi\alpha t^2\right) \quad (1)$$

where rect(x) is a square window function which is 1 for x<1/2 and 0 for x>1/2, T is the pulse width, f_0 is the carrier frequency, and α is the LFM slope given by ±B/T (the example in Figures 4 and 5 is a down-chirp with -B/T). The cross correlation of the transmit and receive LFM pulse can be written as

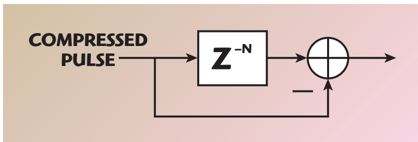
$$R_{xy} = \left(1-\left|\frac{\tau}{T}\right|\right) \cdot \text{sinc}\left(\left(f_d - \alpha\tau\right)T\left(1-\left|\frac{\tau}{T}\right|\right)\right) \cdot \text{rect}\left(\frac{\tau}{2T}\right)e^{-j\pi f_d t} \quad (2)$$

where τ is the time difference of the received signal and f_d is the Doppler frequency of the target. The main benefit here is that the mainlobe of R_{xy} is significantly narrower than the actual pulse width T. In fact, the mainlobe width depends on the bandwidth B and not the pulse duration T. The challenge is in controlling the range sidelobes through windowing and other means to obtain the desired resolution appropriate for the target of interest.

For many radar applications, information about a moving target is needed. Moving target indication (MTI) is

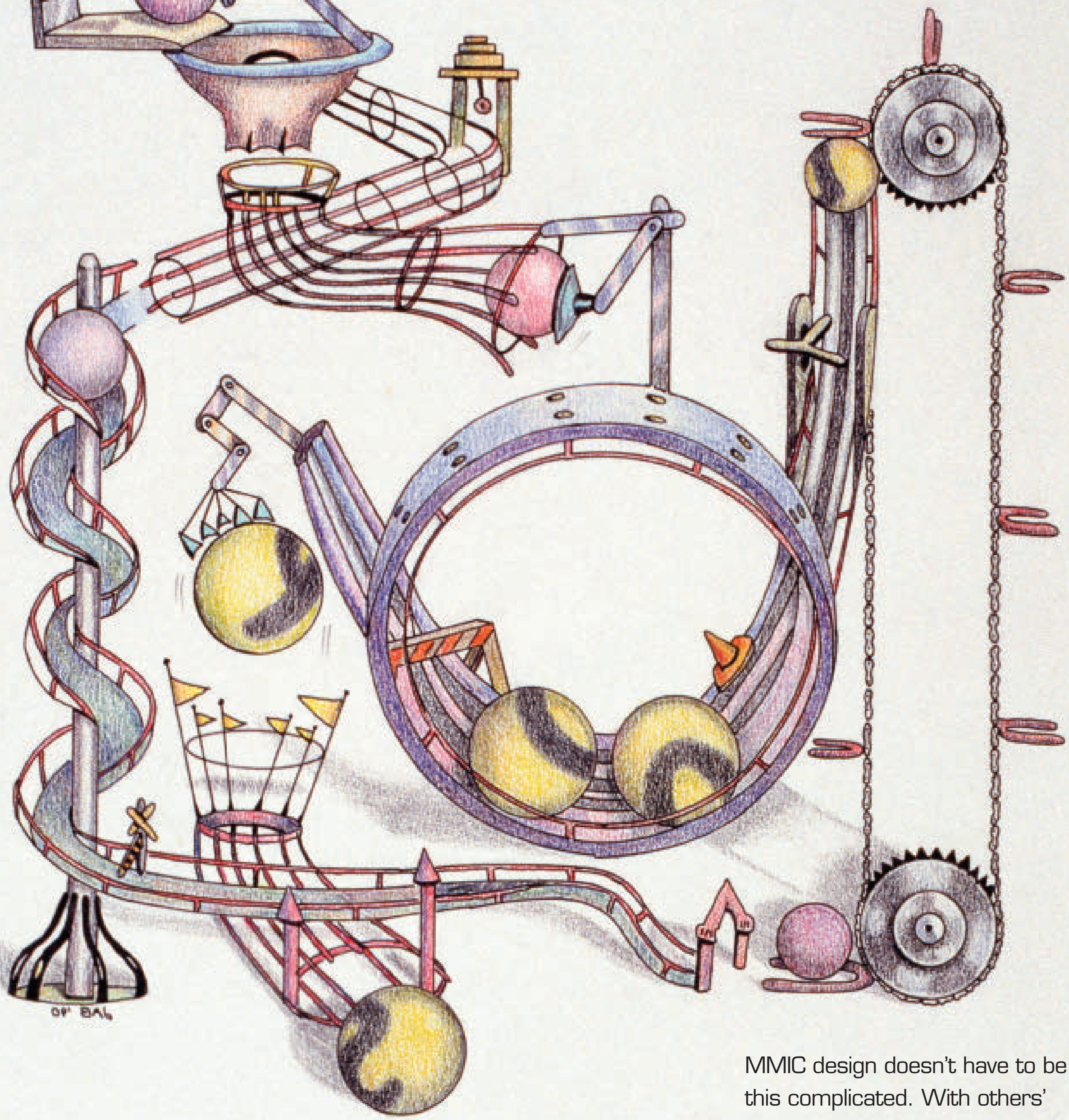


▲ *Fig. 7 Classical delay line canceller architecture for MTI.*



▲ *Fig. 8 A digital implementation of MTI.*

AWR | A National Instruments Company™



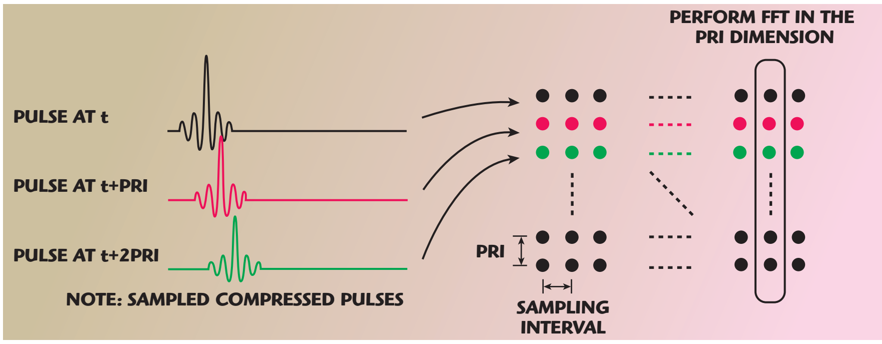
Flow more seamlessly from concept to tapeout.

MMIC design doesn't have to be this complicated. With others' patchwork flows, you have to cross your fingers that your layout will match the schematic specs. If not, you could be heading back to square one. With Microwave Office, you can work seamlessly between schematic and layout, verifying performance along the way and uncovering manual errors. It shortens design cycle time and yields MMICs that are right the first time—with less stress. Sound simple? Grab a test copy at www.awrcorp.com/MWO.

Stop waiting and start designing™

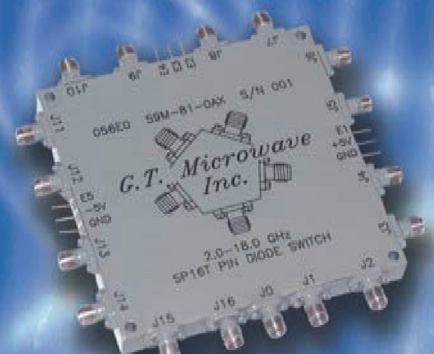
MICROWAVE OFFICE®

© 2013 AWR Corporation. All rights reserved.



▲ *Fig. 9 Graphical illustration of MTD operation.*

GET THE PERFORMANCE YOU NEED
ULTRA BROADBAND SWITCHES



- SP1T to SP128T
- DC - 26.5 GHz
- Reflective
- Absorptive
- Switch Matrixes
- Custom Designs

OPTIONS
- Optimized Narrow Bands
- Up to 120 dB Isolation
- High & Low Power Models
- Phase & Amplitude Matched
- Switching Speed 20 μsec max
- Custom Logic

Electrical Specifications

MODEL	FREQUENCY GHz	MAX INSERTION LOSS	V.S.W.R. MAX
SP1T	2-18 GHz	2.3	2:1
SP2T	2-18 GHz	2.5	2:1
SP4T	2-18 GHz	2.8	2:1
SP8T	2-18 GHz	4.0	2:1
SP16T	2-18 GHz	7.0	2:1

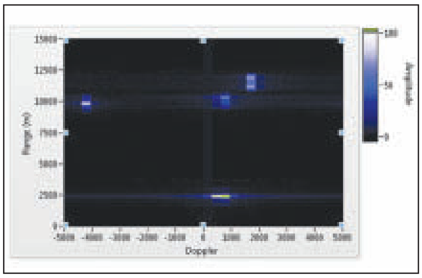
Absorptive • 60dB isolation • 1μsec switching speed • + 20 dBm cw, 1 w max

G.T. Microwave Inc.
2 Emery Avenue
Randolph, NJ 07869 USA
973-361-5700 Fax: 973-361-5722
www.gtmicrowave.com
e-mail: sales@gtmicrowave.com

often the first processing performed at the receiver to discriminate moving targets from stationary objects (or clutter). The main idea is to remove the constant contribution of the stationary clutter in the received signal. The classical approach is to use a delay line canceller (see ***Figure 7***). Today, the delay line canceller can be implemented digitally by a simple filter with a delay corresponding to the range of the clutter. Digital implementation of MTI is shown in ***Figure 8*** where N is the number of samples in the pulse repetition interval. The benefits are that it is very simple to implement and that the delay element can be either hard coded or adaptive providing greater flexibility.

A moving target detector (MTD) is often used to detect and track the motion of the target. In the mid-1970s, MTD was computed using a parallel bank of filters which led to the widespread use of this technique. Today, this is efficiently realized using fast Fourier transforms (FFT) in modern processing platforms. Suppose that the pulse is repeated at a specified pulse repetition interval (PRI). The principle for MTD calculation is shown in ***Figure 9***. ***Figure 10*** is an example MTD output indicating four moving targets.

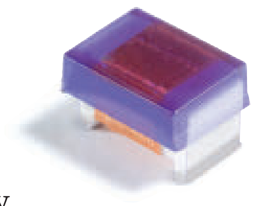
While each of the processing blocks have relatively simple functions, it becomes a complex task to integrate these algorithms, partition them onto appropriate platforms, coordinate and communicate with the RF/microwave front end and compensate for its non-idealities. Does it make sense to implement all of the processing in the FPGA at the cost of hardware, development time and less flexibility? Does it make sense to implement all of the processing on the CPU perhaps at the cost of performance? Or does it make sense to partition the algorithms for the CPU and FPGA (and maybe



▲ *Fig. 10 Example output of MTD indicating four moving targets.*

Better performance. Less effort.

Right out of the box, a better inductor for your aerospace/MIL applications.



Shorten your time-to-market and improve performance with surface-mount chip inductors from Coilcraft CPS. These robust COTS Plus devices are ready to load without further handling or processing…tested to meet your specs, directly from Coilcraft CPS.

ML Series inductors are designed, manufactured and tested to ensure their suitability for mission-critical applications under adverse environmental conditions. Alternate terminations, such as tin/lead, gold, and leach resistant alloy are featured for long term reliability.

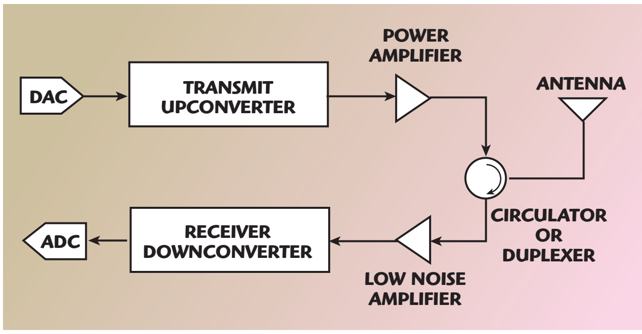
Compared to other 0603 inductors, the ML Series offers higher inductance values, to keep board space to a minimum.

- *Inductance values range from 47nH–22µH*
- *Q ratings are as high as 50 at 250MHz with Self Resonant Frequencies to 16 GHz*
- *Ceramic construction provides high-current handling*
- *MTBF is an amazing 1 billion hours*

Learn more about ML Series and other Coilcraft CPS magnetics by calling us or visiting **www.coilcraft-cps.com** today.

Coilcraft CPS
CRITICAL PRODUCTS & SERVICES

800.981.0363 847.639.6400 cps@coilcraft.com www.coilcraft-cps.com



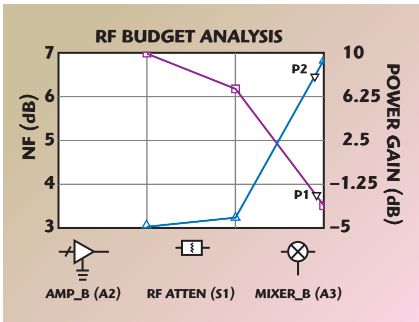
▲ *Fig. 11 High level block diagram of a radar front end transmit and receive unit.*

DSP) such that each algorithm is run in some optimal way? If so, what are the throughput, latency and synchronization requirements between these processing units? These are some of the challenges faced by radar signal processing engineers in developing the next generation of radar systems.

RF/Microwave Front End

The transmitter and receiver unit (see ***Figure 11***) plays a key role in acquiring the information for processing. Many radar systems today operate at S-Band (2 to 4 GHz), X-Band (8 to 12 GHz) and higher. Design choices for the transmitter upconverter and receiver downconverter depend on many factors, such as the target frequency range, available local oscillators, interfaces to the DAC and ADC, phase/amplitude control and cost to name a few. Perhaps the most heavily researched areas are high power amplifier (HPA) and low noise amplifier (LNA) design.

The HPA performs the critical function of amplifying the illumination signal to the highest power permitted without adding distortion, while having high enough efficiency to maintain power consumption within specified limits. Depending on the application, transmit power levels can range from milliwatts to kilowatts. Linearity of the power amplifier is of great importance since nonlinearity can cause pulse degradation and introduce spurs that violate spectral mask requirements or corrupt the receive signal. In recent years, field plate technology has allowed GaAs HPAs to be operated at higher voltages. Field plate technology and air-bridges increase the breakdown voltages of high electron mobility transistors (HEMT). Increased power density, however, introduces heat dissipation issues. Field plate technology has been used with devices that already support higher voltages and power densities, such as gallium nitride (GaN) on silicon carbide (SiC) substrates. PA designers are faced with a multitude of problems in trading off devices, component count, thermal management and miniaturization, all while satisfying the amplification and spurious emission requirements.

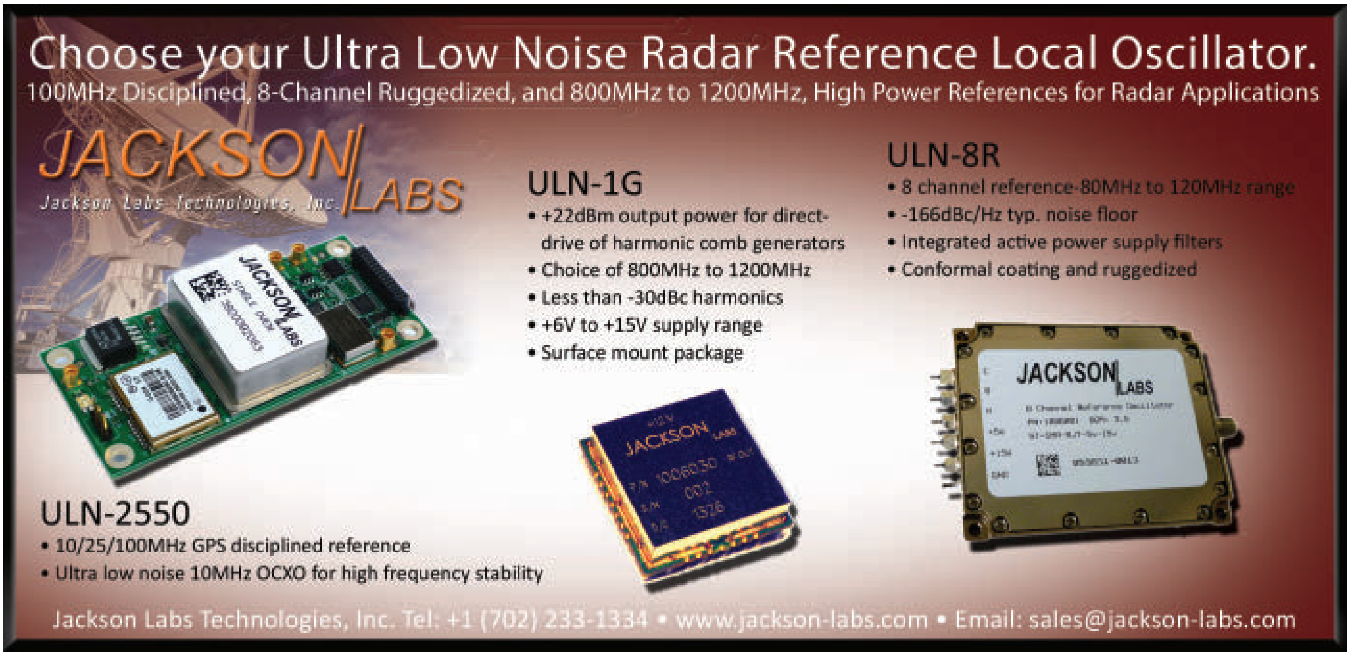


▲ *Fig. 12 Link budget analysis using AWR's Visual System Simulator.*

While LNA design is relatively mature, its performance is crucial to achieving front end sensitivity and overall radar performance goals. Link budget and noise figure analyses have historically been performed with simple hand calculations or spreadsheets; however, use of a graphical tool like AWR's (a National Instruments Company) Visual System Simulator (VSS), or similar, greatly enhances the designer's ability to close in on the specification and spot problem areas (see ***Figure 12***).

Integration – Putting It All Together

The radar system architect has an enormous task of understanding various tradeoffs in the digital domain as well as in the RF/microwave domain and putting it all together. Many years ago, radar systems might have been designed and integrated by a small team of hardware engineers, but today's



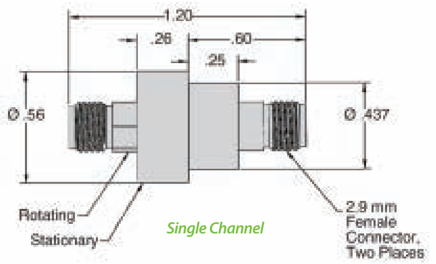
PERFECTION

When you need perfection in satellite high frequency communication.

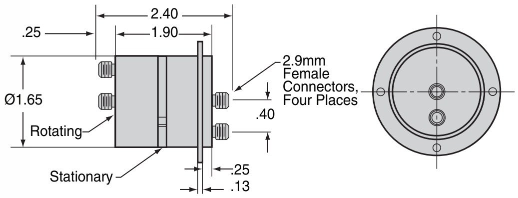
Family of Broadband High Frequency Coaxial Rotary Joints

Single Channel & Dual Channel Rotary Joints — Frequency DC to 40.0 GHZ
MDL's short low torque, high performance coaxial rotary joints as well as our extensive line of waveguide rotary joints have set the standards of the industry .

You've never been in better hands.
Quality from CAD to crate, quick turnaround, and tight economy is what we're all about. Call an MDL specialist today at 800-383-8057 or visit us at mdllab.com.
You'll find that we specialize in perfection.



Single Channel



Dual Channel

400 RS 16
SINGLE CHANNEL SPECIFICATIONS:

ELECTRICAL

FREQUENCY	DC - 18 GHz	
VSWR	DC - 10 GHz	1.20 : 1 MAX.
	10 - 26 GHz	1.35 : 1 MAX.
	26 - 40 GHz	1.75 : 1 MAX.
WOW	1.05 MAX.	
INSERTION LOSS	DC - 10 GHz	0.2 dB MAX.
	10 - 26 GHz	0.4 dB MAX.
	26 - 40 GHz	0.6 dB MAX.
PEAK POWER	Equal to connector rating	

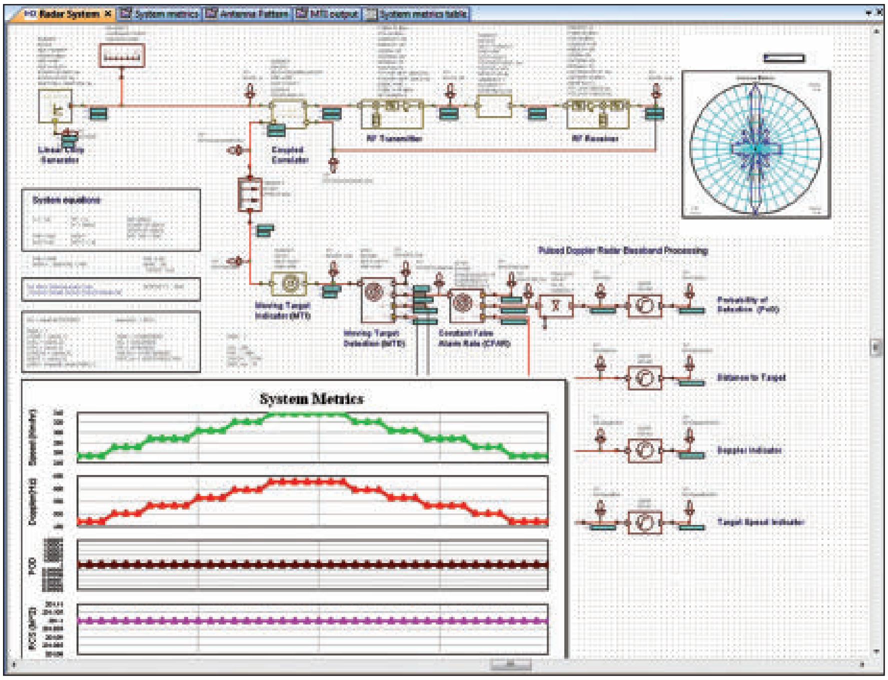
310 RCD 16
DUAL CHANNEL SPECIFICATIONS:

ELECTRICAL	Channel 1	Channel 2
FREQUENCY	7.0 - 22.0 GHz	29.0 - 31.0 GHz
VSWR	1.50:1 MAX.	1.70:1 MAX.
WOW	0.15	0.25
INSERTION LOSS	0.5 dB MAX.	1.0 dB MAX.
ISOLATION	Channel to Channel	50.0 dB MIN.

INTRODUCING
our NEW TOOLS
to help you with your next project...

Scan our code or visit www.mdllab.com/tools to DOWNLOAD OUR MOBILE APP or use our online calculators

Microwave Development Laboratories, 135 Crescent Road, Needham Heights, MA 02494
V: 781-292-6680/6684 • F: 781-453-8629 • E-mail: mdlsales@mdllab.com • www.mdllab.com



▲ *Fig. 13 An example of an integrated tool chain by AWR and National Instruments.*

radar systems are becoming increasingly complex with domain experts from several areas contributing to the development of one system. How can an algorithmic tradeoff be adequately balanced with microwave circuit requirements and cost? There is clearly a greater need for mixed digital-and-RF/microwave design, simulation and a prototype framework so that the corresponding domain experts can communicate with each other to address this complex design problem. One approach is to consider a well-integrated tool chain that supports microwave design, digital signal processing, hardware-in-the-loop (either hardware based processing such as on FPGAs or measurements), and the corresponding hardware capability to support rapid prototyping of designs (see ***Figure 13***). Various systems software packages allow multiple designers to easily create and evaluate subsystem architectures, bringing their designs from concept to simulation and, ultimately, to physical implementation in a single system within a single framework.

CONCLUSION

Today's radar systems are as complex as they are diverse. What is common, however, is that they each contain a digital signal processing section and RF/microwave front end. In this article, we looked at a few key elements in both of these areas with examples for pulse compression radar and discussed several technology challenges as well. While radar systems were previously developed by a few hardware engineers, today's systems often rely on the design contributions of multiple domain experts. Various software tools simplify the complexity of the design process and allow engineers to think across the traditional boundaries. ■

References

1. M. Grossi, A. Fiorello and S. Pagliai, "Advances in Radar Systems by SELEX Sistemi Integrati: Today and Towards the Future," *European Radar Conference Proceedings*, September-October 2009, pp. 310-317.
2. J. Hasch, E. Topak, R. Schnabel, T. Zwick, R. Weigel and C. Waldschmidt, "Millimeter-Wave Technology for Automotive Radar Sensors in the 77 GHz Frequency Band," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 60, No. 3, March 2012, pp. 845, 860.
3. C. Li, J. Cummings, J. Lam, E. Graves and W. Wu, "Radar Remote Monitoring of Vital Signs," *IEEE Microwave Magazine*, Vol. 10, No. 1, February 2009, pp. 47-56.
4. C. Gentner, E. Munoz, M. Khider, E. Staudinger, S. Sand and A. Dammann, "Particle Filter Based Positioning With 3GPP-LTE in Indoor Environments," *IEEE/ION Position Location and Navigation Symposium Proceedings*, April 2012, pp. 301, 308.

Smart RF SWITCH MATRIX

Improve the efficiency of your test setup!

DC to 18 GHz *from* $385

Test multiple parameters or multiple DUTs in a single pass. Quit constantly stopping to connect/disconnect cables! It sounds simple, but you'll quickly appreciate all the "smarts" we built into our new switch matrices. The user-friendly GUI gets you up and running in minutes right out of the box, for step-by-step control, full automation, or remote operation via the internet. They're fully compatible with almost any PC and most third-party lab software,* adding capabilities to existing setups with ease! And the rugged aluminum cases house our patented mechanical switches, the only ones available anywhere, at any price, that offer up to 10 years/100 million cycles of guaranteed performance.† Just go to minicircuits.com for technical specifications, performance data, pricing, and real-time availability—or give us a call to discuss any custom programming needs—and think how much time and money you can save!

Mini-Circuits...we're redefining what VALUE is all about!

Model	# Switches (SPDT)	IL (dB)	VSWR (:1)	Isolation (dB)	RF P_{MAX} (W)	Price $ (Qty. 1-9)
USB-1SPDT-A18	1	0.25	1.2	80	10	385.00
USB-2SPDT-A18	2	0.25	1.2	80	10	685.00
USB-3SPDT-A18	3	0.25	1.2	80	10	980.00
USB-4SPDT-A18	4	0.25	1.2	80	10	1180.00
NEW USB-8SPDT-A18	8	0.25	1.2	80	10	2495.00

* See data sheet for an extensive list of compatible software.

† The mechanical switches internal to 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 patents 5,272,458 6,650,210 6,414,577 7,633,361 7,843,289 and additional patents pending.

30 day MONEY-BACK GUARANTEE! See minicircuits.com/30day for details

Mini-Circuits®

www.minicircuits.com P.O. Box 35166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

489 rev M

A New Understanding of Mismatch Error

Amplitude accuracy is a signal measurement challenge that increases with frequency and in many RF and microwave measurements, mismatch uncertainty is the largest single component of amplitude uncertainty. In instrumentation, it is common for only the magnitude of the reflection coefficient to be specified, and for these measurements this article shows how expected mismatch uncertainties may be lower than previously predicted by a factor of three to six. This article shows how a statistical approach, validated by real-world measurements, can yield more accurate uncertainty bounds than commonly used models. Depending on the need, the benefits of reduced uncertainty can yield a tightening of DUT specifications, of course, or can be traded off for improved yield or measurement speed.

REDUCING MISMATCH UNCERTAINTY: A STATISTICAL APPROACH

The effects of mismatch of microwave components are well known to engineers working at these frequencies, and the total effect of the combined mismatches in a system will be a major component of measurement uncertainty. While the general expectation is that the worst case effects due to each element will not add, the current method of setting uncertainty guard-bands is only modestly different from straightforward worst-case analysis.

Most of the industry uses the statistical methods of the Guide to the Expression of Uncertainty in Measurement (GUM).[1] This article will describe the authors' recent work to develop and validate a more accurate statistical model for mismatch uncertainty, and how to use this model to replace older approaches. It is a briefer version of the authors' longer conference paper[2] and will explain the concepts without the mathematical derivation and details. This material is also covered as part of Agilent Application Note 1449-3.[3] A convenient way to do the computations is an online spreadsheet.[5] The result of using this new model is more accurate estimates of

Joe Gorin and Michael Dobbert
Agilent Technologies, Santa Rosa, CA

Re-Inventing State Of The Art

700 MHz To 6 GHz Single Band Benchtop Amplifiers & Hybrid Power Modules To Complement Our 4 To 18 GHz Designs

Output Power Up To 200 Watts CW

AR's new line of solid state Hybrid Power Modules (HPM's) and benchtop amplifiers not only provide the best value in a single self contained unit, but they're big on power and performance.

In addition to our solid state 4-18 GHz modules and amplifiers, we now have a line of high gain units that instantaneously cover the ultra-wide 0.7 to 6 GHz frequency band.

Our SMA connectorized modules provide output powers up to 30 watts CW in a class A configuration and up to 50 watts with class AB biasing.

The class A benchtop amplifiers available as a complete self- contained air cooled assembly provide output powers up to 200 watts with a 0 dBm input, include an integrated power supply, a digital control panel, gain control, integrated software and RF input protection.

Both the Class A modules and benchtop units provide excellent gain flatness, low noise figure and have the ability to survive an infinite output mismatch to provide trouble free state-of-the-art performance.

Applications for these high performance products are limited only by your imagination but a small sampling are: Jammers, Radars, ECM, ECCM, Data Links, EMC, Wireless, TWTA replacements/drivers and communications.

To obtain more detailed information on these and other products call AR RF/Microwave Instrumentation at 215 723 8181 or visit us at www.arworld.us.

www.arworld.us/hpm

RoHS

ISO 9001:2008 Certified

rf/microwave instrumentation

Other ar divisions: modular rf • receiver systems • ar europe

USA 215-723-8181. For an applications engineer, call 800-933-8181.

In Europe, call ar United Kingdom +44 1908 282766 • ar France +33 147 917530 • ar Deutschland +49 6101 80270-0 • ar Benelux +31 172 423000

www.arworld.us

Copyright © 2013 AR. The orange stripe on AR products is Reg. U.S. Pat. & TM. Off.

Compex

Promises Made, Promises Kept.

Single Layer Ceramic Capacitors
- Broadest Variety Available
- Gold, Tin, Silver and Platinum Terminations
- 150 pF X7R from 10x10 mils
- 1,000 pF from 25x25 mils
- Custom Diced to Your Value and Size

Mounting Shorts
- Instant Bonding Pads
- Height Matching Reduces Lead length and Inductance
- Any Size Available
- Available in Alumina or Aluminum Nitride

Sub-Mounts
- Alumina, Aluminum Nitride, Quartz, Kovar
- Custom Patterns and Shapes
- Thickness from 3 to 100 mils and Beyond
- Thickness Accuracy to 5 microns

A Veteran Owned,
Solar Powered Small Business

ISO 9001:2008
RoHS and REACH Compliant
Established 1976

439 Commerce Lane, West Berlin, NJ 08091
856 335 2277 • www.compexcorp.com

Technical Feature

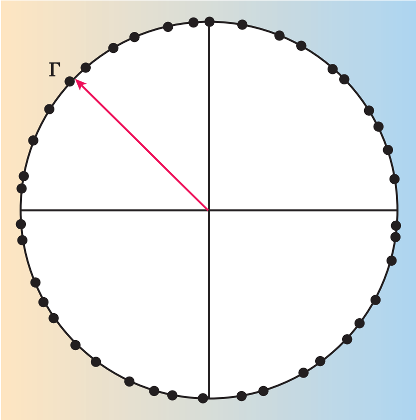


Fig. 1 Simulation of reflection coefficient in the complex plane for a constant magnitude Γ.

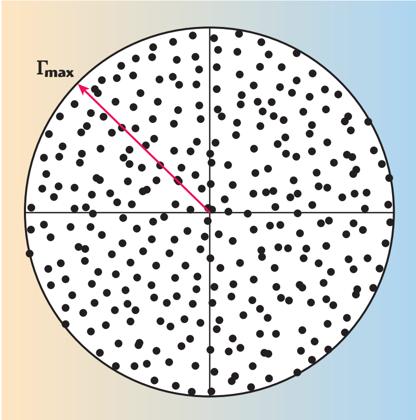


Fig. 2 Simulation with Γ is equally likely anywhere within a circle.

mismatch uncertainty which are three to six times lower than the older methods.

POWER DELIVERY AND MISMATCH

The power delivered to an imperfect power sensor is given by this equation:

$$P_a = P_{gZ0} \frac{1-|\Gamma_\iota|^2}{|1-\Gamma_\iota \Gamma_g|^2}$$

The term P_{gZ0} is the amount of power delivered to an ideal matched load. The numerator term, $1 - |\Gamma_\iota|^2$, is accounted for in the calibration of the power sensor. The denominator term, $|1 - \Gamma_\iota \Gamma g|^2$, represents the mismatch error. If we make the assumption that the cable between the DUT and the power sensor is long, practically speaking we will often not know the phase of the reflections, leading to uncertainty that depends on Γ_ι and Γ_g.

When we want to combine the uncertainty from the mismatches with other measurement uncertainties, using the method of the GUM, we will usually find the standard deviation of the uncertainty and combine that (a sensitivity-weighted root-sum-square addition) with the standard deviation of other uncertainties; we multiply that by the coverage factor, usually 2, to get the 95th percentile measurement uncertainty. In order to do this, we must have a model of the statistical distribution of the magnitudes of Γ_ι and Γ_g.

The older literature documents the assumptions of known reflection magnitude and uniform-inside-a-circle reflection coefficients. This article will emphasize a model of Gaussian distribution in the real and imaginary parts of the reflection coefficient, which results in a Rayleigh distribution of the magnitude of the reflection coefficient.

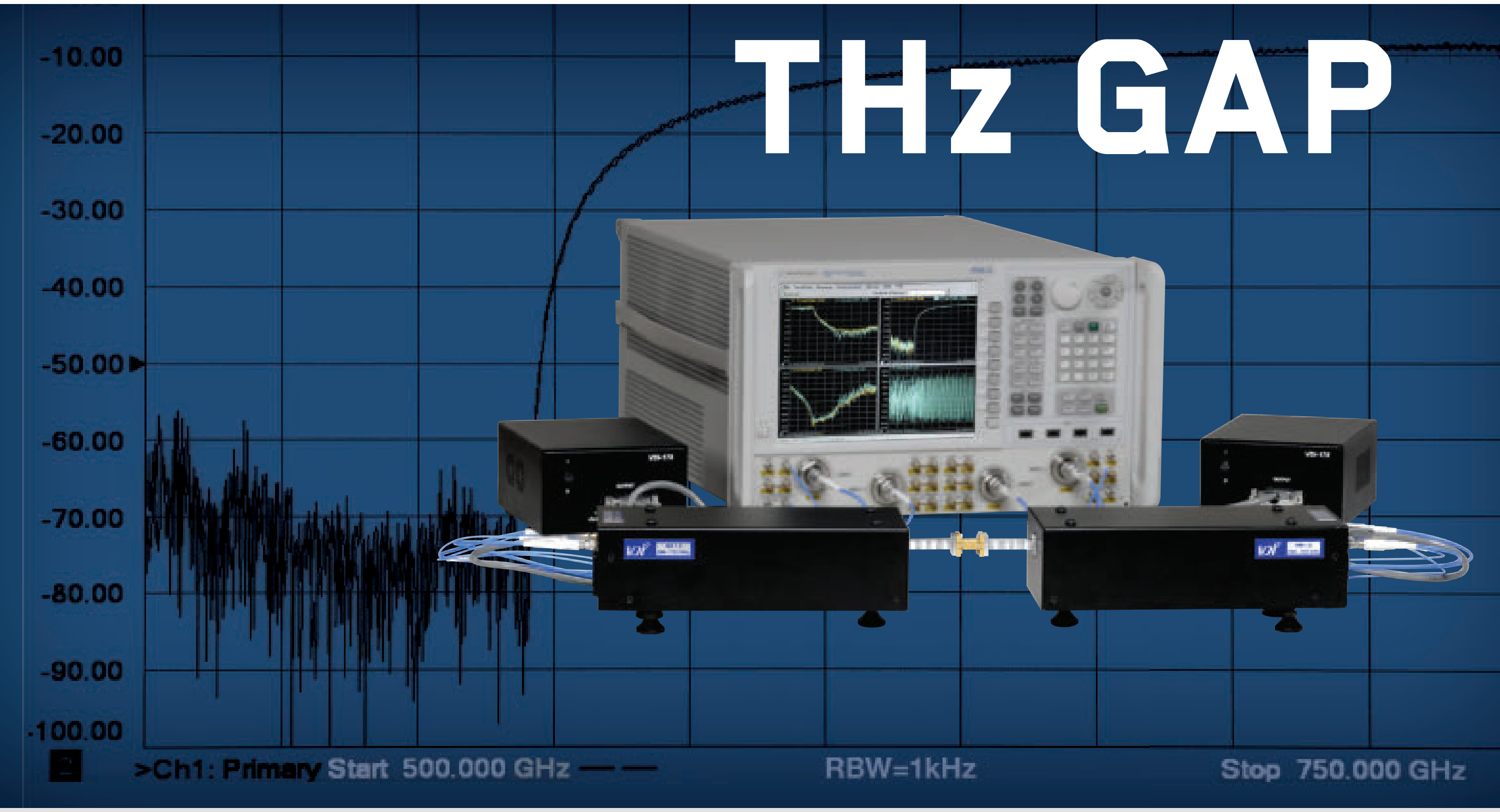
The simplest statistical model, sometimes called the "ring" model, assumes a constant (known) magnitude reflection coefficient with uniformly distributed phase. Classic (and now updated with the information of this article) Application Note 1449-3 from Agilent Technologies[3] calls this "case b." This can be visualized with ***Figure 1*** showing a simulated distribution of the reflection coefficient in the real-imaginary plane.

Because this model is obviously too conservative in many cases, another model has been in use. The "disk" model, shown in ***Figure 2***, assumes that the maximum magnitude is known but the complex reflection coefficient will be equally likely to have a value anywhere within a circle in the complex plane. The effect of modeling both the source and load with the disk model is to give only half as much amplitude uncertainty due to mismatch as for the ring model.

The third model, newly-validated by the research described here, is the "Rayleigh" model, named because the probability density of the magnitude of the reflection coefficient is Rayleigh distributed if the probability density of both complex parts is Gaussian distributed. The simulation is shown in ***Figure 3a***. The simulation figure is annotated with the 95th percentile ring and a "max" ring. These are also shown in the probability density function plot in ***Figure 3b*** on a different scale.

UNMATCHED DYNAMIC RANGE. UNMATCHED PERFORMANCE.

BRIDGE THE THz GAP



VDI'S VNA EXTENSION MODULES

provide high performance frequency extension of vector network analyzers into the THz range. Models are currently available that cover 50GHz to 1.1THz and combine high test-port power with superb dynamic range to offer unparalleled performance. VDI's VNA Extension Modules are compatible with all modern network analyzers. Contact VDI to discuss VNA and Extender configurations that will yield the best performance for your application.

Waveguide Band (GHz)	WR15 50-75	WR12 60-90	WR10 75-110	WR8.0 90-140	WR6.5 110-170	WR5.1 140-220	WR4.3 170-260	WR3.4 220-325	WR2.8 260-400	WR2.8 325-500	WR1.5 500-750	WR1.0 750-1,100
Dynamic Range (BW=10Hz,dB,typ)	120	120	120	120	120	120	115	115	100	100	**100**	60
Dynamic Range (BW=10Hz,dB,min)	100	100	100	100	100	100	100	100	80	80	**80**	40
Magnitude Stability (±dB)	0.15	0.15	0.15	0.15	0.25	0.25	0.3	0.3	0.5	0.5	**0.8**	1
Phase Stability (±deg)	2	2	2	2	4	4	6	6	8	8	**10**	15
Test Port Power (dBm)	6/13	6/10	6/10	6/10	0	-4	-6	-9	-16	-17	**-25**	-35

VIRGINIA DIODES, INC.
434.297.3257 | vadiodes.com

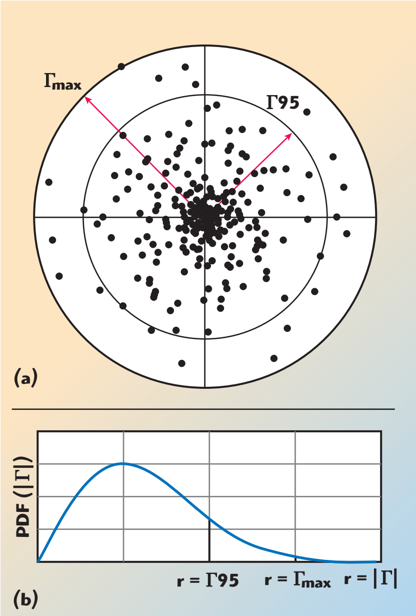


Fig. 3 *Rayleigh simulation (a) and probability density function (b).*

Just as the real and imaginary parts with their Gaussian distributions have no true maximum value, neither does the magnitude of the reflection coefficient with its Rayleigh distribution. In order to compare this distribution with the earlier distributions, let us assume that the maximum value given by the manufacturer of the power sensor corresponds to the equivalent of a "3σ" performance level, such that 99.73 percent of manufactured units pass the "max" level and the remainders are not sold.

We can compare the uncertainties of the three models as shown in ***Table 1***.

To summarize: When we know the maximum magnitude of the reflection coefficient of a source and a load, and we assume one of three statistical distributions for that reflection coefficient, and when assuming a Rayleigh distribution, we assume that the "maximum" is equivalent to a "3σ" yield level, the Rayleigh distribution gives an uncertainty six times smaller than the most commonly used distribution for analysis (the ring distribution) and three times smaller than the uniform distribution.

TABLE I

STANDARD UNCERTAINTY FOR THE THREE MODELS OF DISTRIBUTION

Distribution of Source and Load	*Standard Uncertainty*	*Alternate Statement*
Fixed (Ring)	$\sqrt{2}\Gamma_l\Gamma_g$	
Uniform (Disk)	$\frac{1}{\sqrt{2}}\Gamma max_l\, \Gamma max_g$	
Rayleigh	$0.239\Gamma max_l\, \Gamma max_g$	$\frac{4\sqrt{2}}{\pi}\Gamma mean_l \Gamma mean_g$

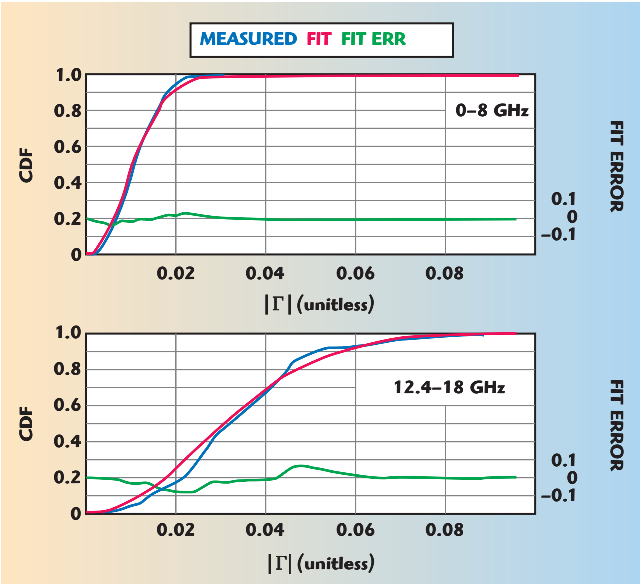


Fig. 4 *FIT of observations to Rayleigh CDF in two frequency regions.*

EVIDENCE AND THEORY AGREE THAT THE DISTRIBUTION SHOULD BE RAYLEIGH

Theory dates to a 1957 paper by Mullen and Prichard[4] that explains how the real and imaginary parts of the reflections of any moderately complex microwave instrument should follow the central limit theorem, yielding a Rayleigh magnitude distribution.

Let us next look at experimental evidence. We will consider three common


RF-LAMBDA
The Power Beyond Expectations
RF
Leading GaN Amplifiers & Switches Solution
Low Noise Amplifier
GaN Power Amplifier
RF GaN PIN Switch
PIN Attenuator Phase shifter
Solution to 60GHz
Millions in Stock!
RF-Lambda
RFSP8TA0118G
F:1-18GHz
Ultra wide band 98%
High Power Handling
Low Noise Figure
Fast Switching Speed
High Isolation
Wire Bond Technology
www.rflambda.com

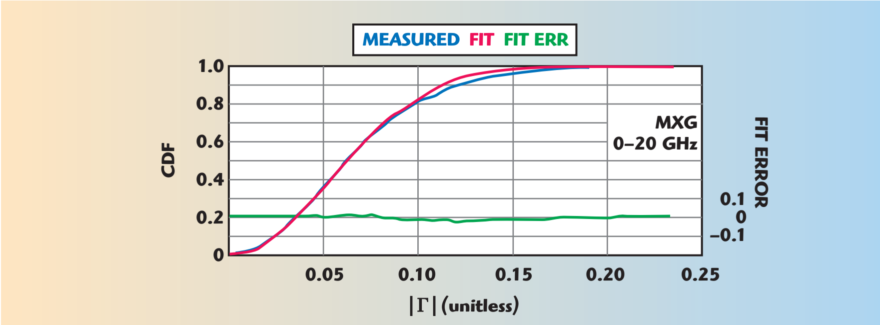


Fig. 5 CDF for a signal generator (Agilent MXG).

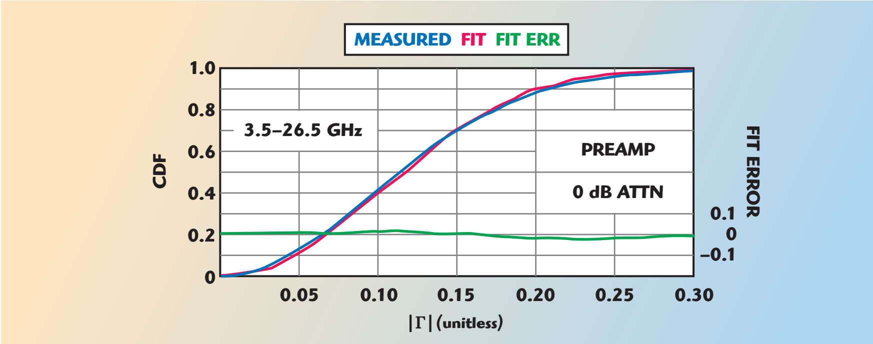


Fig. 6 CDF for the high-band preamp path in a signal analyzer (Agilent PXA, Preamp from 3.5 to 26.5 GHz, 0 dB attenuation).

instruments: a power sensor, a signal generator and a signal analyzer. The authors did their study with the older model 8481A power sensor from Agilent Technologies. The reflection coefficient is specified in the three frequency ranges. For the best and worst ranges, we see plots of the cumulative distribution function (CDF) versus magnitude of the reflection coefficient in ***Figure 4***. The CDF is the integral of the PDF. It is a graphical way of observing the fit that compares distributions without the distractions of using a histogram as the experimental approximation to the PDF. It can be seen that, even for such a simple device as a power sensor, the fit to a Rayleigh distribution is excellent. For a signal source, we see the CDF plot of ***Figure 5***. Finally, one signal path for a signal analyzer is representative of all the signal paths as seen in ***Figure 6***. In all the cases studied, the Rayleigh distribution is an excellent model of the behavior of the instrumentation.

CONCLUSION

The GUM recommends that measurement uncertainties be estimated as accurately as is feasible. Overestimating measurement uncertainties is a disservice to the users of our products and to our business success. Using the Rayleigh distribution in estimating uncertainty is more accurate than established methods and gives three to six times lower mismatch uncertainty. ■

References

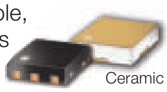
1. Evaluation of Measurement Data – Guide to the Expression of Uncertainty in Measurement JCGM 100:2008 (GUM 1995 with minor corrections), BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML–ISO, Geneva, Switzerland, 2008 (www.bipm.org/en/publications/guides/gum.html).
2. M. Dobbert and J. Gorin, "Revisiting Mismatch Uncertainty with the Rayleigh Distribution," 2011 Conference of NCSL International, August 25, 2011, (http://cp.literature.agilent.com/litweb/pdf/5990-9185EN.pdf).
3. "Fundamentals of RF and Microwave Power Measurements (Part 3) Power Measurement Uncertainty per International Guides," Agilent Application Note AN 1449-3, April 5, 2011, (literature number 5988-9215EN, available online at www.agilent.com).
4. J.A. Mullen and W.L. Pritchard, "The Statistical Prediction of Voltage Standing-Wave Ratio," Microwave Theory and Techniques, *IRE Transactions*, April 1957, Volume 5, Issue 2.
5. "Average Power Sensor Uncertainty Calculator," Agilent Technologies, April 6, 2011.

A perfect fit for almost any PCB!

RCAT/YAT ATTENUATORS DC to 20 GHz from $2.99 ea.(qty. 20)

Our new tiny 2W fixed value absorptive attenuators are now available in molded plastic or high-rel nitrogen-filled ceramic packages. They are perfect building blocks for both broad and narrow-band systems, 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 under the harshest conditions having been qualified to meet MIL requirements including vibration, PIND, thermal shock, gross and fine leak and more, at up to 125°C!



Ceramic

Plastic

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 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/

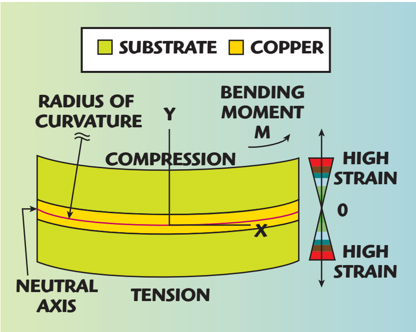
Mini-Circuits®

www.minicircuits.com P.O. Box 35166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

515 rev A

Reliably Bend and Form Microwave PCBs

Most RF/microwave printed-circuit-board (PCB) applications are planar and can be built with a flat circuit board. But some circuit applications may call for a PCB to be bent and formed into a three-dimensional (3D) shape. Bending PCB materials consistently and reliably can be challenging, and many circuit designers will confess to fractured conductors among other problems incurred during their initial experiences in trying to form a PCB into some nonplanar shape. Still, when the basic mechanical principles behind bending and forming PCB materials are better understood and properly applied, such as the capability to predict the minimum bend radius for a particular PCB construction, 3D circuits can be formed with reliable performance and without those fractured conductors.



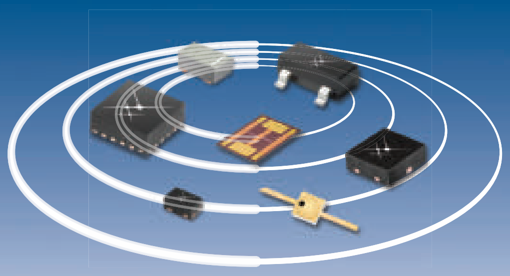
▲ *Fig. 1 A PCB with a single conductive layer circuit with dielectric substrate material above and below, and the tension and compression that result from an applied bend radius.*

A PCB consists of various materials, such as copper and dielectric layers. The layers are very different in terms of their mechanical properties and, accordingly, a PCB is considered a composite beam. When mechanical composite-beam theory is applied to the bending and forming of PCBs, there are four major areas of concern:

1. The applied bend radius and related forces
2. Strain on the different layers of the PCB
3. The neutral axis location
4. The modulus (stiffness of the different materials in the PCB).

A simple example may help to understand the basic concepts of bending a circuit. Although this example is not particularly common in the RF/microwave industry, it is well suited for describing the mechanical issues of bending a PCB. Once these issues are reviewed, some circuit configurations more commonly used in the microwave PCB industry will be considered. This simple initial example consists of a circuit formed on a single conductive layer of copper, with dielectric substrate on both sides of the copper. It is similar to the flexible printed-circuit construction used in very high dynamic flexing applications, such as the read-write servo arm interconnection inside a computer's hard disk drive (HDD). ***Figure 1*** shows a cross-sectional view of this simple single-sided circuit example, with an applied bend radius.

John Coonrod
Rogers Corp., Chandler, AZ



SKYWORKS®

Aerospace and Defense Solutions

Visit Us at MILCOM Booth 739 San Diego, CA November 18–20, 2013

Low Noise Amplifiers (LNAs)

Part Number	Freq. (MHz)	Noise Figure (dB)	Gain (dB)	Input IP3 (dBm)	$P_{1\,dB}$ (dBm)	Vbias (V @ mA)
SKY67015-396LF	30–300	0.80	18.5	7.5	12.5	3.3 @ 18
SKY67151-396LF	700–3800	0.25	26.0	8.5	21.5	5 @ 80

Attenuator

Part Number	Freq. (MHz)	Control Accuracy (Bits)	Attenuation (dB)	Insertion Loss (dB)	Input $P_{1\,dB}$ (dBm)	Input IP3 (dBm)
SKY12343-364LF	10–4000	7	31.75	1.8	35	50

Limiter Diode

Part Number	Freq. (MHz)	Breakdown Voltage (V)	Insertion Loss (dB)	Max. Pulsed Input Power (dBm)	Series Resistance (Ω)	Capacitance (pF)	Recover Time (ns)
SMP1330-040LF	DC–600	20	0.3	70	1.5	0.26	1000

Switching PIN Diode

Part Number	Freq. (MHz)	Breakdown Voltage (V)	Insertion Loss (dB)	Series Resistance (Ω)	Capacitance (pF)	Carrier Lifetime (ns)
SMP1345-040LF	DC–6000	50	0.4	1.5	0.18	100

Schottky Diode

Part Number	Freq. (GHz)	Breakdown Voltage (V)	Video Resistance (Ω)	Capacitance (pF)	Forward Voltage (mV)
SMS7630-061	DC–100	1	5000	0.2	180

Varactor Diode

Part Number	Freq. (GHz)	Breakdown Voltage (V)	Q Factor @ 4 V	C_T @ 4 V (pF)	C_T @ 20 V (pF)
SMV2201–SMV2205 Series	DC–10	22	500	0.73 min. / 0.98 max.	0.18 min. / 0.33 max.

Switches

Part Number	Freq. (MHz)	Insertion Loss (dB)	Isolation (dB)	Input $P_{1\,dB}$ (dBm)	Input IP3 (dBm)	Switching Time (ns)
SKY12208-478LF	20–2700	0.3	45	47	70	85
SKY12211-478LF	50–2700	0.3	47	46	73	32
SKY13286-359LF	100–6000	0.35	34	39	–	500

Phase Locked Loop (PLL) Frequency Synthesizer

Part Number	Freq. (MHz)	Synthesizer	Divide-by	Input $P_{1\,dB}$ (dBm)
SKY73134-11	350–6000	Integer-N	1/2/3/4/8	4

Direct Quadrature Demodulator

Part Number	RF and LO Freq. Range (MHz)	IF Freq. Range (MHz)	Input IP3 (dBm)	Input $P_{1\,dB}$ (dBm)	I/Q Amplitude Imbalance (dB)	I/Q Phase Error (Deg.)
SKY73012	400–3900	DC–250	29	12	±0.3	1s

Low Drop-out (LDO) Linear Regulators

Part Number	Dropout Voltage (mV)	Output Voltage (V)	DC Output Voltage Tolerance (%)	Output Current (mA)	Quiescent Current (μA)
AAT3223IGU3.0T1	190	3.0	±2	250	1.1
AAT3223IGU3.3T1	180	3.3	±2	250	1.1

Skyworks' Green™ products are compliant to all applicable materials legislation and are halogen-free. For additional information, refer to Skyworks Definition of Green™, document number SQ04-0074.
New products indicated in **blue, bold** are continually being introduced at Skyworks.

USA: 781-376-3000 • Asia: 886-2-2735 0399 • Europe: 33 (0)1 43548540 • Email: sales@skyworksinc.com

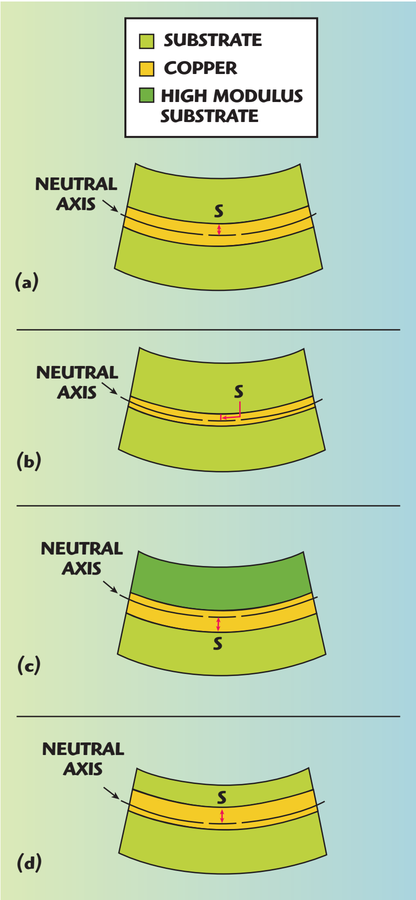
www.skyworksinc.com • NASDAQ: SWKS •

If this circuit board was handheld and bent, the substrate would undergo compression on the inside of the bend and tension on the opposite side of the substrate. A transition from compression to tension would take place within the circuit material, occurring within an almost infinitely thin plane. Within this plane, called the neutral axis of the PCB, there is zero strain. For a balanced circuit board, the neutral axis is located at the geometric center of the board. The example circuit is considered a balanced circuit because it assumes that the substrate layers at the top and bottom of the copper layer have the same thickness and same modulus (stiffness). With thicker top and bottom substrate layers, more force is needed to achieve a given bend in the PCB. In such a case, even though the neutral axis will have zero strain, the amount of strain away from the neutral axis will be significantly increased compared to a circuit with thinner substrate layers.

Understanding the amount of strain at a specific material interface within a PCB is critical when trying to bend a circuit without fracturing its conductors. In general, the threat of fracturing copper is a concern for any copper-substrate interface that must endure strain of any kind. A crack that starts at this interface can propagate through the thickness of the copper, resulting in a fractured conductor.

A PCB's neutral axis exhibits zero strain; the strain increases at any distance from the neutral axis. Essentially, further distance from the neutral axis translates into higher strain, and higher strain translates into increased potential for circuit fracturing. For the example circuit, a thinner copper layer will be a better choice for bending without fracturing the copper. For a PCB with thinner copper, the copper-substrate interface furthest from the neutral axis will be a shorter distance from the neutral axis than a PCB with thicker copper. For this reason, thin copper is used with the thin balanced circuitry inside HDDs.

Figure 2 shows the variations for this example circuit. In Figure 2a, the balanced circuit will have the same strain(s) on the top copper-substrate interface as on the bottom copper-substrate interface. This will also be true for Figure 2b, although with thinner copper, the copper-substrate interface will be closer to the neutral axis and will exhibit less strain. Figure 2c shows a geometrically balanced circuit (substrate layers of equal thickness). However, the top substrate layer uses high modulus substrate material, and the neutral axis will shift toward the high modulus material, creating a greater distance between the neutral axis and the bottom copper-substrate interface. With this high modulus substrate layer, this lower metal-substrate interface will suffer much more strain than the top copper-substrate interface. Finally, Figure 2d shows a circuit that uses the same substrate materials, although with a thinner substrate layer at the top than at the bottom. As a result, the neutral axis will shift toward the thicker material and create



▲ *Fig. 2 Neutral axis location and maximum strain(s) on one of the copper-substrate interfaces for balanced circuit (a), balanced circuit with thinner copper (b), geometrically balanced circuit with high modulus substrate on one layer (c), and offset balanced circuit with the same substrate material of different thicknesses (d).*


QUINSTAR
TECHNOLOGY, INC.
Complete Millimeter-Wave
Solutions for
Defense Applications
• Amplifiers (low noise and power)
• Sources, Mixers, Multipliers, Detectors
• Antenna, Polarizers, OMTs
• Cryogenic products
• Integrated subsystems
• Isolators, Circulators, Attenuators
• Switches, Power Dividers, Couplers
• Adapters, Filters, Terminations
• Waveguide bends, straights, and twists
QuinStar Technology, Inc
24085 Garnier St. Torrance CA 90505
T:310.320.1111
www.QuinStar.com
VISA

higher strain on the top copper-substrate interface.

The neutral axis location is a serious concern when bending and forming PCBs, but the modulus of the different layers within the PCB is also very important. The modulus has an impact on the neutral axis location as well as increasing the strain within the circuit. PCBs intended to be bent or formed should be fabricated with nonwoven glass reinforced materials. Many PCBs are constructed with woven-glass reinforcement. A woven-glass layer has areas of voids between knuckles of glass strands and these different areas of the woven-glass layer cause large transitions in modulus in isolated areas. Stress can be concentrated at these transitions and high strains develop in these areas where the modulus value changes significantly over a short distance; such variations in modulus value can also be difficult to model. Due to these issues, circuit materials with woven-glass reinforcement should be avoided when fabricating a circuit that will be bent or formed.

TABLE I

MODULUS VALUES FOR VARIOUS PCB MATERIALS INTENDED TO BE BENT OR FORMED

	Modulus (kpsi)
Copper	17,000
PTFE with micro-fiber glass	175
Ceramic filled PTFE	300
LCP (Liquid Crystalline Polymer)	330
FEP	80
Soldermask	350

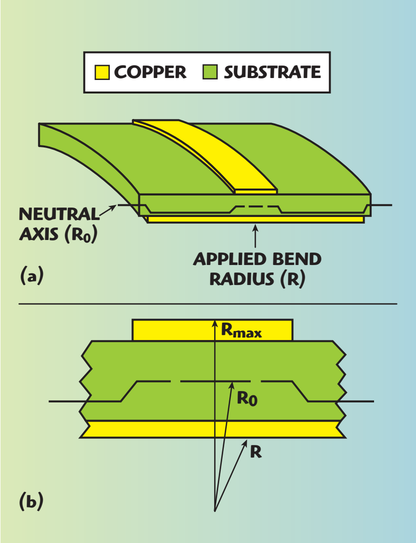


Fig. 3 A microstrip transmission line circuit with an applied bend radius in three-dimensional view (a) and cross-sectional view with the isolated area of the signal conductor on top and ground plane on bottom (b).

The modulus values of the various materials used to produce a PCB can be significantly different. The modulus value for copper is typically the highest in a PCB, normally orders of magnitude higher than the modulus value of the substrate. ***Table 1*** shows modulus values for various materials used in PCBs intended to be bent or formed.

Since copper is the highest-valued modulus component in a circuit construction, it is important to consider when evaluating mechanical models to reduce strain for better bending and forming capability. When considering the amount of strain within a circuit, reducing the amount of copper will reduce the overall strain. Copper can be reduced by making the various copper layers thinner, reducing the percentage of copper per copper layer, or reducing the number of copper layers.

To understand how bending and forming circuits can impact circuit designs employed in the microwave industry, it might be helpful to examine how bent circuits are made using microstrip transmission lines. Such circuits are often formed for 3D antennas and interconnections that are nonplanar. As an example, ***Figure 3*** shows a simple microstrip transmission line with an applied bend radius. The neutral axis will be at different locations depending on where it is evaluated within the cross-sectional view of the circuit.

When bending and forming microstrip circuits, the signal layer is typically considered more critical than the ground plane for strain modeling and predicting copper fracturing. If micro-fractures appear on the ground plane copper, it will probably have less electrical impact than the narrower signal conductor. Following that reasoning, Figure 3b shows maximum radius R_{max} as the high strain plane that would need to be modeled to predict copper fracturing

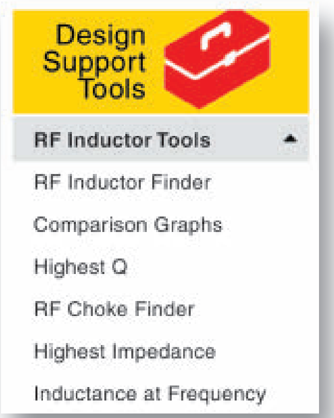
From Search to Samples in Seconds

Our web tools help you quickly pick the perfect inductor. Then get free samples overnight!

We make picking inductors fast, easy, and almost fun!

Start with a quick parametric search for parts that meet your specs. (We even show you volume pricing.) Click to instantly compare Q, L, Z and ESR for multiple inductors.

Looking for inductors with the highest impedance or Q factors? There are tools for that! All based on real data, not theoretical models.



When you've picked your inductors, just click to get free samples. Do it by 5:00 p.m. CST and they'll ship to you the same day!

See how fast *you* can go from search to samples. Visit **coilcraft.com/tools.**

Coilcraft®

WWW.COILCRAFT.COM

coilcraftdirect.com
No min order. Next day delivery.

during PCB bending and forming. In the case of the signal conductor, R_{max} is at the furthest distance from the neutral axis.

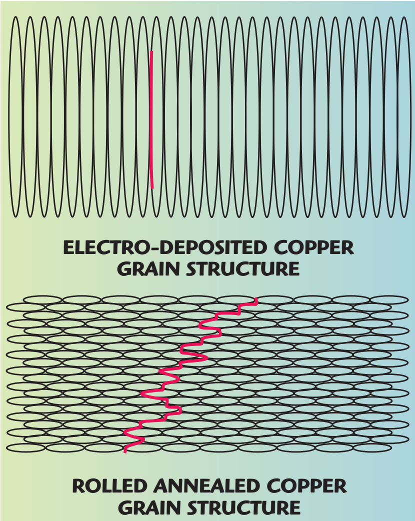
To calculate values for the neutral axis and the percent strain, an Excel® worksheet can be created to predict those values. Predictions can be made based on the following equations for the neutral axis, R_0, and the percent strain (% strain):

$$R_0 = \frac{\sum_{i=1}^{n} E_i Y_i A_i}{\sum_{i=1}^{n} E_i Y_i}$$

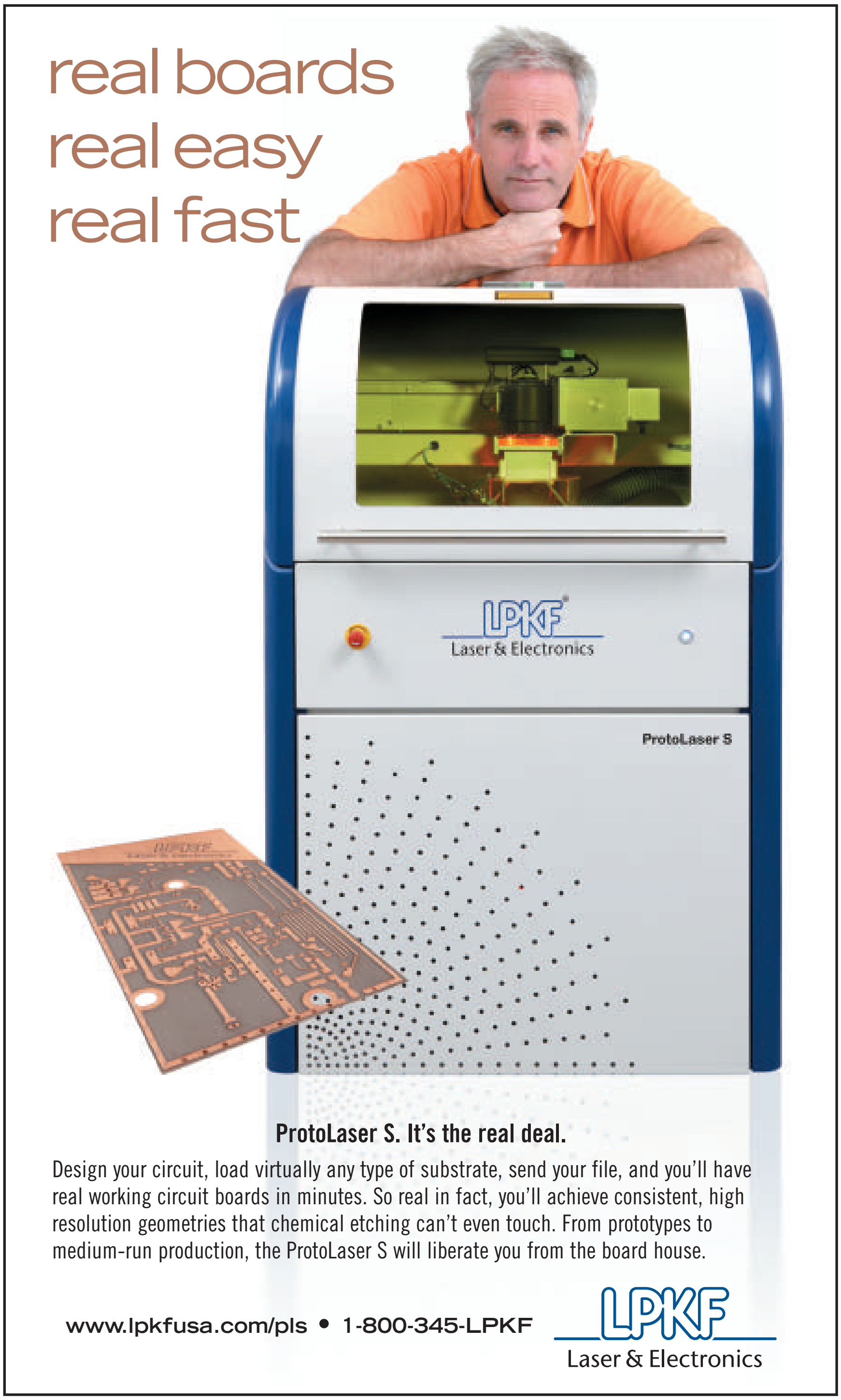
$$\%strain = \frac{(2\pi R_{max}) - (2\pi R_0)}{(2\pi R_0)} 100 \quad (1)$$

with Y_i being the mean distance from the origin for each layer of material, where the origin is considered the bottom of the circuit where the bend radius is applied. Parameter E_i is the modulus of each layer within the circuit while A_i is the area of each layer. The neutral axis location, R_0, is the distance from the origin or bottom of the circuit, as shown in Figure 3b.

If performing calculations for different PCBs and different materials, it might be useful to have some strain values as guidelines or reference points. For example, studies have been done in the flexible circuit industry that give a correlation of strain to copper fracturing and when using smooth rolled copper the maximum strain is 2 percent. PCBs with rolled annealed copper handle bending and forming much better than PCBs with standard electrodeposited (ED) copper. Still, some confusion exists between these two copper types because of the way they are tested. PCB copper is typically tested for elongation within a plane, where a copper foil is pulled apart in a planar manner but without any bend. When a bend radius is applied, rolled copper will perform much better than standard ED copper due to its copper surface roughness and copper grain structure. ***Figure 4*** offers an exaggerated and simple drawing to explain this issue. When a bend is applied to standard ED copper, the peaks of the surface will be pulled apart from each other and a crack will easily form.



▲ *Fig. 4 An exaggerated, simple comparison of standard ED copper and rolled copper. The red lines show potential for crack initiation and propagation for the different types of copper.*



Emerson Network Power Connectivity Solutions delivers innovation in interconnect technology for maximum signal integrity. Your system's performance can be enhanced and assured by Emerson Connectivity Solutions through:

- Harsh environment optical connectors
- Twinax and microwave cable assemblies
- High performance RF & microwave connectors and components

Emerson Connectivity Solutions brings together technology and engineering to create innovative customer solutions.

Get Connected...

EmersonConnectivity.com

Toll free: 800-247-8256
Phone: 507-833-8822

Connectivity Solutions

EMERSON™
Network Power

Emerson Network Power and the Emerson Network Power logo are trademarks and service marks of Emerson Electric Co. ©2011 Emerson Electric Co.

EMERSON. CONSIDER IT SOLVED.™

TABLE II

RESULTS OF BEND RADIUS STUDY PERFORMED ON MICROSTRIP TRANSMISSION LINE PCB

Bend Radius (in.)	*Neutral Axis (in.)*	*Strain (%) @ R_max*	*Mandrel Test*
0.250	0.0031	1.21	Pass
0.125	0.0031	2.36	Pass
0.100	0.0031	2.92	Fail
0.078	0.0031	3.68	Fail

Once a crack is initiated in ED copper, the fracture will readily propagate through the thickness of the copper.

In the case of rolled copper and with an applied bend radius, there are no distinct stress concentrators and it is difficult for a crack to initiate. The smoother surface makes it more difficult for a crack to start and even if it does, the grain structure of the rolled copper does not allow the fracture to propagate easily through the thickness of the copper.

PCB bending and forming can be affected by copper and other plating materials applied to a circuit board. For example, a PCB with ED copper plated on top of smooth rolled copper can cause issues with bending and forming. Because copper is the highest modulus material in the PCB, the additional copper thickness is not desired and will raise the strain of the circuit board. Also, the plating of ED copper has a vertical grain structure that makes it easy for a crack to form when a bend radius is applied. The intermetallic boundary between the rolled copper and the ED copper plating can act as a stress concentrator and cause fracturing of the copper during bending and forming.

Electroless nickel/immersion gold (ENIG) plating is commonly used as a finish for PCB conductors. The same issues apply as mentioned with plating rolled copper with ED copper, however, an additional concern is that nickel is very brittle and can initiate fracturing easily when the circuit is bent.

Bend radius is an important concern for PCBs that must be bent and formed. Put simply, a smaller bend radius will cause more strain on the PCB's interfaces, resulting in conditions where fractures are more likely. To demonstrate the mechanical theory, a simple study was conducted where microstrip circuits of the same construction were bent around a controlled radius (metrology measurement mandrels). Many precautions were taken to ensure that the forces on the circuit were uniform around the mandrel when applying the bend radius. ***Table 2*** shows the results of this study/model in terms of percent strain compared to the circuit bending information using different bend radius.

The mandrel testing results shown in Table 2 were produced using a simple microstrip transmission line circuit, made from a print/etch process and did not use plated through-holes (PTH). The PCB's ½ oz. rolled

Anritsu | Since 1895

Over 100 years of

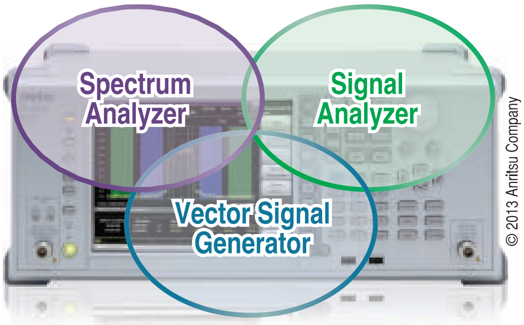
Advancing

the World's Communications History

If you believe the past is instrumental in shaping the future then you'll understand why Anritsu is synonymous with Innovation. Over 100 years of experience and innovation is in our equipment, including our Signal/Spectrum Analyzer (MS2830A).

2 | 4

Spectrum/Signal Analyzer/Signal Generator



MS2830A

© 2013 Anritsu Company

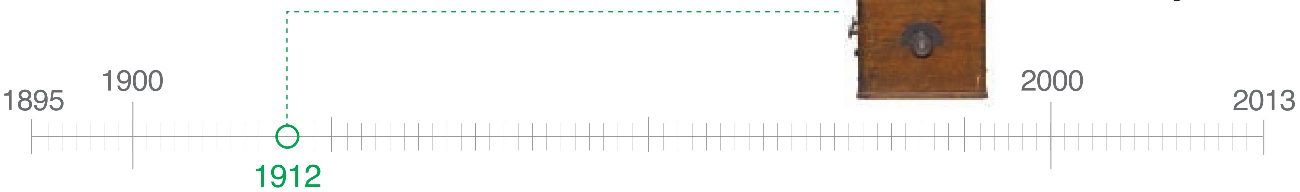
First One-Box TRx Tests

True innovation solves a challenge and makes something better. In 1912 Anritsu successfully inserted voice onto a radio carrier signal to invent the TYK radiotelephone, improving how we communicate and forming the basis of today's smartphones. More recently, building on this heritage of innovation, Anritsu was the first company to release an all-in-one, high-performance spectrum analyzer, incorporating both a spectrum analyzer and a signal generator in one cabinet, providing a new level of efficiency.

All-in-one innovation

Put it to work for you. Learn more and download our FREE White Paper, **Top 3 issues when characterizing wide bandwidth wireless transmitters**, at: www.goanritsu.com/MJTRXOneBox

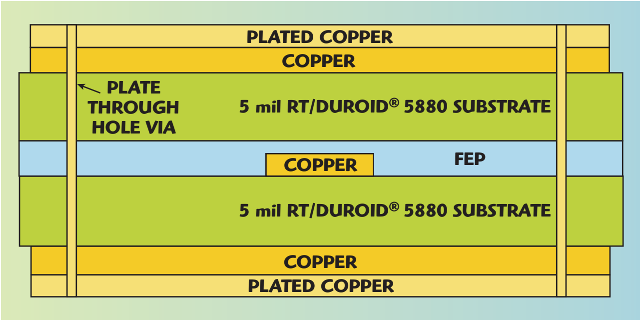
Phone communication advances with voice on a radio carrier signal



USA/Canada *1-800-ANRITSU* ***Europe*** *44 1582-433433*
Japan *81 (46) 296-1208* ***Asia-Pacific*** *(852) 2301-4980*
South America *55 (11) 3283-2511*

Anritsu

Discover What's Possible™



▲ *Fig. 5 A cross-sectional view of a stripline transmission line circuit.*

copper did not have any copper plating on top, and no other finish or solder mask was applied (PCB used a 5 mil thick PTFE laminate). In addition, the pass/fail results from the mandrel test yielded a failed response when the circuit was found to have microcracks in the copper when inspected at 30×.

It should be noted that the value of 2 percent for maximum strain provided previously is a general guideline and that this value may appear to be conservative next to the results shown in Table 2. The 2 percent value is a general guideline and if a greater population of circuits was tested, a better trend might have been found for this particular example circuit construction.

A real microwave application example, but a more difficult PCB construction to model is a stripline transmission-line circuit. The application requirements were that the circuit be bent once, bend radius of 0.200 in., circuit using 1 oz. copper and ENIG plating on the outer ground layers. The application required low insertion loss of 1.0 dB/in. or less at Ka-Band frequencies, specifically at 31 GHz.

Electrically, a thin laminate was needed, with low dissipation factor and smooth copper for minimal conductor loss. A PCB with lower dielectric constant would make it possible to use a wider conductor and reduce conductor loss. The material chosen was 5-mil-thick Rogers RT/duroid® 5880 laminate and is available in a minimum thickness of 5 mils with rolled copper. For the mechanical requirements, the laminate does not use woven-glass reinforcement and consists of low modulus substrate. ***Figure 5*** shows a cross-sectional view of the stripline circuit used for this example.

For this example, it is possible to have relatively low strain on the internal signal layer, because the neutral axis will be very near this copper layer. However, the top and bottom ground planes will be very far from this PCB's neutral axis and they will experience much higher amounts of strain when a bend radius is applied.

Several mechanical models were run and found changes had to be made. ***Table 3*** shows the results of some of the mechanical models, using 1, ½ and ¼ oz. copper. As the values in Table 3 indicate, strain on the signal layer in the stripline example was not a concern. However, the higher strain numbers for the outer ground planes may be some cause for concern. The original model had strain figures of

Where Performance Counts

Bandpass • Bandreject • Highpass • Lowpass • Transmit • Receive • Duplexers • Multiplexers

Military • Commercial
Wireless • Space

Eastern Wireless TeleComm understands just how much is on the line with each and every product we make. We continually provide the highest quality filter products, design support, and service to our customers each and every time. Where Performance Counts, Count on EWT.

Specializing in custom design and manufacturing of RF and Microwave filters and filter based products to 50 GHz.

www.ewtfilters.com

Eastern Wireless TeleComm, Inc.
Tel: 410.749.3800 Fax: 410.749.4852
sales@ewtfilters.com

about 3.5 to 3.6 percent for the outer copper layers, a range where copper fracturing is a risk. After reviewing the specifications for the model, it became evident that the 1 oz. copper thickness could be reduced, making it possible to achieve improvements in strain values by using thinner copper layers in ½ and ¼ oz. copper circuit models.

TABLE III

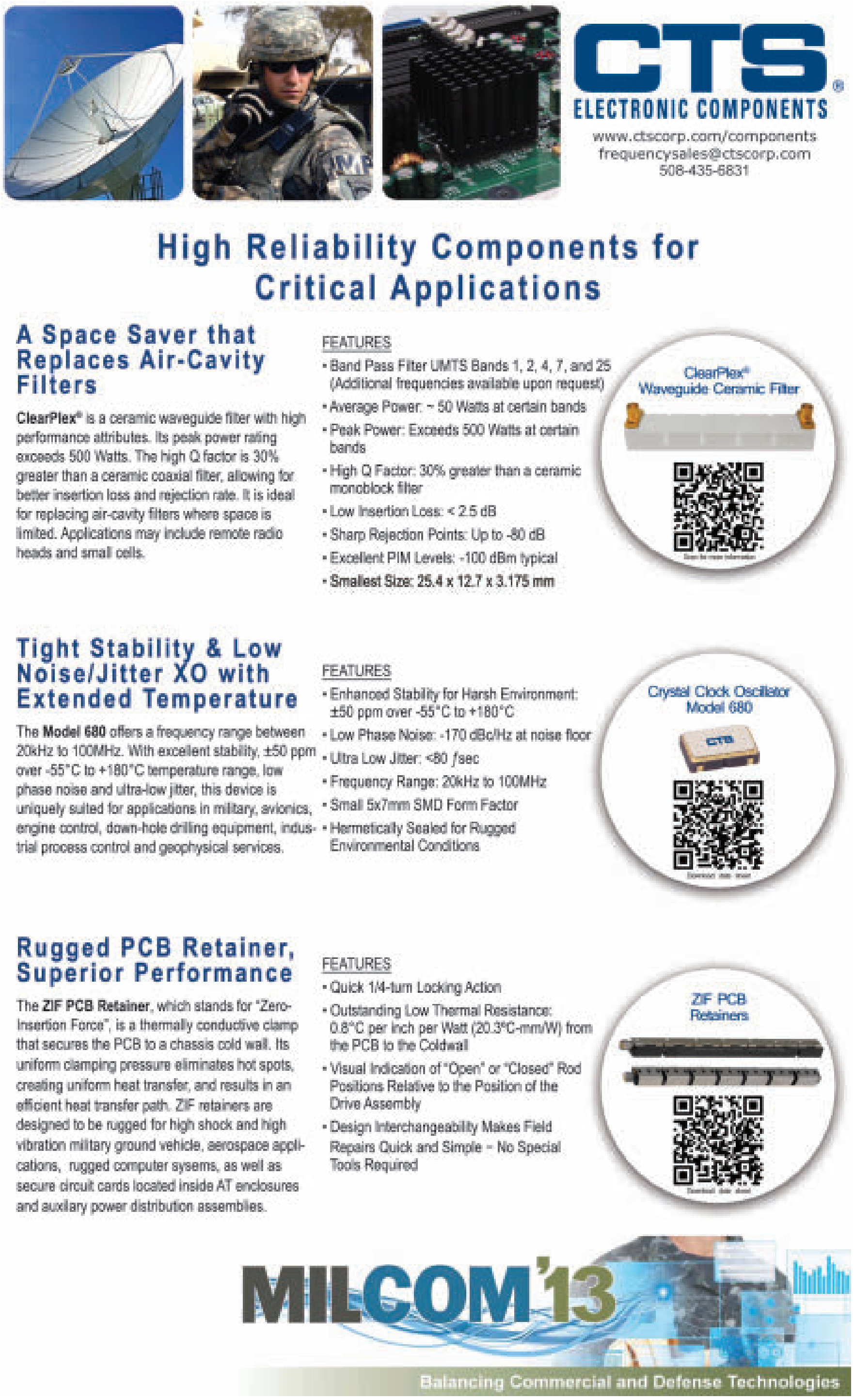
RESULTS OF MECHANICAL MODELS FOR VARIOUS MATERIALS

	Strain (%) on copper layers		
	Top Ground	*Center, Signal*	*Bottom Ground*
1 oz. - 5 mil material	3.631	0.508	3.543
½ oz. - 5 mil material	3.14	0.342	3.054
¼ oz. - 5 mil material	2.926	0.272	2.844

Even with thinner copper, strain values were 2.8 and 2.9 percent for the stripline models – of some concern, but accepted as being within the limits of the different tradeoffs for this study. To gain a real-world perspective, prototype circuits were fabricated based on the model parameters, then bent into shape and inspected for copper fracturing. These prototypes did suffer copper fracturing, so changes were necessary. After evaluating several different models and prototype builds, successful results were obtained by addressing a number of issues. For example, the original prototype circuits featured plated copper at an average thickness of 1.2 mils and this was reduced to an average of 0.5 mils. The thinner copper improved the strain numbers to about 2.2 percent.

The ENIG plating used in the first round of these stripline prototype circuits was also viewed as a potential cause of copper fracturing, and was replaced with immersion silver. Implementing these changes in the prototype stripline circuits improved their bending capabilities significantly, although a small percentage of problems existed when evaluating a large number of circuits after bending. It was then determined to heat the circuits during the bending process. The substrate is based on polytetrafluoroethylene (PTFE) and this material becomes softer (its modulus decreases) as it is heated. The same applies to the FEP bonding layer. Heating results in less strain during the circuit bending/forming process, improving upon the mechanical model. A heating fixture was assembled to form the circuit around a controlled mandrel and at a temperature of +250°F. After fine tuning the fixture to ensure even pressure was applied to the circuit, with strain evenly distributed, very good results were obtained.

There are always tradeoffs with any new circuit design. The same applies when considering mechanical engineering for a circuit. Understanding the multiple tradeoffs for the stripline circuit example is typical of the process required for obtaining a microwave PCB that can be bent and formed reliably. ■



Planar Monolithics Industries, Inc.

Offering State-Of-The-Art RF and Microwave Components & Integrated Assemblies From DC to 40GHz

- Amplifiers
- Attenuators - Variable
- DLVA & ERDLVA & SDLVA's
- DTO's & Frequency Synthesizers
- Filters
- Form, Fit & Function Products
- IFM's & Frequency Discriminators
- Integrated MIC/MMIC Modules
- I/Q Vector Modulators
- Limiters & Detectors
- Log Amplifiers
- Pulse & Bi-Phase Modulators
- Phase Shifters
- Rack & Chassis Mount Products
- Receiver Front Ends & Transceivers
- Single Sideband Modulators
- SMT & QFN Products
- Solid-State Switches
- Switch Matrices
- Switch Filter Banks
- Threshold Detectors
- USB Products

High Speed DLVA's, ERDLVA's & SDLVA's to 40GHz

I/Q Vector Modulators Covering 85MHz to 18GHz within a single unit

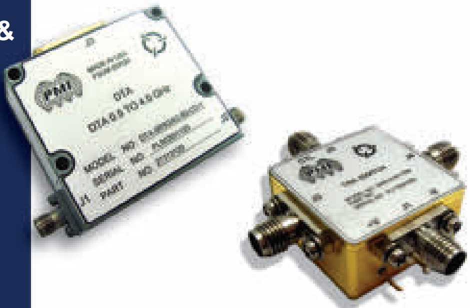
Supporting EW, ECM & ESM Systems

Analog & Digital Phase Shifters and Bi-Phase Modulators to 40GHz

Digitally Tuned Oscillators (DTO's) and Frequency Synthesizers

Frequency Discriminators, IFM's, Receiver Front Ends & Transceivers

Solid-State Switches, Attenuators & Pulse Modulators to 40GHz



West Coast Operation:
4921 Robert J. Mathews Pkwy, Suite 1
El Dorado Hills, CA 95762 USA
Tel: 916-542-1401 Fax: 301-662-1731
Email: sales@pmi-rf.com

East Coast Operation:
7311-F Grove Road
Frederick, MD 21704 USA
Tel: 301-662-5019 Fax: 301-662-1731
Website: www.pmi-rf.com

Hermetic Sealing, High Reliability to Mil-Std-883, Small Quantity Requirements accepted.
We offer Custom Designs

ISO9001/2008 REGISTERED

High Performance Optical Oscillators for Microwave and mm-wave Applications

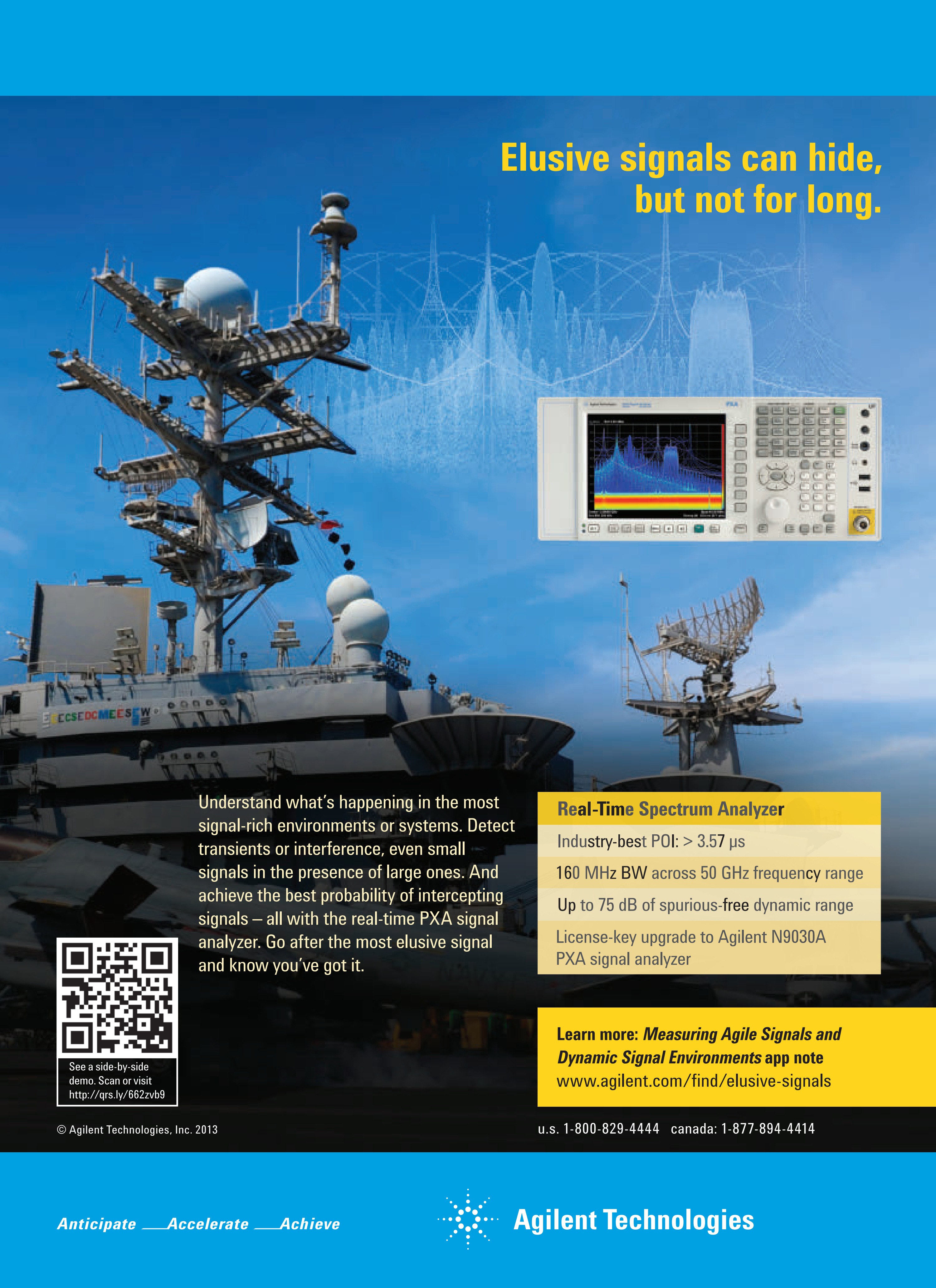
Exponential growth in our appetite for information underscores the need for communications systems capable of transmitting, receiving and processing of ever-increasing data at higher data rates. Since system capacity is limited by bandwidth and channel capacity, current approaches for addressing this challenge include systems with multi-input to multi-output capabilities. Given the inherent relationship between cost and scaling in these architectures, a more effective approach to meet present and future needs is the use of low noise carriers at microwave, mm-wave and higher frequency.

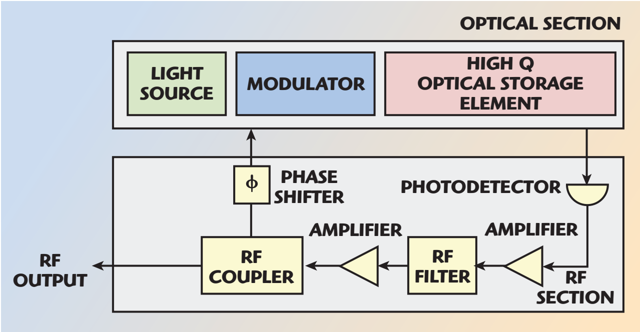
Reference oscillators generate the carrier waves in systems that receive and transmit information. The ideal carrier signal is a pure sinusoid, with a frequency many times larger than the information rate, which is modulated on it. This is because the capacity or the information bandwidth of a system is a fraction of its carrier's frequency. Furthermore, any noise that spoils the "spectral purity" of the carrier's sinusoidal signal further limits this capacity. Thus, reference oscillators with higher spectral purity at higher frequencies are required to meet the demands of high throughput information links. The same requirements pertain to high performance test and measurement systems, and high performance radar, which have similar needs for high frequency and high spectral purity.

OPTICAL VERSUS OTHER OSCILLATOR TECHNOLOGIES

Traditionally, quartz oscillators have been used for high spectral purity carriers.[1] Indeed, today's high performance quartz oscillators provide unmatched spectral purity, but for frequencies at or below a few hundred MHz. In systems where data rates exceed these frequencies, high quality quartz oscillators cannot be used directly; rather, the oscillator frequency must be multiplied to accommodate the data rate. Frequency multiplication is widely used, but at the penalty of system complexity, as well as the multiplication of oscillator noise. Other types of electronic oscillators producing signals at higher frequencies (such as SAW oscillators, dielectric resonator oscillators [DRO], and Gunn oscillators) have relatively high associated noise. This is because oscillators essentially consist of a narrowband high Q element (such as a resonator) that filters the noise generated by an amplifier within a feedback loop, resulting in self-sustained oscillation. The high Q el-

Lute Maleki
OEwaves, Pasadena, CA


Elusive signals can hide, but not for long.
Understand what's happening in the most signal-rich environments or systems. Detect transients or interference, even small signals in the presence of large ones. And achieve the best probability of intercepting signals – all with the real-time PXA signal analyzer. Go after the most elusive signal and know you've got it.
Real-Time Spectrum Analyzer
Industry-best POI: > 3.57 μs
160 MHz BW across 50 GHz frequency range
Up to 75 dB of spurious-free dynamic range
License-key upgrade to Agilent N9030A PXA signal analyzer
See a side-by-side demo. Scan or visit http://qrs.ly/662zvb9
Learn more: Measuring Agile Signals and Dynamic Signal Environments app note
www.agilent.com/find/elusive-signals
© Agilent Technologies, Inc. 2013
u.s. 1-800-829-4444 canada: 1-877-894-4414
Anticipate ___Accelerate ___Achieve
Agilent Technologies



▲ *Fig. 1 Schematic diagram of the generic Opto-Electronic Oscillator.*

ement in conventional oscillators typically determines both the frequency of operation and the achievable spectral purity. Since a resonator's size (volume) decreases with increasing frequency, high frequency electronic resonators have lower Q, resulting in lower oscillator spectral purity.

Photonic oscillators do not have these inherent limitations. Since microwave, mm-wave and even THz signals are a fraction of the frequency of light, the use of optical elements minimizes loss with increased frequency. Furthermore, optical waveguides and resonators can be produced with extremely low loss, providing very high Q elements for photonic oscillators. Finally, as described in this article, the extremely high Q of certain optical resonators enables the emergence of nonlinearities that can be put to advantage for generations of reference signals.

OPTO-ELECTRONIC OSCILLATOR

The most widely known photonic oscillator is the opto-electronic oscillator (OEO).[2] The OEO is based on a feedback loop that converts modulated light from a laser to RF (microwave/mm-wave) frequency. In its generic form (see ***Figure 1***), the modulated light is generated by direct modulation of the laser current, or by use of an amplitude, or phase modulator. The modulated light passes through a high Q energy storage element, before it is detected by a high frequency photodetector (PD). The output of the PD is amplified, adjusted for phase, and fed back to the modulator to complete the loop. The high Q element in the optical segment of the loop can be a long fiber delay, in which case the center frequency of a filter in the electronic segment of the loop determines the frequency of operation. Alternatively, the high Q energy storage element may be an optical resonator, in which case its free spectral range (FSR) sets the frequency of the oscillator. The feedback loop consists of electronic and optical components, which can be interchanged in the optical or electrical segment of the loop. In its most common configuration the gain elements, the filter and the phase shifter are included in the RF segment.

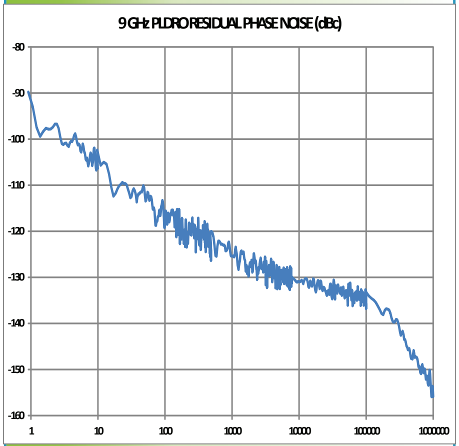
OEO is a versatile architecture that allows for the interchange of components in the optical loop with their electronic counterparts, or vice versa. For example, the needed gain in the loop can be provided with either an electronic amplifier or an optical amplifier. The same is true for the element that adjusts the phase in the loop to keep the oscillator stable. Furthermore, since the center frequency of the filter determines the operation frequency, any desired frequency supported by the bandwidth of the modulator, the gain elements, and the PD may be obtained. Conveniently, the use of a tunable filter can produce a tunable OEO with the unique feature of same spectral purity for any frequency within the bandwidth.[3] More importantly, even the light source can be inside the loop. This may be accomplished by using an optical amplifier with its output connected to its input, and by coupling it to the modulator as part of the optical segment of the OEO. This latter scheme is known as a coupled opto-electronic oscillator, or COEO (see ***Figure 2*** and ***Figure 3***), and includes the benefit of an active element to multiply the Q of the oscillator.[4] In the configuration shown in Figure 2, the optical signal is produced in the upper loop with an optical gain. The optical loop and the RF loop are coupled through the modulator.

Examples of OEOs with various configurations are now numerous and may be readily found in the literature.[5] OEOs with fiber delay lines as the energy storage elements that produce signals with frequencies as high as

exyn corporation

We have specialized in Low Phase Noise Fixed Frequency Sources since 1998.

A plot of our new quieter PLDRO line.



- Crystal reference phase noise to -130 dBc/Hz @ 100 Hz @ 100 MHz
- Dual loop output frequency resolution +/- 0.001 Hz
- Internal reference stability to +/- 10 ppb
- 5 - 1000 MHz External reference
- Frequency: 10 MHz to 35 GHz
- Power output: +10 to +24 dBm
- Wide operating temperature range: -55° to +85°
- Spurious: < -90 dBc

We welcome your custom requirements.

Nexyn offers the best performance and reliability on the market.

1287 Forgewood Ave.
Sunnyvale, CA 94089
Tel: (408) 962-0895
Fax: (408) 743-5354
sales@nexyn.com

www.nexyn.com

Upgrade your system

1. Significant Size Reduction

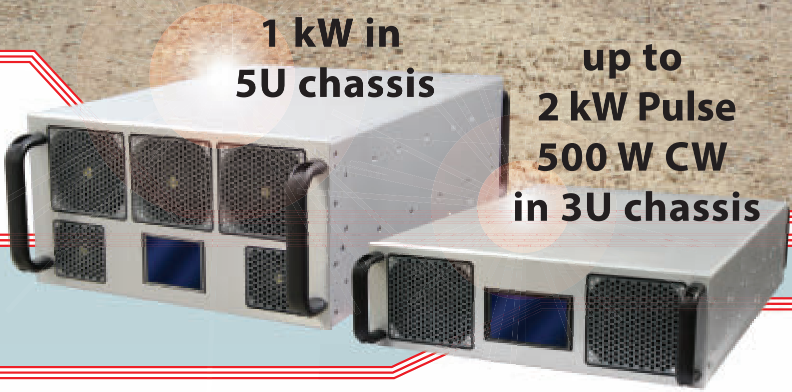
   Major Improvement In Power Density

2. Scalable Output Power Architecture

3. Remote Monitoring and Control

4. Designed into
   - ✔ EW/Communications
   - ✔ SATCOM
   - ✔ Radar Applications

1 kW	SKU 2126	20 - 500	MHz
	SKU 2066	500 - 1000	MHz
	SKU 2162	20 - 1000	MHz
	SKU 2170	1000 - 3000	MHz
500 W	SKU 2173	20 - 500	MHz
	SKU 2174	500 - 1000	MHz
	SKU 2175	20 - 1000	MHz



NEXT GENERATION **Power Amplifiers**

Certified to ISO 9001:2008
TÜVRheinland Precisely Right.

www.EmpowerRF.com

EMPOWER RF SYSTEMS, INC.

316 West Florence Ave., Inglewood, CA 90301 USA, Phone: +1(310)412-8100, Fax: +1(310)412-9232

HIGH POWER BROAD BAND
LIMITERS
0.5 - 12 GHz

New

40 WATT CW

- Low Limiting Threshold (+6 dBm Typical)
- 40 Watt CW and 200 Watt Peak (1 microsec) power handling capabiity
- Built-In DC Block @ input and output
- Hermetically Sealed Module
- Typical Recovery Time is less than 10 Microsec

Typical Performance @ + 25 Deg. C

MODEL	FREQ. RANGE (GHz)	MAXIMUM INSERTION LOSS (dB)	MAX VSWR	MAX LEAKAGE @ 40 W CW INPUT (dBm)
LS0510 P40B	0.5 – 1.0	0.5	1.4:1	+21
LS0520 P40B	0.5 – 2.0	0.6	1.4:1	+21
LS0540 P40B	0.5 – 4.0	0.8	1.4:1	+21
LS0560 P40B	0.5 – 6.0	1.3	1.5:1	+21
LS05012P40B	0.5 – 12.0	1.7	1.7:1	+21
LS1020 P40B	1.0 – 2.0	0.6	1.4:1	+21
LS1060 P40B	1.0 – 6.0	1.2	1.5:1	+21
LS1012P40B	1.0 – 12.0	1.7	1.7:1	+21
LS2040P40B	2.0 – 4.0	0.7	1.4:1	+20
LS2060P40B	2.0 – 6.0	1.3	1.5:1	+20
LS2080P40B	2.0 – 8.0	1.5	1.6:1	+20
LS4080P40B	4.0 – 8.0	1.5	1.6:1	+20
LS7012P40B	7.0 – 12.0	1.7	1.7:1	+18

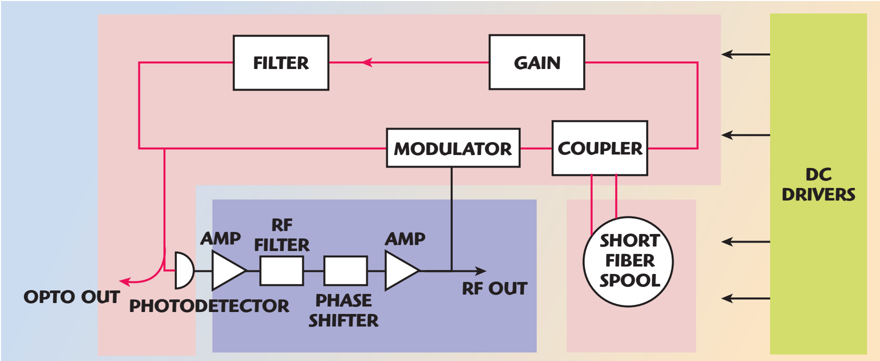
Note: 1. Insertion Loss and VSWR tested at -10 dBm.
Note: 2. Typical limiting threshold: +6 dBm.
Note: 3. Power rating derated to 20% @ +125 Deg. C.

Other Products: Detectors, Amplifiers, Switches, Comb Generators, Impulse Generators, Multipliers, Integrated Subassemblies

Please call for Detailed Brochures

Herotek

155 Baytech Drive, San Jose, CA 95134
Tel: (408) 941-8399 . Fax: (408) 941-8388
Email: info@herotek.com
Website: www.herotek.com
Visa/Mastercard Accepted

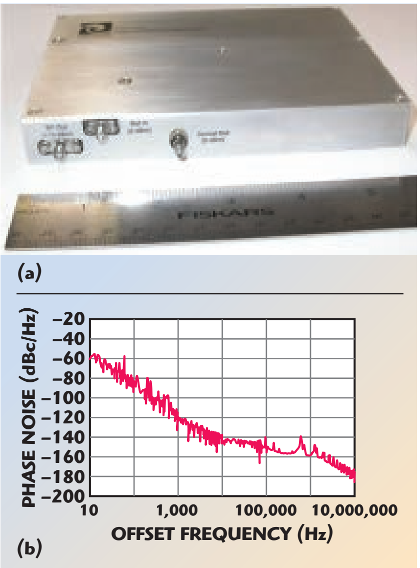


▲ *Fig. 2 The Coupled Opto-Electronic Oscillator.*

48 GHz have been demonstrated. An X-Band OEO with spectral purity of –163 dBc/Hz at 10 kHz has also been demonstrated.[6] These architectures generally employ several km of optical fiber, which results in rack mountable units. A high performance compact OEO about the size of a computer mouse pad has also been developed.[7]

Aside from their size, fiber based OEOs are also unsuitable for certain applications where the noise spectrum must be absolutely smooth. This is because OEO is inherently a multi-mode oscillator, with the filter selecting the oscillating mode. Modes other than the one selected by the filter, present due to the length of the loop (in which the fiber is the longest element), are suppressed; unless the loop is so long as to produce modes with frequency separation smaller than the filter bandwidth. In this case the surviving modes, although much diminished by the filter, appear as noise peaks in the oscillator phase noise spectrum. Since narrowband electronic filters at X-Band and higher frequencies are difficult to realize, high performance OEOs exhibit noise peaks in the spectrum starting at a frequency corresponding to the length of the fiber, and at harmonics of this frequency, with diminishing amplitude based on the filter shape.

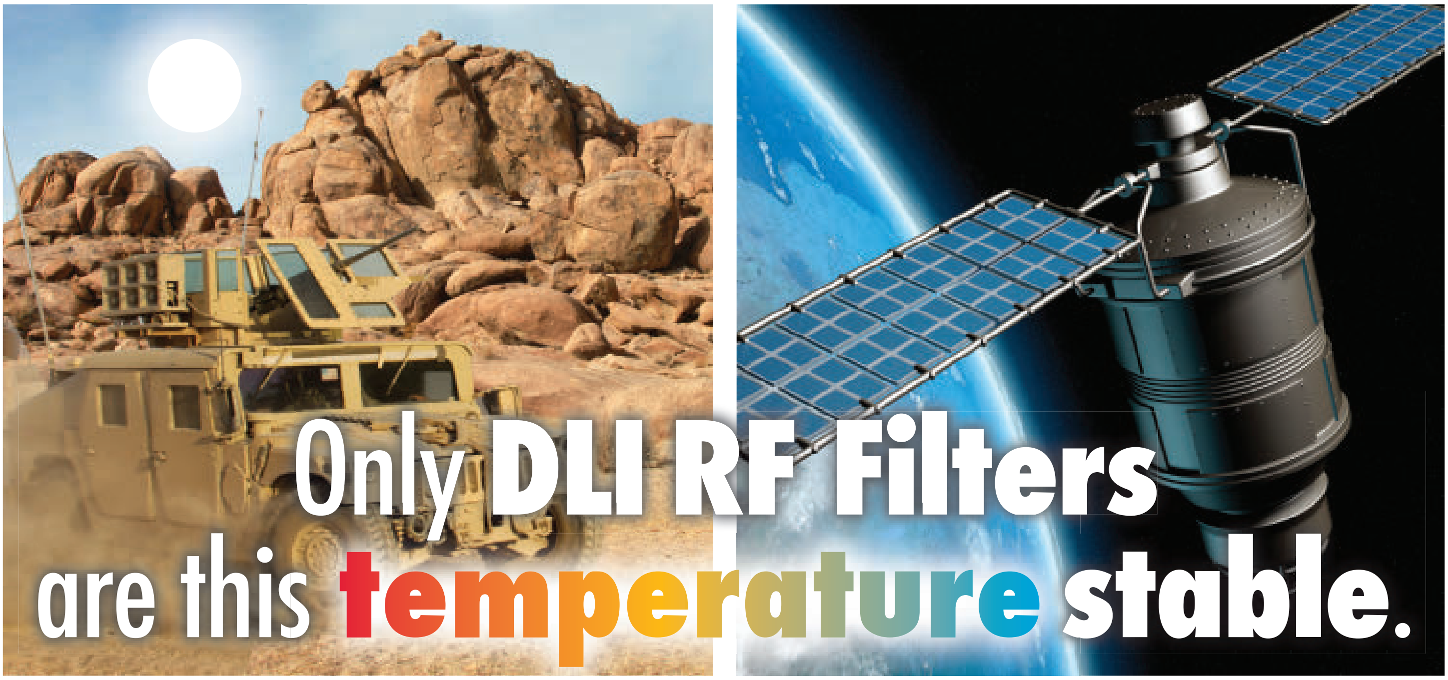
One approach for avoiding this problem is the use of an optical resonator in place of the fiber. High-Q optical resonators such as Fabry-Perot cavities are readily available, and can serve both as the filter and the storage element. This approach has been employed with COEO to successfully reduce the phase noise due to the so called "super mode" noise peaks.[8] The COEO architecture already reduces the noise peaks due to the smaller length of fiber, and thus wider frequency interval between the modes of the oscillator to make filtering of the unwanted modes more effective. The use of the Fabry-Perot cavity aids this approach to further clean up the spectral density of the phase noise. Despite this gain, implementation of the Fabry-Perot cavity in the loop leads to additional complexity, and more sensitivity to environmental disturbances such as temperature variations and vibration.

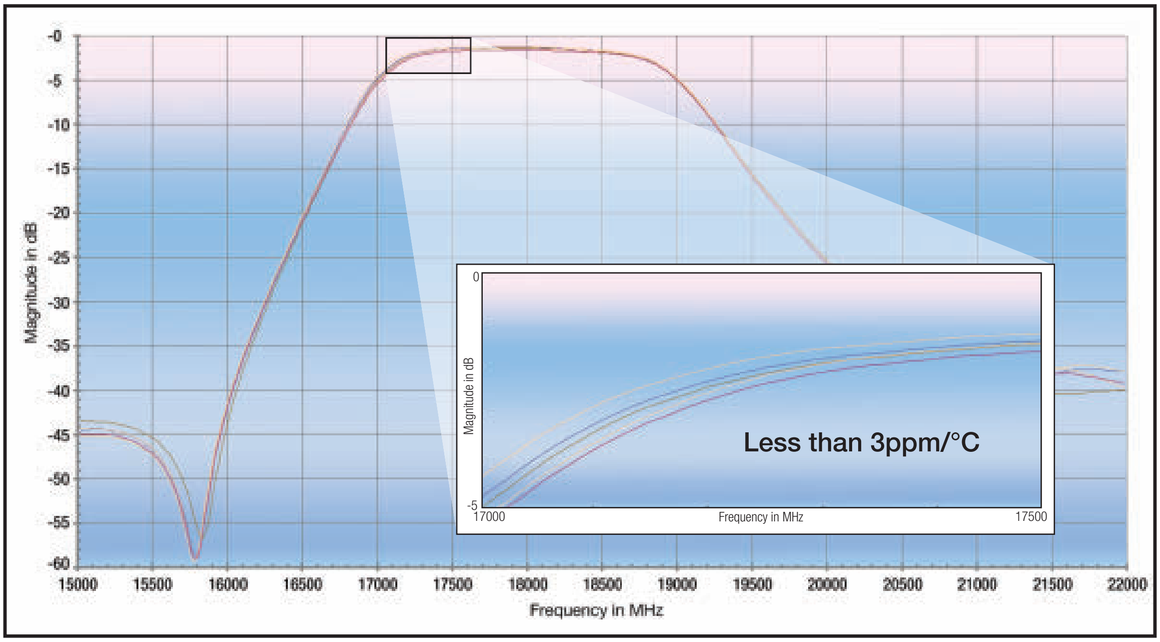


▲ *Fig. 3 Packaged COEO (a) and its phase noise spectrum at 10 GHz (b).*

WHISPERING GALLERY MODE OSCILLATOR

Recently, a new type of miniature optical resonator has been employed for use in the OEO. Known as whispering gallery mode (WGM) resonators, these are structures made with a transparent material and are geometrically axio-symmetric, ranging in size from a few mm to a few tens of microns in diameter (see ***Figure 4***).[9] This resonator is made out of glass by heating the tip of an optical fiber.

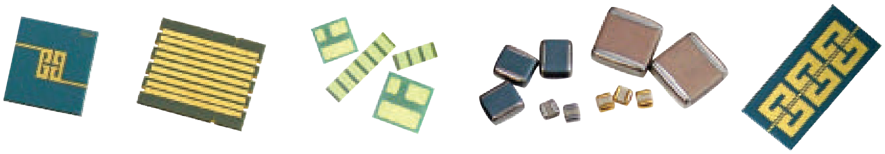




Temperature Performance FFL04852

Frequency Response FFL04852 Temperature Data (-55°C to +125°C)

Designed on DLI's proprietary CF ceramic for extreme temperature stability.



Go ahead, subject DLI RF Filters to your application extremes.

Lightweight, small, custom filter solutions that perform.

Just ask DLI for the test data.

DLI DIELECTRIC LABORATORIES

A DOVER COMPANY

CMP

CERAMIC & MICROWAVE PRODUCTS

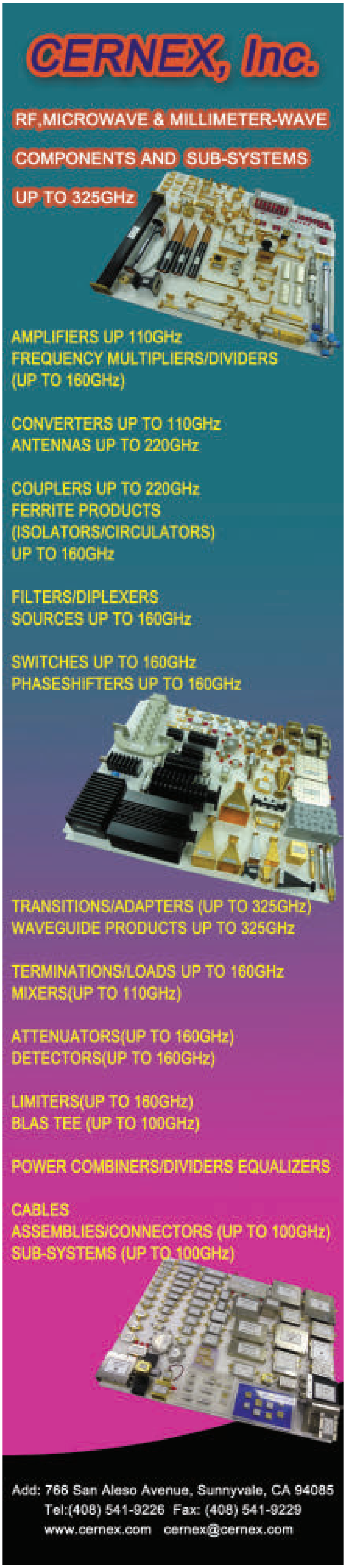
Electronic Components & Microwave Solutions

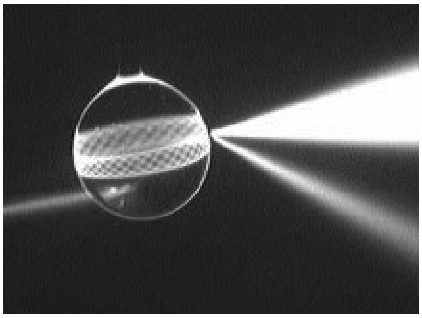
BSC FILTERS • DOW-KEY MICROWAVE • NOVACAP • SYFER TECHNOLOGY

DIELECTRIC LABORATORIES • K&L MICROWAVE • POLE/ZERO • VOLTRONICS

www.dilabs.com

See us at MILCOM Booth 134

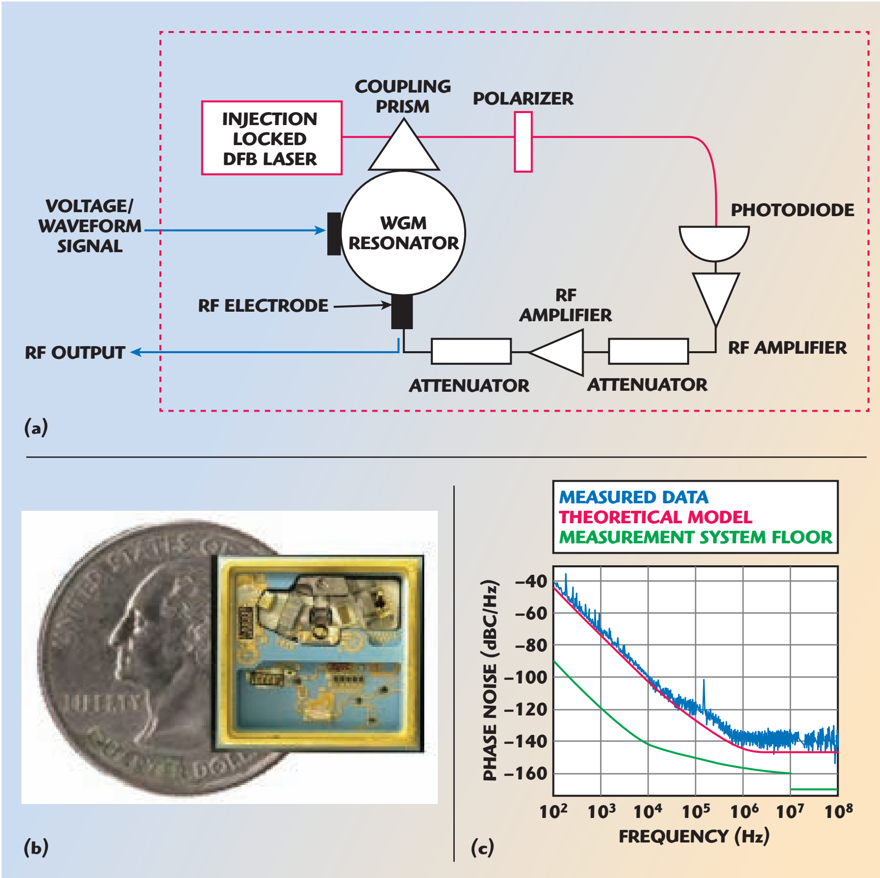




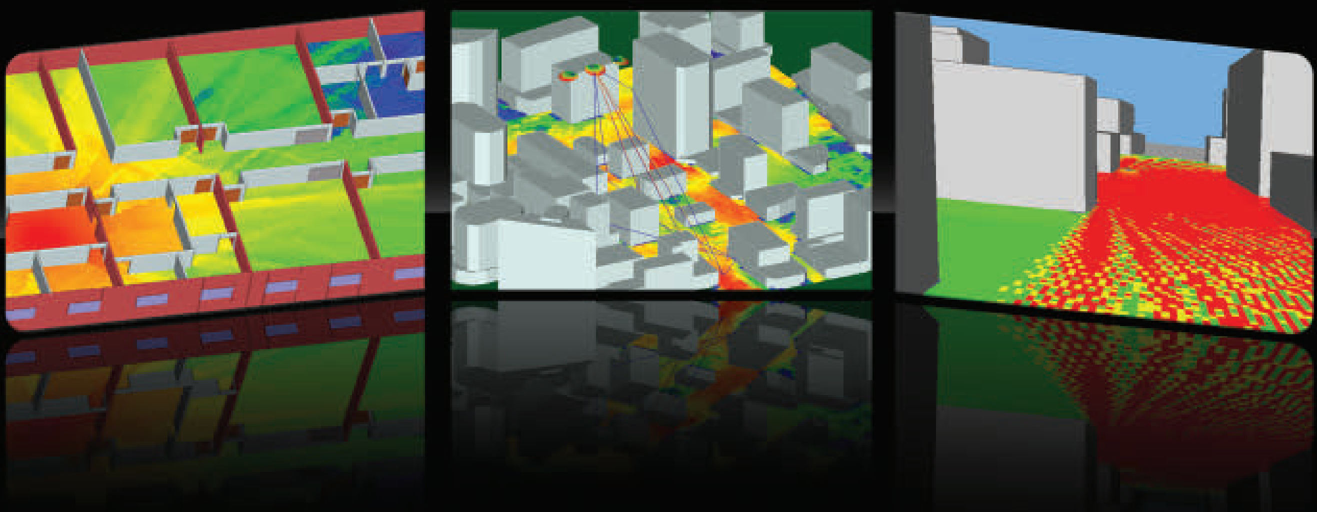
▲ *Fig. 4 A spherical whispering gallery mode optical resonator. This photograph was obtained by submerging the sphere and the fiber in a liquid.*

Light is coupled in with a fiber faintly visible on the left. Excited modes are visible as a band of light that forms close to the surface of the sphere at the equator. The name whispering gallery mode was coined by Lord Rayleigh to describe special acoustic modes supported by high (acoustic) Q structures such as the dome of St. Peter's cathedral in London. The optical counterparts are modes that propagate close to the surface of the resonator and display extremely high quality factors, so that light may be trapped in them for 100 micro-seconds or longer. The narrow bandwidth associated with high Q in WGMs can be used as an optical filter in the OEO loop. More importantly, WGM resonators made of electro-optic material such as lithium niobate can be used to serve both as the high Q element in the OEO loop, and as the modulator function. Since whispering gallery modes extend outside the resonator with an evanescent tail, light can be coupled in and out of the resonator with any structure that produces an evanescent field, such as a prism or a fiber taper. Oscillators of this type have recently been introduced in a miniature package the size of a postage stamp, producing spectrally pure signals at X- and Ka-Bands (see ***Figure 5***).[10]

The advent of femto second (fs) mode lock lasers has provided a new approach for generation of spectrally pure RF signals. These lasers consist of an optical material with Kerr nonlinearity placed in an optical cavity to produce a train of short pulses that in frequency domain represent an optical frequency comb (see ***Figure 6***).[11]



▲ *Fig. 5 Schematic diagram of a microresonator-based OEO (a) and photo of the packaged component (b). The oscillator produces the performance shown in (c) at 12 GHz.*



Remcom's Wireless InSite®

Radio Propagation Software for Wireless Communication Planning

Wireless InSite is a suite of ray-tracing models and high-fidelity EM solvers for the analysis of site-specific radio propagation and wireless communication systems. It provides efficient and accurate predictions of propagation and communication channel characteristics in complex urban, indoor, rural and mixed-path environments.

Wireless EM Propagation Capabilities for a Variety of Applications

- Indoor WiFi
- Moving vehicle or aircraft
- LTE and WiMax throughput analysis
- Tower placement for urban coverage
- Ad-hoc and temporary networks
- Base station coverage analysis
- Microcell coverage

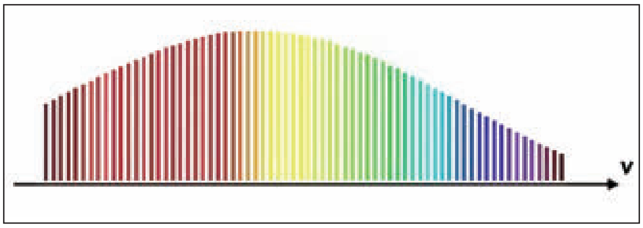
Visit **www.remcom.com/wireless-insite** to learn more about recent enhancements in Wireless InSite

REMCOM®

+1.888.7.REMCOM (US/CAN) | +1.814.861.1299
www.remcom.com

Visit us at MILCOM Booth #943.

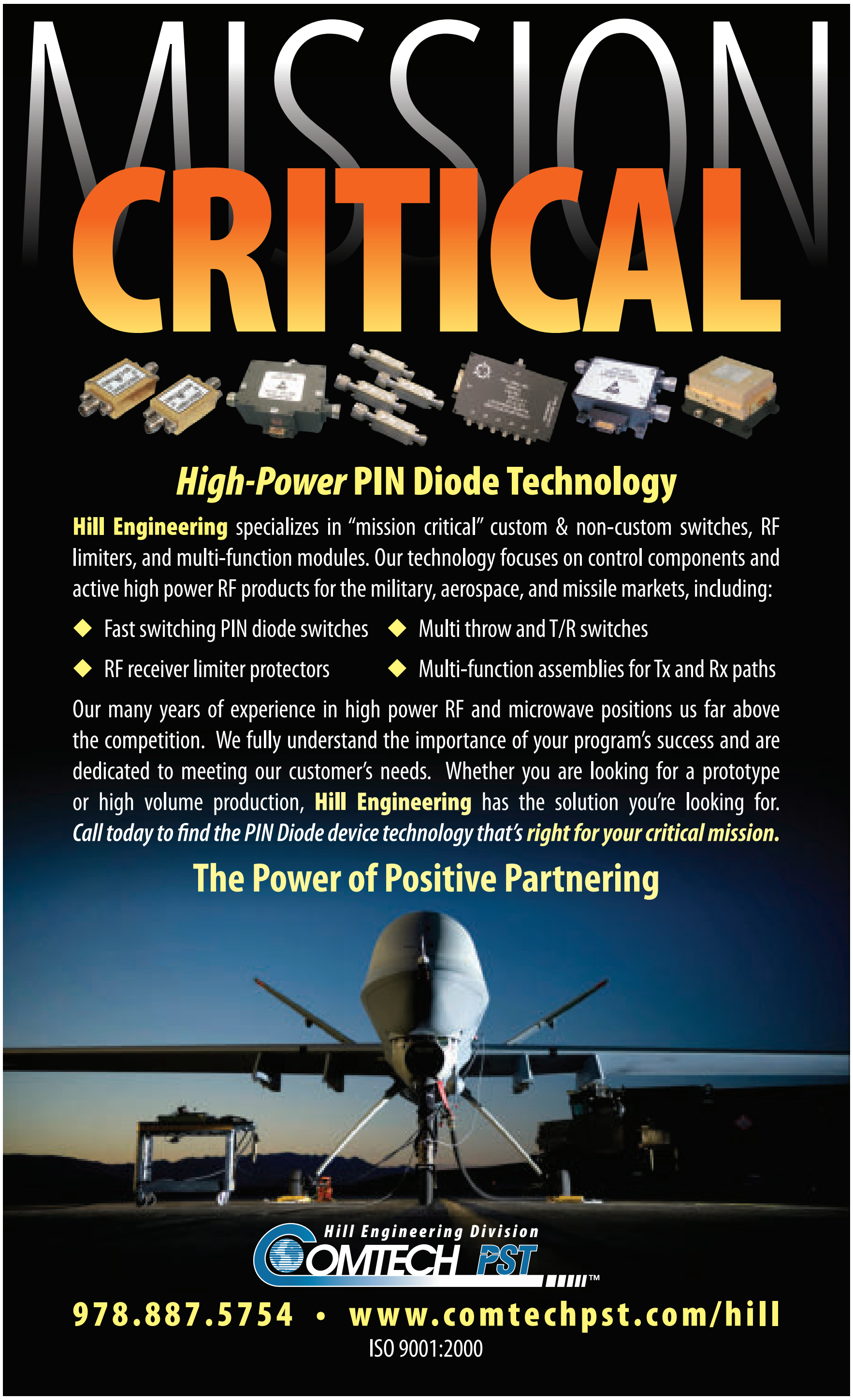
The harmonics of this optical comb are coherent, and can mix on a photodetector to produce an RF signal at the output. Optical frequency combs produced by fs mode lock lasers can span an octave, a property that allows stabilizing them by comparing the frequency of a comb tine multiplied by 2 with its second harmonic, to lock the frequency interval of the comb. This scheme results in realization of a true frequency divider to relate the optical frequency to the comb repetition rate. As with any divider, the fs comb divides the noise of the laser by the ratio of the laser frequency to the RF repetition rate. So by locking the laser to a high finesse optical cavity and narrowing its linewidth, the output of the photodiode on which the comb harmonics mix can result in an exceptionally low noise RF signal. Such a scheme has produced the lowest noise for close to carrier frequencies at 10 GHz.[12] Despite their great promise, fs mode lock lasers are relatively large in size, as compared to electronic oscillators, and are susceptible to environmental perturbations. They also are limited in frequency to RF and X-Band.



▲ *Fig. 6 An optical frequency comb can be generated with a fs pulsed mode lock laser.*

Recently, a new generation of optical frequency comb has been demonstrated with the WGM resonator. One of the consequences of the extremely high Q of WGM resonators is that a small amount of input power can generate a large power density in the mode. Thus a few milliwatts of light can build up to MW levels in the tiny volume of a high Q mode. Such large power densities excite nonlinearities, such as Brillioun, Raman, and parametric effects, depending on the characteristics of the resonator host material. In material with cubic nonlinearity, four-wave mixing can be excited. In this process, two photons from a light field exciting a given mode can be transferred to two photons each in a mode on either side of the excited mode.[13] If the field in the originally excited mode is strong enough, the fields in adjacent modes will grow to a point where their own adjacent modes are excited. This cascaded parametric process can produce a comb of frequencies separated by the FSR of the modes in the resonator (see ***Figure 7***).[14]

Certain parameters such as the frequency of the laser and geometry of the resonator may be adjusted to a point where all tines of the comb are coherent with respect to each other, and can beat to produce a highly spectrally pure signal. Since crystalline WGM optical micro-resonators can be readily fabricated with an FSR in X-Band or at higher frequencies, the approach promises a new generation of small, low power, and highly spectrally pure microwave and mm-wave



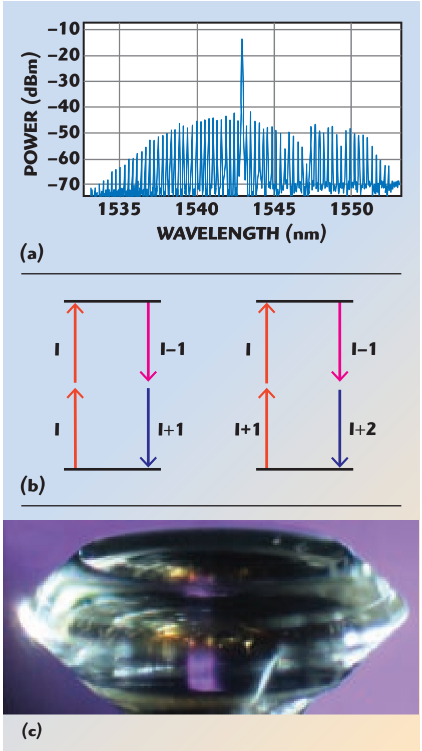

Make
CONTACT
When Performance Matters…
Carlisle Interconnect Technologies offers a full line of single-piece machined Mil-Std, AECMA, EN, BACC, ESC and MDC contacts. We also offer a full range of contact types including Crimp, Printed Circuit Tail, Coaxial, Twinax, Triax, Thermocouple, Solder Cup, Wire Wrap and specialized custom designs. We will meet your delivery date!
sales@CarlisleIT.com | 310.536.0444
www.CarlisleIT.com
CARLISLE®
INTERCONNECT TECHNOLOGIES

sources.[15] Such an all-optical oscillator has been produced at OEwaves in a tiny package the size of a postage stamp (see ***Figure 8***).[16] A feature of this oscillator, related to its tiny size, is its extremely low acceleration sensitivity, smaller than 10^{-11}/g for a bare, uncompensated device. This low level of acceleration sensitivity is unprecedented in any type of uncompensated oscillator previously demonstrated.

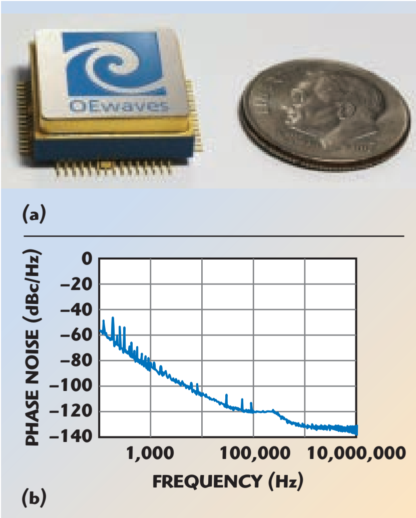
Finally, mechanical resonances of WGM resonators can also be excited with light, when properly designed.[17] These opto-mechanical resonances are in the MHz range, and are rather weak, so they do not readily compete with high performance quartz oscillator. Nevertheless, they provide an optical means for RF generation that may find use in future integrated photonics circuits. The study of Kerr combs produced by WGM resonators is by no means complete, and researchers continue to shed light on many aspects of it, particularly as pertains to production of spectrally pure microwave and mm-wave signals.

CONCLUSION

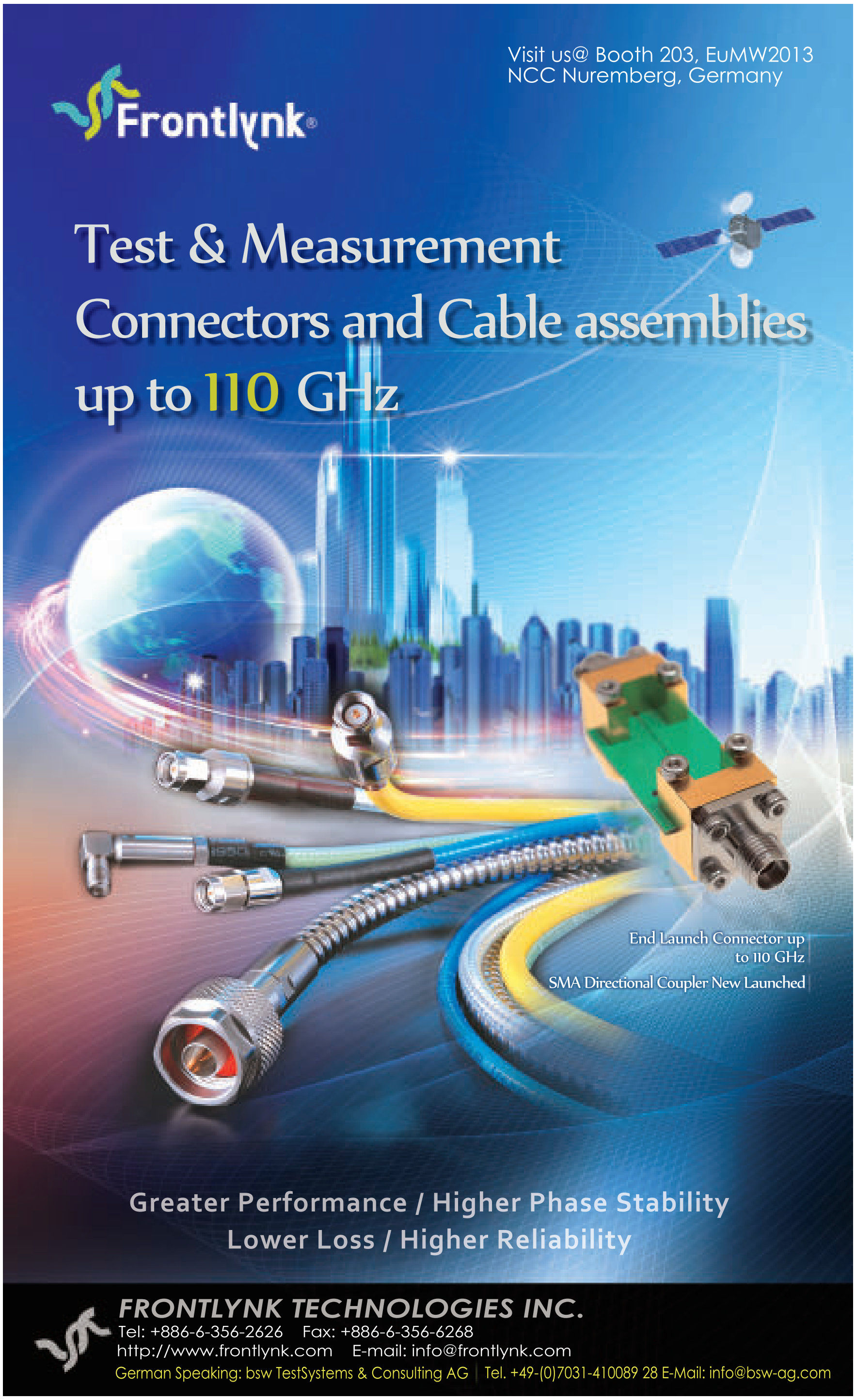
The subject of optical generation of microwave and mm-wave reference signals is fairly new. However, the technology is evolving rapidly, and already presents a new and compelling approach for improving the performance of advanced data, communications, ra-



▲ *Fig. 7 An optical frequency comb (a) produced via four-wave mixing process (b) with a magnesium fluoride resonator (c).*



▲ *Fig. 8 Packaged Kerr comb oscillator (a) and its phase noise at Ka-Band (b).*



Filters for Cellular, Satcom, and Defense Systems

22 Years of Custom Filter Design and Manufacturing Expertise...and Thousands of Standard Models Too!

Cellular and public safety

- All wireless bands
- Low-PIM for LTE
- >40 dB rejection 700 kHz from passband edges
- Indoor or weatherized

Satellite communications

- INMARSAT
- Iridium
- GPS
- All satcom bands to 40 GHz
- Low and high power

Defense systems

- DC through 40 GHz
- Screening to MIL-STD
- GSA-approved vendor
- Land, sea, and airborne

CUSTOM CAPABILITIES

Our library of custom filter designs let us meet your requirements fast – with exceptional performance. Indoor, outdoor, SMT, connectorized, low and high power, custom footprints, military screening, and much more.

For quick-turn filter, duplexer, and triplexer models visit: www.AMCrf.com

ANATECH ELECTRONICS INC
RF & Microwave Filters & Products

Bring us your challenge, we'll provide the answer

www. anatechelectronics.com

E-mail: sales@anatechelectronics.com   Call us at (973) 772-4242 dar and other systems that require high performance oscillators with small size, weight and power, at frequencies in the range of 10 to 300 GHz. This exciting field is still growing and is poised to radically change the way we think of the generation of high performance signals for electronic applications. ■

References

1. J.R. Vig, "Quartz Crystal Resonators and Oscillators for Frequency Control and Timing Applications – A Tutorial," www.ieee-uffc.org/frequency-control/tutorials.asp.
2. X.S. Yao and L. Maleki, "Optoelectronic Oscillator for Photonic Systems," *IEEE Journal of Quantum Electronics*, Vol. 32, No. 7, July 1996, pp. 1141-1149.
3. D. Eliyahu and L. Maleki, "Tunable, Ultra-Low Phase Noise YIG based Opto-Electronic Oscillator," *IEEE MTT-S International Microwave Symposium Digest*, Vol. 3, June 2003, pp. 2185-2187.
4. S. Fedderwitz, A. Stoehr, S. Babiel, V. Rymanov and D. Jager, "Optoelectronic Band Oscillator With Gigahertz Tuning Range and Low Phase Noise," *IEEE Photonics Technology Letters*, Vol. 22, No. 20, October 2010, pp. 1497-1499.
5. X.S. Yao, L. Davis and L. Maleki, "Coupled Optoelectronic Oscillators for Generating Both RF Signal and Optical Pulses," *Journal of Lightwave Technology*, Vol. 18, No. 1, January 2000, pp. 73-78.
6. P. Devgan, "A Review of Optoelectronic Oscillators for High Speed Signal Processing Applications," *ISRN Electronics*, Vol. 2013, Article ID 401969, 2013, 16 pages.
7. D. Eliyahu, D. Seidel and L. Maleki, "Phase Noise of a High Performance OEO and an Ultra Low Noise Floor Cross-Correlation Microwave Photonic Homodyne System," *IEEE International Frequency Control Symposium Proceedings*, May 2008, pp. 811-814.
8. D. Eliyahu and L. Maleki, "Modulation Response (S21) of the Coupled Opto-electronic Oscillator", *IEEE International Frequency Control Symposium Proceedings*, August 2005, pp. 850-856.
9. J.M. Kim and D. Cho, "Optoelectronic Oscillator Stabilized to an Intra-Loop Fabry-Perot Cavity by a Dual Servo System," *Optics Express*, Vol. 18, No. 14, July 2010, pp. 14905-14912.
10. A.B. Matsko and V.S. Ilchenko, "Optical Resonators With Whispering-Gallery Modes-Part I: Basics," *IEEE Selected Topics in Quantum Electronics*, Vol. 12, No. 1, January-February 2006, pp. 3-14.
11. L. Maleki, V.S. Ilchenko, A.A. Savchenkov and A.B. Matsko, *Practical Applications of Microresonators in Optics and Photonics*, CRC Press, Boca Raton, FL, 2009, pp. 133-210.
12. L. Maleki, "Sources: The Optoelectronic Oscillator," *Nature Photonics Technology Focus*, Vol. 5, No. 12, December 2011, pp. 728-730.
13. K. Volyanskiy, P. Salzenstein, H. Tavernier, M. Pogurmirskiy, Y.K. Chembo and L. Larger, "Compact Optoelectronic Microwave Oscillators Using Ultra-High Q Whispering Gallery Mode Disk-Resonators and Phase Modulation," *Optics Express*, Vol. 18, No. 21, October 2010, pp. 22358-22363.
14. T. Udem, R. Holzwarth and T.W. Hansch, "Optical Frequency Metrology," *Nature*, Vol. 416, No. 6877, March 2002, pp. 233-237.
15. F. Quinlan, T.M. Fortier, M.S. Kirchner, J.A. Taylor, M.J. Thorpe, N. Lemke, A.D. Ludlow, Y. Jiang, C.W. Oates and S.A. Diddams, "Ultralow Phase Noise Microwave Generation With an Er:Fiber-Based Optical Frequency Divider," *Optics Letters*, Vol. 36, No. 13, August 2011, pp. 3260-3262.
16. A.B. Matsko, A.A. Savchenkov, D. Strekalov, V.S. Ilchenko and L. Maleki, "Optical Hyperparametric Oscillations in a Whispering Gallery Mode Resonator: Threshold and Phase Diffusion," *Physical Review A*, Vol. 71, No. 3, 2005, p. 33804.
17. P. Del'Haye, A. Schliesser, O. Arcizet, T. Wilken, R. Holzwarth and T.J. Kippenberg, "Optical Frequency Comb Generation From a Monolithic Microresonator," *Nature*, Vol. 450, No. 7173, December 2007, pp. 1214-1217.

With today's emphasis on superior performance in a smaller, lighter, more cost-effective package, why settle for yesterday's chip and wire solutions?

Narda Defense Technology Solutions has pioneered the development of high-performance, densely packaged integrated microwave assemblies and subsystems in footprints previously unachievable. By leveraging commonly available multi-layer board materials with unique interconnection techniques, and incorporating DSP and sophisticated monitor and control functions, our solutions are currently redefining "State of the Art." For more information, please visit our website at **www.nardamicrowave.com/defense**, or call us at **(631) 231-1700**.

- Module and Subsystem Solutions to 40 GHz
- Frequency Converters, LNAs, BUCs & SSPAs
- EW, Radar, Radio and SATCOM Applications
- Pin Diode Switch Products

narda Defense Technology Solutions

Routing. Conditioning. Streamlined.

One perfectly integrated, dependable signal routing and conditioning box. That's your goal. That's Aeroflex / Weinschel's promise. And that's why defense programs such as JSF, SSEE, JTRS, GMR, and EPLARS have put their faith in us. Our subsystems are easy to control and configure and perform various duties as:

Antenna Interface and Control Units

RF Distribution and Interface Units

Fading Simulators

Attenuators and Switch Matrices

Features include high port-to-port isolation, low phase noise, dynamic ranges up to 95 dB, and high power capability through 40 GHz.

From ATE to EW, we have the answers. Call us.

800-638-2048 / 301-846-9222
www.aeroflex.com/weinschel
weinschel-sales@aeroflex.com

AEROFLEX
A passion for performance.

Highly Efficient 10 W GaN Class F Power Amplifier Using DPD

This article describes the design of a 2.12 GHz Class F transmitter power amplifier (PA) using Cree's CGH40010 GaN HEMT. Input and output matching networks are designed to approximate the fundamental and second harmonic impedances obtained in source and load pull simulations. It achieves both high efficiency and excellent linearity by employing the digital predistortion (DPD) technique. Measurements using continuous wave (CW) signals demonstrate a high power-added efficiency (PAE) of 75.2 percent at the maximum output power of 39.4 dBm. For a 20 MHz 4-carrier Wideband Code Division Multiple Access (WCDMA) excitation signal with 7.1 dB peak-to-average power ratio (PAPR), adjacent channel power ratios (ACPR) of the PA are –28.3 and –27.5 dBc at an average output power of 33.3 dBm. This is improved to –51.9 and –54.0 dBc after DPD. For a 20 MHz Long Term Evolution (LTE) signal with 6.6 dB PAPR, ACPR of the designed PA below –53 dBc is achieved after DPD at the same average output power. Drain efficiency (DE) of the PA is 37.8 percent with an average output power of 33.3 dBm.

In order to obtain high spectral efficiency and throughput in modern wireless communication systems, complex modulation schemes such as WCDMA and LTE are normally employed at the cost of large high PAPR. This requires that the PA in these systems operate at large back-off power levels to satisfy linearity requirements, resulting in poor efficiency. It is a challenge to maintain high efficiency during operation over the wide instantaneous power range of modern modulation signals such as WCDMA and LTE, while meeting their demanding linearity requirements.[1]

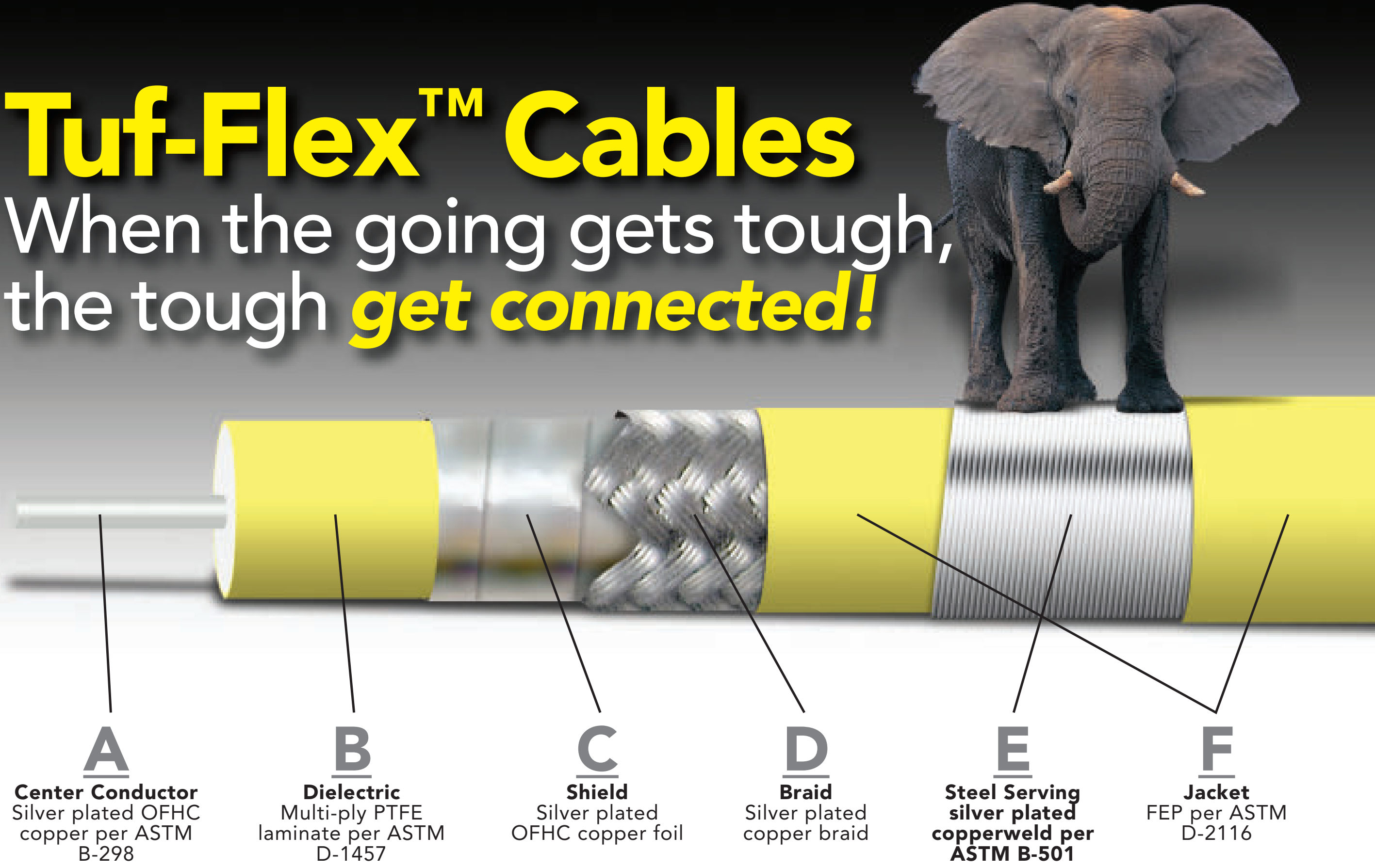
Switching mode PAs, such as Class E, Class F and inverse Class F,[2-4] have demonstrated high efficiency, but have the problem of poor linearity caused by the bias at cut-off. To avoid the nonlinear distortions caused by the PAs, DPD is considered one of the most cost effective methods among all the linearization techniques.

In the past few years, many behavioral models have been proposed to characterize the nonlinear and memory effects of the PA.[5-7] Among these models, the Volterra series model is considered a general way to model a nonlinear system with memory effects, but it has high computational complexity. The dynamic deviation reduction-based Volterra series model proposed by A. Zhu et al.[8,9] and the subse-

Lianqing Ji, Zhiming Xu, Jianyi Zhou and Jianfeng Zhai
Southeast University, Nanjing, Jiangsu, China

Tuf-Flex™ Cables

When the going gets tough, the tough *get connected!*



TUF-FLEX offers an internal layer of silver plated copperweld protection that is crush resistant & offers exceptional resistance to kinking in lieu of external armor.

TUF-FLEX Cable Performance vs. Crush Force

Force (lbs)	Max VSWR	Max Loss (dB)
0	1.20	1.3
45	1.20	1.3
90	1.20	1.3
160	1.20	1.3
200	1.22	1.3
225	1.28	1.3

Results of crush and bend tests on IW's TUF-FLEX cable assemblies, using 2 ft long samples of our 1803 cable. Results show max VSWR and insertion loss over a frequency range of .04 to 18 GHz.

For crush force testing, the cable was placed between two 1 inch diameter plates with force applied to the top plate. The same cable was then tested using successively smaller bend radii to a minimum bend radius of 1.5".

*Call us today with your project specs and we'll show you the most reliable way to **get connected** in the industry.*

INSULATED WIRE, INC.
203.791.1999
www.iw-microwave.com
sales@iw-microwave.com

Scan code to find out how you can ***get connected***

We're how the microwave industry ***gets connected!***

Universal Microwave Components Corporation

UMCC

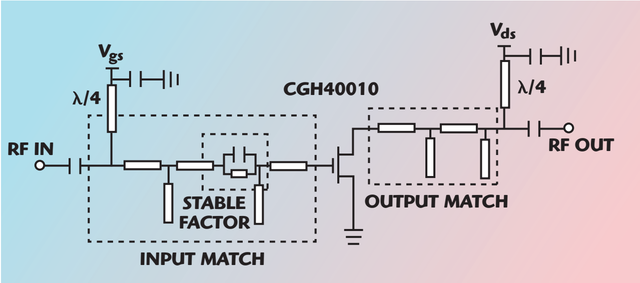
RF & Microwave Design and Manufacturing
Covering Frequencies from DC to 20 Ghz
Serving the Industry Since 1993

"Quality Products at Competitive Prices"
"Custom Designs are Available"

Product Line:
- Solid State Variable Attenuators
- Solid State Switches
- Directional Couplers
- Hybrid Couplers (90/180 Deg)
- Power Dividers / Combiners
- DC-Blocks & Bias Tee's

5702-D General Washington Drive
Alexandria, Virginia 22312 USA
Tel: (703) 642-6332, Fax: (703) 642-2568
Email: sales @ umcc111.com

www.umcc111.com



▲ *Fig. 1 Circuit topology of the Class F power amplifier.*

quent simplified vision[10,11] not only significantly reduce the complexity of the Volterra series model, but also make the extraction of model parameters more flexible.

This article describes the design of a Class F 2.12 GHz transmitter PA using Cree's CGH40010 GaN HEMT. The input and output matching networks are designed to optimally approximate the fundamental and second harmonic impedances obtained in source and load pull simulations. The simplified second-order dynamic deviation reduction-based Volterra series model[10,11] is used to improve linearity. Both techniques optimize the PA's intrinsic efficiency-linearity tradeoff. Experimental results with a 20 MHz 4-carrier WCDMA signal and a 20 MHz LTE signal reveal that the digital predistorted Class F PA achieves high efficiency and excellent linearity at an average output power of 33.3 dBm.

CLASS F POWER AMPLIFIER DESIGN

With an infinite number of harmonic terminations, 100 percent drain efficiency is theoretically achievable with square voltage and half-rectified sine current for Class F operation. However, it is not practical in a realistic design to consider an infinite number of harmonic terminations. In this work, only the fundamental and second harmonic impedances are considered. The topology of the circuit is shown in ***Figure 1***.

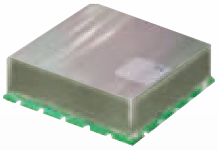
The output matching network presents a short at the second harmonic and conjugately matches the transistor's fundamental output impedance to 50 Ω. The input matching network provides the proper second harmonic impedance at the transistor's gate to improve efficiency and provides an impedance match with 50 Ω at the fundamental. A resistor connected serially on the input is used to improve circuit stability. To prevent damaging the Class F operation, the λ/4 bias line is placed at the outer side of the network rather than at the drain or gate port of the transistor.

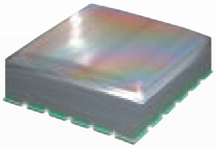
LOAD PULL/SOURCE PULL SIMULATION

The Class F PA design is biased with a gate voltage of -2.8 V and a drain voltage of 28 V. The input power level is set to 26 dBm. The load pull/source pull simulation using Cree's CGH40010 large signal transistor model is carried out with Agilent's Advanced Design System (ADS) software. The objective is to maximize PAE with a high output power. In this setup, the optimized source and load impedances at the fundamental and second harmonics are determined. The simulation is performed as follows:

1. Set the fundamental source impedance at a default value and perform a fundamental load pull simulation to determine the optimum fundamental load impedance (Z_{L_fund}). With a load impedance of Z_{L_fund}, perform a fundamental source pull simulation to obtain the optimum fundamental source impedance (Z_{S_fund}). After several iterations, the optimum fundamental impedances are found to be Z_{S_fund} of (9.1-j1) Ω and Z_{L_fund} of (12.5+j15.8) Ω.
2. Perform harmonic load pull simulations with Z_{S_fund} and Z_{L_fund}. In this simulation, only the second harmonic is considered and the impedance value is restricted to be purely reactive. The optimum second harmonic load impedance (Z_{L_2nd}) is j120 Ω.
3. Perform harmonic source pull simulation. The optimum second harmonic source impedance (Z_{S_2nd}) is -j18.3 Ω.

Design of the input and output matching network can be conducted with the optimized impedance values. The design approach has been reported in many experimental works.[12,13] ***Figure 2*** shows the simulated drain





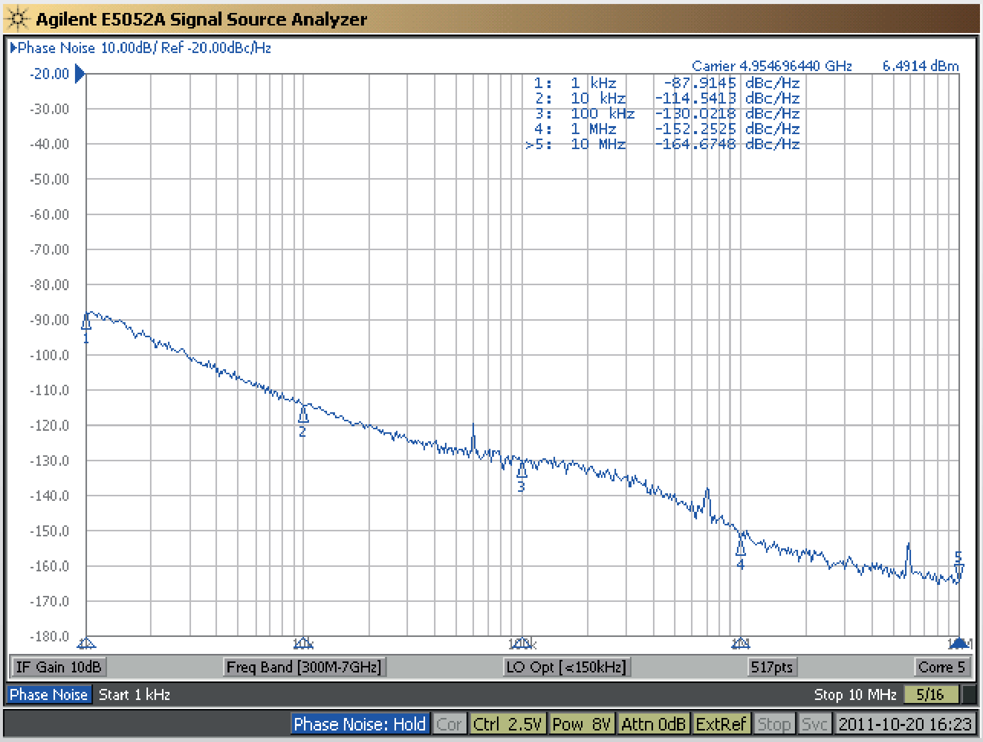
APA Wireless TECHNOLOGIES

Looking for a Fundamental 5GHz VCO with -115dBc @10KHz phase noise?

Features:
- High Frequency
- Fundamental/ No sub-harmonics
- Small SMT Package
- Enhanced humidity/ vibration sensitivity
- Eliminates doubler in PLL/ power savings

Does your DRO or VCO give you -115 dBc @ 10 KHz?? Not likely!

APA's high frequency **fundamental mode** 5 GHz CRO's give you that and more. Fantastic phase noise performance in a small surface mount package and proven APA reliability that won't break your budget. Plus fundamental operation, no sub-harmonics to filter out, no costly doublers, just a pure outstanding 5 GHz signal.



VISIT US AT APAWireless.com

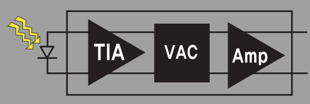
New MMICs

CATV Amplifier 50 ~ 1200 MHz

Part No.	Vd/Id (V/mA)	Gain (dB)	Pout[1] (dBμV)	CSO/CTB (dBc)	Package
AWB312	5.0/110	12.5	94	62/69	SOT89
AWB317	5.0/112	17.5	95	61/82	SOT89
AWB319	5.0/112	20.5	94	61/78	SOT89
AWB512	8.0/123	12.4	101	60/73	SOT89
AWB517	8.0/124	17.5	101	61/74	SOT89
AWB519	8.0/123	20.4	99	61/73	SOT89

1) CENELEC 42 ch

Optical Receiver 50 ~ 1200 MHz



Voltage controlled attenuator included

Part No.	Vd/Id (V/mA)	Opt. Pin (dBm)	Pout (dBμV)	CSO/CTB (dBc)	Package
ASA303A	5.0/220	-8~+1	84[1]	72/66	QFN24
ASA306B	5.0/270	-10~+2	92[1]	78/69	QFN24
ASA406B	5.0/330	-8~+2	87[2]	66/69	QFN24
ASA506B	5.0/380	-8~+2	90[2]	70/75	QFN24

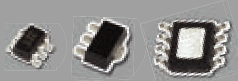
1) CENELEC 42 ch
2) PAL 98 ch

IF Amplifier 3.3 V, DC ~ 1000 MHz

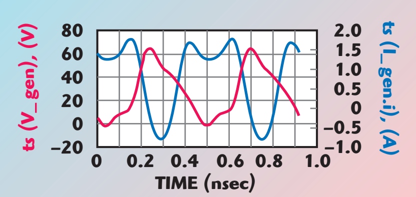
Part No.	Id (mA)	Gain (dB)	OIP3 (dBm)	OP1dB (dBm)	Package
ASF150	85	17.2	38.0	19	SOT89
ASF153	85	22.6	38.0	20	SOT89
ASF140	86	17.2	38.5	19	SOT343
ASF143	87	22.6	38.0	20	SOT343

Digital Attenuator 500 ~ 3000 MHz

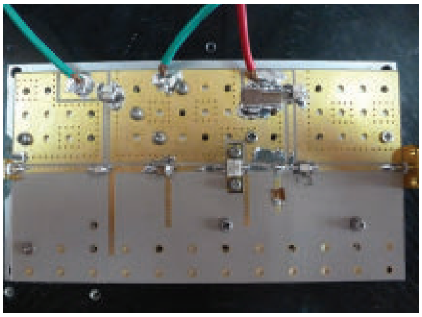
Part No.	Attn. (dB)	I.L. (dB)	IIP3 (dBm)	IP1dB (dBm)	Package
AAT530B5	31.0	2.0	42	24	QFN16
AAT530B6	31.5	2.0	42	24	QFN16



ASB Inc.
Daejeon, South Korea
Tel: +82-42-528-7225
www.asb.co.kr
Contact us at sales@asb.co.kr



▲ *Fig. 2 Simulated drain voltage and current waveforms.*

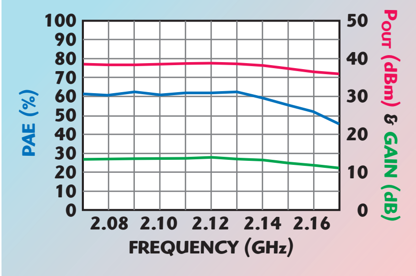


▲ *Fig. 3 Photograph of the designed Class F power amplifier.*

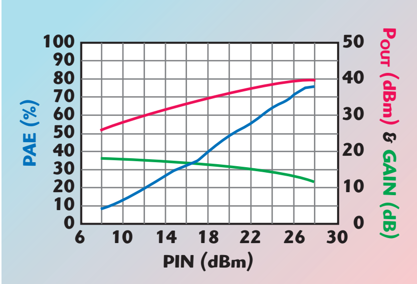
voltage and current waveforms of the proposed Class F PA. Some distortion of the ideal Class F waveforms may be due to nonlinear parasitics associated with the transistor package. With the optimized source and load impedances, a simulated maximum PAE of 80 percent is predicted at 2.12 GHz with an output power of 40.1 dBm and a transducer power gain of 13 dB.

IMPLEMENTATION AND MEASUREMENT RESULTS

The Class F PA is fabricated on a Taconic RF-35 substrate with a relative dielectric constant of 3.5 and a thickness of 30 mils (see ***Figure 3***). The gate is biased at –2.8 V, and the drain voltage is 28 V. ***Figure 4*** shows the measured PAE, output power and gain with an input power of 25 dBm from 2.07 to 2.17 GHz. The PAE is greater than 60 percent and output power is



▲ *Fig. 4 Measured PAE, Gain and Pout versus input frequency with an input power of 25 dBm.*

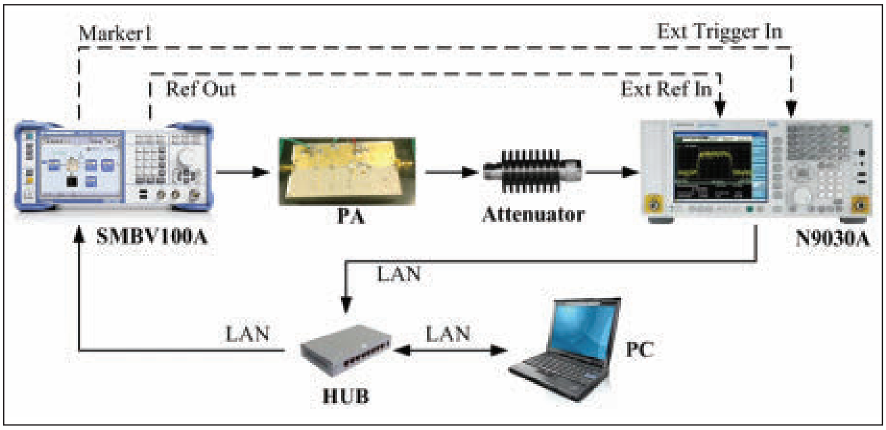


▲ *Fig. 5 Measured PAE, Gain and Pout versus input power at 2.12 GHz.*

greater than 38 dBm from 2.07 to 2.14 GHz. ***Figure 5*** shows the PAE, output power and gain at 2.12 GHz with the input CW signal power level swept from 8 to 28 dBm. A peak PAE of 75.2 percent is achieved with a maximum output power of 39.4 dBm. The actual efficiency may deviate significantly from its theoretical maximum due to device characteristics, bias points, matching network complexity, as well as device and packaging parasitics.

DIGITAL PREDISTORTION EXPERIMENTAL RESULTS

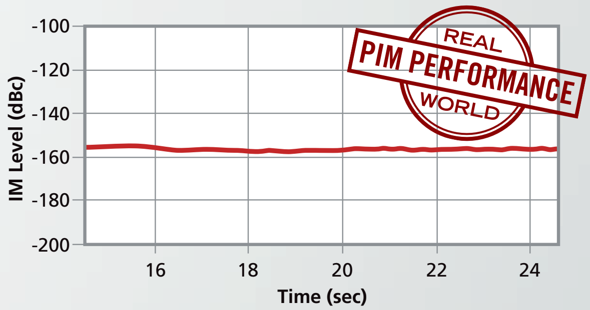
The DPD model employed is a simplified version derived from the second-order truncated dynamic deviation reduction-based Volterra model,[9] which can be written as:[10]



▲ *Fig. 6 The experimental validation platform for linearization.*

The perfect PIM cable assembly. For the not-so-perfect world.

Achieving flat PIM performance in the lab is hard enough. But in the real world, keeping PIM at bay is nearly impossible. Until now. SRX™ jumper cables from San-tron are the first and only flat PIM cable assemblies that stand up under tough conditions. They deliver impressive PIM performance of -158 dBc standing still and degrade just 2 dB under heavy vibration. Offering a bend radius of 2.5 inches, power handling of 160 W, and attenuation of 13 dB per 100 feet, you can snake them around anywhere.



Learn more about our complete line of SRX solutions by downloading our SRX brochure at **Santron.com**.

Download the SRX brochure at santron.com

San·tron

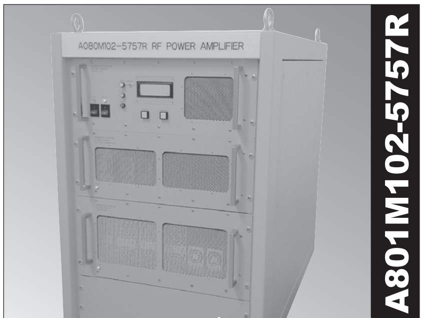
Always Thinking

ES MICROWAVE LLC.

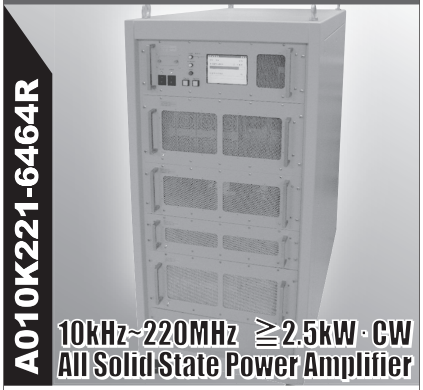
Since 1985 we have offered our custom design filters and sub-assemblies in combline, interdigital and suspended-substrate technologies.

Broadband
Suspended-Substrate
Filters, Diplexers, Triplexers, Quadruplexers, Quintuplexers, Sextuplexers...

ES Microwave, LLC
8031 Cessna Avenue, Gaithersburg, MD 20879
P: 301-519-9407 F: 301-519-9418
www.esmicrowave.com



80MHz~1000MHz ≧500W · CW
All Solid State Power Amplifier
New design, Very Small Size!!



10kHz~220MHz ≧2.5kW · CW
All Solid State Power Amplifier
www.rk-microwave.com
R&K Company Limited
721-1 MAEDA, FUJI-City, SHIZUOKA-Pref. 416-8577 JAPAN
Tel : +81-545-31-2600
Fax : +81-545-31-1600
E-mail : info@rkco.jp

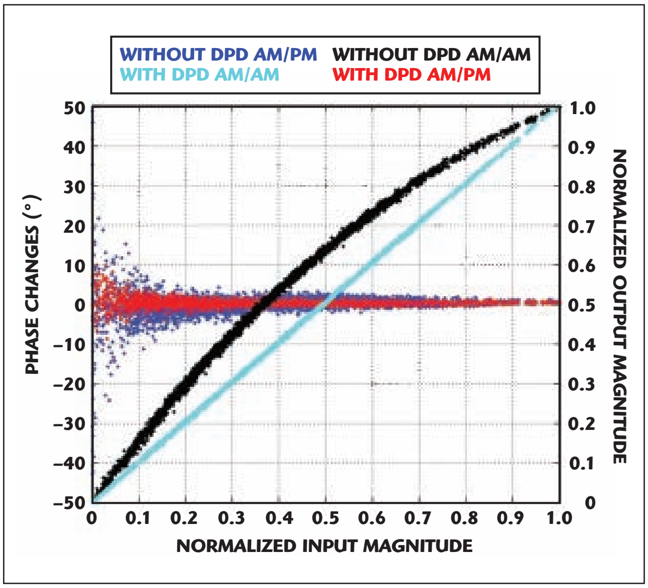
$$
\begin{aligned}
\tilde{u}(n) = &\sum_{k=0}^{\frac{P-1}{2}} \sum_{i=0}^{M} \tilde{g}_{2k+1,1}(i)\left|\tilde{x}(n)\right|^{2k} \tilde{x}(n-i) \\
&+ \sum_{k=1}^{\frac{P-1}{2}} \sum_{i=1}^{M} \tilde{g}_{2k+1,2}(i)\left|\tilde{x}(n)\right|^{2(k-1)} \tilde{x}^2(n)\tilde{x}^*(n-i) \\
&+ \sum_{k=1}^{\frac{P-1}{2}} \sum_{i=1}^{M} \tilde{g}_{2k+1,3}(i)\left|\tilde{x}(n)\right|^{2(k-1)} \tilde{x}(n)\left|\tilde{x}(n-i)\right|^2 \\
&+ \sum_{k=1}^{\frac{P-1}{2}} \sum_{i=1}^{M} \tilde{g}_{2k+1,4}(i)\left|\tilde{x}(n)\right|^{2(k-1)} \tilde{x}^*(n)\tilde{x}^2(n-i)
\end{aligned} \quad (1)
$$

where $\tilde{u}(n)$ and $\tilde{x}(n)$ are the complex envelopes of the input and output of the PA, respectively, and $\tilde{g}_{2k+1,i}(\cdot)$ is the complex Volterra kernel. The symbol $(\cdot)^*$ represents the complex conjugate operation and $|\cdot|$ is the magnitude. P and M are the nonlinear order and memory depth, respectively. Only odd-order nonlinearities are considered – i.e., P is an odd number, because the effects from even order kernels can be omitted in a band-limited modulation system.

The experimental platform[4] in ***Figure 6*** is used to validate the linearity improvement of the designed Class F PA. It consists of a vector signal generator (Rohde & Schwarz SMBV100A), a vector signal analyzer (Agilent N9030A), a PC with Matlab and Agilent's 89600 vector signal analyzer (VSA) software, and the fabricated Class F PA. All the instruments and the PC are connected to a local area network (LAN). The excitation signal can be downloaded from the PC (MATLAB®) to the vector signal generator and the data collected in the vector signal analyzer can be transferred to the PC through the LAN.

The PA operating at 2.12 GHz is excited by a 4-carrier WCDMA signal with 7.1 dB PAPR. A total of 3556 I/Q samples with an oversampling factor of 4 are generated in MATLAB and downloaded to the vector signal generator. The 20 MHz WCDMA signal is generated by configuring the vector signal generator with a sample rate of 80 Msps. The excitation signal is modulated and up-converted to 2.12 GHz in the SMBV100A, and then distorted by the PA. After appropriate attenuation, the output distorted signal from the PA is down-converted and demodulated by the N9030A. A total of 7112 I/Q samples are captured with a sample rate of 80 Msps. After time alignment and normalization, 3556 samples are used for the PA modeling.

In order to accurately model the nonlinearity and memory effects, the nonlinearity order in the Volterra model is set to 9, while the memory depth is set to 7. The AM/AM and AM/PM plots of the PA with and without DPD are shown in ***Figure 7***. You can see that



▲ *Fig. 7 AM-AM and AM-PM plots for the Class F power amplifier with and without DPD.*

UP TO **100 Watt**

AMPLIFIERS

NOW! 100 kHz to 18 GHz

from $945 ea. qty. (1-9)

High-powered performance, across wide frequency ranges. These class A linear amplifiers have set a standard throughout the RF & microwave industry. Rugged and reliable, they feature over-voltage and over-temperature protection, including the ability to withstand opens and shorts! And they're all in stock, whether with a heat sink/fan (for design labs and test benches), or without (for quick integration into customer assemblies). Go to minicircuits.com, and it's easy to select the models that meet your needs, including new features like TTL-controlled RF output. Place an order today, and you can have them in your hands as soon as tomorrow—or if you need a custom model, just give us a call for an engineer-to-engineer discussion of your requirements!

Model (with heat sink/fan*)	Frequency (MHz)	Gain (dB)	Pout @ Comp. 1 dB (W)	Pout @ Comp. 3 dB (W)	$ Price (Qty. 1-9) with heat sink	$ Price (Qty. 1-9) without* heat sink
LZY-22+	0.1-200	43	16	32	1495	1470
ZHL-5W-1	5-500	44	8	11	995	970
• ZHL-100W-GAN+	20-500	42	79	100	2395	2320
• ZHL-50W-52	50-500	50	40	63	1395	1320
• ZHL-100W-52	50-500	50	63	79	1995	1920
LZY-1+	20-512	43	37	50	1995	1895
• ZHL-20W-13+	20-1000	50	13	20	1395	1320
• ZHL-20W-13SW+	20-1000	50	13	20	1445	1370
LZY-2+	500-1000	46	32	38	1995	1895
NEW ZHL-100W-13+	800-1000	50	79	100	2195	2095
ZHL-5W-2G+	800-2000	45	5	6	995	945
ZHL-10W-2G	800-2000	43	10	13	1295	1220
ZHL-30W-252+	700-2500	50	25	40	2995	2920
ZHL-30W-262+	2300-2550	50	20	32	1995	1920
ZHL-16W-43+	1800-4000	45	13	16	1595	1545
ZVE-3W-83+	2000-8000	36	2	3	1295	1220
ZVE-3W-183+	5900-18000	35	2	3	1295	1220

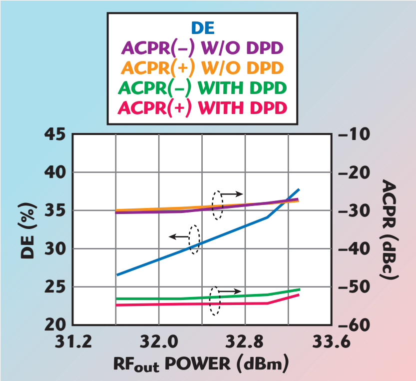
Listed performance data typical, see minicircuits.com for more details.

** To order **without** heat sink, add **X** suffix to model number (example: LZY-22X+).*

• Protected under U.S. Patent 7,348,854

Mini-Circuits®

www.minicircuits.com P.O. Box 35166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com



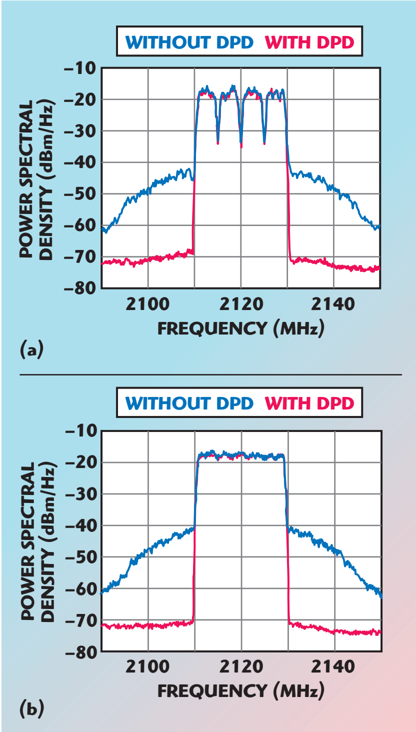
▲ *Fig. 8 Measured drain efficiency and ACPR versus average output power level with and without DPD.*

both nonlinear distortion and memory effects have been successfully compensated. Comparison of the experimental results with the different average output powers are shown in ***Figure 8***. Excellent linearization results in terms of ACPR below –50 dBc are obtained after DPD at the average output power of no higher than 33.3 dBm.

Figure 9(a) shows the measured power spectral density (PSD) of the PA for the WCDMA excitation signal with and without DPD at an average output power of 33.3 dBm. Measured ACPRs are improved to –51.9 dBc (lower) and –54.0 dBc (upper) from –28.3 dBc (lower) and –27.5 dBc (upper), respectively. ***Figure 9(b)*** shows the PSD of the PA for the 20 MHz LTE excitation signal at the same output power. ACPR is suppressed to below -53 dBc after DPD. A drain efficiency (DE) of 37.8 percent is achieved. In ***Table 1***, the linearized Class F PA described in this article is compared with a selection of other state-of-the-art linearized switching mode PAs.

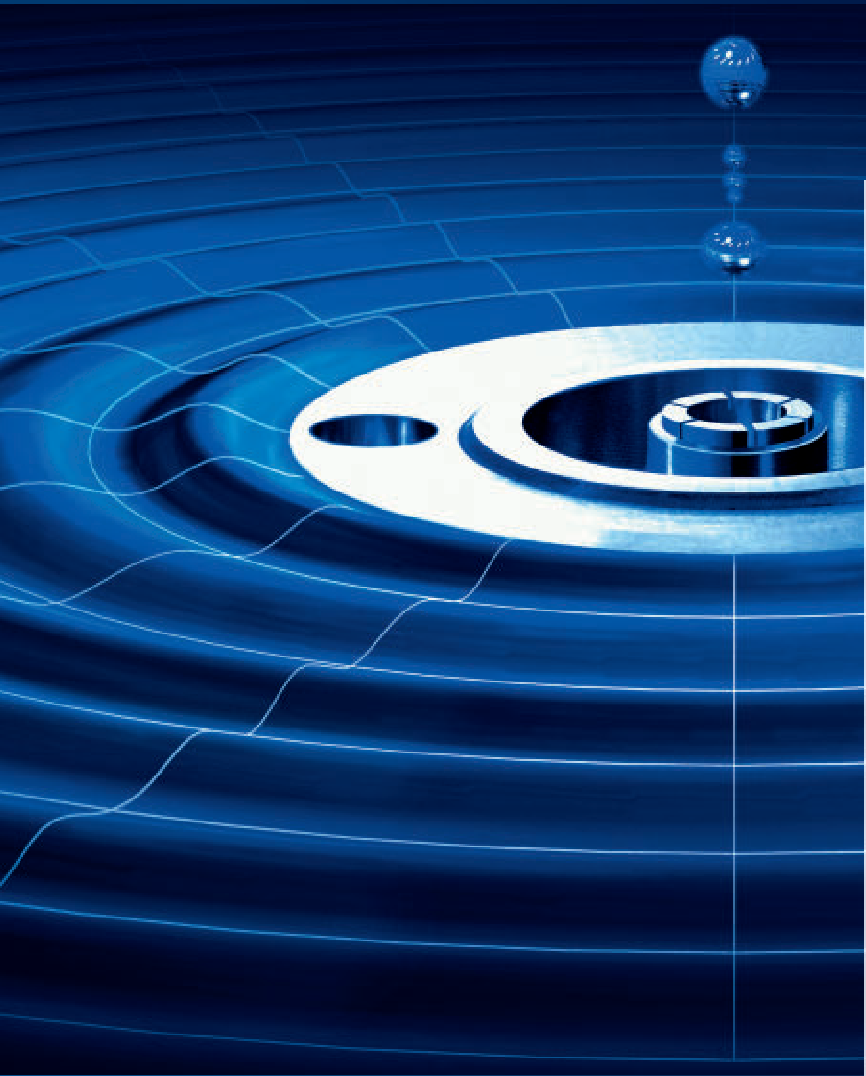
CONCLUSION

A Class F power amplifier using Cree's CGH40010 GaN HEMT for a 2.12 GHz transmitter application is described. The input and output matching networks are designed to approximate the optimum fundamental and second harmonic impedances obtained through source and load pull simulations. The PA demonstrates 75.2 percent peak PAE with a maximum output power of 39.4 dBm. For the 20 MHz 4-carrier WCDMA signal, the ACPR is suppressed to –51.9



▲ *Fig. 9 Measured PSD of the power amplifier output with and without DPD for a 20 MHz 4-carrier WCDMA signal (a). Measured PSD of the PA output with and without DPD for a 20 MHz LTE signal (b).*

Rosenberger



Test, Measurement & Calibration

RF and microwave components from Rosenberger play a key role in a variety of test, measurement & calibration applications. The product range includes

- **RF high precision connectors**, adaptors and devices, e.g. connector heads, opens, shorts or loads of all popular connector series such as RPC-N, -7.00, -3.50, -2.92, 2.40, -1.85 or -1.00 mm
- **Calibration and verification kits** for a number of coaxial standard test interfaces
- **Test cables & test devices**, e.g. VNA microwave test cables, high performance cable assemblies, airlines, interchangeable port connectors, T-calibration adaptors
- **Automated Test Equipment (ATE) products** Multiport Mini-Coax connectors for semiconductor test equipment applications

New:

- Monolithic compliant interconnects – 0.8 mm pitch
- Ruggedized test port adaptors – for VNA applications

Exploring new directions

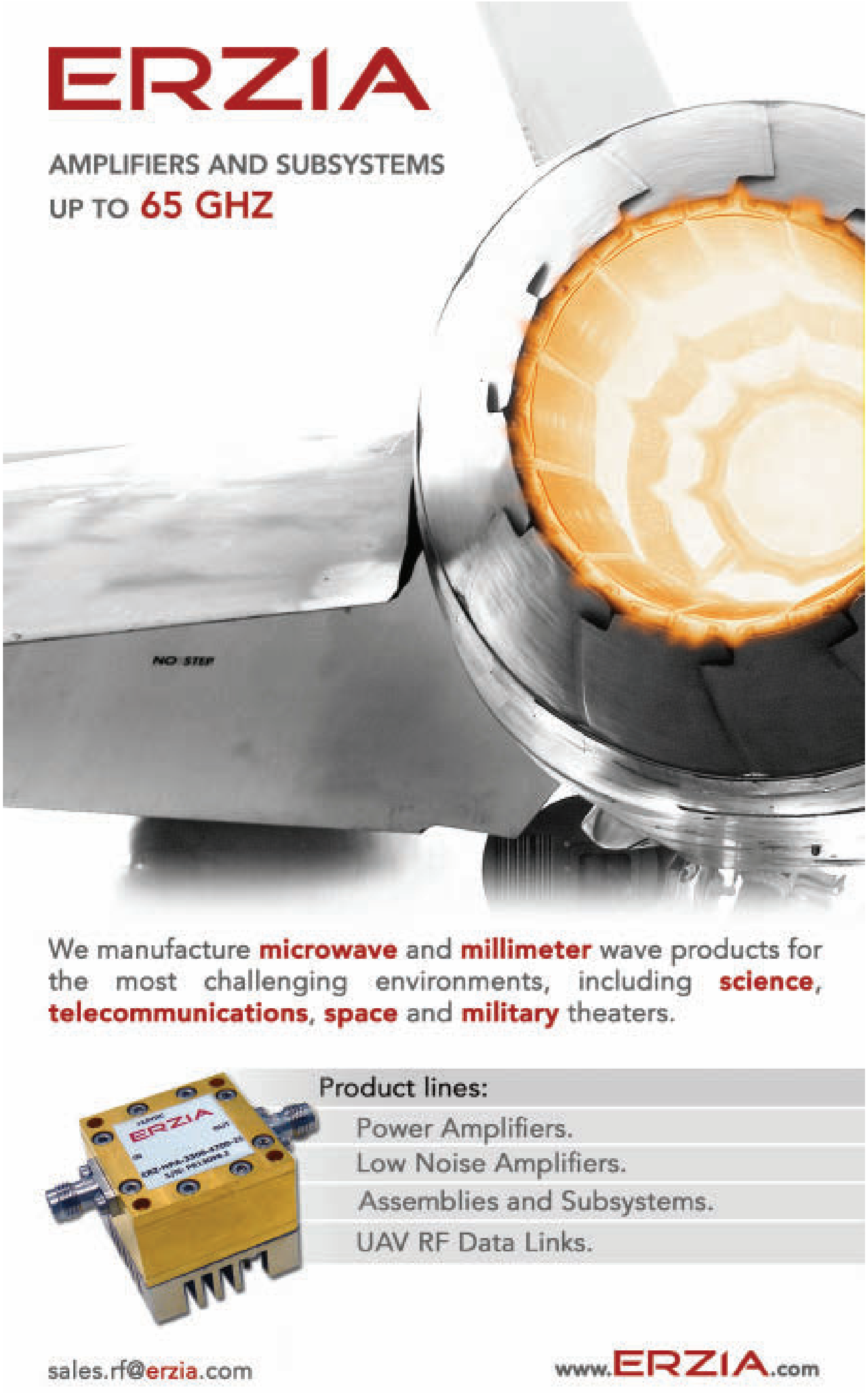
Europe
Rosenberger
Hochfrequenztechnik GmbH & Co. KG
Hauptstraße 1 – 83413 Fridolfing
Germany
Tel. +49-86 84-18-0
info@rosenberger.de
www.rosenberger.com

North America
Rosenberger
of North America, LLC.
1100 Professional Drive #100
USA-Plano, Texas 75074
Phone: + 1 - 972 - 423 8991
salesinfo@rosenbergerna.com
www.rosenberger.com/us_en

and –54 dBc by using DPD techniques. For the 20 MHz LTE signal, the ACPR is improved to below –53 dBc after DPD. A DE of 37.8 percent is achieved at an average output power of 33.3 dBm. ■

TABLE I
LINEARIZED SWITCHING MODE PA COMPARISON

Ref	PA	Sig. BW (MHz)	DE (%)	Pout (dBm)	Freq. (GHz)	ACPR after DPD (dBc)
3	Class E	10	45	33.5	2.1	-50(-)/-50(+)
4	Class F^{-1}	20	31.3	33.6	2.55	-51.9(-)/-54.1(+)
14	Class F^{-1}	10	27.9	29.8	3.3	—
This article	Class F	20	37.8	33.3	2.12	-51.9(-)/-54(+)



ACKNOWLEDGMENT

This work is supported in part by the National Natural Science Foundation of China under Grant 60702163, in part by the National Science and Technology Major Project of China under Grant 2010ZX03007-002-01, and 2011ZX03004-003.

References

1. F.H. Raab, P. Asbeck, S. Cripps, P.B. Kenington, Z.B. Popovic, N. Pothecary, J.F Sevic and N.O. Sokal, "Power Amplifiers and Transmitters for RF and Microwave," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 50, Issue 3, August 2002, pp. 814-826.
2. D. Schmelzer and S.I. Long, "A GaN HEMT Class F Amplifier at 2 GHz With >80 Percent PAE," *IEEE Journal of Solid-State Circuits*, Vol. 42, Issue 10, September 2007, pp. 2130-2136.
3. N. Ui and S. Sano, "A 45 percent Drain Efficiency, -50 dBc ACLR GaN HEMT Class E Amplifier with DPD for W-CDMA Base Station," *IEEE MTTS International Microwave Symposium Digest*, June 2006, pp. 718-721.
4. J. Wang, Y. Xu and X. Zhu, "Digital Predistorted Inverse Class-F GaN PA With Novel PAPR Reduction Technique," *IEEE International Microwave Symposium Digest*, June 2011, pp. 1-4.
5. H. Ku and J.S. Kenney, "Behavioral Modeling of Nonlinear RF Power Amplifiers Considering Memory Effects," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 51, Issue 12, December 2003, pp. 2495-2504.
6. L. Ding, G.T. Zhou, D.R. Morgan, Z. Ma, J.S. Kenney, J. Kim and C.R. Giardina, "A Robust Digital Baseband Predistorter Constructed Using Memory Polynomials," *IEEE Transactions on Communications*, Vol. 52, Issue 1, January 2004, pp. 159-165.
7. D.R. Morgan, Z. Ma, J. Kim, M.G. Zierdt and J. Pastalan, "A Generalized Memory Polynomial Model for Digital Predistortion of RF Power Amplifiers," *IEEE Transactions on Signal Processing*, Vol. 54, Issue 10, October 2006, pp. 3852-3860.
8. A. Zhu, J.C. Pedro and T.J. Brazil, "Dynamic Deviation Reduction-Based Volterra Behavioral Modeling of RF Power Amplifiers," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 54, Issue 12, December 2006.
9. A. Zhu, P.J. Draxler, J.J. Yan, T.J. Brazil, D.F. Kimball and P.M. Asbeck, "Open-Loop Digital Predistorter for RF Power Amplifiers Using Dynamic Deviation Reduction-Based Volterra Series," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 56, Issue 7, July 2008, pp. 1524-1534.
10. L. Guan and A. Zhu, "Simplified Dynamic Deviation Reduction-Based Volterra Model for Doherty Power Amplifiers," *Workshop on Integrated Nonlinear Microwave and Millimetre-Wave Circuits (INMMIC)*, April 2011, pp. 1-4.
11. L. Guan and A. Zhu, "Dual-Loop Model Extraction for Digital Predistortion of Wideband RF Power Amplifiers," *IEEE Microwave and Wireless Components Letters*, Vol. 21, Issue 9, pp. 501-503.
12. Y. Xu, J. Wang and X. Zhu, "Analytical Design of an Inverse Class F Power Amplifier for Linear Amplification," *Microwave Journal*, Vol. 54, Issue 5, May 2011, p. 146.
13. D.Y.T. Wu and S. Boumaiza, "10 W GaN Inverse Class F PA With Input/Output Harmonic Termination for High Efficiency WiMAX Transmitter," *IEEE 10th Annual Wireless and Microwave Technology Conference*, April 2009, pp. 1-4.
14. D.Y.T. Wu, D. Frebrowski and S. Boumaiza, "First-Pass Design of High Efficiency Power Amplifiers Using Accurate Large Signal Models," *IEEE 11th Annual Wireless and Microwave Technology Conference*, April 2010, pp. 1-4.

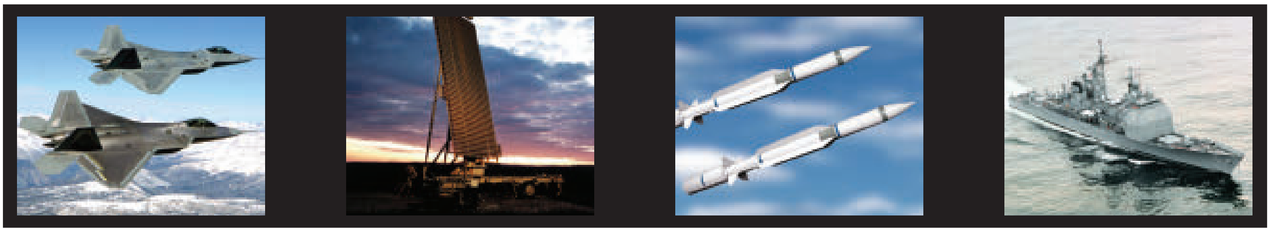
Harness the Legacy of Teledyne Storm's Cabling Expertise

Our Heritage is Your Heritage

More than 30 years of microwave cable design and manufacturing expertise goes into our multi-channel harness assemblies...assemblies built to satisfy the challenging requirements of a wide range of airborne, ground, and sea-based defense systems.

Put our reputation for **technical expertise** and **outstanding customer service** to the test.

Contact us today for a harness solution designed to meet *your* needs.



TELEDYNE
STORM MICROWAVE
Everywhereyoulook™

10221 Werch Drive
Woodridge, Illinois 60517
Tel 630.754.3300
Toll Free 888.347.8676

Download our Multi-Channel Microwave Solutions brochure at www.teledynestorm.com/mj1013

Miniaturized Microstrip Balun Filter

A balun bandpass filter, very miniaturized, is demonstrated. It utilizes a combination of diagonal end-shorted coupled lines and parallel end-shorted coupled lines, both with shunt lumped capacitors instead of the $\lambda g/4$ line branches of the conventional Wilkinson power divider. The proposed balun, based on that phase inverter, is included in the diagonal end-shorted coupled lines. Since these coupled lines with a lumped capacitor have a shunt resonance, the new balun can be a bandpass filter at the same time. A compact balun filter, operating at 1 GHz for experimental verification, is fabricated on a PCB substrate, with coupled lines of 15° electrical length. The die area is 3×21 mm. The balun filter achieves good amplitude and phase characteristics, as well as proper filtering performances.

Baluns are key components in many wireless and mobile communication systems, as well as microwave and millimeter-wave or RF circuits, such as double balanced mixers, push-pull amplifiers, frequency doublers and multipliers, in order to reduce the noise and higher-order harmonics and improve the dynamic range of the systems. In many cases, the input or output port of these baluns needs to be connected to a bandpass filter. Therefore, proper integration of the balun and bandpass filter is of practical importance to reduce the cost and size of wireless circuit systems.

Over the last few years, a lot of research has been conducted to realize the integration of the balun and bandpass filter. Some of them were based on the conventional Marchand balun with two identical coupled lines.[1,2] Integrated, symmetric, four port balun bandpass filters were developed by applying specific boundary conditions.[3,4] However, these balun bandpass filters were developed from the classic quarter- and half-wave resonators. Therefore, a major challenge for size reduction of balun filters still remains. Recently, a balun filter, composed of a hybrid resonant circuit employing shunt and series resonance circuits, has been developed.[5] These resonators are relatively compact, $\lambda g/10$ in length, where λg is the guided wavelength at the center frequency.

In this article, a balun filter for size miniaturization is introduced, using the Wilkinson power splitter structure. One side branch, which has a pair of diagonally end-shorted coupled lines and lumped capacitors, acts as a 3 $\lambda g/4$ line section. The other side, which has a pair of parallel end-shorted coupled lines and lumped capacitors, is operated as a $\lambda g/4$ line section. The method of adding lumped capacitors to the conventional coupled line section can largely reduce the required electrical length of a coupled line. To demonstrate its miniaturized application, a proposed balun filter was designed and fabricated. Compared with other miniaturized balun filters of different types, the realized balun bandpass filter is capable of providing a smaller size as well as maintaining good output balanced signals and useful bandpass filter.

REDUCED SIZE BALUN FILTER DESIGN THEORY

Size Reduction Method of the Quarter-Wavelength Transmission Line

The quarter-wavelength transmission line has been playing a very important role in

In-Ho Kang and Xin Guan
Korea Maritime University,
Busan, South Korea

"Quietly the Best"

Solutions for the Most Demanding Applications

ULTRA LOW NOISE OSCILLATORS

ONYX IV OCXOs - Low-G - Low Noise - Low Cost - 5 MHz to 130 MHz

Part Number	Description	Output Frequency	Typical Phase Noise (dBc/Hz, static, free-running)					Temperature Stability (Ref: +25°C)	G-Sensitivity (per G, per axis)	Package Size (inches)
			10 Hz	100 Hz	1 kHz	10 kHz	100 kHz+			
501-22578-01	Standard ONYX IV OCXO	10 MHz	-125	-150	-160	-165	-165	±2E-8, 0 to +50°C	N/A	1 x 1 x 0.5"
501-26709-02	Standard Rugged ONYX IV OCXO	10 MHz	-125	-150	-160	-165	-165	±5E-8, -20 to +70°C	≤ 3E-10	1 x 1 x 0.5"
501-26719-03	Premium Rugged ONYX IV OCXO	10 MHz	-135	-158	-163	-165	-165	±5E-8, -20 to +70°C	≤ 2E-10	1 x 1 x 0.5"
501-24761-02	Standard Rugged ONYX IV OCXO	100 MHz	-90	-122	-140	-160	-165	±5E-7, -20 to +70°C	≤ 3E-10	1 x 1 x 0.5"
501-24762-02	Premium Rugged ONYX IV OCXO	100 MHz	-95	-127	-152	-165	-172	±5E-7, -20 to +70°C	≤ 3E-10	1 x 1 x 0.5"
501-24762-03	Premium Rugged ONYX IV OCXO	100 MHz	-95	-127	-152	-165	-172	±5E-7, -20 to +70°C	≤ 2E-10	1 x 1 x 0.5"

10 & 100 MHz Models In Stock!

Citrine OCXOs - Ultra Low Noise - Vibe Iso - Low-G - 1 MHz to 700 MHz

Part Number	Description	Output Frequency	Typical Phase Noise (dBc/Hz, static, free-running)					Natural Mount Resonance	G-Sensitivity (per G, per axis)	Ext Ref Freq	Package Size (inches)
			10 Hz	100 Hz	1 kHz	10 kHz	100 kHz+				
501-24825	ULN OCXO	100 MHz	-100	-130	-158	-176	-176	N/A	≤ 3E-10	N/A	2 x 2 x 0.7"
501-25900	Golden ULN OCXO	100 MHz	-108	-138	-163	-183	-188	N/A	≤ 5E-10	N/A	2 x 2 x 0.7"
501-24942	Vib Isolated ULN OCXO	100 MHz	-100	-130	-158	-176	-176	~50 Hz	≤ 3E-10	N/A	2.8 x 3.0 x 1.15"
501-26231	Vib Isolated ULN PLOCXO	100 MHz	-100	-130	-158	-176	-176	~30 Hz	≤ 3E-10	10 MHz	2.8 x 3.0 x 1.75"
501-23792	ULN OCXO Plus (x5)	500 MHz	-85	-115	-142	-159	-160	N/A	≤ 3E-10	N/A	2 x 2 x 1.3"
501-25999	Vib Isolated ULN OCXO Plus (x5)	500 MHz	-85	-115	-142	-159	-160	~30 Hz	≤ 5E-10	N/A	2.8 x 3.0 x 1.75"

NEW
-188 dBc/Hz

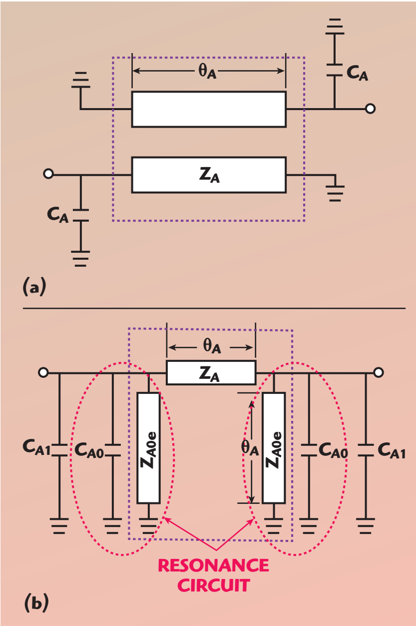
MXO OCXOs - Multiplied - Ultra Low Noise - 200 MHz to 12 GHz

Part Number	Description	Output Frequency	Typical Phase Noise (dBc/Hz, static, free-running)					G-Sensitivity (per G, per axis)	Ext Ref Freq	Package Size (inches)
			10 Hz	100 Hz	1 kHz	10 kHz	100 kHz+			
501-24145	Multiplied OCXO (100 MHz x 5)	500 MHz	-85	-115	-143	-159	-160	≤ 5E-10	N/A	2.25 x 4 x 1"
501-26838	Golden MXO (100 MHz x 5)	500 MHz	-91	-121	-146	-167	-170	≤ 5E-10	N/A	3.25 x 4 x 1"
501-23950	Multiplied PLOCXO (100 MHz x 5)	500 MHz	-85	-115	-143	-159	-160	≤ 5E-10	10 MHz	3.45 x 4 x 1"
501-24146	Multiplied OCXO (100 MHz x 10)	1 GHz	-79	-109	-136	-153	-154	≤ 5E-10	N/A	2.25 x 4 x 1"
501-21081	Multiplied PLOCXO (100 MHz x 10)	1 GHz	-79	-109	-136	-153	-154	≤ 5E-10	10 MHz	3.45 x 4 x 1"
501-24229	Multiplied OCXO (100 MHz x 100)	10 GHz	-57	-87	-113	-131	-132	≤ 5E-10	N/A	4.16 x 4 x 1"
501-24230	Multiplied PLOCXO (100 MHz x 100)	10 GHz	-57	-87	-113	-131	-132	≤ 5E-10	10 MHz	5.36 x 4 x 1"

NEW
-170 dBc/Hz

Wenzel Associates, Inc.
"Quietly the Best"
www.wenzel.com
2215 Kramer Lane, Austin, Texas 78758
512-835-2038 • sales@wenzel.com

Croven Crystals
Wenzel International, Inc.
www.crovencrystals.com
500 Beech Street, Whitby, Ontario, Canada
905-668-3324 • crovensales@crovencrystals.com



▲ *Fig. 1 Diagonally shorted miniaturized coupled lines with shunt lumped capacitors (a) and its equivalent circuit (b).*

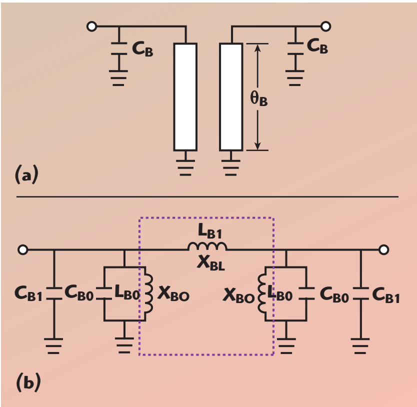
many microwave circuits. However, in many cases, it is too large to be compatible with other parts of microwave systems. The size reduction method proposed by Hirota[6] has the limitation of using a high impedance transmission line in an extremely reduced size.

One method of improving size reduction is by replacing the high impedance section by the diagonally shorted coupled lines with shunt lumped capacitors,[7] as shown in ***Figure 1***. It is equivalent to a quarter-wave transmission line if the following equations are satisfied:

$$Z_A = \frac{Z_0}{\sin\theta_A} = \frac{2Z_{Aoe}Z_{Aoo}}{Z_{Aoe}-Z_{Aoo}} \tag{1}$$

$$C_A = C_{A0} + C_{A1} = \frac{1}{\omega Z_{Aoe}\tan\theta_A} + \frac{\cos\theta_A}{\omega Z_0} \tag{2}$$

where Z_A, Z_0, θ_A and ω are the characteristic impedance of the shorted coupled lines, the characteristic impedance of the quarter-wavelength line, the electrical length of the shorted line and the angular frequency, respectively. C_{A0} is the lumped capacitor for the miniaturization of transmission line, C_{A1} is the capacitor for the resonance with shunt distributed inductor and C_A is the combination of C_{A0} and C_{A1}. Z_{oe} and Z_{oo} are the even- and odd-mode characteristic impedance of the coupled lines. However, this miniaturized coupled line is actually operated as a 3 λg/4 line section, because the diagonally end-shorted coupled line section includes a phase inverter and has previously been used in a rat race coupler.[8]



▲ *Fig. 2 Parallel, end shorted, miniaturized coupled lines with shunt lumped capacitors (a) and its equivalent circuit (b).*

Another method is utilizing parallel end shorted coupled lines, with shunt lumped capacitors.[9] ***Figure 2*** shows its schematic diagram (a) and its equivalent circuit (b), when Equations 3 and 4 are satisfied.

$$Z_B = \frac{2Z_{Boe}Z_{Boo}}{Z_{Boe}-Z_{Boo}} = \frac{Z_0}{\tan\theta_B} \tag{3}$$

$$C_B = C_{B0} + C_{B1} = \frac{1}{\omega Z_{Boe}\tan\theta_B} + \frac{1}{\omega Z_0} \tag{4}$$

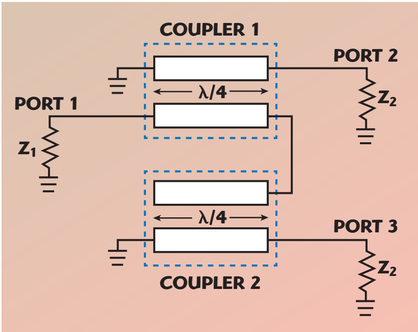
Ordinary Balun Design

Among the various kinds of baluns, a planar version of Marchand balun has been adopted for a long time, due to its various advantages. This kind of balun has been well developed.[10] A block diagram of the balun is shown in ***Figure 3***. It provides balanced outputs to load terminations Z_2, from an unbalanced input with source impedance Z_1. In general, the impedances Z_1 and Z_2 are different. When the source and load impedances are equal to Z_1, it gives the best attainable S matrix of a lossless balun as follows:

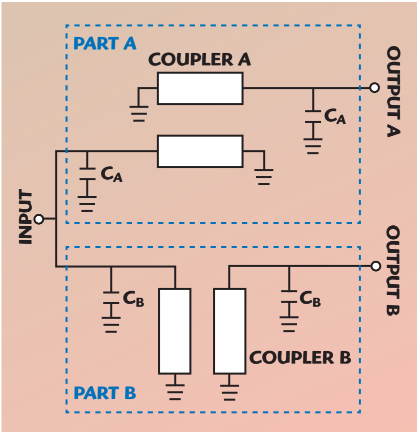
$$[S]_{balun} = \begin{bmatrix} 0 & \frac{j}{\sqrt{2}} & \frac{-j}{\sqrt{2}} \\ \frac{j}{\sqrt{2}} & \frac{1}{2} & \frac{1}{2} \\ \frac{-j}{\sqrt{2}} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \tag{5}$$

New Structure for Miniaturized Balun Filter

By employing two pairs of coupled lines instead of the λg/4 transmission line in the structure of the traditional Wilkinson power divider, a miniaturized coupled line balun is proposed (as shown in ***Figure 4***). Since a coupled line section, grounded at the diagonal end in one branch of the modified Wilkinson power splitter balun, acts as a phase inverter, the phase difference is 180° at the output ports A and B. In addition, by comparing the baluns of figures 3 and 4, a balun with coupled lines becomes a bandpass filter with two shunt resonant circuits. Contrary to the Marchand balun, the miniaturized circuit has significant advantages, having a miniaturized balun and bandpass filter at the same time. The theoretical analysis is described as follows, in order to



▲ *Fig. 3 Block diagram of a symmetrical Marchand balun as two identical couplers.*



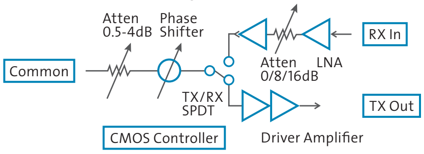
▲ *Fig. 4 New structure for a miniaturized balun filter.*

Industry First Integrated X-Band Chip For Commercial Applications

Setting New Standards in Radar Speed & Accuracy with a Small, Cost-effective Package for Weather, Marine & Avionics

The X-Band Core Chip is a highly integrated, high-performance solution setting new standards for speed and accuracy in phased array radar applications. Building on a legacy of results across the entire frequency range, the X-Band features an integrated logic driver for system architecture simplicity *and* performance.

X-Band Core Chip Block Diagram



The surface-mount 7 x 7 mm plastic package is the industry's smallest and most cost-effective solution for space-constrained designs. The technology's versatility and flexibility make it ideal for weather, wildfire and related commercial radar applications.

Fully tested and ready to ship, the X-Band Core Chip is another industry first from MACOM's experienced engineering team.

Order samples and get more information at www.macomtech.com/x-band

MACOM™

Partners in RF & Microwave

prove it functions as a balun.

The corresponding Y parameters of two kinds of coupled lines expressed in terms of the even- and odd-mode characteristic admittances Y_{oe} and Y_{oo} are given as follows:

$$\left[Y_{couplerA}\right]=\begin{bmatrix} Y_{A11} & Y_{A12} \\ Y_{A21} & Y_{A22}\end{bmatrix}=$$

$$\begin{bmatrix} -j\dfrac{Y_{Aoo}+Y_{Aoe}}{2}\cot\theta_A & -j\dfrac{Y_{Aoo}-Y_{Aoe}}{2}\csc\theta_A \\ -j\dfrac{Y_{Aoo}-Y_{Aoe}}{2}\csc\theta_A & -j\dfrac{Y_{Aoo}+Y_{Aoe}}{2}\cot\theta_A \end{bmatrix} \quad (6)$$

$$\left[Y_{couplerB}\right]=\begin{bmatrix} Y_{B11} & Y_{B12} \\ Y_{B21} & Y_{B22}\end{bmatrix}=$$

$$\begin{bmatrix} -j\dfrac{Y_{Boo}+Y_{Boe}}{2}\cot\theta_B & j\dfrac{Y_{Boo}-Y_{Boe}}{2}\cot\theta_B \\ j\dfrac{Y_{Boo}-Y_{Boe}}{2}\cot\theta_B & -j\dfrac{Y_{Boo}+Y_{Boe}}{2}\cot\theta_B \end{bmatrix} \quad (7)$$

After shunting the capacitors at each side of the coupled lines, the Y parameters of two parts are:

$$\left[Y_A\right]=\begin{bmatrix} Y_{A11}+j\omega C_A & Y_{A12} \\ Y_{A21} & Y_{A22}+j\omega C_A\end{bmatrix} \quad (8)$$

$$\left[Y_B\right]=\begin{bmatrix} Y_{B11}+j\omega C_B & Y_{B12} \\ Y_{B21} & Y_{B22}+j\omega C_B\end{bmatrix} \quad (9)$$

By a series of relationship about the properties of the two kinds of coupled lines deduced from Equations 1 to 4, every element of Y parameters in Equations 8 and 9 can be worked out as follows:

$$Y_{A11}+j\omega C_A = Y_{A22}+j\omega C_A = -j\frac{Y_{Aoo}+Y_{Aoe}}{2}\cot\theta_A + j\left(\frac{1}{Z_{Aoe}\tan\theta_A}+\frac{\cos\theta_A}{Z_0}\right)$$
$$= j\left(-\frac{1}{2}Y_{Aoo}\cot\theta_A - \frac{1}{2}Y_{Aoe}\cot\theta_A + Y_{Aoe}\cot\theta_A + \frac{\cos\theta_A}{Z_0}\right)$$
$$= j\left(-\frac{Y_{Aoo}-Y_{Aoe}}{2}\frac{\cos\theta_A}{\sin\theta_A}+\frac{\cos\theta_A}{Z_0}\right) = j\left(-\frac{\cos\theta_A}{Z_A\sin\theta_A}+\frac{\cos\theta_A}{Z_0}\right)=0 \quad (10)$$

$$Y_{A12}=Y_{A21}=-j\frac{Y_{Aoo}-Y_{Aoe}}{2}\csc\theta_A = -j\frac{Y_A}{\sin\theta_A}=-jY_0 \quad (11)$$

$$Y_{B11}+j\omega C_B = Y_{B22}+j\omega C_B = -j\frac{Y_{Boo}+Y_{Boe}}{2}\cot\theta_B + j\left(\frac{1}{Z_{Boe}\tan\theta_B}+\frac{1}{Z_0}\right)$$
$$= j\left(-\frac{1}{2}Y_{Boo}\cot\theta_B - \frac{1}{2}Y_{Boe}\cot\theta_B + Y_{Boe}\cot\theta_B + \frac{1}{Z_0}\right)$$
$$= j\left(-\frac{Y_{Boo}-Y_{Boe}}{2}\frac{1}{\tan\theta_B}+\frac{1}{Z_0}\right) = j\left(-\frac{1}{Z_A\tan\theta_A}+\frac{1}{Z_0}\right)=0 \quad (12)$$

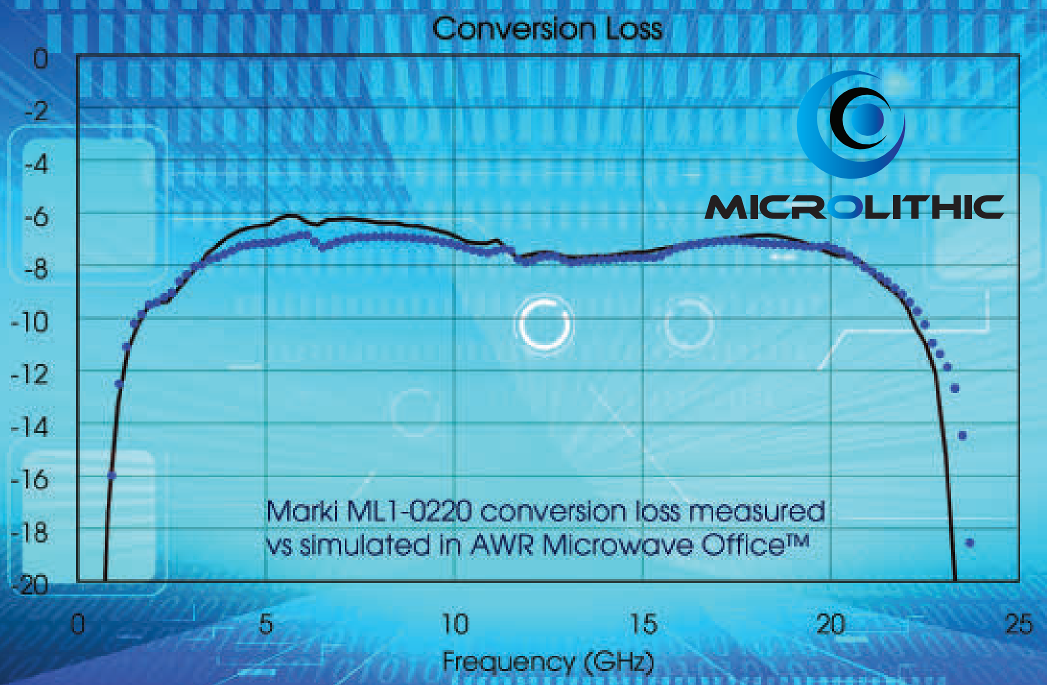
COST-EFFECTIVE
HERMETIC MICRO D CONNECTORS

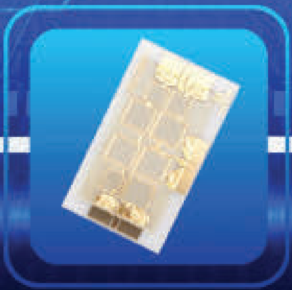
Standard 9 to 51 pin configurations available
or let us design to your custom requirements

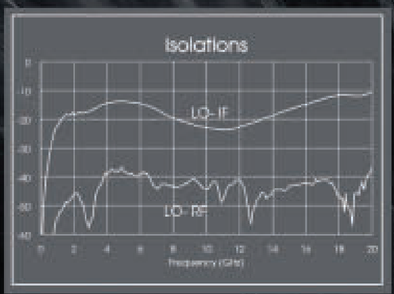
SHP
SPECIAL HERMETIC PRODUCTS, INC.
Hi-Rel By Design

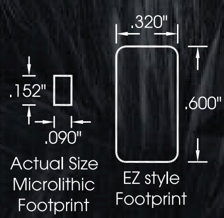
CONTACT US TODAY
(P) 603-654-2002 (F) 603-654-2533
www.shp-seals.com email: sales@shp-seals.com
CERTIFIED ISO 9001:2008

MIXERS YOU CAN SIMULATE









Marki Microwave offers accurate simulation models for all new Microlithic mixers.
These models can predict isolations and spurious products.
Microlithic mixers feature superior performance with a 14x size reduction.

Marki microwave

Markimicrowave.com/microlithic

$$Y_{B12} = Y_{B21} = j\frac{Y_{Boo} - Y_{Boe}}{2}\cot\theta_B = j\frac{Y_B}{\tan\theta_B} = jY_0 \tag{13}$$

where Y_0 is the characteristic admittance of the equivalent quarter-wave transmission line of the two kinds of coupled lines. Y_1 is assumed as the characteristic admittance of one branch of the modified power divider for the matching of input point of view. Then, the relationship below is satisfied:

$$Y_0 = \frac{Y_1}{\sqrt{2}} \tag{14}$$

Thus, the Y parameters of the whole tri-port circuit can be derived:

$$[Y] = \begin{bmatrix} Y_{A11} + Y_{B11}\omega + j\omega C_A + j\omega C_B & Y_{A12} & Y_{B12} \\ Y_{A21} & Y_{A22} + j\omega C_A & 0 \\ Y_{B21} & 0 & Y_{B22} + j\omega C_B \end{bmatrix}$$

$$= \begin{bmatrix} 0 & -jY_0 & jY_0 \\ -jY_0 & 0 & 0 \\ jY_0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & \frac{-jY_1}{\sqrt{2}} & \frac{jY_1}{\sqrt{2}} \\ \frac{-jY_1}{\sqrt{2}} & 0 & 0 \\ \frac{jY_1}{\sqrt{2}} & 0 & 0 \end{bmatrix} \tag{15}$$

Based on the port terminations defined previously, Equation 15 can be converted to the scattering parameter matrix:

$$[S] = ([Y_1] - [Y])([Y_1] + [Y])^{-1}$$

$$= \begin{bmatrix} Y_1 - Y_{11} & -Y_{12} & -Y_{13} \\ -Y_{21} & Y_1 - Y_{22} & -Y_{23} \\ -Y_{31} & -Y_{32} & Y_1 - Y_{33} \end{bmatrix} \begin{bmatrix} Y_1 + Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_1 + Y_{22} & Y_{23} \\ Y_{31} & Y_{32} & Y_1 + Y_{33} \end{bmatrix}^{-1}$$

$$= \frac{1}{2Y_1^3} \begin{bmatrix} Y_1 & \frac{jY_1}{\sqrt{2}} & \frac{-jY_1}{\sqrt{2}} \\ \frac{jY_1}{\sqrt{2}} & Y_1 & 0 \\ \frac{-jY_1}{\sqrt{2}} & 0 & Y_1 \end{bmatrix} \begin{bmatrix} Y_1^2 & \frac{jY_1^2}{\sqrt{2}} & \frac{-jY_1^2}{\sqrt{2}} \\ \frac{jY_1^2}{\sqrt{2}} & \frac{3Y_1^2}{2} & \frac{Y_1^2}{2} \\ \frac{-jY_1^2}{\sqrt{2}} & \frac{Y_1^2}{2} & \frac{3Y_1^2}{2} \end{bmatrix} = \begin{bmatrix} 0 & \frac{j}{\sqrt{2}} & \frac{-j}{\sqrt{2}} \\ \frac{j}{\sqrt{2}} & \frac{1}{2} & \frac{1}{2} \\ \frac{-j}{\sqrt{2}} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \tag{16}$$

This is equivalent to Equation 5, the S matrix of the ordinary Marchand balun. It is also the best attainable S-parameter matrix of a lossless balun, which is matched at the input ($S_{11} = 0$) and has transmission coefficients of -3 dB ($|S_{21}| = |S_{31}| = (1/2)^{½}$) with opposite phase.

SIMULATION AND MEASUREMENT RESULTS

To validate the analytical results and demonstrate the design approach, the circuit parameters are converted to physical filter structures and simulated by ADS and HFSS. For the sake of simplifying the fabrication procedure as easy as can be realized, the circuit is implemented with microstrip transmission lines.

The initial miniaturized balun filter model illustrated in ***Figure 5***, drawn in HFSS, where the electrical length of the coupled-lines being 15° at 1 GHz, was obtained. The electrical length is flexibly chosen and could be miniaturized further. When the even-mode impedance Z_{oe} was arbitrarily chosen as 80 Ω, the value of the lumped capacitor CA and CB was calculated to be 9.68 pF, according to Equations 2 and 4 and the odd-mode impedance of the coupled-line Z_{oo} was 50 Ω, making the coupling coefficient K = 0.23.

The layout of the balun filter drawn with AutoCAD and its photograph are shown in ***Figure 6***. The dimensions of the circuit are 3×21 mm (not including the extended ports for testing). The width of the coupled lines is 0.65 mm, the length is 8.2 mm and the slot between the two coupled lines is 0.54 mm. The balun filter is realized on a PCB substrate having a thickness of 0.8 mm and a dielectric constant ε_r = 4.4. For measurement convenience, all the balanced and unbalanced ports impedances are fixed to be 50 Ω.

In ***Figure 7***, the measured S_{11}, S_{21} and S_{31} are compared with the simula-

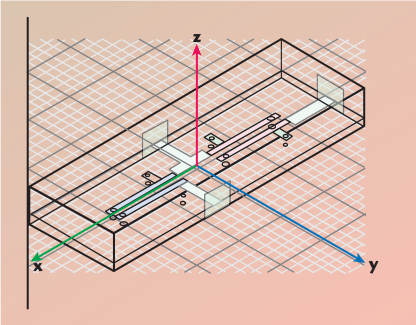


Fig. 5 Initial two-stage miniaturized balun filter model drawn in HFSS.

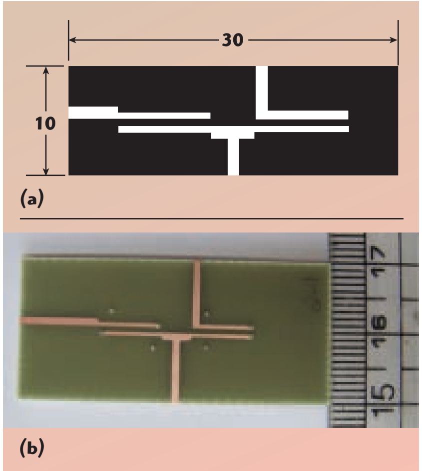


Fig. 6 Layout of the two-stage circuit drawn with AutoCAD (a) and its photograph (b).

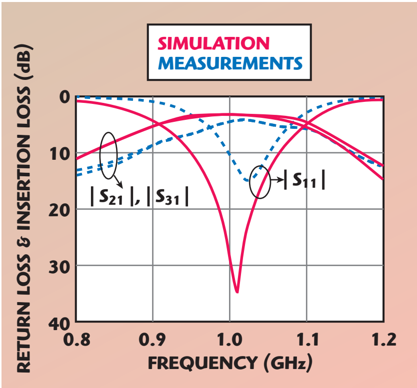
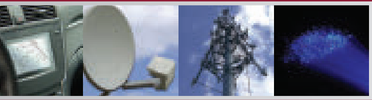


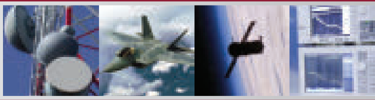
Fig. 7 Simulated and measured frequency performance.

GaN Power Amplifiers

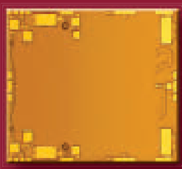
Wideband 50 Ω Matched Power to 25W



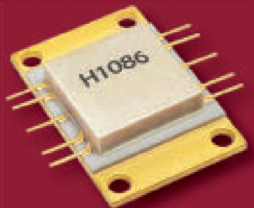
Analog, Digital & Mixed-Signal
ICs, Modules, Subsystems & Instrumentation



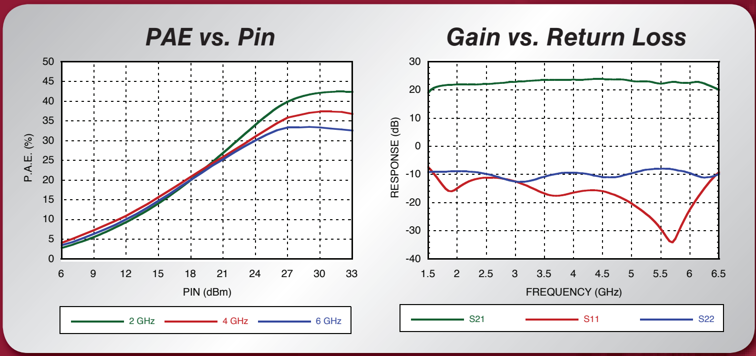
25W Power Amplifiers 2 to 6 GHz



HMC1086



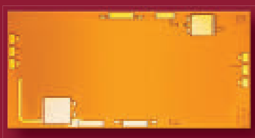
HMC1086F10



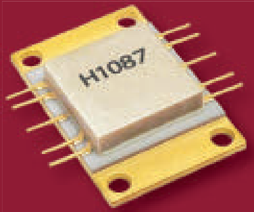
Features

- ***High Output IP3: +48 dBm***
- ***35% PAE***

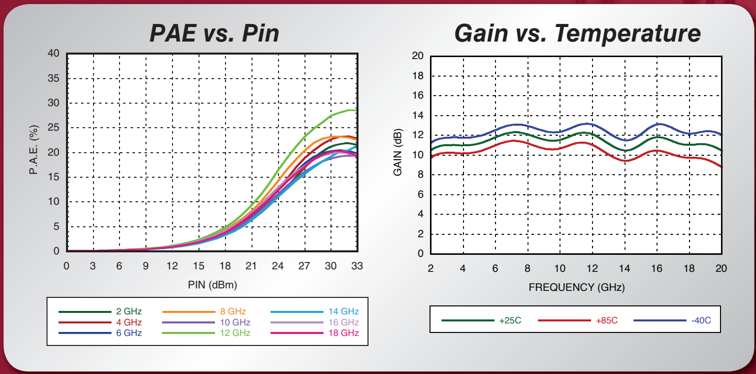
8W Power Amplifiers 2 to 20 GHz



HMC1087



HMC1087F10



Features

- ***High Output IP3: +45 dBm***
- ***24% PAE***

IN STOCK GaN MMIC POWER AMPLIFIERS

Part Number	Frequency (GHz)	Function	Gain (dB)	OIP3 (dBm)	Psat (dBm)	Power Gain @ Psat (dB)	Bias Supply	Package
HMC1086	2 - 6	GaN MMIC PA, 25W	22	+48	+44.5	14	+28V @ 1100 mA	Chip
HMC1086F10	2 - 6	GaN MMIC PA Flange-Mount, 25W	23	+46	+44.5	11	+28V @ 1100 mA	F10
HMC1087	2 - 20	GaN MMIC PA, 8W	11	+45	+39	5.5	+28V @ 850 mA	Chip
HMC1087F10	2 - 20	GaN MMIC PA, Flange-Mount 8W	11	+43.5	+38.5	6.5	+28V @ 850 mA	F10

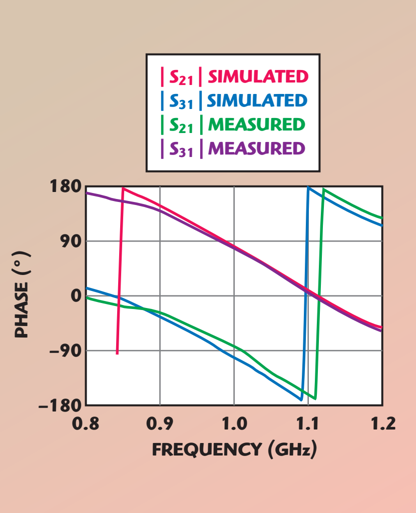
For General Communications, Test Instrumentation, and Radar Applications.

Hittite MICROWAVE CORPORATION

2 Elizabeth Drive • Chelmsford, MA 01824
978-250-3343 tel • 978-250-3373 fax
www.hittite.com • gan@hittite.com
View the latest releases - click on "New Products"

Download Hittite at the App Store

TABLE I COMPARISON OF DIFFERENT TYPES OF BALUN FILTERS				
Reference	*This Work*	*[5]*	*[11]*	*[12]*
Technology	PCB	PCB	LTCC	PCB
Center Frequency (GHz)	1	2.7	2.2	3
Electrical Length	λg/24	λg/10	λg/2.3	–
Bandwidth	$0.23f_0$	$0.11f_0$	$0.045f_0$	$0.087f_0$
Insertion Loss (dB)	4.2	4.43	5.26	5.33
Die Area (mm²)	3×21	14.9×15.2	1.22×0.76	50×50
Year	2012	2010	2012	2011



▲ *Fig. 8 Simulated and measured phase.*

tion results from HFSS. The insertion loss for the simulated result by HFSS is 3.22 dB and the measurement result is 0.98 dB worse. The measurement performances agree well with the simulation. The additional loss is caused by surface and edge roughness of the metal, inferior metal conductivity, the dielectric loss of the substrate, and so on, which were not taken into account in the calculations.

Finally, ***Table 1*** summarizes the characteristic of several published bandpass balun filters compared with this work. The proposed bandpass filter in this article shows the advantage of more compact size and good insertion loss characteristics.

CONCLUSION

In this article, the design theory and procedure for a balun bandpass filter with extremely small size is carried out, utilizing the combination of diagonal shorted coupled lines and parallel end shorted coupled lines, both with shunt lumped capacitors, which offers good amplitude and phase balance performance (see ***Figure 8***). In contrast with the conventional Marchand balun with two coupled lines, the proposed balun has the advantage that offers a miniaturized balun and a bandpass filter at the same time. In addition, this approach is theoretically able to reduce up to an extremely

NITRONEX

The Largest family of GaN RF Power Devices on Silicon Just got Bigger

GaN Essentials™

48V 100W HEMT

Broadband coverage with one circuit

3 Reference Designs:

30MHz – 512MHz
100MHz – 1000MHz
200MHz – 2000MHz

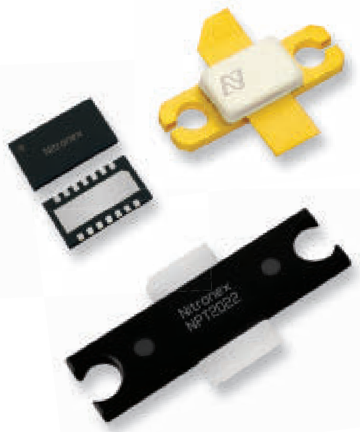
Evaluation boards available at:
applications@nitronex.com

Introducing the Newest Family of 48V GaN RF Power Devices

Psat (W)	Plastic
12	NPT2018 (3X6 DFN)
25	NPT2019 (3X6 DFN)
50	NPT2021 (T0272)
100	NPT2022 (T0272)

Psat (W)	Ceramic
50	NPT2020 (AC360)
100	NPT2010 (AC360)

Covering frequencies from DC up to 4 GHz.



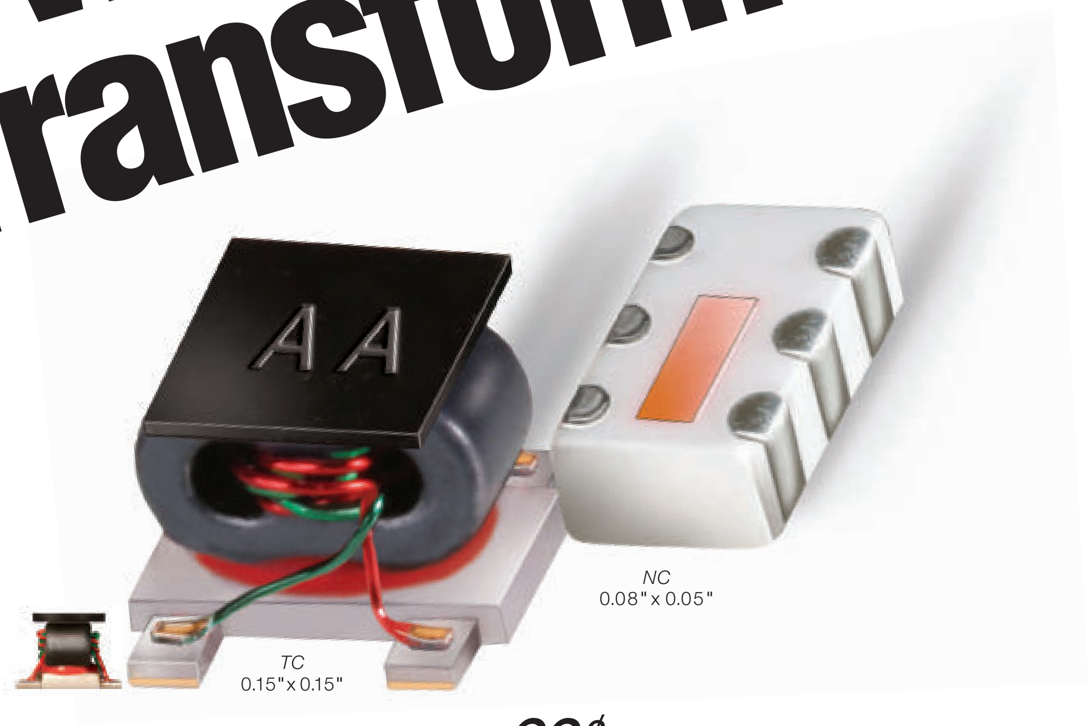
Higher performance. Lower cost. • New products. New capabilities. Proven Technology.

Broadband / General Purpose RF Power Transistors • GaN MMICs

nitronex.com
A GaasLabs Company

TINY

Wideband Transformers



0.15-8000 MHz as low as 99¢ each (qty. 1000) RoHS compliant.

Rugged, repeatable performance.
At Mini-Circuits, we're passionate about transformers. We even make own transmission line wire under tight manufacturing control, and utilize all-welded connections to maximize performance, reliability, and repeatability. And for signals up to 8 GHz, our rugged LTCC ceramic models feature wrap-around terminations for your visual solder inspection, and they are even offered in packages as small as 0805!

Continued innovation: Top Hat.
A Mini-Circuits exclusive, this new feature is now available on every open-core transformer we sell. Top Hat speeds customer pick-and-place throughput in four distinct ways: (1) faster set-up times, (2) fewer missed components, (3) better placement accuracy and consistency, and (4) high-visibility markings for quicker visual identification and inspection.

More models, to meet more needs
Mini-Circuits has over 250 different SMT models in stock. So for RF or microwave baluns and transformers, with or without center taps or DC isolation, you can probably find what you need at minicircuits.com. Enter your requirements, and Yoni2, our patented search engine, can identify a match in seconds. And new custom designs are just a phone call away, with surprisingly quick turnaround times gained from over 40 years of manufacturing and design experience!

Mini-Circuits®

www.minicircuits.com P.O. Box 35166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

377 rev AA

IEEE Wireless and Microwave Technology Conference
WAMICON 2014
Co-located with the International Microwave Symposium and ARFTG
Marriott Waterside Hotel and Marina
Tampa, FL
June 6, 2014

Call for Papers

The 15th annual IEEE Wireless and Microwave Technology Conference (WAMICON 2014) will be held in Tampa, Florida on June 6, 2014. The conference will address up-to-date multidisciplinary research needs and interdisciplinary aspects of wireless and RF technology. The program includes both oral and poster presentations.

Topics of interest include:

Emerging RF and Microwave Technologies
Biomedical Applications, Wireless Sensing, Energy Harvesting, Wireless PowerTransfer, Terahertz Technologies, Nano Devices and Circuits. Other emerging wireless and microwave topics will also be considered.

Wireless Communications
Cognitive Radio, 4G and Advanced Data Networks,Ultra-Wideband (UWB), MIMO, Multi-Carrier, Spread Spectrum, Channel Characterization and Modeling and Software Defined Radios (SDR). Additionally, papers on Point-to Point and Point-to-Multipoint Systems including MESH Sensor Networks will be considered.

Submission Instructions

Authors are asked to submit papers electronically in .PDF format. To be considered for publication, an initial submission of 3 pages, clearly describing the concept and results must be submitted prior to February 14, 2014 deadline. Final manuscript of 3-6 pages will be requested only after paper acceptance. Submissions will be evaluated for originality, significance of the work, technical soundness and interest to a wide audience. Visit **www.wamicon.org** for complete details of submission.

Important Dates

Paper Due:	*February 14, 2014*
Author Notification:	*March 10, 2014*
Final Papers Due:	*March 30, 2014*

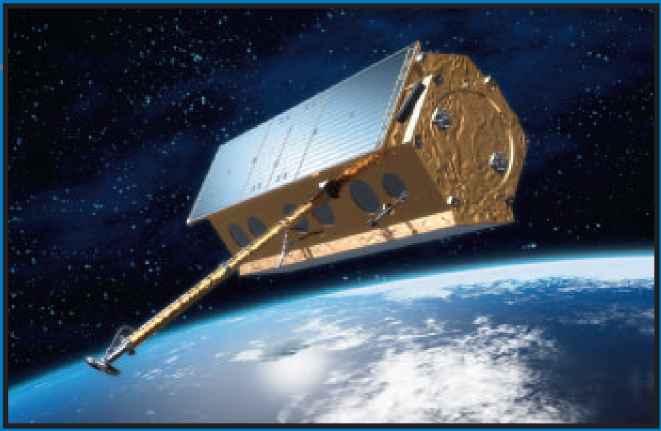
Sponsorship Opportunities Available!
Email: alen.fejzuli@electrotechnik.com
jassurian@reactel.com

small size to some extent. To demonstrate the feasibility and validity of the design equation, a miniaturized balun filter, with the size of 3×21 mm, is designed and fabricated on a PCB substrate. The electrical length of the coupled lines for the fabrication could be chosen as short as 15°. The measurements agree well with the simulation results. This class of balun filter is expected to be invaluable in the design of miniaturized balanced microwave circuits. ■

References

1. K.S. Ang, Y.C. Leong and C.H. Lee, "Analysis and Design of Miniaturized Lumped-distributed Impedance-transforming Baluns," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 51, No. 3, March 2003, pp. 1009-1027.
2. R. Kravchenko, K. Markov, D. Orlenko, G. Sevskiy and P. Heide, "Implementation of a Miniaturized Lumped-distributed Balun in Balanced Filtering for Wireless Applications," *2005 European Microwave Conference Digest*, Vol. 2, pp. 1303-1306.
3. C.H. Wu, C.H. Wang and C.H. Chen, "Novel Balance Coupled-line Bandpass Filters with Common-mode Noise Suppression," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 55, No. 2, Part 1, February 2007, pp. 287-295.
4. C.H. Wu, C.H. Wang, S.Y. Chen and C.H. Chen, "Balanced-to-unbalanced Bandpass Filters and the Antenna Application," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 56, No. 11, Part 1, November 2008, pp. 2474-2482.
5. T. Yang, M. Tamura and T. Itoh, "Compact Hybrid Resonator with Series and Shunt Resonances Used in Miniaturized Filters and Balun Filters," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 58, No. 2, February 2010, pp. 390-402.
6. T. Hirota, "Reduced-size Branch-line and Rat-race Hybrids for Uniplanar MMIC's," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 38, No. 3, March 1990, pp. 270-275.
7. I. Kang, S. Shan, X. Wang, Y. Yun, J. Kim and C. Park, "A Miniaturized GaAs MMIC Filter for the 5 GHz Band," *Microwave Journal*, Vol. 50, No. 11, November 2007, pp. 88-96.
8. S.P. Marsh, "A Wide-band Stripline Hybrid Ring," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 16, No. 6, June 1968, pp. 361-368.
9. I. Kang and J.S. Park, "A Reduced-size Power Divider Using the Coupled Line Equivalent to a Lumped Inductor," *Microwave Journal*, Vol. 46, No. 7, July 2003, pp. 72-79.
10. K.S. Ang and I.D. Robertson, "Analysis and Design of Impedance Transforming Marchand Balun," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 49, No. 2, February 2001, pp. 402-406.
11. T. Yang, M. Tamura and T. Itoh, "Compact and High-performance Low-temperature Co-fired Ceramic Balun Filter Using the Hybrid Resonator and Symmetric Four-port Network," *IET Microwave Antennas and Propagation*, Vol. 6, No. 2, 2012, pp. 121-126.
12. C.H. Ng, E.H. Lim and K.W. Leung, "Compact Microstrip Patch Balun Filter," *IEEE 2011 Cross Strait Quad-Regional Radio Science and Wireless Technology Conference Digest*, Vol. 1, pp. 1749-1751.

Instantly Improve the Performance of Your Phased Array Radar!

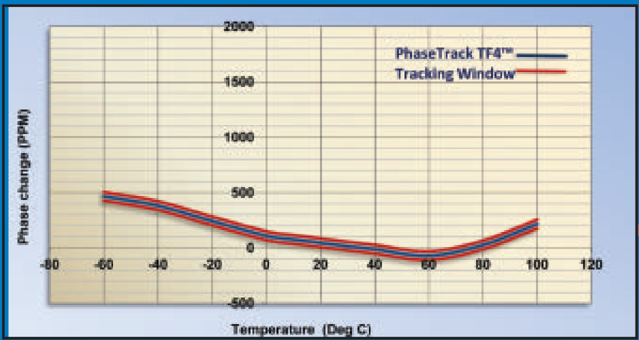


Phased Array Radar system performance has long been limited by the phase change over temperature of coaxial cables.

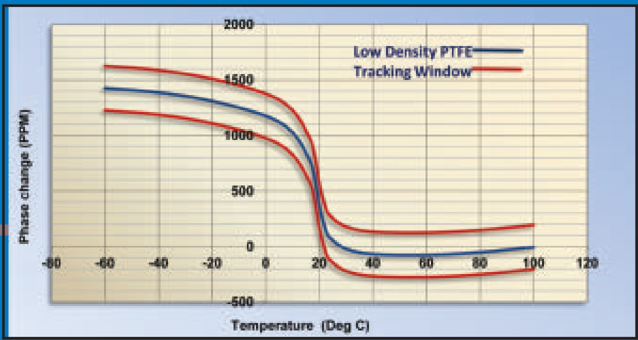
Not anymore!

TF4™ - our proprietary, ultra stable dielectric material significantly improves Phased Array Radar system performance by reducing the phase change of the interconnecting coaxial cables.

Typical PhaseTrack TF4™ Performance



Typical Low Density PTFE Performance



- Available NOW in various flexible coaxial cable and semi rigid coaxial cable assembly sizes
- Perfect for all Ground, Naval, Airborne or Spaceflight Phased Array Radar applications
- Frequency ranges to 40 GHz
- Wide range of connector types available
- Best Phase Tracking and Absolute Phase Change performance available

TIMES MICROWAVE SYSTEMS
An Amphenol Company

World Headquarters: 358 Hall Avenue, Wallingford, CT 06492 • Tel: 203-949-8400, 1-800-867-2629 Fax: 203-949-8423
International Sales: 4 School Brae, Dysart, Kirkcaldy, Fife, Scotland KY1 2XB UK • Tel: +44(0)1592655428
www.timesmicrowave.com

Fusion Processing of Surface Mount Components to Mitigate Tin Whiskers

With the implementation of the European RoHS directive, lead-free mandates have resulted in obsolescence of commercially available electronic components with tin-lead finishes. This raises the risk of system failures as related to tin whisker formation as a tin finish without lead can ultimately develop conductive tin whiskers that result in electrical shorts within circuitry.

Mission critical applications requiring tin-lead finishes need to establish other design approaches or consider mitigating RoHS components that are only available with pure tin finishes. The first option is not practical given that alternate component options are not commercially available with tin-lead finishes. This article will explore a tin whisker mitigation process applicable to both passive and active components that utilizes a thermo-chemical fusion process in order to prevent whisker formation.

BACKGROUND

Tin whiskers are single crystal filament growths that are known to achieve lengths of up to one inch. Tin whiskers grow unpredictably on pure tin surfaces and whiskers can cause catastrophic short circuits as they are conductive.

Pure tin, which contains less than 0.1 percent lead, is a high reliability risk because of its propensity to form tin whiskers. There is a consensus that at least 3 percent lead is needed to prevent tin whisker formation. To date there is no clear understanding of the mechanism of tin whisker growth although stresses, internally and externally, to the tin surface are believed to be contributing factors.

Globally, electronic components continue to move toward lead-free finishes and solder assembly with continued implementation of the European RoHS directive. Certain countries, such as the United States, have not mandated similar directives, but have no choice other than to follow suit given that their products are sold worldwide.

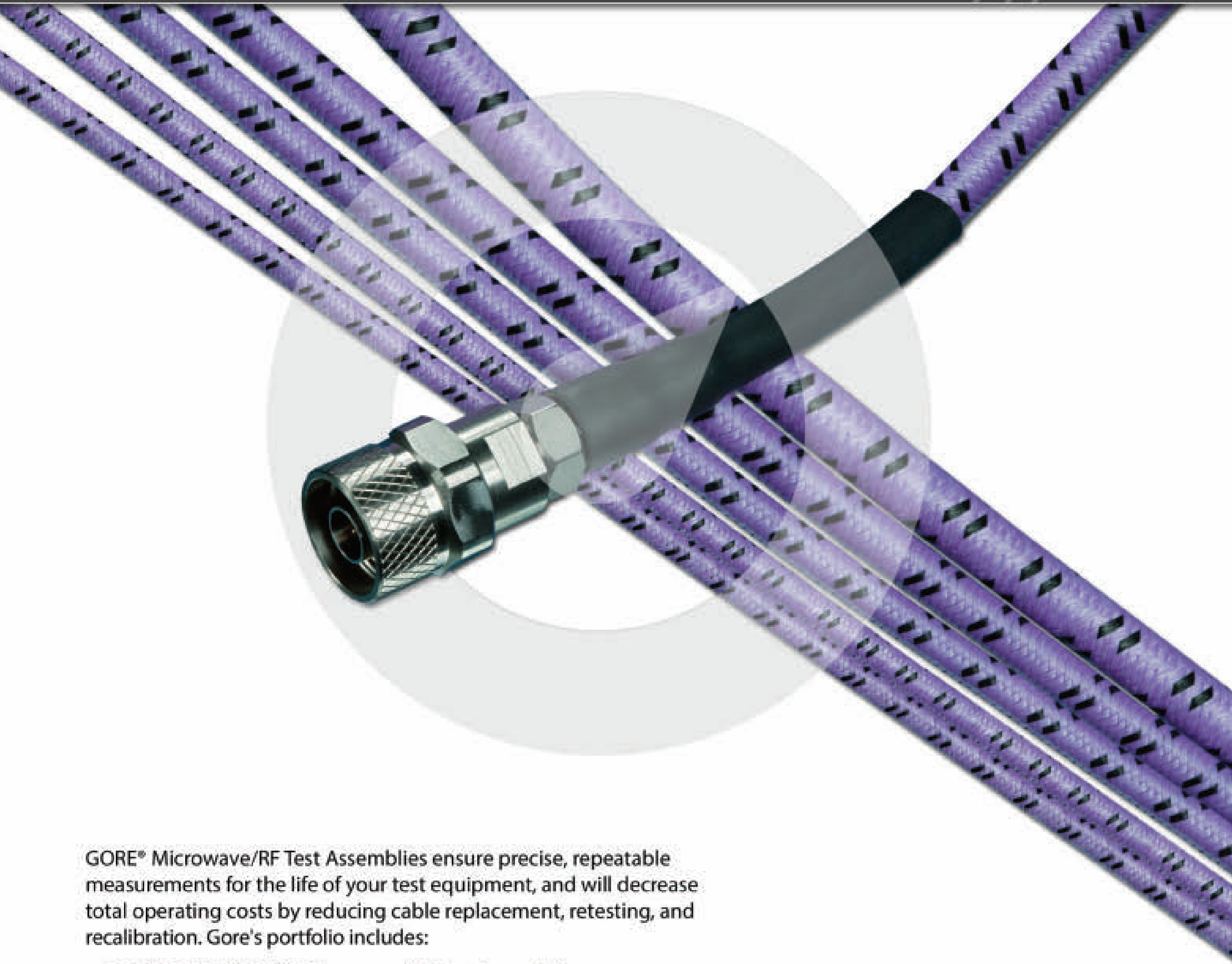
ISSUES WITH LEAD-FREE

Components need to withstand higher circuit board assembly temperatures. Lead-free solders typically require re-flow temperatures of 40°C and above that of tin-lead alloys. In-

Scott Sentz
AEM Inc., San Diego, CA

Performance Over Time

GORE® Microwave/RF Test Assemblies offer unmatched precision, repeatability and durability.



GORE® Microwave/RF Test Assemblies ensure precise, repeatable measurements for the life of your test equipment, and will decrease total operating costs by reducing cable replacement, retesting, and recalibration. Gore's portfolio includes:

- **GORE® PHASEFLEX® Microwave/RF Test Assemblies –** Provide excellent phase and amplitude stability with flexure.
- **18 GHz High Throughput Production Test Assemblies –** Optimize system performance while reducing cost of test and ownership.
- **110 GHz Test Assemblies –** Engineered to be flexed, formed and repositioned while maintaining excellent electrical performance.
- **VNA Microwave Test Assemblies –** Provide exceptional performance for precision test applications with frequencies through 67 GHz.
- **General Purpose Test Assemblies –** Excellent electrical performance for everyday test applications.

GORE

Creative Technologies Worldwide

gore.com/test

Choose GORE® Microwave/RF Test Assemblies.
For the life of your test equipment.

GORE, PHASEFLEX, the purple cable and designs are trademarks of W. L. Gore & Associates.

stead of 220°C for tin-lead, lead-free solders are typically recommended to re-flow at 260°C. Aside from equipment conversion costs, components and circuit boards have to be manufactured to withstand typical lead-free soldering temperatures of 40°C higher than tin-lead.

Two separate but related issues stand out with lead-free:

1. Lead-free solders
2. Lead-free plating

Wetting properties of no-lead solders are not as good as tin-lead.[1] Actually, the same reference also cited tin-lead as more stable than other tin based no-lead alloys as measured by their electrode reduction potential. Wetting difficulties could lead to voids in the solder joint.

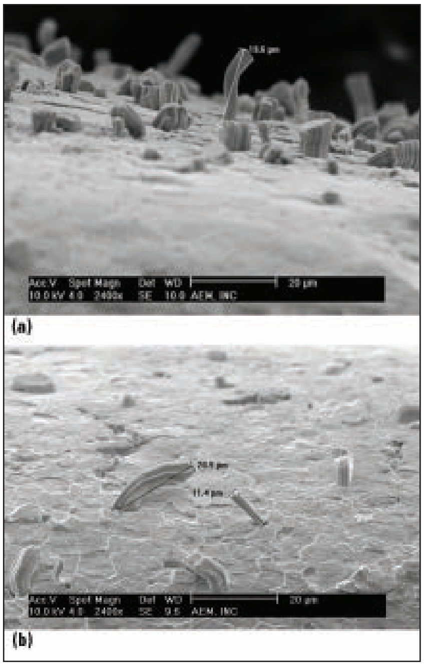
Leaded components can be solder dipped, but chip size components (01005 and larger) must use plating techniques to yield solderable surfaces. For inexpensive passive chip components, palladium-nickel, the only other commonly used plating for components besides tin-lead and pure-tin, would raise the price beyond being competitive. What is left is only pure-tin if lead were to be eliminated.

The most critical lead-free issue has to be the propensity of pure-tin plated components to develop whiskers. As of yet there is no pure-tin plating that can claim to be whisker-free even those claiming to offer stress relief through a "matte" finish. Whiskers appear at unpredictable times and neither the onset conditions nor the growth habits are well understood. Furthermore, there is no accepted tin whisker growth acceleration method. From the body of knowledge on this subject, pure-tin plating will form whiskers under certain sets of unpredictable conditions.

TIN WHISKERS

For tin whisker formation, a current theory is that diffusion related to intermetallic formation may cause stresses in the tin layer that are relieved with whisker growth; additionally, stresses related to the component's environment (i.e. thermal, mechanical, electrical, atmospheric) may contribute as well. Stresses can also come from the plating conditions, from the substrates, or from external scratches/bends on the pure-tin surface. Organic brightener additives that give shine but add stress to tin plating are theorized to contribute to whisker growth while a "matte" tin finish without the additives is less prone to grow whiskers.

It is further theorized that copper substrates are more prone to form whiskers than other metals because of the formation of tin-copper intermetallics where the volume increase contributes to stress on the tin-layer. Additionally, tin-nickel intermetallics are also well known and tin whiskers can grow with either precious metal ceramic chip capacitors (silver electrodes, silver termination and nickel barrier below the tin) or base metal (nickel electrodes, copper termination and nickel barrier below the tin) versions of the same OEM device. Both versions of this pure-tin ceramic chip capacitor grew measurable whiskers after 88 temperature cycles from -55° to +85°C. See ***Figure 1*** which shows tin whisker formation.



▲ *Fig. 1 Tin whiskers on a multilayer ceramic capacitor - precious metal construction (a) and base metal construction (b).*

WAYS TO AVOID TIN WHISKERS

Until there is an accepted accelerated test for tin whiskers, pure-tin finishes will be prohibited in mission critical programs where failure is not an option. Prohibition of pure-tin usually takes one of two forms: blanket prohibition for a program and prohibition by program risk. The latter is an attempt to quantify the risk in terms of program life and difficulty of equipment replacement to justify the costs of enforcing blanket prohibition of pure tin. Risk assessment is weighing the necessity of whether the risk of tin whiskers is worth the efforts and expense of guarding against pure tin from "sneaking" into electronic components and assemblies.

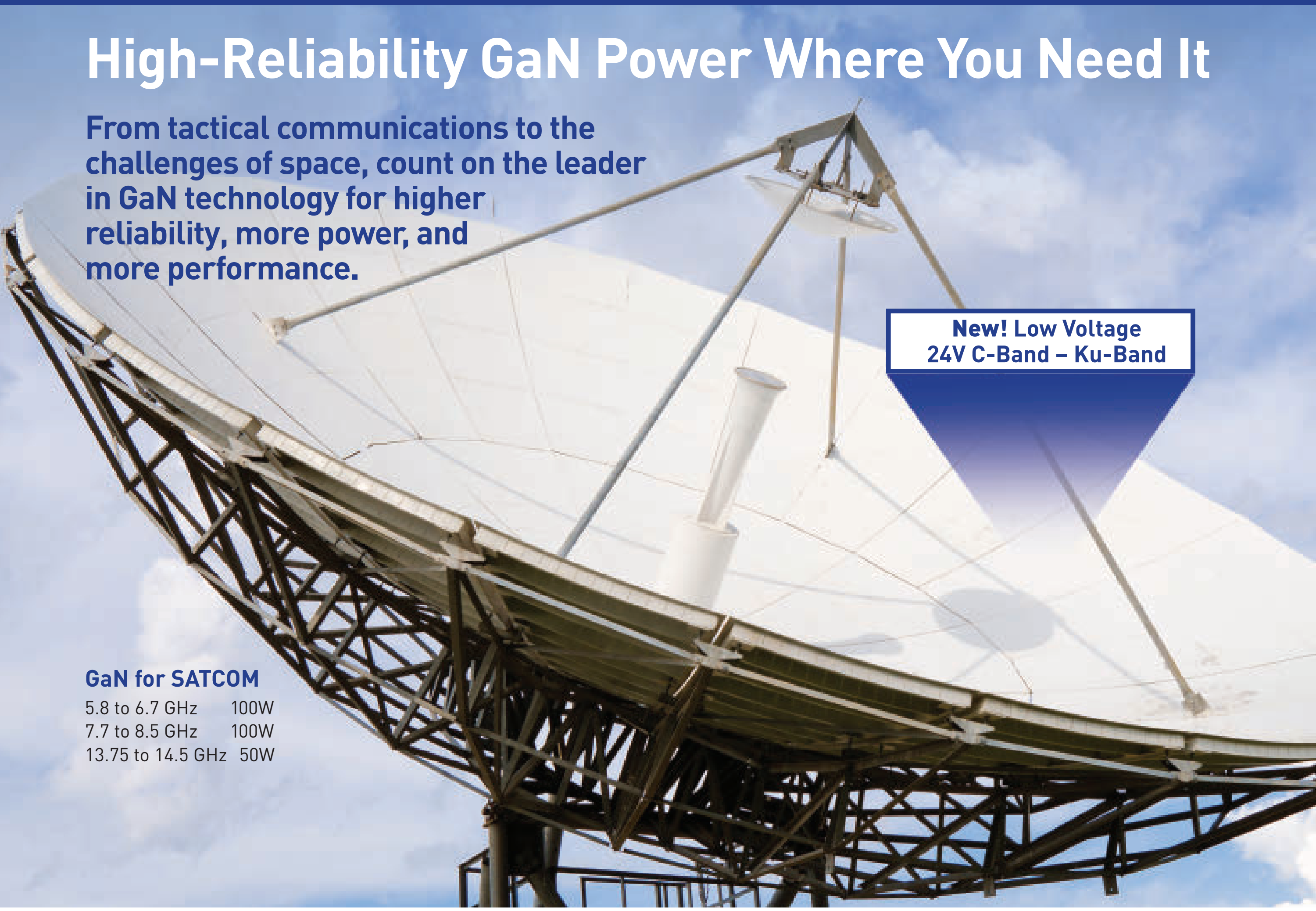
Enforcement of pure-tin prohibition across an entire program could take one or more steps from the following sequence:

- Procurement/subcontract vendor notices
- Incoming materials inspection
- Mitigation of materials available only in tin plate

Pure-tin prohibition is usually enforced on the vendor side through notices first in quote or bid activities and later in requirements within purchase orders. Vendors and their distributors are then required to provide certification that the product shipped does not contain exposed pure-tin. This requirement is more easily met at the factory level than at the distributor level since there are clearer identifications of product and product coding at the factory level. Risks increase with increased product handling, especially with components that are not clearly marked with catalog number and lot date codes. With unmarked chip size components this could be a problem even at the factory level, especially since a single factory is likely to produce both versions. With the likelihood that components get re-reeled, the mix-up between pure-tin and tin-lead components at the distributor level is understandably tenuous.

Incoming materials inspection to guard against accidental receipt of pure-tin products is usually the next level of assurance. Incoming materials inspection is practiced in high reliability industries such as space and medical. The added tool to protect against pure-tin is the X-ray fluorescence (XRF) at the receiving dock. Handheld XRF machines are available and are calibrated to detect lead in components, enabling easier analysis on a lot sampling basis. Alternatively, samples from the incoming lot could be sent to analysis labora-

Radar, Wireless Communications, SATCOM, and Space



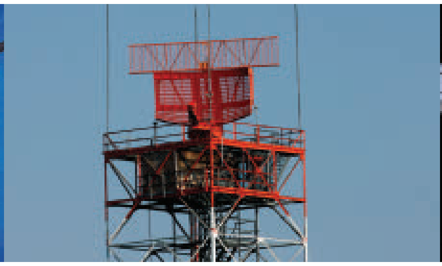
High-Reliability GaN Power Where You Need It

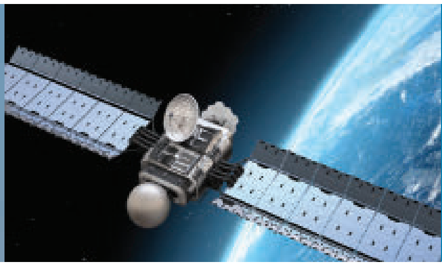
From tactical communications to the challenges of space, count on the leader in GaN technology for higher reliability, more power, and more performance.

New! Low Voltage 24V C-Band – Ku-Band

GaN for SATCOM

5.8 to 6.7 GHz 100W
7.7 to 8.5 GHz 100W
13.75 to 14.5 GHz 50W

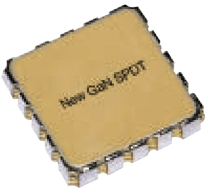




GaN for Mobile

UHF to 3.5 GHz
10/30/45/70/100W

SPDT Switch
VHF to 6.0 GHz 15W
VHF to 3.5 GHz 30W
VHF to 2.5 GHz 60W



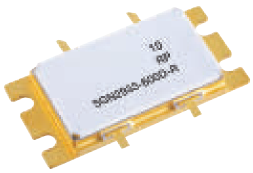
To learn more, contact usacomm@sei-device.com

GaN for Radar

S-Band
2.9 to 3.3 GHz 600W Discrete & Pallet
3.1 to 3.5 GHz 600W Discrete & Pallet

C-Band
5.2 to 5.4 GHz
120W Discrete

X-Band
9.2 to 10 GHz
120W Discrete



To learn more, contact usaradar@sei-device.com

GaN for Space

UHF to 2.5 GHz
4/8/20/50/100W

To learn more, contact usaspace@sei-device.com

www.sei-device.com

SUMITOMO ELECTRIC
Ingenious Dynamics

tories for Energy Dispersion, X-ray Spectroscopy (EDXS) using the same principle as XRF. Mostly, inspectors look for a minimum three percent lead content, the level commonly found in formerly ubiquitous tin-lead "solder plate."

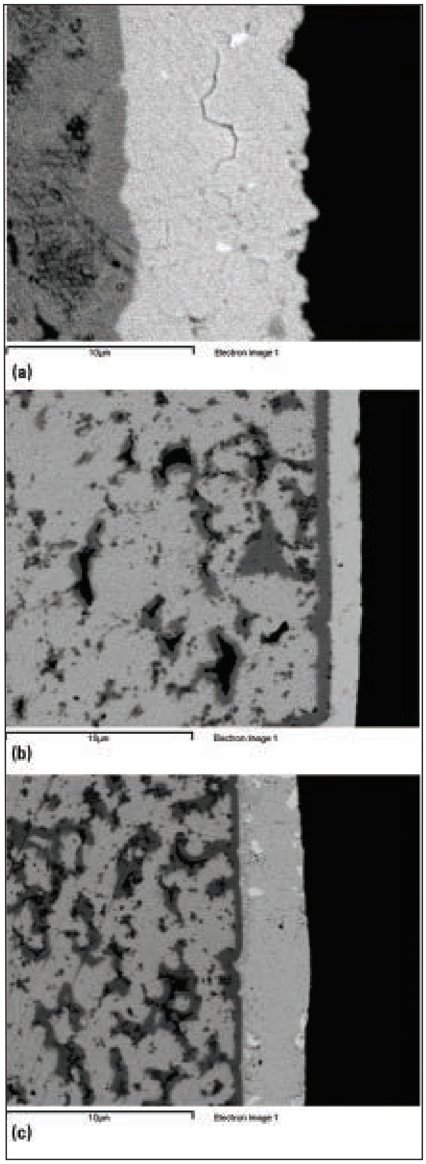
Blanket prohibition of pure-tin plate is currently practiced where the offered electronic equipment is to be "fail safe." This includes industries in the satellite, space exploration, medical devices, missiles and other high-technology weapons or where life and limb are at risk. However, blanket prohibition is possible only when other acceptable plating or mitigation methods are still available (or where re-designs are possible to use alternative components that are still available in tin-lead).

Tin whisker mitigation of electronic components can be divided into two main categories, leaded and un-leaded surface mount technology (SMT) devices.

- Leaded active or passive devices:
  Pure-tin leaded devices can be dipped in standard tin-lead solder. Preheating can prevent thermal shock which can lead to cracking and de-lamination. Robotic handling improves precise dipping angle and travel. However, it is very difficult to dip inside the meniscus at the lead egress points of leaded devices, which increases the chance of potential tin whisker growth in these areas. Additionally, dipping of chip components introduces the risk of thermal shock and terminal coverage variation.
- SMT chip size active or passive devices:
  Pure-tin plated chip-size devices are too small and not practical to dip in tin-lead solder. To do so would risk the chance of thermal shock and present handling problems during dipping especially for small case sizes such as 01005 and 0201. The ideal mitigation would convert pure-tin into the previously universally used "solder plate" with at least three percent lead content.

FUSION PROCESSING

The concept behind the fusion process is to treat the pure-tin plated terminal to give it solder plate attributes of five percent lead content. This is achieved by adding lead to the pure-tin plating. Furthermore, the lead must be evenly distributed in the entire pure-tin plated area which is accomplished through a low temperature fusion process that melts the tin and tin-lead and homogenizes the two layers into a monolithic tin-lead layer.



▲ *Fig. 2 SEM photo of historic industry baseline solder plate, ~3% lead (a), pure-tin plate, (b) and fusion processed for tin whisker mitigation, 5%+ lead (c).*

Figure 2 shows scanning electron microscope (SEM) cross-sectional pictures of a typical terminal of a ceramic electronic chip component. Under back-scatter scans in the SEM, lead particles are white and tin is the lightest gray and outer-most layer to the right.

www.SignalAntenna.com

DC-20 GHz!
CUSTOM DESIGNS
HI POWER
HELIX

B'BAND ANTENNAS
LOG PERIODIC
OMNI
EMC TEST
MAN-WORN
OTH HF RADAR

SAS antennas at work protecting our forces:

Signal Antenna Systems, Inc.
8-B Hangar Way
Watsonville, CA 95076
Phone: (831) 722-9842
Email: info@signalantenna.com
Signal Antenna Systems, Inc.

HUBER+SUHNER
Excellence in Connectivity Solutions

Low loss cable family is extended

SUCOFLEX 404 – the insertion loss revolution
- Applicable up to 26.5 GHz
- Lowest loss on the market up to 26.5 GHz
- Best phase stability versus temperature

SUCOFLEX 406 – set new standards
- Applicable up to 18 GHz
- Minimal electrical losses
- High level of phase stability in a broad range of temperature

HUBER+SUHNER AG
9100 Herisau/Switzerland, hubersuhner.com

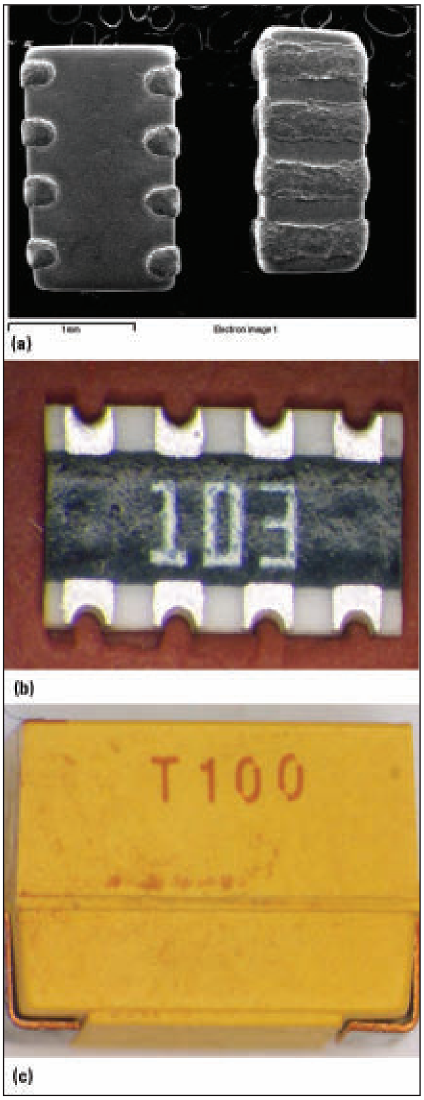
The dark gray area immediately adjacent to the left is the nickel barrier (see Figure 2a). This termination cross section is representative of the historic industry standard of approximately three percent lead, achieved by co-plating tin lead (typically 90-10) in methanesulfonic acid (MSA) solution. Again, this co-plating is known commonly as "solder plate." Figure 2b shows the cross-section of a typical pure-tin version of the same device produced by the same manufacturer; the light gray tin area has no lead, and no visible white particles. Figure 2c is the same pure-tin micrograph 2b chip component after fusion re-processing. Notice the distribution of lead (white particles) throughout the previously pure-tin layer; with minimum of five percent lead there is additional security from a tin whisker mitigation standpoint.

CAPABILITY OF FUSION PROCESSING FOR TIN WHISKER MITIGATION

Fusion processing for tin whisker mitigation (TWM) can be effective with the following:

1. All passive monolithic chip components where:
   - Tin plating is part of the termination process
   - Component is intended for solder assembly
2. Some passive SMT components where:
   - Pre-tinned leads are molded
   - Component is intended for solder assembly
3. Some active discrete SMT chip size, components

TWM utilizing fusion processing may not be as effective where compo-



▲ *Fig. 3 Components processed with fusion TWM process; chip capacitor array (a, b) and tantalum chip capacitor (c).*

The 4th Applied Electromagnetics Conference, an initiative of IEEE AP-MTT Joint Chapter, Kolkata section, shall be held during **18 – 20 December 2013** at & in association with the KIIT University, Bhubaneswar. With more than 100,000 temples, Bhubaneswar is known as *City of Temples* and is a junction of Hindu, Buddhist and Jain archeological monuments. The Khandagiri & Udayagiri are rich with partly natural and partly artificial caves of archaeological, historical and religious importance most of which were carved out as residential blocks for Jain monks. A dumb witness of the Kaling War, the Dhauligiri has many rock edicts besides a dazzling white peace pagoda on the hill top built by the *Japan Buddha Sangha* and the *Kalinga Nippon Buddha Sangha* in the 1970s.

The panel of distinguished speakers includes, among others Prof. Raj Mitra, *Penn University, USA;* Prof. Lotfollah Shafai, *University of Manitoba, Canada;* Prof. Mats Gustafsson, *Lund University, Sweden;* Prof. Yahia M. M. Antar, *Royal Military College, Canada.*

As in its previous editions, the AEMC in 2013 aims at providing an opportunity for presentation, discussion and promotion of research on contemporary topics in applied electromagnetics. The AEMC 2013 will focus on new ideas and the latest developments for both academia and industry throughout the international community.

Students are encouraged to participate in Student Paper Contest and Student Project Contest. Free tutorials and short courses are being planned for all interested participants.

Papers are invited in the following 18 tracks: Antennas for Defence and Space Applications (ADS), Antenna Theory and Techniques (ATT), Bioelectromagnetics (BEM), CAD Algorithms and Techniques (CAD), Computational Electromagnetics (CEM), Dielectric Resonator Antennas (DRA), Electromagnetic Compatibility (EMC), EM Education (EME), Electromagnetic Materials (EMM), Electronic Packaging and Interconnects (EPI), Materials for Antenna Technology (MAT), Microwave Devices and Circuits (MDC), Microstrip and Printed Antennas (MPA), Mobile and Wireless Antennas (MWA), Radar and Satellite Technology (RST), Tera Hertz Technology (THT), Transformation Electromagnetism (TREM), Wave Propagation and Remote Sensing (WPR).

For more information please visit: http://www.ieee-aemc.org


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

FeaturedWhitePapers

The information you need, from the technology leaders you trust.

Anritsu

VNA's High-Speed Architecture Advances Radar Pulse Measurement Timing Resolution and Accuracy

AR's Complete Product Catalog for EMC, Wireless and RF Testing

bonding source

Laser Cutting Epoxy Film

RichardsonRFPD An Arrow Company

Normalized Phase Noise in Devices Powered by the UltraCMOS® Devices

By: Peregrine Semiconductor

TEGAM

A New Coaxial Flow Calorimeter for Accurate RF Power Measurements up to 100 Watts and 1 GHz

Check out these new online Technical Papers featured on the home page of Microwave Journal at mwjournal.com.

Microwave Journal

Frequency Matters.

nents have open sub-assemblies (i.e., wire-wound chip inductors, devices with radial leads, or tightly formed reverse J-leads). If there is any doubt, pre-evaluation testing is performed. For products where no source of tin-lead plated terminations are available, solder dipping appears to be the best short term solution for leaded components.

Figure 3 shows examples of passive components that have been processed using the fusion TWM process. The resistor and capacitor chip arrays were fusion processed with all 24 surfaces passing XRF and EDXS screening for five percent minimum lead content. The tantalum chip capacitor fusion process resulted in the inside and outside surfaces of the formed leads passing XRF and EDXS screening for five percent minimum lead content as well.

A current (but not limited) listing of compatible component types for the fusion TWM process is:

- Surface mount chip capacitors (01005 to 2220 package size or larger)
- Surface mount chip resistors (0402 to 2220 package size or larger)
- Surface mount chip inductors (0402 to 1812 package size or larger)
- Surface mount chip beads (0402 to 1812 package size or larger)
- Surface mount fuses (0402 to 1812 package size or larger)
- Surface mount varistors (0603 to 1812 package size or larger)
- Resistor arrays/capacitor arrays/chip bead arrays
- Molded body diodes (SMA, SMB, SMC, SMD packages with reverse J-leads and molded body MOSFETs)
- DPAK packages
- SOT-23 and SOT-223 packages
- DO-214AB package
- QFN packages
- Tantalum capacitors (all standard sizes)
- Lug connectors
- EMIFL packages and most chip and molded body filters.

CONCLUSION

Tin whisker growth is a high reliability risk when pure-tin is present anywhere in the electronics assembly. The fact is that when there is pure tin, whiskers may appear. The onset is unpredictable, but inevitable. As of right now there is no definitive theory of tin whisker genesis, nor is there an accepted accelerated whisker test method to validate these claims. There are a lot of activities in industry, government and academia to develop and qualify an accelerated whisker test methodology as well as understand tin whisker growth and prevention. CALCE and NASA (especially Goddard Space Center) are active in this endeavor, as is the industry group iNEMI. ■

References

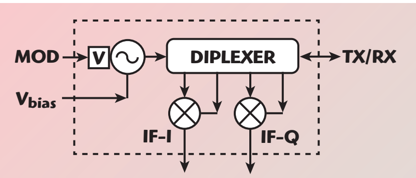
1. Samsung Electronics, Evaluated Technical Data: "The Comparison of Reduction Potential on Materials."
2. CALCE Tin Whisker Site, www.calce.umd.edu/tin-whiskers/
3. NASA Tin Whisker Site, http://nepp.nasa.gov/WHISKER/

Coaxial Connectors
DC-71 GHz
and Adapters
DC-71 GHz
Multiport
Assemblies
DC to 40 GHz
Spectrum
Elektrotechnik GmbH
where quality is needed
TAKE OFF WITH OUR PRODUCTS
20 pages Capability Brochure
is available now and free of charge
Adapters
DC to 65 GHz
Coaxial
Delay Lines
DC to 40 GHz
Cable Assemblies
DC to 71 GHz
Waveguide to
Coax Adapters
Phase-Adjusters
DC to 63 GHz
Gain Amplitude
Equalizers
Telephone: +49-89-3548-040
Fax: +49-89-3548-0490
Email: Sales@Spectrum-et.com
www.spectrum-et.com
Hornet-07E

K-Band FMCW Ranging Sensor Modules

Microwave sensor modules are key components in any radar system. Today, the industry is continuously seeking low cost and high performance sensors for target speed, direction and ranging (distance) measurement for both commercial and military applications. Some of the applications include collision avoidance detection, liquid level sensing, traffic control, missile guidance and object profiling.

SAGE Millimeter has introduced a K-Band low cost FMCW sensor module with model number SSP-24303-D1 for speed, direction and ranging measurement. The FMCW based sensor is a true ranging sensor, meaning it can detect both still and moving target distance. The operation frequency of the featured sensor is at 24.125 GHz. The sensor is based on traditional TE10 waveguide cavity mode and packaged Gunn/varactor device technology, which offers low phase noise, high frequency stability and high sensitivity. Compared to its MMIC device/planar circuit based counterpart, model SSP-24303-D1 delivers lower harmonic and spurious emission and improved false signal detection due to the instinct waveguide cut-off nature. The entire sensor module is configured within a single die-cased aluminum housing, which allows low cost production.



▲ *Fig. 1 FMCW sensor module block diagram.*

Figure 1 is the function block diagram of the featured FMCW sensor module. From the function block diagram, one can see that three main function components are indicated: 1) Varactor tuned oscillator (VTO), 2) I/Q dual channel mixer and 3) diplexer. Due to its flexible design, the FMCW sensor module can be easily transformed into various function modules without redesigning, new circuits or additional tooling implementations. For example, if the VTO is replaced by a fixed tuned oscillator by extracting the varactor diode from the oscillator circuit, the module is transformed into a Doppler speed sensor with directional detector capacity. Furthermore, the sensor can be downgraded to a single channel Doppler sensor by extracting one Schottky diode from its I or Q channel to form speed detection only modules for simple speed measurement applications.

Table 1 shows the main electrical and mechanical specifications of the featured sensor

SAGE Millimeter Inc.
Torrance, CA

RF & Microwave Switching Solutions

- DC to 40 GHz
- Up to 5 Million Cycles
- High Power Capability
- Signal Integrity up to 25Gbps
- Excellent Insertion Loss Repeatability
- Ultra Low Passive InterModulation (PIM)
- SPDT, SP3T to SP10T, Transfer Switches, RF Switch Matrices

Reliability - Repeatability - Lifetime

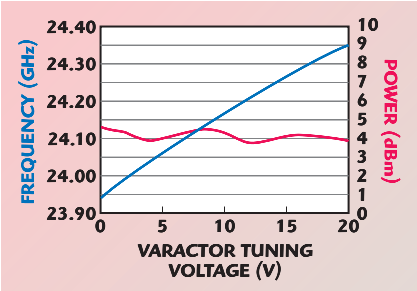
+44 1236 453 124
www.teledyne-europe.com
sales_europe@teledyne.com

TELEDYNE RELAYS Everywhereyoulook™

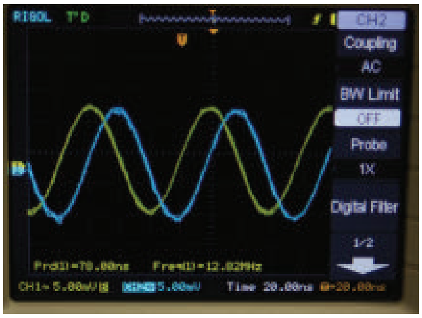
TELEDYNE COAX SWITCHES Everywhereyoulook™

TABLE I SPECIFICATIONS OF SSP-24303-D1 MODULE	
TX Frequency (GHz)	24.125
TX Power (dBm, Min)	+3.0
Frequency Modulation Bandwidth (MHz, Min)	±150
Frequency Modulation Rate (kHz, Typ)	250
Frequency Modulation Voltage (Volts, Typ)	0 to +20
Mechanical Tuning Bandwidth (MHz, Min)	±250
Receiver I/Q Phase Δ (Degree, Max)	90°±30°
Receiver I/Q Amplitude Δ (dB, Max)	0 dB ±3 dB
IF Frequency Range (MHz, Min)	DC to 100
IF Offset Voltage (Volts, Typ)	-0.5 to -1.0
Frequency Stability (MHz/°C, Max)	-0.80
Phase Noise (dBc/Hz @ 100 kHz Offset, Typ)	-95
Power Stability (dB/°C, Max)	-0.03
Oscillator Bias Voltage/Current (VDC/mA, Typ)	+5.0/250
RF Connector	WR-42 Waveguide, UG595/U Flange
Oscillator Bias Connector	Solder Pin
Frequency Modulation Connector	Solder Pin
IF Connectors	Solder Pins
Dimension/Weight (Typ)	0.8" W × 0.8" H × 1.0" D / 1.2 oz

module. The typical output power and frequency versus tuning voltage is shown in ***Figure 2***. From the tuning curve, very flat power output and near linear tuning characteristics are observed. The flat power output level and high linear tuning performance are highly desirable features for system integrators to configure and develop their system hardware and software algorithms. The featured sensor module is also equipped with a mechanical self-locking tuning structure for easy frequency setting/trimming and simple frequency mechanical adjustment. ***Figure 3*** shows the I/Q channel output, which displays well-balanced and near 90 degree phase difference between the two signals.



▲ *Fig. 2 K-Band FMCW ranging sensor tuning characteristic.*



▲ *Fig. 3 Sensor module I/Q channel output.*

The RF interface of the sensor module is a standard WR-42 waveguide, which allows quick interface with various antenna structures. SAGE Millimeter offers a variety of antennas to interface with the featured sensor module directly. These standard antennas include microstrip antennas (5° × 7°, 5° × 15°, and 12° × 12° half power beamwidth) and lens corrected antenna (12° × 12° half power beamwidth) models. All antennas have at least 20 dB sidelobe rejections to allow for proper applications. Custom designed antennas are also available on request.

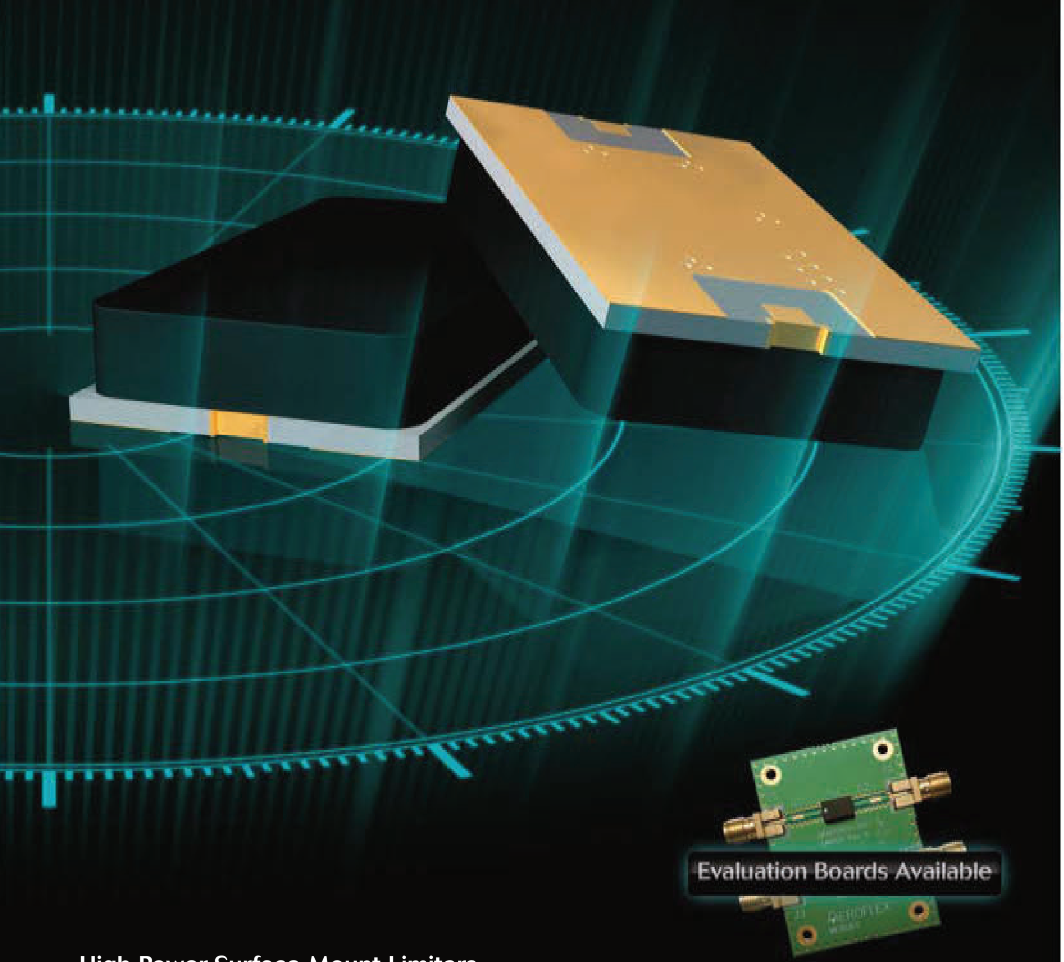
As mentioned previously, many sensor modules can be transformed from the featured module's existing design and housing hardware. SAGE Millimeter offers many model numbers to cover sensor modules with various function capacities, such as single channel FMCW ranging sensor, single and dual channel Doppler sensors, and sensor heads with various integrated antenna options.

VENDOR**VIEW**

SAGE Millimeter Inc.,
Torrance, CA
(424) 757-0168,
info@sagemillimeter.com,
www.sagemillimeter.com.

Protecting your radar system just got a whole lot easier

AEROFLEX
METELICS



New high power surface mount limiters from Aeroflex / Metelics are making your receiver/ protector sections a whole lot easier to design. These drop-in devices include 11 completely integrated components that have been optimized for S and C band radar systems. In comparison to silicon and GaAs MMICs, which lack thermal capacity and thermal conductivity, these devices offer stable peak power handling through 8 GHz.

- **Frequency bands from 20 to 8000 MHz**
- **100 W C.W. and 1 KW Peak Power Handling**
- **Flat Leakage Power of 20 dBm**
- **8 x 5 x 2.5 mm SMT Packaging**

We've put our semiconductor experience to work in developing a variety of broadband and octave band models. Call or visit our website for details.

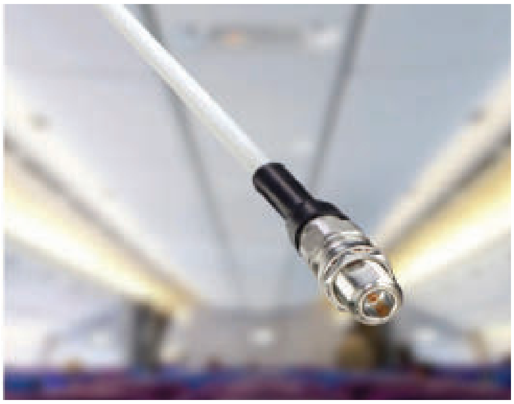
603-641-3800

www.aeroflex.com/metelics

High Power Surface Mount Limiters

Part Number	Type	Frequency (MHz)	Loss (dB)	C.W. Power (W)
LM200802-M-A-300	Medium Power Broadband	20-8000	1.4	20
LM501202-L-C-300	Octave Band, Low Power	500-2000	0.4	5
LM501202-M-C-300	Octave Band, Medium Power	500-2000	0.4	30
LM202602-H-A-300 LM202602-H-C-300	High Power	2000-6000	0.85	4
LM202802-L-C-300	Octave Band, Low Power	2000-8000	1.0	5
LM202802-M-C-300	Octave Band, Medium Power	2000-8000	1.2	30
LM401102-Q-B-301 LM401102-Q-C-301	Octave Band, High Power "Quasi-Active"	400-1000	0.3	125
LM102202-H-C-301 LM102202-Q-C-301	Octave Band, High Power "Quasi-Active"	1000-2000	0.35	125
LM202402-Q-C-301	Octave Band, High Power "Quasi-Active"	2000-4000	0.5	100
LM202402-Q-E-301	Octave Band, High Power "Quasi-Active"	2000-4000	0.5	125
LM202402-Q-F-301	Octave Band, High Power "Quasi-Active"	2000-4000	0.5	100
LM202802-Q-C-301	Octave Band, High Power "Quasi-Active"	2000-8000	1.1	125
LM2933-Q-B-301	High Power, Passive Two-stage Power Limiter	2900-3300	0.6	100

AEROFLEX
A passion for performance.



Leaky Feeder Antennas for Airborne Wi-Fi

Today's airline passengers expect to have easy access to internet servers, email and in-flight entertainment while airborne. GORE™ Leaky Feeder Antennas improve signal propagation while potentially reducing the amount of hardware required on the plane. These antennas provide reliable connectivity to different wireless systems, including picocells for mobile phone coverage and access points for airborne Wi-Fi. Ideal for both wide-body and single-aisle passenger aircraft, these antennas significantly reduce dead spots, enabling passengers to connect to wireless networks throughout the cabin. Typical applications for the leaky feeder antennas include Wi-Fi 801.11 a/b/g/n/ac and WiMAX as well as connectivity to Bluetooth, GSM and MMS.

With a single antenna installed along the length of the cabin, passengers can access wireless networks from their laptops, tablets, mobile phones and in-flight entertainment systems regardless of their location in the cabin. These antennas dramatically reduce dead spots because of the proprietary technology that maintains excellent antenna gain and coupling loss over a broad range of frequencies and antenna lengths (see ***Figures 1*** to ***6***) as measured according to IEC 61196-4, Free Space Method. GORE Leaky Feeder Antennas provide consistent connectivity across a broad frequency range — from 400 MHz up to 6 GHz — making the antennas compatible with numerous communication standards (see ***Table 1***).

INTEGRATED HARDWARE RUNS MULTIPLE PROTOCOLS

Wireless technology used in aircraft generally requires separate antennas for each wireless protocol. However, the leaky feeder antennas enable integrated hardware to run multiple proto-

W. L. Gore & Associates
Landenberg, PA

The Exelis microwave systems business has been designing and manufacturing high performance direct, digital-based (DDS) synthesizers and radio frequency (RF) waveform generators for more than twenty years. If your radar, identification of friend or foe (IFF), electronic warfare (EW) or signals intelligence systems (SIGINT) requires fast switching and clean signals, trust the expertise of Exelis for the most sophisticated solutions today. Our expertise is in low spurious, wideband solutions from DC to 26 GHz.

www.exelisinc.com/microwavesystems

Exelis is a registered trademark and "The Power of Ingenuity" is a trademark, both of Exelis Inc.
Copyright © 2013 Exelis Inc. All rights reserved.

cols through a single antenna, reducing the quantity of access points necessary to ensure signal coverage. This reduces the cost for wireless access as well as reducing exposure to wireless radiation.

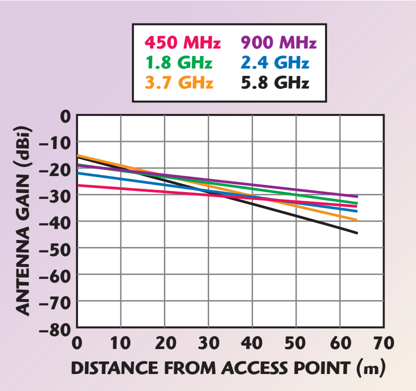
These lightweight antennas reduce equipment costs by offering a single solution that provides connectivity for a variety of electronic devices. Because of their durable construction, these leaky feeder antennas do not require any maintenance for the life of the aircraft, further reducing operating costs. They offer easy installation for new production as well as retrofit applications in both single-aisle and wide-body aircraft.

DURABLE, FLAME-RETARDANT CONSTRUCTION

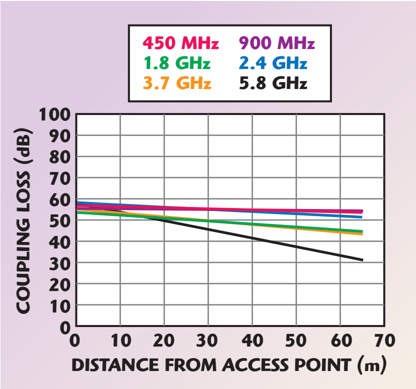
The engineered fluoropolymers used in the construction of GORE™ Leaky Feeder Antennas are inherently flame-retardant. They meet Airbus ABD0031 and FAR Part 25.1359(d) specifications for flame and smoke toxicity, ensuring reliable flame protection without the need for additional flame retardants. These materials are also resistant to abrasion and cut-through, reducing the potential for damage during installation.

GORE™ Leaky Feeder Antennas make possible new in-flight systems that allow aircraft passengers to use their own mobile phones and other electronic devices. They can make calls, send texts and access the internet just like they do when sitting in their offices: simply pick up the device and start using it.

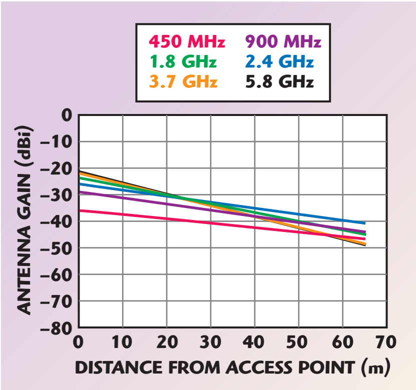
W. L. Gore & Associates Inc., Landenberg, PA, www.gore.com/electronics.



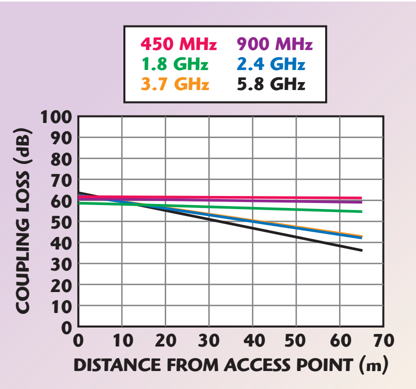
▲ *Fig. 1 Antenna Gain: GORE™ Leaky Feeder Antennas 355.*



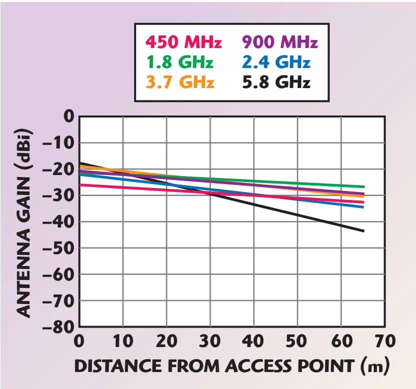
▲ *Fig. 2 Coupling Loss: GORE™ Leaky Feeder Antennas 355.*



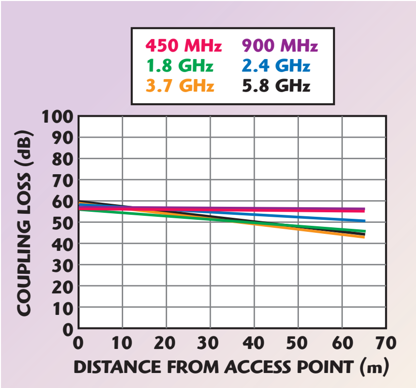
▲ *Fig. 3 Antenna Gain: GORE™ Leaky Feeder Antennas 280.*



▲ *Fig. 4 Coupling Loss: GORE™ Leaky Feeder Antennas 280.*



▲ *Fig. 5 Antenna Gain: GORE™ Leaky Feeder Antennas 500.*



▲ *Fig. 6 Coupling Loss: GORE™ Leaky Feeder Antennas 500.*

TABLE I

PRODUCT SPECIFICATIONS

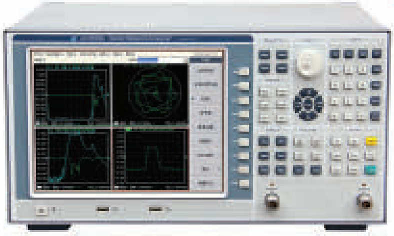
	Properties	LFA280	LFA355	LFA500
Electrical	Operating Voltage (V RMS)	300		
	Impedance (ohms)	50+5/-2		
	Frequency Range (MHz)	400 to 6000		
Mechanical	Nominal Cable Diameter (mm)	6.5	8.1	11.7
	Minimum Bend Radius (mm)	40	50	70
	Operating Temperature Range (°C)	-55 to 85		
	Maximum Weight (g/m)	72	85	153
	Flame and Smoke Toxicity	Airbus ABD0031 and FAR Part 25.1359(d)		

CETC 41

Expert of Measurement Instrument from China

Economic choice to improve throughput

AV3656A Vector Network Analyzer



Frequency Range: 100 kHz~3 GHz
System Dynamic Range: 125 dB, IF bandwidth 10 Hz
Effective Directivity: ≥46dB
Port Impedance: 50 Ω, 75 Ω (optional)
Interface: USB, GPIB, LAN, VGA, standard parallel port
10.4 inch true color LED touch screen

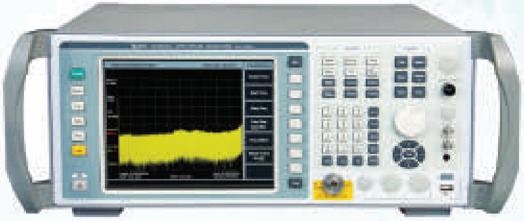
Perfect balance between high frequency and purity

AV1464B Synthesized Signal Generator

Frequency Range: 250 kHz ~ 40 GHz
Frequency Resolution: 0.001 Hz
Power Range: -110 dBm ~+8 dBm
SSB Phase Noise:-110 dBc/Hz@10 kHz (Carrier 10 GHz)
Support frequency modulation, amplitude modulation, phase modulation and pulse modulation
Support 110 GHz frequency multiplying source module spread spectrum

No signal is invisible

AV4036G Spectrum Analyzer



Frequency Range: 3 Hz~50 GHz
Resolution Bandwidth: 1 Hz~8 MHz
Sideband Noise (Carrier 1 GHz): -114 dBc/Hz@10 kHz
Frequency Counter Resolution: 0.001 Hz
DANL: -152 dBm, typical
1 dB Compression Point: +3 dBm, typical
TOI: +16 dBm, typical
All digital IF design

Please visit www.ei41.com for more information

The 41st Institute of China Electronics Technology Group Corporation

Address: No. 98, Xiangjiang Rd, Economy & Technology Development Zone, Qingdao, China
Tel: +86-532-86896691
Fax: +86-532-86889056
Post Code: 266555
E-mail: eiqd@ei41.com

An ISO 9001 Certified Company

Femto Size Coupler Line

In order to more accommodate both data-hungry, well-served subscriber markets like Europe and North America, and emerging markets like India, Brazil, and China where basic, lower-cost cellular plans and wireless internet access are the current objective, participants at all levels of the wireless infrastructure segment continue to evolve. One sign of this process is the increased appearance of lower-power, small cell base stations that are designed to be cost effective and easy to deploy and maintain. Another indication is the need for lower cost, higher performing passive components – in ever-smaller package sizes – at the sub assembly level.

As a case in point, Anaren Microwave has introduced a new family of Xinger®-III brand, Femto-sized hybrid and directional couplers offering noteworthy advances in both electrical and physical characteristics. The line includes five hybrid coupler part numbers and two directional couplers covering 700 to 3800 MHz with performance tuned for UMTS, AMPS, GSM, WCDMA, LTE and WiMAX applications.

FOOTPRINT FRIENDLY

As RF amplifier designers know, standard coupler footprints for all bands and coupling values make both board design and board population/production stages easier and more efficient. This is especially true given the current emphasis on using one standard board layout across multiple applications or systems. It can also be a benefit later in a board layout's life cycle, should any of the components surrounding the coupler need to be swapped out or updated.

Measuring 0.200 × 0.125 inches (5.08 × 3.18 mm) and reflecting the latest iteration of the company's well known multi-layering innovations, this new Femto-size coupler line is quite literally a fit for such size-minded manufacturers, offering an industry-standard, much reduced footprint without any sacrifice in performance compared to Anaren's larger, still available counterparts.

HYBRIDS

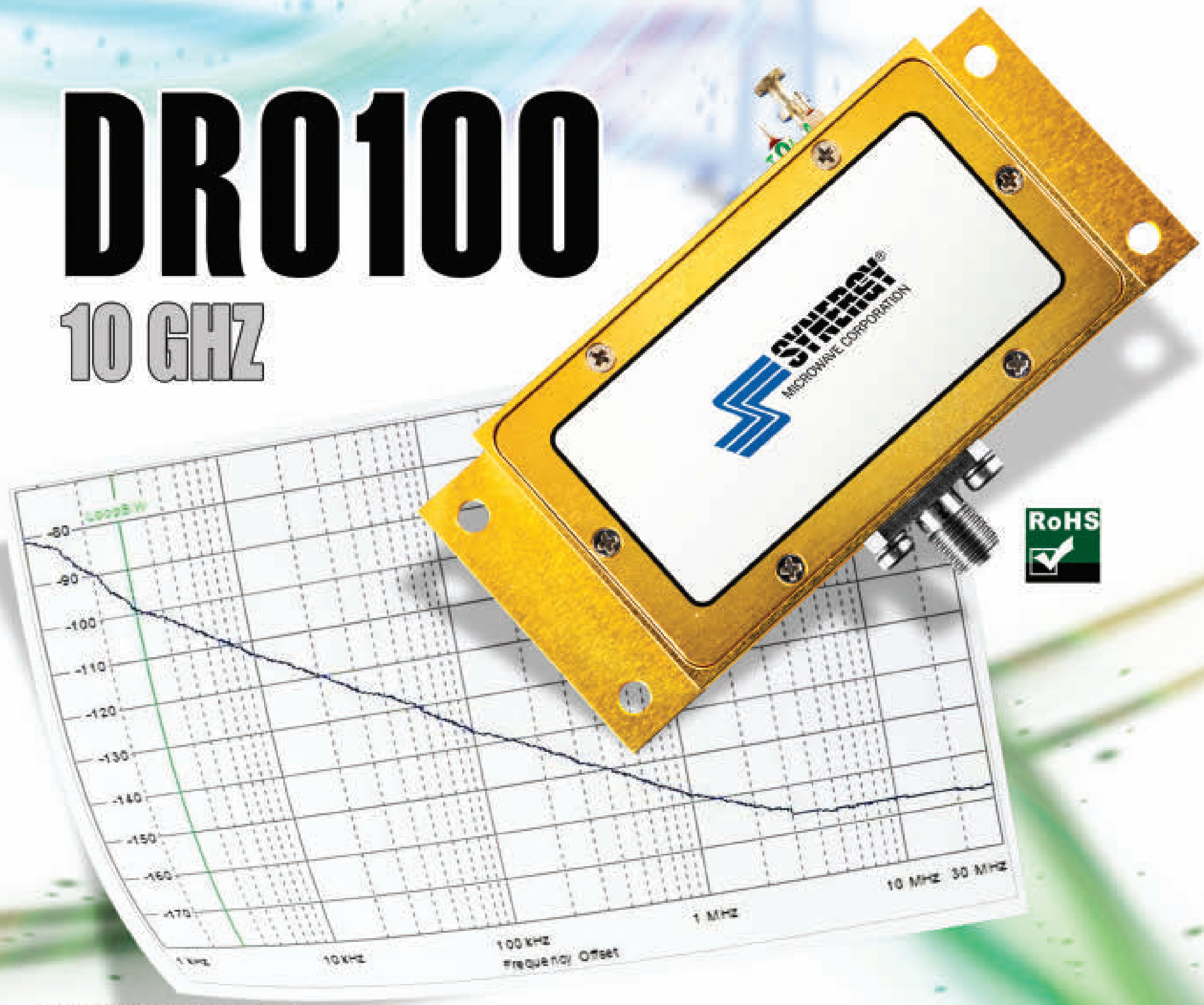
Even in this compact form factor, the new Xinger-III Femto hybrids offer a low insertion loss of less than 0.15 dB and tight amplitude balance and high isolation – which can be critical to OEMs seeking to squeeze every last bit

Anaren Microwave
Syracuse, NY

Optimized Tuning Frequency Band, Exceptional Phase Noise Performance Dielectric Resonator Oscillator

DRO100

10 GHZ



Patented Technology

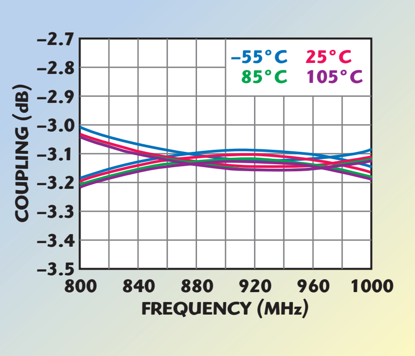
Call Factory For Your Specific Requirement

SYNERGY®
MICROWAVE CORPORATION

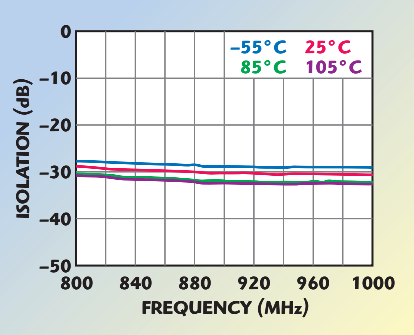
Phone: (973) 881-8800 | Fax: (973) 881-8361
E-mail: sales@synergymwave.com
Web: WWW.SYNERGYMWAVE.COM
Mail: 201 McLean Boulevard, Paterson, NJ 07504

TABLE I HYBRID COUPLER SPECIFICATIONS							
Part No.	**Dimensions in./(mm)**	**Frequency (MHz)**	**Power (W) (avg)**	**Insertion Loss (dB)* (max)**	**Amplitude Balance (max)***	**Return Loss (dB)* (min)**	**Operating Temp**
X3C07F1-03S	0.200" × 0.125" (5.08 × 3.18 mm)	600-900	25	0.15	±0.3	25	-55° to +105°C
X3C09F1-03S	0.200" × 0.125" (5.08 × 3.18 mm)	800-1000	25	0.15	±0.3	25	-55° to +105°C
X3C19F1-03S	0.200" × 0.125" (5.08 × 3.18 mm)	1700-2300	25	0.15	±0.3	25	-55° to +105°C
X3C25F1-03S	0.200" × 0.125" (5.08 × 3.18 mm)	2300-2700	25	0.15	±0.3	25	-55° to +105°C
X3C35F1-03S	0.200" × 0.125" (5.08 × 3.18 mm)	3300-3800	25	0.15	±0.3	25	-55° to +105°C

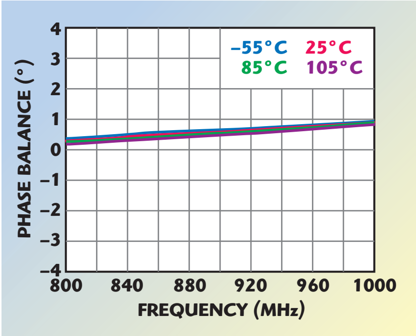
* Performance listed for narrow bands.



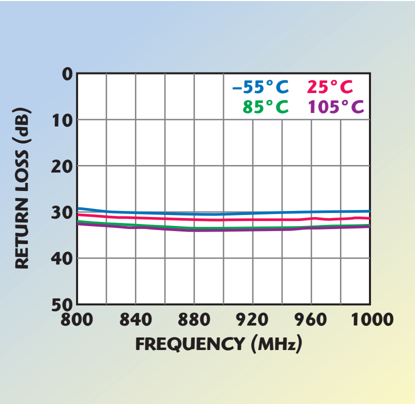
▲ *Fig. 1 Coupling for X3C09F1-03S (feeding port 1).*



▲ *Fig. 2 Isolation for X3C09F1-03S (feeding port 1).*



▲ *Fig. 3 Phase balance for X3C09F1-03S (feeding port 1).*



▲ *Fig. 4 Return loss for X3C09F1-03S (feeding port 1).*

of performance out of their systems.

One example from the family is model X3C09F1-03S, which can be used for applications in 800 to 1000 MHz. This part exhibits a maximum insertion loss (IL) of 0.15 dB maximum over its full frequency range and at extreme temperature ranges that are not a-typical in today's stations – from -55°C all the way up to 105°C. This small, 90 degree coupler also achieves 23 dB minimum isolation from 800 to 1000 MHz with 26 dB minimum isolation from 869 to 894 MHz and 925 to 960 MHz (see ***Table 1***). The same part, which is a fair representative of the entire family, also offers a maximum VSWR of 1.15:1 from 800 to 1000 MHz, with maximum VSWR of 1.12:1 from 869 to 894 MHz and maximum VSWR of 1.12:1 from 925 to 960 MHz. The hybrid's small size and carefully controlled transmission lines result in worse-case amplitude balance of ±0.3 from 800 to 1000 MHz. And the phase balance is within ±4 degrees from 800 to 1000 MHz, within ±2 degrees of 90 degrees from 869 to 894 MHz, and within ±2 degrees of 90 degrees from 925 to 960 MHz (see ***Figures 1*** to ***4***). These are high performance specifications for the hybrid category and should be of interest to the RF system

TABLE II DIRECTIONAL COUPLER SPECIFICATIONS.							
Part No.	**Dimensions in./(mm)**	**Frequency (MHz)**	**Power (W) (avg)**	**Insertion Loss (dB)* (max)**	**Directivity (min)***	**Return Loss (dB)* (min)**	**Operating Temp**
X3C09F1-20S	0.200" × 0.125" (5.08 × 3.18 mm)	700-1000	25	0.05	25	25	-55° to +105°C
X3C19F1-20S	0.200" × 0.125" (5.08 × 3.18 mm)	1700-2700	25	0.05	25	25	-55° to +105°C

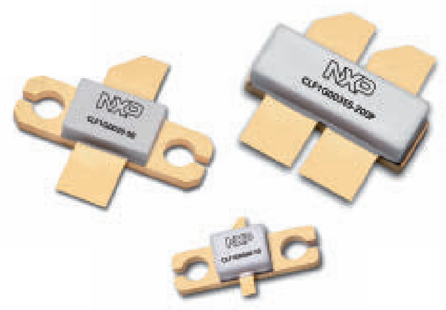
* Performance listed for narrow bands.

UNLEASH RF

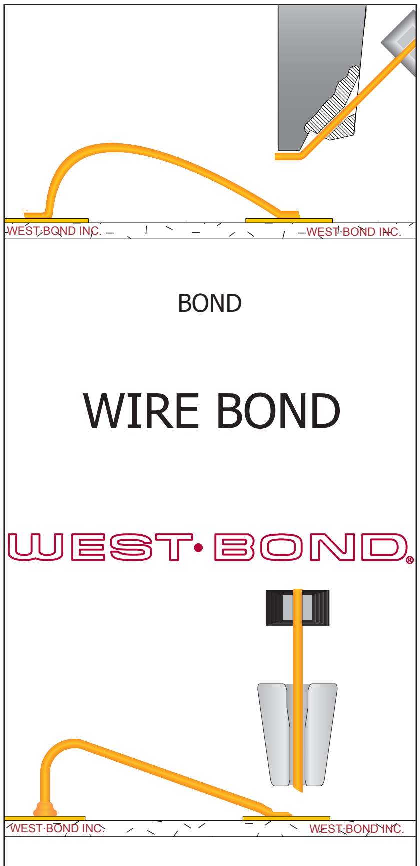
Helping You Realize a Clear Competitive Advantage

Engineers rely on NXP for the broad portfolio, manufacturing muscle, and unrivaled RF expertise to realize a new experience—in design freedom, reliable supply and consistent performance. We deliver proven, enabling technology to RF and microwave industry leaders. As a result, customers in a wide range of industries are realizing a clear advantage in their products, their reputations and their businesses.

Gain a clear advantage as NXP takes GaN mainstream with the first generation GaN broadband amplifier family



Unleash the performance of your RF and microwave designs



www.westbond.com

Microwave Journal

WHAT CAN YOU FIND AT mwjournal.com

BUYER'S GUIDE

Use this invaluable reference source for locating companies, their products and services.

Is your company in the guide?

Visit the Buyer's Guide to List Your Company

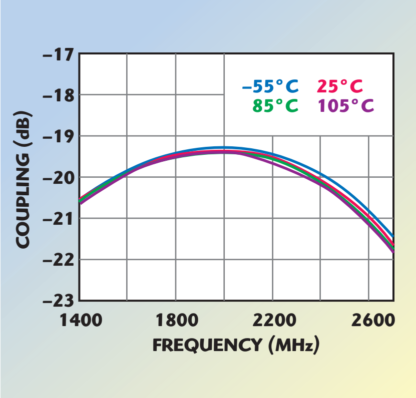


Fig. 5 Coupling for X3C19F1-20S (feeding port 1).

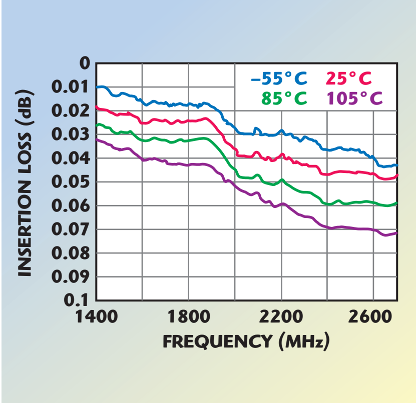


Fig. 7 Insertion loss for X3C19F1-20S (feeding port 1).

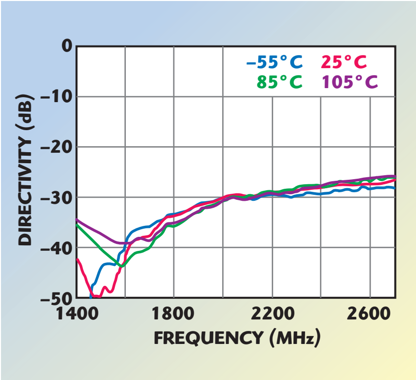


Fig. 6 Directivity for X3C19F1-20S (feeding port 1).

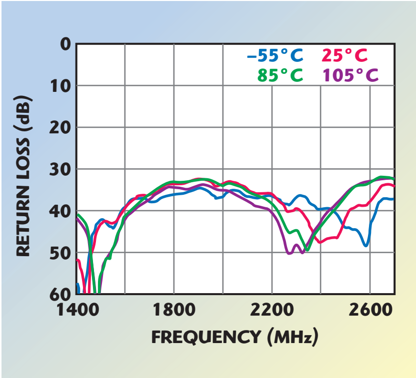


Fig. 8 Return loss for X3C19F1-20S (feeding port 3).

designer seeking to maximize performance. Anaren currently derates all parts assuming RoHS compliant SAC (96.5Sn3.0Ag0.5Cu) solder.

DIRECTIONALS

The new line-up of Xinger-III Femtos also offer very low loss for the directional couplers category (max 0.1 dB). As an example from this branch of the family, 20 dB directional coupler model number X3C19F1-20 can handle 25 W CW input power from 1400 to 2700 MHz in a package measuring 0.200 × 0.125 inches (see ***Table 2***). The mean coupling is 20.5 and varies 1.50 dB across the full frequency range, with maximum insertion loss of 0.1 dB and maximum VSWR of 1.22:1. The minimum full-band directivity is 20 dB, with directivity of 25 dB and insertion loss of only 0.05 dB from 1805 to 1880 MHz, 1930 to 1990 MHz and 2110 to 2170 MHz (see ***Figures 5*** to ***8***).

OTHER ADVANTAGES

Beyond electrical performance, these Femto couplers afford other useful characteristics. Most noteworthy, their softboard construction offers coefficient of thermal expansion (CTE) properties that match commonly used FR4, G-10, RF-35, RO4003 and polyimide. Of importance particularly in the aforementioned, hotter running micro-cell stations – this material choice can help avoid solder cracks that are not uncommon when ceramic solutions operate at high temperatures.

Additionally, these new Femtos are RoHS and REACH compliant. They offer very stable RF performance up to 105 degrees, making them well-suited to today's high temperature micro cells (see Figures 1-6). And should mounting temperatures exceed 105°C, they'll still perform reliably provided the input power is derated per the derating curve on each part's datasheet.

VENDORVIEW

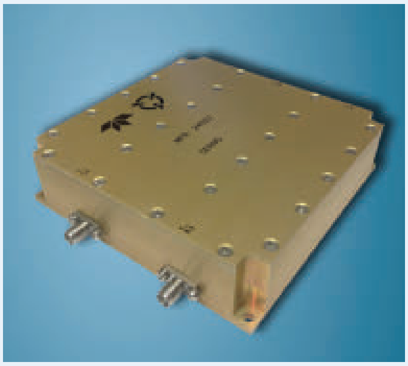
Anaren Microwave,
Syracuse, NY
(800) 411-6496,
www.anaren.com.

NATE
National Association of Tower Erectors

Your partner in safety, standards and education.

www.natehome.com

Tech Brief



Dual-Band Switchable Ka-Band BUC

The 290-310 Ka-Band block up-converter (BUC) from Teledyne Microwave Solutions is designed to convert an L-Band IF input in the range of 1 to 2 GHz to an RF output in one of two externally-selectable RF bands within the Ka-Band spectrum. Though the selectable bands in the standard configuration include 29 to 30 GHz and 30 to 31 GHz, the converter can be optionally-configured to address any two portions of the Ka-Band in segments of 1 GHz or less.

The linear output power is 10 dBm minimum with 30 dB minimum gain. The group delay variation over the full band is 2 nsec maximum. Input power is up to 5 dB and input voltage is +8 to +36 VDC.

The BUC-290-310 is packaged in a hermetically-sealed module for maximum performance and reliability, and has a footprint of 4" × 4", making it an excellent choice for airborne and mobile applications that require minimal size and weight.

Available options include:

- Auto-ranging DC input
- Internal or external reference (10 or 50 MHz)
- Direct L.O. injection
- Bias via coax or external connector
- Type N or SMA IF input connector

Teledyne Microwave Solutions, Mountain View, CA (800) 832-6869, microwave@teledyne.com, www.teledynemicrowave.com.

EDI CON 2014
Electronic Design Innovation Conference
电子设计创新会议

April 8-10, 2014
Beijing International Convention Center
Beijing, China

Where the Experts Speak...

Three full days of peer-reviewed, industry-focused technical papers, workshops, expert panels and guest keynotes on market and technology trends in China and beyond.

RF, Microwave, High Speed Digital & EMC/EMI Design

Exhibition

- Test & Measurement Equipment
- Test Solutions
- EDA/CAD Software
- Components, Modules
- Subsystems
- RFICs & MMICs
- Cables/Connectors
- Materials
- Semiconductor Foundries
- Manufacturing Services

Host Sponsor:
Agilent Technologies

Diamond Sponsor:
ROHDE&SCHWARZ

Corporate Sponsor:
AWR
NATIONAL INSTRUMENTS

Gold Sponsors:
Anritsu
CST
Mini-Circuits
RichardsonRFPD An Arrow Company
SPIRENT

Organized by:
horizon house®
ACT
Microwave Journal

www.EDICONCHINA.com

Affordable Vector Signal Generators

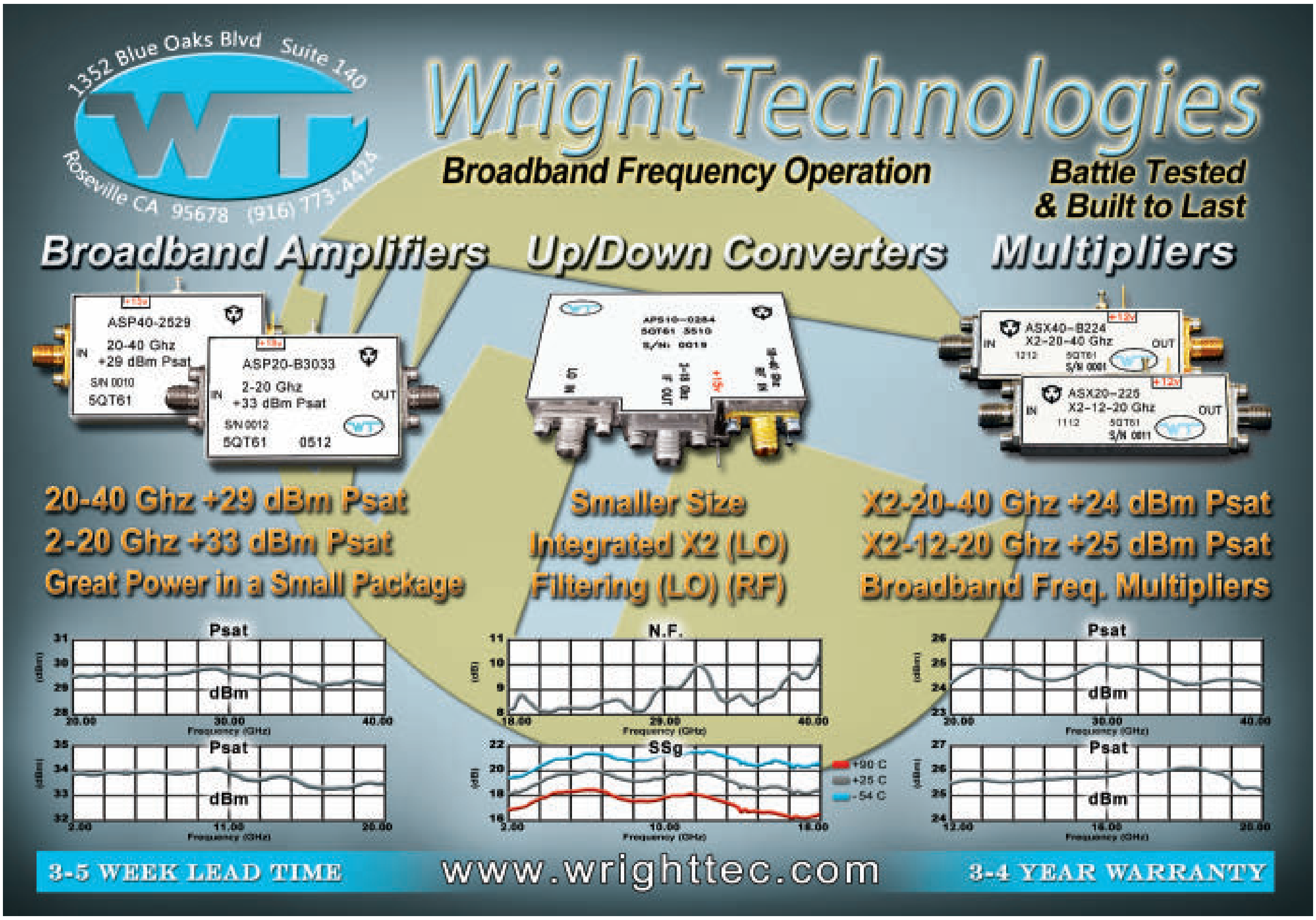
Stanford Research Systems has introduced the SG390 Series vector signal generators — high performance, affordable RF sources. Three new RF signal generators, with carrier frequencies from DC to 2.025, 4.050 and 6.075 GHz, support both analog and vector modulation. The instruments utilize a new RF synthesis technique which provides spur free outputs with low phase noise (–116 dBc/Hz at 1 GHz) and excellent frequency resolution (1 µHz at any frequency). Both analog modulation and vector baseband generators are included as standard features.

The instruments use an ovenized SC-cut oscillator as the standard timebase, providing a 100 fold improvement in the stability (and a 100 fold reduction in the in-close phase noise) compared to instruments which use a TCXO time-base.

The SG390 Series signal generators are based on a new frequency synthesis technique called rational approximation frequency synthesis (RAFS). RAFS uses small integer divisors in a conventional phase-locked loop (PLL) to synthesize a frequency that would be close to the desired frequency (typically within ±100 ppm) using the nominal PLL reference frequency. The PLL reference frequency is adjusted so that the PLL generates the exact frequency. Doing so provides a high phase comparison frequency (typically 25 MHz) yielding low phase noise while moving the PLL reference spurs far from the carrier where they can be easily removed. The end result is an agile RF source with low phase noise and essentially infinite frequency resolution, without the spurs of fractional-N synthesis or the cost of a YIG oscillator.

The generator has built-in support for the most common vector modulation schemes: ASK, QPSK, DQPSK, π/4 DQPSK, 8PSK, FSK, CPM, QAM (4 to 256), 8VSB, and 16VSB. It also includes built-in support for all the standard pulse shaping filters used in digital communications: raised cosine, root-raised cosine, Gaussian, rectangular, triangular and more. Lastly, it provides direct support for the controlled injection of additive white Gaussian noise (AWGN) into the signal path.

Stanford Research Systems Inc., Sunnyvale, CA (408) 744-9040, www.thinkSRS.com, info@thinkSRS.com.



SIX DAYS ■ THREE CONFERENCES ■ ONE EXHIBITION

EUROPEAN MICROWAVE WEEK 2014
NUOVA FIERA DI ROMA, ROME, ITALY
OCTOBER 5 - 10, 2014

EuMW 2014
CONNECTING THE FUTURE
EUROPEAN MICROWAVE WEEK
ROME, ITALY
5-10 OCTOBER 2014
www.eumweek.com

EUROPE'S PREMIER MICROWAVE, RF, WIRELESS AND RADAR EVENT

EuMW 2014 will be held in the extraordinary and beautiful 'Eternal City' of Rome. Bringing industry, academia and commerce together, European Microwave Week 2014 is a SIX day event, including THREE cutting edge conferences and ONE exciting trade and technology exhibition featuring leading players from across the globe. EuMW 2014 will offer you the unique opportunity to be connected to the future of microwave technology.

The Exhibition (7th – 9th October 2014)

- 8000 sqm of gross exhibition space
- 5,000 key visitors from around the globe
- 1,700 - 2,000 conference delegates
- In excess of 250 international exhibitors (including Asia and US as well as Europe)

The Conferences:

- European Microwave Integrated Circuits Conference (EuMIC) 6th – 7th October 2014
- European Microwave Conference (EuMC) 6th – 9th October 2014
- European Radar Conference (EuRAD) 8th – 10th October 2014
- Plus Workshops and Short Courses (From 5th October 2014)
- In addition EuMW 2014 will include the 'Defence, Security and Space Forum'.

EuMA European Microwave Association
Official Publication: Microwave Journal
Organised by: horizon house
Supported by: IET The Institution of Engineering and Technology
Co-sponsored by: MTT-S
Co-sponsored by: IEEE

EuMIC 2014
The 9th European Microwave Integrated Circuits Conference
Co-sponsored by: Electron Devices Society, GAAS

44TH EUROPEAN MICROWAVE CONFERENCE 2014
The 44th European Microwave Conference
Co-sponsored by: APS

EuRAD 2014
The 11th European Radar Conference
Co-sponsored by: AESS, APS

Interested in exhibiting?

Call +44(0) 20 7596 8742 or visit www.eumweek.com

High Performance 9 GHz Signal Sources

The SignalCore SC5502A and SC5503A are 9 GHz synthesized CW signal sources with instrument grade performance in stunningly compact sizes. To meet demanding low phase noise applications, these sources employ multiple phase-locked loop architectures with YIG oscillators at the heart of their synthesizers. They have automatic leveling control (ALC) circuits to ensure precise amplitude control over frequency and temperature. Frequency accuracy is provided by an onboard 10 MHz temperature compensated crystal oscillator (TCXO) that can be phase-locked to an external reference source if required.

The frequency range is 50 MHz to 9 GHz with exact frequency tuning resolution of 1 Hz. Phase noise measured for 1 GHz carrier at offsets of 10 kHz and 1 MHz are –120 and –150 dBc/Hz, respectively. Amplitude range is from –60 to 10 dBm with amplitude resolution of 0.1 dB.

The SC5502A is offered for PXI/cPCI Express platform while the SC5503A is available for USB, SPI, or RS-232 interfaces. To make integration of SignalCore's modules into your system quick and easy, the company offers full implementation instructions, driver software and examples with each platform module. A soft front panel application is included that allows basic control without the need for programming. Driver code may be available upon request.

Both SC5502A and SC5503A may be used as standalone CW signal sources, or as LO sources for frequency conversion systems such as the SignalCore IQ modulators and demodulators. They are designed to meet the requirements of many modern applications such as wireless device testing, software-defined radio research, point-to-point radio, multi-channel coherent systems and other academic and military programs.

SignalCore,
Austin, TX (512) 501-6000,
sales@signalcore.com,
www.signalcore.com.

Microwave Journal

Frequency Matters.

Go Mobile

with the NEW MWJ APP

Get the free Microwave Journal Magazine App that includes the monthly issue, favorite archives and real-time industry news, blogs and interviews. Available on iTunes, Google Play and Amazon.

Download Now

http://bit.ly/VQxL2o

Download your MWJ app now
at www.mwjournal.com/MWJapp

IEEE MTT-S

IMS2014 - Tampa Bay, Florida

POWERING THE WAVES

For more information please visit:

HTTP://IMS2014.MTT.ORG

IMS IS HEADED TO FLORIDA!

SUBMIT YOUR PAPER

CONFERENCE DATES: ***1- 6 JUNE 2014!***

The IEEE Microwave Theory and Techniques Society's 2014 International Microwave Symposium (IMS2014) will be held 1 - 6 June 2014 in Tampa, Florida as the centerpiece of Microwave Week 2014. IMS2014 offers technical sessions, interactive forums, plenary and panel sessions, workshops, short courses, industrial exhibits, application seminars, historical exhibits, and a wide variety of other technical and social activities, including a guest program. As usual, the Microwave Week technical program also comprises the RFIC Symposium (www.rfic2014.org) and the ARFTG conference (www.arftg.org). Unique to Microwave Week 2014, Florida's own WAMICON (www.wamicon.org) will be held jointly with ARFTG for this year. With over 9,000 participants and 600 industrial exhibits of state-of-the-art microwave products, Microwave Week is the world's largest gathering of Radio Frequency (RF) and microwave professionals and the most important forum for the latest research advances in the field.

PAPER SUBMISSION: Authors are invited to submit technical papers describing original work on radio-frequency, microwave, millimeter-wave, and terahertz (THz) theory and techniques. The deadline for submission is 9 December 2013. Paper submissions should be three pages in length (PDF format), and should not exceed one megabyte in file size. Hardcopy and email submissions will not be accepted. Please refer to the IMS2014 website (www.ims2014.mtt.org) for detailed instructions concerning paper submission. Authors must adhere to the format provided in the conference paper template available on the symposium's website. It is the authors' responsibility to obtain all required company and government clearances prior to submission. Please don't wait until the last day to start using the paper submission process. Those unfamiliar with the process may encounter paper formatting or clearance issues that may take time to resolve.

A double blind review process will be used. Papers will be evaluated on the basis of originality, content, clarity, and relevance to the symposium. For accepted papers, the electronic submission of a final manuscript along with a copyright assignment to the IEEE will be required no later than 3 March 2014. Symposium proceedings will be recorded on electronic media and archived in IEEE-Xplore. Authors of accepted papers should consider submitting an extended version of their symposium paper for possible publication in the IEEE Transactions on Microwave Theory and Techniques.

Come join us in Tampa, Florida and enjoy the flagship Microwave Theory and Techniques Society (MTT-S) Conference on the beautiful Gulf Coast of Florida.

EMERGING TECHNICAL AREAS:

IMS2014 enthusiastically invites submission of papers that report state-of-the-art progress in technical areas that are outside the scope of those specifically listed in this Call for Papers, or that may be new to the symposium, but are of interest to our attendees.

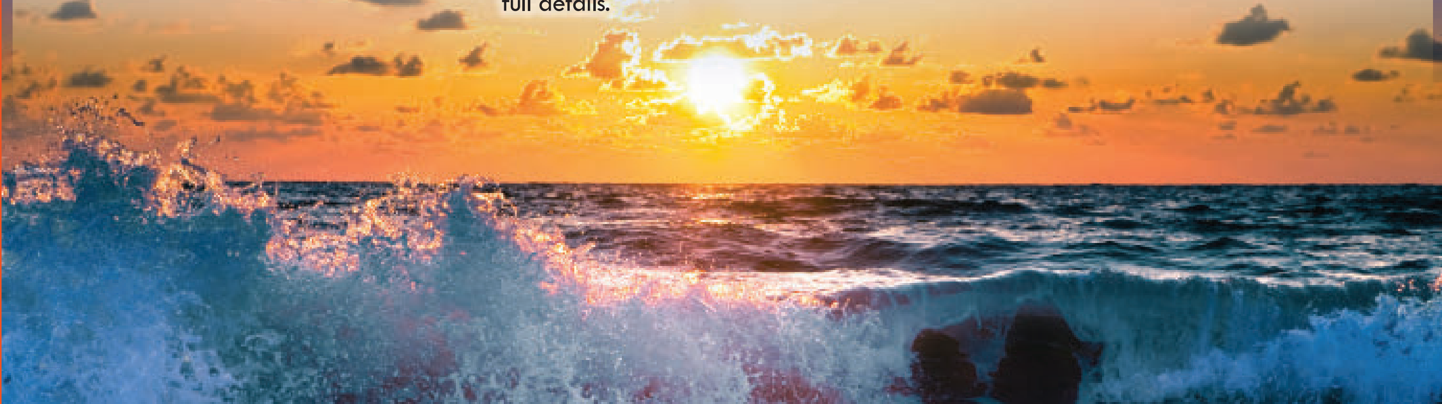
STUDENT PAPER AND STUDENT DESIGN COMPETITIONS:

Eligible students are encouraged to submit papers for the student paper competition. The papers will be evaluated using the same standards as all contributed papers. In addition, eligible students or student teams are invited to consider taking part in student design competitions during the IMS2014, which are organized and sponsored by various Technical Committees (TC) of the MTT-S Technical Coordination Committee (TCC). Please visit the IMS2014 website for full details.

MICROAPPS:

The Microwave Application Seminars serve as a forum for exhibitors at the IMS to present the technology behind their commercial products and their special capabilities. The presentations are open to all conference and exhibit attendees.

Electronic Submission Deadline:
9 December 2013
All submissions must be made through email:
tpc_microapps@ims2014.org



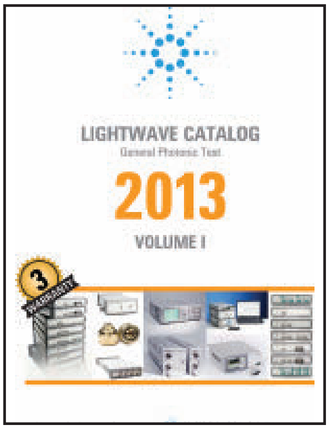
Catalog Update

Lightwave Catalog

VENDORVIEW

Agilent's new 2013 Lightwave Catalog set is now available. This three-volume set is the largest catalog for high-performance optical T&M products, with information on the new optical modulation analyzer, transceiver test, single and multimode applications, products for the Telecom and Datacom market and also a brand new volume on bit error ratio test solutions. The set can be downloaded as three PDFs from Agilent's website or you can request to have hard copies sent to you.

Agilent Technologies Inc.,
www.agilent.com.

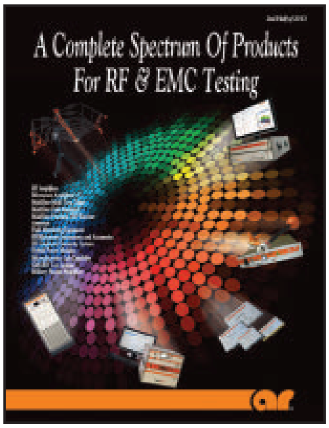


EMC & RF Testing Catalog

VENDORVIEW

AR's new product catalog is now available from your local AR sales associate. The catalog is easy to use, with "find-it-fast" charts and color coding to help get right to whatever you need for RF and EMC testing. It is available for free download, either in full or by section on the company's website.

AR RF/Microwave Instrumentation,
www.arworld.us.

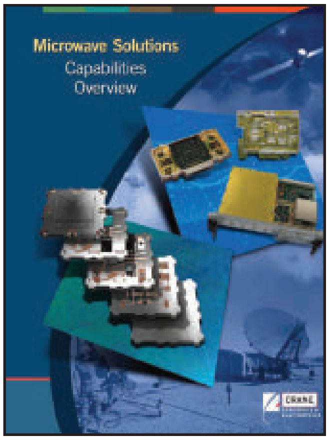


Microwave Capabilities Catalog

VENDORVIEW

Crane Aerospace & Electronics Microwave Solutions launched an updated Microwave Capabilities Catalog that features a wide range of product solutions from component level devices to complex, advanced integrated microwave assemblies. Products are illustrated from major product areas and represent the breadth of technical capability of Crane. The company's microwave brands include Merrimac, Signal Technology and Polyflon.

Crane Aerospace & Electronics,
www.craneae.com.

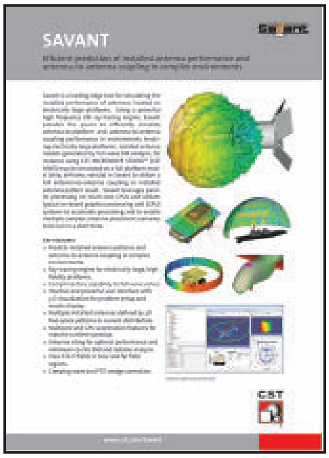


Savant Brochure

VENDORVIEW

Aircrafts, ships, land vehicles and satellites have complicated electromagnetic (EM) environments. Savant, a product of Delcross Technologies distributed worldwide by CST, is a simulation tool that predicts installed antenna performance and antenna-to-antenna coupling in complex environments. The brochure details the key features of the computational electromagnetic tool, as well as the different result types and visualization tools available. Representative graphical results, such as an installed performance simulation on a humvee, are illustrated, along with the user interface.

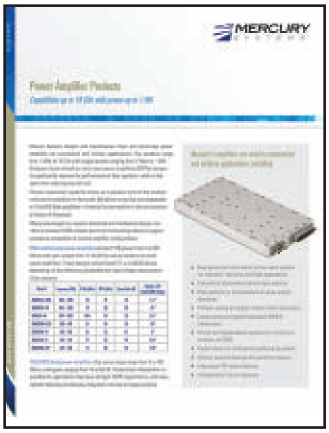
Computer Simulation Technology AG,
www.cst.com.



PA Products Brief

Mercury Systems' linear and ultra-linear power amplifiers for commercial and military applications are designed to operate up to 18 GHz with output powers ranging from 1 W up to 1 kW. These linear and ultra-linear power amplifiers continuously demonstrate their ability to significantly improve the performance of our customers' systems, while reducing size and cost. Pioneer linearization capability allows Crane to produce some of the smallest multi-carrier power amplifiers in the world with a fraction of the power.

Mercury Systems,
www.mrcy.com.



Product Brochure

MIcable Inc. produces a wide variety of high quality coaxial cable assemblies with flexible, conformable and semi-rigid cables and customer specified connectors. MIcable offers prototypes or volume quantities, all fully tested up to 40 GHz and delivered on time. This product brochure highlights a few of the company's products along with providing performance data.

MIcable Inc.,
www.micable.cn.

Product Catalog

Microsemi's brand new product catalog is now available online. Products include: ASICs and FPGAs; discrete; display and drivers; high reliability; ICs; memory, processors and storage; modules and hybrids; relays and contactors; RF, microwave and millimeter; services; software and IP, and systems and subsystems. These solutions are targeted at defense/security, aerospace, communications and industrial applications. When performance matters, reliability is vital and security is non-negotiable, customers choose Microsemi.

Microsemi,
www.microsemi.com.

RF/Microwave Components Catalog

VENDORVIEW

Narda Microwave-East announced the availability of its newly updated RF and microwave components catalog. The 360 plus-page catalog features more than 700 in-stock components available for immediate delivery or in very short turnaround times. Catalog 32 is available in either printed form or on a CD. It provides technical specifications, outline drawings, application notes and technical articles to help guide engineers and purchasing agents in component selection. The catalog also includes detailed summaries of Narda's growing family of Integrated Microwave Assemblies (IMA).

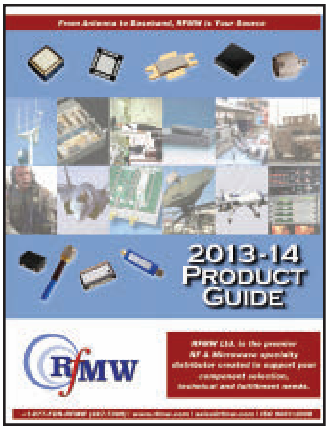
Narda Microwave East,
www.nardamicrowave.com.

2013-2014 Product Guide

VENDORVIEW

Celebrating its 10-year anniversary, RFMW has seen a continual acceptance of its "niche" philosophy in that "RFMW Ltd. is a specialty electronics distribution company focused on RF and Microwave technology." It serves customers that require RF and microwave components and semiconductors, as well as component engineering support. RFMW continues to expand its list of products from selective suppliers with RF/microwave expertise. RFMW deploys a highly experienced, technically skilled team to assist customers with component selection and fulfillment.

RFMW Ltd.,
www.rfmw.com.



RF/Microwave Assembly and Products Brochure

SemiGen announces the release of its RF/Microwave Assembly and Products Brochure. The brochure entails the overview of the company's contract RF/microwave assembly services, testing services and the RF supply center featuring microwave PIN diodes, limiter diodes and passive components. The brochure details the company's full assembly and test capabilities and includes detailed information on the RF/microwave components and bonding supplies.

SemiGen Inc.,
www.semigen.net.

Product Catalog

This catalog provides you with descriptions and classifications of products including attenuators and terminations, coaxial switches, phase shifters, directional couplers, power meters, power dividers/combiners, and precision adapters and test accessories. The catalog can be downloaded from the company's website.

Shanghai Huaxiang Computer Communication Engineering Co. Ltd.,
www.shx-sh.com.

Harness Capabilities Brochure

The Teledyne Storm Microwave Multi-Channel Microwave Solutions brochure details the company's capabilities in the design and manufacture of both standard and custom multi-channel microwave harness assemblies. The harnesses, found in a wide range of airborne, ground and sea-based military and commercial applications, are backed by Teledyne Storm's more than 30 years of microwave cable design and manufacturing expertise. The brochure includes a case study.

Teledyne Storm Microwave,
www.teledynestorm.com.

Sn/Pb Conversion Process

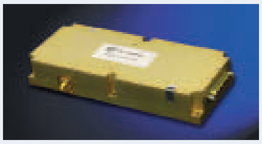
AEM announced a hi-rel-qualified Sn/Pb (tin/lead) conversion process designed to mitigate the formation of tin whiskers in surface-mount components.

The AEM process eliminates potential damage to sensitive electronic devices caused by conventional hot-solder dipping while ensuring that converted component terminations contain a minimum of 5 percent Pb as verified by SEM/EDS and XRF inspection methods. AEM's Sn/Pb conversion process is best suited for chip-scale passive components.

AEM Inc.,
www.aem-usa.com.

High Power Pulsed Amplifier

Aethercomm has recently completed a high power SSPA using GaN with a frequency range covering 6 to 18 GHz, Aethercomm part number SSPA 6.000-18.00050. This broadband



power amplifier offers high power over a multi-decade bandwidth with excellent power added efficiency. It produces 25 to 50 W Psat typical. The amplifier design includes an external DC blanking command that enables and disables the module in less than 20.0 µSec and is housed in an 8.50"(w) by 3.50" (l) by 1.38" (h) module.

Aethercomm Inc.,
www.aethercomm.com.

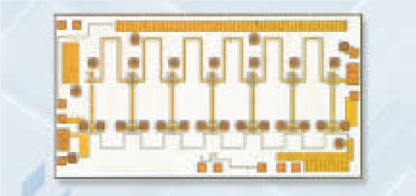
GaN Amplifier

COMTECH PST introduced a new GaN amplifier for applications in the X-Band radar market.

The AB linear design operates over the 8.5 to 10 GHz frequency range and is intended for use in radar applications. The amplifier design features include options for control of phase and amplitude to allow for integration into high power systems utilizing conventional binary or phased array combining approaches for power levels of up to 10 kW.

COMTECH PST,
www.comtechpst.com.

GaAs MMIC



Custom MMIC announced the addition of the CMD192 to its growing MMIC library of standard products. The CMD192 is a wideband DC to 20 GHz GaAs MMIC distributed amplifier available in die form. This amplifier delivers greater than 20 dB of gain with a corresponding output 1 dB compression point of +22 dBm and a noise figure of 2.8 dB at 18 GHz. The CMD192 is suitable for microwave radio and VSAT, telecom infrastructure, test instrumentation, and military and space applications.

VENDORVIEW

Custom MMIC,
www.custommmic.com.

Radar Transistor

Newly introduced, the IGN2731M200 S-Band radar transistor is capable of producing more than 60 percent efficiency. This GaN on SiC HEMT transistor is designed for the 2.7 to 3.1 GHz instantaneous operating frequency band and offers peak output power = 200 W at 300 us/10 percent/44 V. It utilizes a complete gold metallization system: chip, wire bond and package. It features internal impedance prematching structures. Production devices are 100 percent high power RF tested in a fixed tuned broadband RF test fixture.

Integra Technologies Inc.
www.integratech.com.

Image Reject Mixer

RCIR-161LH+ is a surface-mount image reject mixer that operates in a frequency range from 80 to 168 MHz. Features include: excellent image rejection of 32 dB typical, low conversion loss of 6.1 dB typical and is aqueous washable. Applications include: VHF, military and avionics. Price: $19.95 each, Qty: 10.

VENDORVIEW

Mini-Circuits,
www.minicircuits.com.

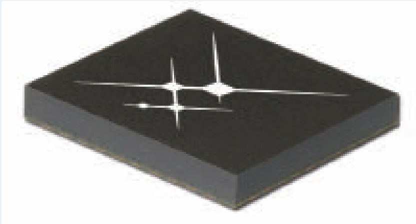
SP5T Switches

RFMW announced design and sales support for two new Peregrine Semiconductor SP5T switches targeting T/R and filter-band switching in land mobile radio (LMR) and military radio applications where high power handling (17 W) is required. Both the PE42850 and PE42851 feature low power consumption of 130 microamperes which helps to extend battery life in mobile applications. The Peregrine PE42851 covers the frequency range of 100 to 1000 MHz while the PE42850 extends the low end frequency to 30 MHz.

VENDORVIEW

Peregrine Semiconductor, distributed by RFMW Ltd.,
www.psemi.com.

Differential Attenuator



Skyworks Solutions Inc. unveiled a new device for cellular infrastructure, VHF/UHF military and public safety radios. The SKY12408-321LF is a 50 to 600 MHz, 6 dB differential attenuator that is pin-for-pin compatible with its 12 dB SKY12407-321LF attenuator, but ideal for IF radio applications requiring lower overall attenuation and gain control. The new solution also offers a novel differential I/O design and fast settling time for applications that down convert to a low Intermediate frequency.

VENDORVIEW

Skyworks Solutions Inc.,
www.skyworksinc.com.

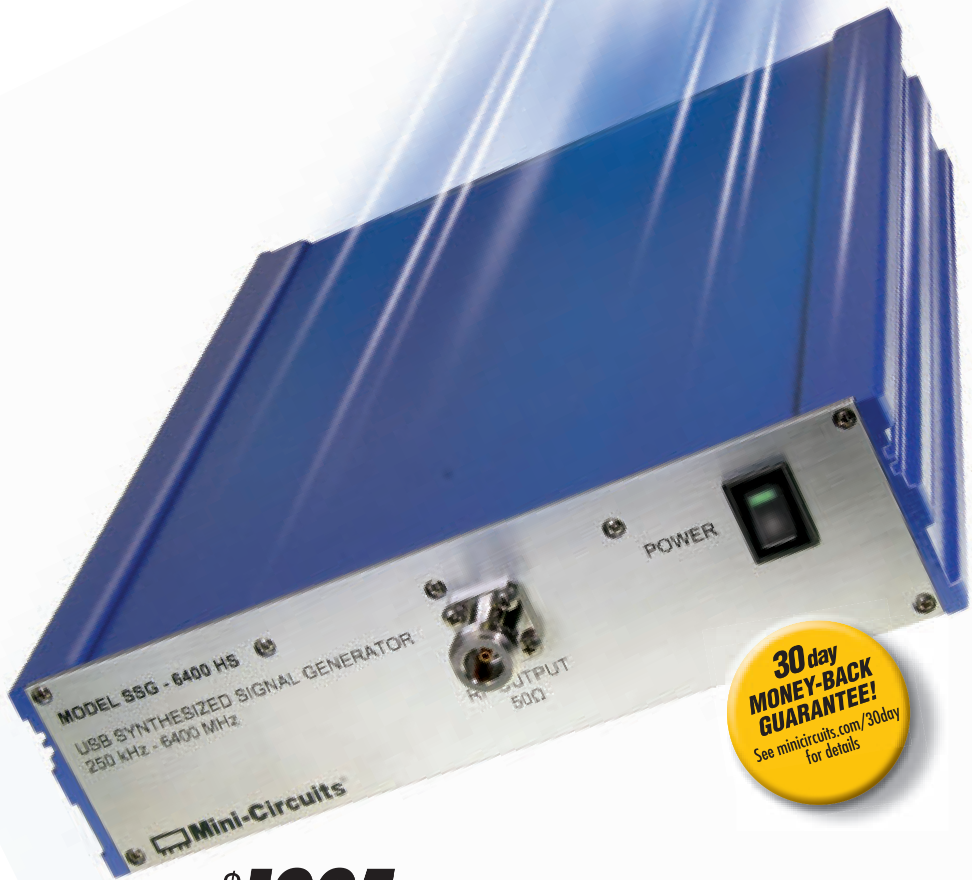
Wet Tantalum High-Energy Capacitor

Vishay Intertechnology introduced a new wet tantalum high-energy capacitor with low maximum ESR down to 0.025 Ω at +25°C and 1 kHz, and the highest capacitance of any similar device on the market. Manufactured to withstand high stress and hazardous environments, the HE4 features a unique case design for improved reliability and performance in military and aerospace applications. The HE4 utilizes Vishay's proven SuperTan® hybrid cathode technology in combination with industry-leading anode designs to achieve its low ESR.

Vishay Intertechnology Inc.,
www.vishay.com.

SIGNAL GENERATORS

To fit your budget.



from $1995 ea.

0.25 to 6,400 MHz

More models for more applications, all small enough to fit into a laptop case – **and all at game-changing prices!**

You asked, so we're growing our line of synthesized signal generators to meet your needs. Four unique models now offer capability to fit your application without burdening you with the cost of extra features you don't need. All models are cased in a compact, rugged metal package (as small as 8.37"x8.5"x 2.15") and feature pulse modulation, frequency and power level scheduling, frequency and power hopping, USB control, and easy-to-use GUI software. Our newest model, SSG-6400HS also features expanded frequency range from 0.25 to 6400 GHz, AM, PM, and FM capability, fast tuning (<300µs), and Ethernet control. You can even set power levels in step sizes as small as 0.01 dB and frequencies in step sizes as small as 0.001 Hz. Visit minicircuits.com to find the right model for your application with detailed specs, great prices, and off-the-shelf availability!

Models and Key Features

New
SSG-6400HS *$4,995*
- 0.25 to 6400 MHz
- AM, PM, FM, and pulse modulation
- USB and TCP/IP Ethernet Control
- Fast tuning (<300 µs)
- +10 dBm max. output pwr.

SSG-4000LH *$2,395*
- 25 to 4000 MHz
- Pulse modulation
- USB Control
- Low Harmonics (-66 dBc typ.)
- +10 dBm max. output pwr.

SSG-6000 *$2,695*
- 25 to 6000 MHz
- Pulse modulation
- USB Control
- 0.5 Hz frequency resolution
- +10 dBm max. output pwr.

SSG-4000HP *$1,995*
- 25 to 4000 MHz
- Pulse modulation
- USB Control
- High Power (+20 dBm max.)

Mini-Circuits®

www.minicircuits.com P.O. Box 35166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

519 rev B

New Products

Components

Femto Couplers

Richardson RFPD announced that it is taking orders for Xinger® III Femto Couplers. The

Femto family is a new class of Xinger® couplers which are available in a miniature 5 × 3 mm footprint. There is no electrical performance tradeoff with the reduced footprint. The new devices cover a wide frequency range (700 to 2700 MHz), offer outstanding insertion loss, and 25 W power handling at 105°C mounting temperature, making them ideal for small cell or active antenna systems.

VENDORVIEW

Anaren, distributed by Richardson RFPD Inc., www.anaren.com.

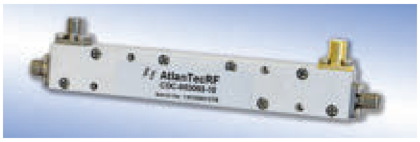
Bandpass Filters

Anatech's cavity bandpass filters for 700 MHz LTE are available for all uplink and downlink bands and meet the stringent requirements posed by dense channel spacing. They have more than 40 dB of rejection at 700 kHz from passband to stopband at band edges, low insertion loss, and PIM as low as -150 dBc. Models are available for indoor and outdoor installation and can have Type-N or 7/16 DIN connectors. Anatech can also quickly build bandpass filters for 700 MHz to meet custom requirements.

VENDORVIEW

Anatech Electronics Inc., www.anatechelectronics.com.

Directional Couplers



Two new high performance directional couplers from AtlanTecRF cover the entire frequency range from 375 MHz to 18 GHz with at least 3 GHz of overlap. Available in a choice of 10, 20 or 30 dB, the 50 W couplers with SMA connectors and built-in terminations will operate over a temperature range of -55° to +55°C, making them suitable for use in applications from airborne ECM to the benign test bench.

VENDORVIEW

AtlanTecRF, www.atlantecrf.com

Transmitter Capacitor Equivalents

ATC announced the introduction of a new family of high RF power capacitor assembly transmitter capacitor equivalents. ATC's extensive line of high RF power capacitor assemblies offers a cost-effective alternative to large and costly fixed vacuum capacitors, doorknobs and transmitter capacitors. ATC assemblies are ideal for the most demanding applications requiring high RF power at low frequencies. They are constructed with the finest materials and are engineered to provide the most reliable performance in the most demanding applications.

American Technical Ceramics, www.atceramics.com.

Digitally Controlled Attenuator

Model A6P-68N-0JL is a phase invariant digitally controlled PIN diode attenuator that operates from 6 to 18 GHz. It is capable of 63.75 dB range in monotonic 0.25 dB steps. The attenuation flatness is ±3.0 dB at 64 dB and the delta phase is ±15° at 64 dB. With a maximum VSWR of 2.0:1 and an insertion loss less than 7 dB, this phase invariant attenuator is digitally controlled via 8 bits of TTL compatible binary logic with a switching speed less than 1.0 µSec.

G.T. Microwave Inc., www.gtmicrowave.com.

Waveguide to Coaxial Adapter

The company has announced the optimization of the WR28 waveguide to coaxial adapter. It operates over 26.5 to 40 GHz in the full waveguide frequency range, with a VSWR of less than 1.25:1, insertion loss less than 0.3 dB and power handling is 50 W (average). The material is copper with a gold plating finish. The optimized design features integral machining for optimum electrical performance and high reliability.

HengDa Microwave, www.hdmicrowave.com.

Right Angle Adapter

Mesa Microwave introduced a new TNC (F) to TNC (M) right angle adapter. Specs include DC to 18 GHz, operating temperature of 65° to +165°C and VSWR of 1.25:1. Visit the company's website to learn more about its full line of RF components such as precision coaxial connectors, cable assemblies and electronic components.

Mesa Microwave, www.mesamicrowave.com.

Absorptive Switch

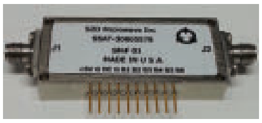
PMI Model No. P8T-500M40G-60-T-55-292FF is a high speed, single pole, eight throw,

absorptive switch operating over the frequency range of 0.5 to 40 GHz. This switch has over 60 dB of isolation and is capable of switching within 50 ns.

VENDORVIEW

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

Digital Attenuator



S2D Microwave Inc. offers a broadband, high performance RF/microwave 7 bit digital attenuator. This is a high performance compact unit with low insertion loss, fast switching speed, high power handling, low harmonic distortion, stable attenuation vs. temperature and TTL 7 bit attenuation control. Specs include: frequency: 0.5 to 20 GHz, insertion loss: 8.0 dB max, VSWR: 2:1 max, attenuation range: 61 dB, RF power handling: 22 dBm CW, 2 W peak (1 µS PW) and switching speed: 100 ns typ.

S2D Microwave Inc., www.s2dmicrowave.com.

Low Pass Filter

The unique surface-mount low pass filter, model number FLS-100, has a passband from DC to 92 MHz and a cut-off frequency at 100 MHz. The passband loss is 1 dB maximum and has sharp stopbands of 20 dB (min.) at 135 MHz and 35 dB (min.) at 175 MHz. The passband VSWR is 1.3:1 typical and can handle 1 W. Built in a small surface mount package 0.840" × 0.520" × 0.440". Contact the factory for other LP as well as BP and HP models.

Synergy Microwave Corp., www.synergymwave.com.

Amplifiers

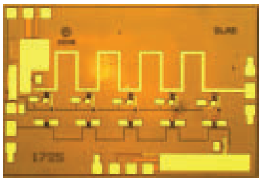
Solid State Amplifiers

With AR's dual band amplifiers, you have freedom like never before. You pick the power from 5 to 80 W. You pick the bandwidth from 0.7 to 8 GHz, 0.7 to 10.6 GHz or 0.7 to 18 GHz. The company puts it together for you in one package that costs less, weighs less and takes less space than two separate amplifiers.

VENDORVIEW

AR RF/Microwave Instrumentation, www.arworld.us.

Low Noise Amplifier



Eclipse Microdevices' EMD-1725 is a 40 GHz GaAs MMIC PHEMT distributed general purpose low noise amplifier. This 2.3 × 1.55 × 0.1 mm thick LNA has a small signal gain of 15 dB and is ideal for applications that require a typical P1dB output power of +15 dBm at 36 GHz, while requiring only 110 mA from a +8 V supply. The EMD-1725 has a slightly positive gain slope above 15 GHz which is ideal for most commercial and industrial applications.

Eclipse Microdevices, www.eclipsemicrowave.com.

eLEARNING center

October Short Course Webinars

RF/Microwave Training
RF and Microwave Filters
Sponsored by: AWR and Rohde & Schwarz
Live webcast: 10/2/13, 11:00 AM ET

Innovations in EDA
Designing with 4G Modulated Signals for Optimized Multi-Standard Transceiver ICs
Presented by: Agilent Technologies
Live webcast: 10/3/13, 10:00 AM ET or 1:00 PM ET

Technical Education Training
VCO Fundamentals
Sponsored by: Mini-Circuits
Live webcast: 10/15/13, 11:00 AM ET

Market Research Series
Technology Trends for Land-Based Electronic Warfare Systems
Sponsored by: Rohde & Schwarz
Live webcast: 10/17/13, 11:00 AM ET

Technical Education Training
Novel Very-Near-Field Measurement Technique to Test Large Directional Antennas in Minutes
Presented by: EMSCAN
Live webcast: 10/30/13, 11:00 AM ET

CST Webinars
High-Speed Serial Link: Full-Wave EM Modeling Methodology and Measurement Correlation
Live webcast: 10/1/13, 11:00 AM ET

Simulation and Measurement: Complementary Design Tools
Live webcast: 10/17/13, 11:00 AM ET

MIMO Antenna Systems for Advanced Communication
Live webcast: 10/24/13, 11:00 AM ET

Electromagnetic Simulation of Composite Materials and Cable Harnesses in Aircraft
Live webcast: 10/31/13, 11:00 AM ET

Past Webinars On Demand

Technical Education Training Series
- Fundamentals of Envelope Tracking and Test
- INSIGHT– Analysis and Diagnostic Software for Antenna Measurement Post Processing
- Filtering Solutions Improve Dynamic Range of IMD
- An Introduction to Continuous Mode RF Power Amplifier Design
- RF PCB Design
- Fundamental Tradeoffs for Space, Air and UAV SAR

CST Webinar Series
- Modeling and Simulation of Metamaterial-based Devices for Industrial Applications
- High Speed and High Power Connector Design

Innovations in EDA/Signal Generation & Analysis
Presented by: Agilent EEsof EDA/Agilent Technologies
- Advanced Passive Intermodulation (PIM) Measurement System
- Designing Custom RF and Analog Filters Through Direct Synthesis
- Beyond CMOS vs. GaAs – Finding the Best Technology Mix for a Handset PA

Agilent in Aerospace/Defense Series
- Vector Modulation and Frequency Conversion Fundamentals
- LTE Design and Test Challenges for Public Safety Radio and SDR Applications
- Multi-Antenna Array Measurements Using Digitizers

Agilent in LTE/Wireless Communications Series
- Validating Performance of Satellite Navigation Systems and Receivers
- MIMO Over the Air (OTA) Handset Performance and Testing
- Your LTE Devices Need to Pass Conformance Tests – Now What?

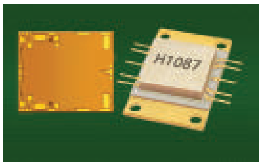
FieldFox Handheld Analyzers Series
Presented by: Agilent Technologies
- Correlating Microwave Measurements Between Handheld and Benchtop Analyzers

RF/MicrowaveTraining
- Mixers and Frequency Conversion

Register to attend at mwjournal.com/webinars

Microwave Journal
Frequency Matters.

GaN MMIC PA



Hittite announced the HMC1086F10, a 25 W GaN MMIC power amplifier that operates between 2 and 6 GHz, and is provided in a 10-lead flange mount package. The amplifier typically provides 23 dB of small signal gain, +44 dBm saturated output power and delivers +46 dBm output IP3 at +33 dBm output power per tone. The amplifier draws 1100 mA quiescent current from a +28 V DC supply. It features compact die sizes, high output power capability and simplified biasing.

VENDORVIEW

Hittite Microwave Corp., www.hittite.com.

Zero-Drift Amplifier

Linear introduced the LTC2057HV, a zero-drift amplifier featuring self-calibrating circuitry that provides high DC precision and stability over changes in temperature, time, input range and supply voltage. With 5 µV input offset voltage, 0.025 µV/°C offset drift and 220nVP-P low frequency noise with no 1/f noise, the LTC2057HV offers more than 140 dB dynamic range while operating on a 60 V (±30 V) supply. This wide dynamic range enables tiny signals to be amplified in the presence of much larger signals without saturating the amplifier or losing precision.

VENDORVIEW

Linear Technology, www.linear.com.

Broadband Amplifier

Model MSH-4482501 is a new ultra-broadband amplifier offering low noise figures, good gain flatness, and output power. This model operates on 1 to 6 GHz with 28 dB gain, noise figure of 2.5 dB, +24 min. Pout (1 dBm), VSWR 2.0:1, and DC power +12.0 V/300 mA. The bandwidth makes this amplifier useful for many applications including ECM instrumentation and test sets.

Microwave Solutions, www.microwavesolutions.com.

Low Noise/High Gain Amplifier

MITEQ's new model JS5-26004000-27-10P is a state-of-the-art 26 to 40 GHz low noise high gain amplifier with only 2.7 dB maximum noise figure and +10 dBm minimum P1dB. This model has a gain of 36 dB minimum in a small hermetically sealed package with field replaceable K-connectors. MIL-883 screening is also available. Different options such as low gain, noise figure and power output are also available.

MITEQ, www.miteq.com.

Materials

Antenna Grade Laminates

Rogers Corp. Advanced Circuit Materials Division introduced improved high frequency materials to address several market needs. The improved RO4700JXR™ Series antenna grade laminates were designed for use in base station, RFID and other antenna designs and combine low-loss dielectric with low-profile copper foil for reduced passive intermodulation (PIM) and low insertion loss. The specially formulated RO4700JXR thermoset resin system incorporates a hollow microsphere filler resulting in a light weight, low density laminate, which is approximately 30 percent lighter weight than woven-glass PTFE materials.

VENDORVIEW

Rogers Corp., www.rogerscorp.com.

Antenna

Omni Antenna

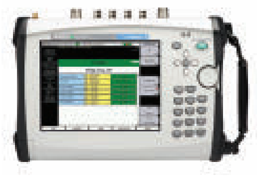
Signal Antenna Systems' (SAS) UWB300 is an ultra-wide vertical omni, suitable for transmit/rcv, and covers 300-12, 400 MHz (useable to 20 GHz), with dipole or better gain. SAS is a small dynamic organization dedicated to the design, development and production of state of the art antennas and related systems for military and commercial applications in the frequency range of 0.01 to 13 GHz. SAS provides design services as well as products, all supported by outdoor and indoor (anechoic chamber) test facilities.

Signal Antenna Systems, www.signalantenna.com.

Test Equipment

Handheld Tester

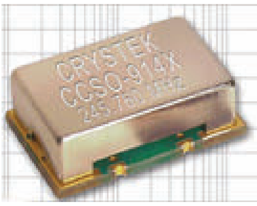
Anritsu Co. introduced the MT8220T BTS Master, a multi-function handheld durable tester with all the capabilities network operators, subcontractors, installers, and regulatory authorities need when measuring base stations. The third generation of Anritsu's field-proven BTS Master family, the MT8220T has improved performance, including a standard GPS receiver, enhanced two-port dynamic range, faster LTE scanner, and expanded spectrum analysis capability, in a design that is thinner and lighter than previous models.



VENDORVIEW

Anritsu Co., www.anritsu.com.

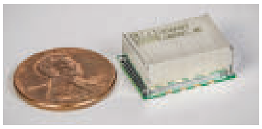
Clock Oscillator



Crystek Crystals announced the release of a 245.760 MHz SAW clock oscillator (in single frequency band), the CCSO-914X-245.760. Crystek designed the module using proprietary circuitry and surface acoustic wave (SAW) resonator technology to provide ultra-low jitter/phase noise performance with true SineWave output. The resulting oscillator features -150 dBc/Hz phase noise at 10 KHz offset and a noise floor of -169 dBc/Hz.

Crystek Crystals, www.crystek.com.

OCXO

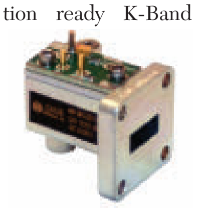


NEL Frequency Controls announced the release of a new, tiny ultra low phase noise OCXO at 100 MHz. The O-CS8-0X Series comes in a 14 × 21 × 6.8 mm surface-mount package. This OCXO offers superior close-in phase noise of -135 dBc/Hz and -180 dBc/Hz phase noise on the floor. The O-CS8-0X features an SC-cut crystal and a frequency range of 80 to 120 MHz. Stabilities range from ±50 ppb with temperatures of -55° to 85°C. It has a Sine wave +17 dBm output.

NEL Frequency Controls Inc., www.nelfc.com.

Gunn Oscillator

Model SOL-24307-42-VG is a low cost, production ready K-Band varactor tuned Gunn oscillator. The VCO's center frequency is set at 24.125 GHz with ±150 MHz frequency modulation bandwidth and +7 dBm nominal output power. The VCO operates from a single +5 V DC power supplier and typically draws 250 mA current and requires 0 to +15 V voltage swing for electrical tuning. The VCO is designed and manufactured to meet FCC Parts 15 regulations and exhibits -0.8 MHz/°C frequency and -0.03 dB/°C power stability.



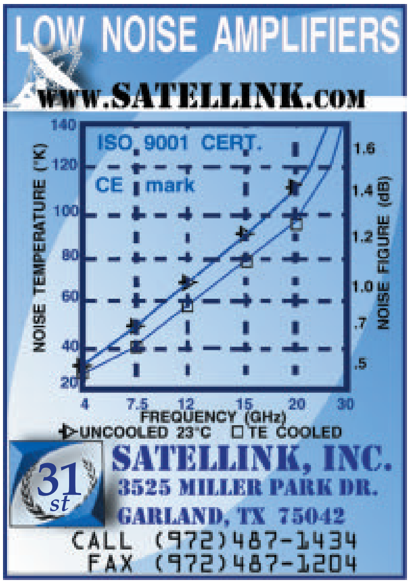
VENDORVIEW

SAGE Millimeter Inc., www.sagemillimeter.com.

SSPO

Tokyo Keiki introduced an ISM band (2.45 GHz) power source. The solid state power oscillator (SSPO) operates with 28 V DC and offers up to 1 kW output, including 2.45 GHz oscillator, power amplifier, I/F control cards, protection circuits, monitor, etc. Features are: small size, light weight and long operating life (>10 years). Output power (1 to 100 W at CW) and frequency (2.4 to 2.5 GHz) are adjustable as per your request.

Tokyo Keiki Inc., www.tokyo-keiki.co.jp.


LOW NOISE AMPLIFIERS
WWW.SATELLINK.COM
ISO 9001 CERT.
CE mark
NOISE TEMPERATURE (°K)
NOISE FIGURE (dB)
FREQUENCY (GHz)
UNCOOLED 23°C
TE COOLED
31 st
SATELLINK, INC.
3525 MILLER PARK DR.
GARLAND, TX 75042
CALL (972)487-1434
FAX (972)487-1204


LOGUS
Since 1961
HIGH-REL
Waveguide Switches
WR10 thru WR975
Ground · Sea
Air · Space
Ultralight
VALUE · QUALITY · FAST DELIVERY
LOGUS.com
p: 561-842-3550
f: 561-842-2196


AST Advanced Switch Technology
20
MICROWAVE SWITCHES FOR THE TELECOM INDUSTRY
AST'S OUTDOOR SWITCHES
For all outdoor & severe weather applications
754 Fortune Crescent, Kingston, ON, K7P 2T3, Canada
Tel: 613 384 3939 - e-mail: info@astswitch.com
WWW.ASTSWITCH.COM

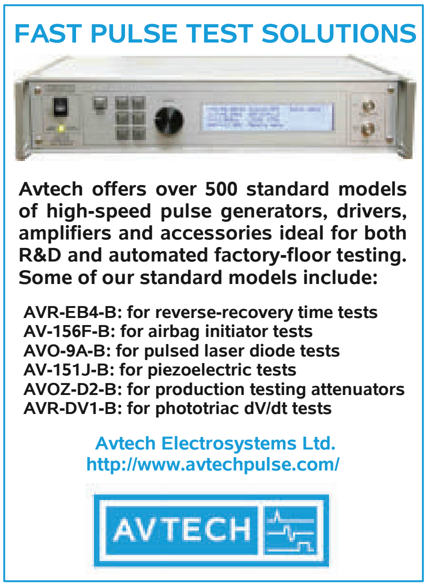

AT&T 3G
Microwave Journal
See Our
Augmented
Reality Issue
Coming
January 2014

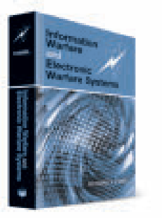

KR Electronics
www.krfilters.com
ISO 9001:2008 Certified
Custom & Standard Filters
40+ Years of Military & Commercial Applications
Bandpass
Anti-Aliasing
Highpass
Video Filters
Diplexers
Delay Equalized
Surface Mount
Lowpass
Notch
Root Cosine
Equalizers
Linear Phase
Absorptive
Matched
KR Electronics, Inc.
Avenel, NJ
www.krfilters.com
sales@krfilters.com
Phone 732.636.1900
Fax 732.636.1982


DI COAX SETUPS
•Std Sizes •Cal Std's •Loading Aids
M07T 1 MHz - 18 GHz, 1000T 1 MHz - 5 GHz
1500T 1 MHz - 3 GHz, 3000T 1MHz - 2 GHz
Model M07T with Platform
μ,ε, σ - MuEpsln™ sfwr
Granular Materials, Liquids, Solids
www.damaskosinc.com
(610)358-0200 fax(610)558-1019


AST Advanced Switch Technology
MICROWAVE SWITCHES FOR THE TELECOM INDUSTRY
WAVEGUIDE SWITCHES - COAXIAL SWITCHES - DUAL SWITCHES
WE ARE THE WAVEGUIDE & COAXIAL SWITCH EXPERTS
YOUR #1 SOURCE FOR MICROWAVE SWITCHES
QUALITY, SERVICE & QUICK DELIVERIES UNMATCHED IN THE INDUSTRY
Celebrating 1992 - 2012
20 YEARS
754 Fortune Crescent, Kingston, ON, K7P 2T3, Canada
Tel: 613 384 3939 - Fax: 613 384 5026
e-mail: info@astswitch.com
WWW.ASTSWITCH.COM


SECTOR MICROWAVE
INDUSTRIES, INC.
* DPDT
* TYPE N, SMA, BNC, TNC
* MANUAL OVERRIDE
* DC THROUGH 23 GHZ.
(631) 242-2300 FAX (631) 242-8158
www.sectormicrowave.com


FAST PULSE TEST SOLUTIONS
Avtech offers over 500 standard models of high-speed pulse generators, drivers, amplifiers and accessories ideal for both R&D and automated factory-floor testing. Some of our standard models include:
AVR-EB4-B: for reverse-recovery time tests
AV-156F-B: for airbag initiator tests
AVO-9A-B: for pulsed laser diode tests
AV-151J-B: for piezoelectric tests
AVOZ-D2-B: for production testing attenuators
AVR-DV1-B: for phototriac dV/dt tests
Avtech Electrosystems Ltd.
http://www.avtechpulse.com/
AVTECH



Information Warfare and Electronic Warfare Systems

Richard A. Poisel

Information warfare/information operations (IW/IO) has evolved as an approach to bring information technologies (IT) to the battlefield. This book is one of the first in the field to address communication electronic warfare (EW) systems in the context of information warfare. Authored by a recognized leading authority, Richard Poisel, this book includes EW system performance and presents results of system simulations that have not appeared previously in any related literature. The book explores the properties of information, the properties of information communication means, information theory, EW system architectures and two operational simulations – one in Northeast Asia and the other in urban terrain.

This book focuses on EW and how EW systems and principles can be employed in the IW/IO discipline. EW includes all aspects of electronic systems that radiate electromagnetic waves in some sense. It is a fairly broad area, but this book focuses on communications EW and how well EW systems operate against an adversary's attempts to exchange information. The taxonomy of EW includes three separate but related areas that are covered in this book: electronic support, electronic attack and electronic protection.

This book is intended for technical engineering personnel who are either new to the EW field or are practicing professionals who would like a different view of evaluating EW system performance. A degree in engineering is generally required with a working knowledge of linear system theory. The book includes linear mathematical systems that are usually considered within the domain of matrix theory. Some of the material is useful for understanding the characteristics of information as a discipline and is relatively nontechnical in nature. A working knowledge of probability theory is also useful; however, the necessary fundamental material is introduced when needed. Overall, this is a good book for engineers looking to explore or learn more about EW systems.

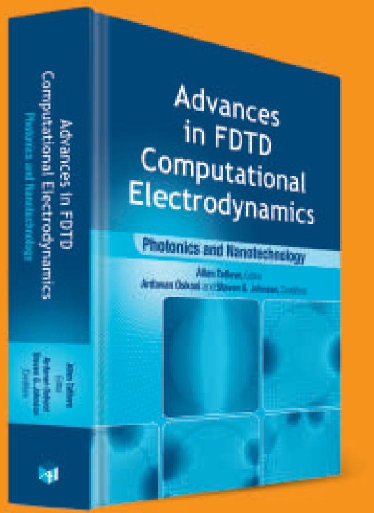
To order this book, contact:

Artech House
685 Canton Street
Norwood, MA 02062
(800) 225-9977
or
16 Sussex Street,
London, SW1V 4RW, UK
+44 (0) 20 7596 8750

415 pages, $129
ISBN: 978-1-60807-705-2

ARTECH HOUSE

New 2013 Publication!



Advances in FDTD Computational Electrodynamics: Photonics and Nanotechnology

Allen Taflove, Editor
Ardavan Oskooi and Steven G. Johnson, Coeditors

Edited by an outstanding team of authorities in computational electrodynamics, including the pioneer of the FDTD method, this book helps you understand the latest developments in:

- Computational modeling of nanoscale optical microscopy and microchip lithography;
- Modeling plasmonics, including nonlocal dielectric functions, molecular interactions, and multi-level semiconductor gain;
- Nanoscale biophotonics, especially for detecting early-stage cancers;
- Quantum vacuum, including the Casimir effect and blackbody radiation.

Hardcover • 670 pp. • 2013
ISBN: 978-1-60807-170-8 • $139 / £92

US: **Call** 1-800-225-9977 (in the U.S. or Canada), or 1-781-769-9750, ext. 4030
Fax to: 1-781-769-6334
E-mail to: artech@ArtechHouse.com

UK: **Call** +44 (0)20 7596 8750
Fax to: +44 (0)20 7630-0166
E-mail to: artech-uk@ArtechHouse.com

For complete description and to order, visit
ArtechHouse.com
Plus shipping/handling and applicable taxes.

ARTECH HOUSE
BOSTON | LONDON
685 Canton Street, Norwood, MA 02062 USA
16 Sussex Street, London SW1V 4RW UK

IEEE Advancing Technology for Humanity

IEEE COMCAS 2013

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

David Intercontinental Hotel, Tel Aviv, Israel, October 21-23, 2013

Take advantage of our advanced registration at reduced cost!

3-day International IEEE Conference
2-day Technical Exhibition with over 90 displays

IEEE COMCAS 2013, ***The International IEEE Conference on Microwaves, Communications, Antennas and Electronic Systems***, continues the tradition of providing a multidisciplinary forum for the exchange of ideas, research results, and industry experience in the areas of microwaves, communications, antennas, solid state circuits, electromagnetic compatibility, electron devices, radar and electronic systems engineering. It includes a technical program, industry exhibits, and invited talks by international experts in key topical areas.

Keynotes speakers will be **Dr. Adam Drobot**, Past President, Advanced Technology Solutions and CTO, Telcordia Technologies, Inc., USA.

The conference program will be complemented with a Technical Exhibition of over 90 displays, offering attendees from industry, academia and government a unique opportunity to network with relevant companies, vendors and technologies from Israel and abroad.

The conference will take place in Tel Aviv, ranked by Lonely Planet third in the list of top 10 cities of the world for 2011, as well as among the 10 best beach cities of the world. Tel-Aviv is not only the cultural center of Israel and a major touristic attraction in itself (declared a "World Cultural Heritage Site" by UNESCO in 2003), but also a convenient base for country-wide tours of major cultural, historical, religious and natural attractions such as Jaffa, Jerusalem, Nazereth, Capernaum, The Sea of Galilee, The Dead Sea, Massada and more.

On both a professional and personal level, we have something for everyone and we look forward to welcoming you in Tel Aviv!

Conference Chair:
Shmuel Auster

Technical Program Chair and Co-chairs:
Stephen B. Weinstein, Richard V. Snyder, Peter de Maagt, Lance M. Kaplan

For further information and registration forms:

www.comcas.org

Diamond Patron: Agilent Technologies

Platinum Patrons: Mini-Circuits, Intel, Interlligent RF & Microwave Solutions, Herley - Israel A Kratos Company, M/A-COM, Mi Summit, TriQuint Reach Further • Reach Faster, CST

Gold Patrons: Anritsu Discover What's Possible, ANSYS, AWR, EIM, Integra Technologies, Inc., RFMD, SVG, Sonnet

Patrons: IAI Elta, Orbit/FR

Media Support: Microwave Journal, Commtech Knowledge

Technical Co-Sponsors: AESS, EuMA, IET, MTT-S, Region 8

Advertising Index

Sales Representatives

Microwave Journal
Frequency Matters.

Carl Sheffres, Publisher

Ed Kiessling, Traffic Manager

Eastern and Central Time Zones
Chuck Boyd
Northeast Reg. Sales Mgr.
(New England, New York, Eastern Canada)
685 Canton Street
Norwood, MA 02062
Tel: (781) 769-9750
FAX: (781) 769-5037
cboyd@mwjournal.com

Michael Hallman
Eastern Reg. Sales Mgr.
(Mid-Atlantic, Southeast, Midwest)
4 Valley View Court
Middletown, MD 21769
Tel: (301) 371-8830
FAX: (301) 371-8832
mhallman@mwjournal.com

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

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

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

Israel
Liat Heiblum
Oreet International Media
15 Kineret Street
51201 Bene-Berak, Israel
Tel: +972 3 570 6527
FAX: +972 3 570 6526
liat@oreet-marcom.com

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

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

China
Michael Tsui
ACT International
Tel: 86-755-25988571
Tel: 86-21-62511200
FAX: 86-10-58607751
michaelT@actintl.com.hk

Hong Kong
Mark Mak
ACT International
Tel: 852-28386298
markm@actintl.com.hk

CERAMIC FILTERS

LOW PASS BANDPASS HIGH PASS

45 MHz to 15 GHz *from* 99¢ *ea. qty.3000*

Over ~~167~~ 185 models...only 0.12 x 0.06" These tiny hermetically sealed filters utilize our advanced Low Temperature Co-fired Ceramic **(LTCC)** technology to offer superior thermal stability, high reliability, and very low cost, making them a must for your system requirements. Visit our website to choose and view comprehensive performance curves, data sheets, pcb layouts, and everything you need to make your choice. You can even order direct from our web store and have units in your hands as early as tomorrow!

***Wild Card** KWC-LHP LTCC Filter Kits* *only* $98

Choose any 8 LFCN or HFCN models
Receive 5 of ea. model, for a total of 40 filters
Order your KWC-LHP FILTER KIT TODAY!

RoHS compliant U.S. Patents 7,760,485 and 6,943,646

Now available in small-quantity reels at *no extra charge:*
Standard counts of 20, 50, 100, 200, 500, 1000 or 2000. Save time, money, and inventory space!

Mini-Circuits®

www.minicircuits.com P.O. Box 35166, Brooklyn, NY 11235-0003 (718) 934-4500 sales@minicircuits.com

Knowledge Feed

Sources: Kumar, Liu, Sengupta and Divya, "Evolution of Mobile Wireless Communication Networks: 1G to 4G," IJECT, December 2010. 4GAmericas.org, "Infographic: Mobile Broadband Connected Future." White, "Tablets trump smartphones in global website traffic" Adobe Digital Marketing blog, March 6, 2013. Meeker and Wu, "Internet Trends 2013" kpcb.com. Ericsson Consumer Insight Summary Report, June 2013.

© 2013 CommScope, Inc. MM-107138-EN (8/13)

Fast. Accurate.
Power Meters from Rohde & Schwarz.

- World's fastest
- More than 9500 measurements/s
- USB capable

For decades, RF professionals have trusted power measurement solutions from Rohde & Schwarz. With their unrivaled speed and fidelity, the R&S®NRP-Z8x USB wideband power sensors are the market leaders.

More to explore:
www.rohde-schwarz.com/ad/powersensors

ROHDE&SCHWARZ

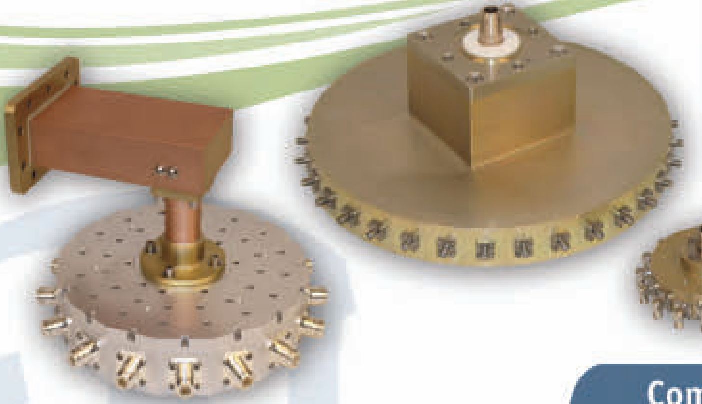
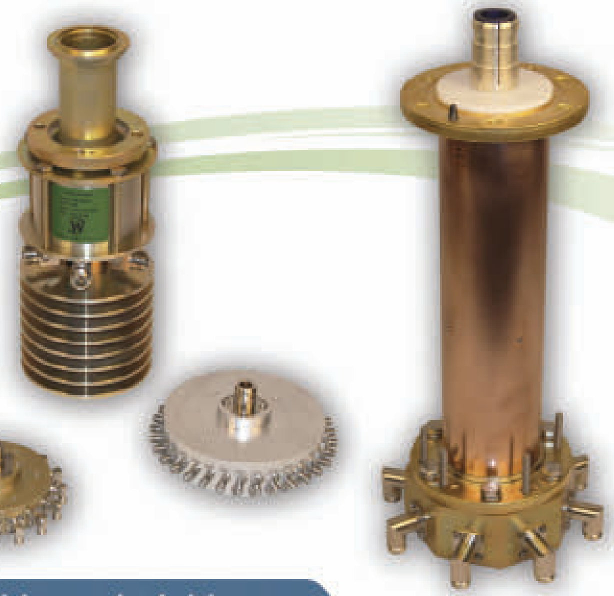
WERLATONE®

Mismatch Tolerant®

HIGH POWER, MULTI-OCTAVE PERFORMANCE

Radial Combiners

- Multi-kW Power Levels
- Lowest Loss
- Custom Designs Available

Combiners / Dividers

Model	Type	Frequency (MHz)	Power (W CW)	Insertion Loss (dB)	VSWR	Connectors (Sum Port, Inputs/Outputs)
D8182	5-Way	1175-1375	1,500	0.4	1.35:1	1 5/8" EIA, N Female
D8454	8-Way	370-450	10,000	0.25	1.30:1	3 1/8" EIA, N Female
D9710	8-Way	1000-2500	2,000	0.3	1.40:1	1 5/8" EIA, N Female
D9529	8-Way	2305-2360	1,000	0.2	1.15:1	7/16 Female, N Female
D9528	8-Way	2305-2360	2,000	0.2	1.15:1	7/8" EIA, N Female
D5320	12-Way	470-860	500	0.3	1.30:1	All N Female
D9194	16-Way	2305-2360	1,000	0.2	1.15:1	7/16 Female, SMA
D9527	16-Way	2305-2360	2,000	0.2	1.15:1	7/8" EIA, N Female
D9706	16-Way	2700-3500	6,000	0.35	1.35:1	Waveguide, N Female
D6857	32-Way	1200-1400	4,000	0.5	1.35:1	1 5/8" EIA, TNC

Werlatone®, Inc.
17 Jon Barrett Road
Patterson, NY 12563
T 845.278.2220
F 845.278.3440
www.werlatone.com

Mismatch Tolerant® is a registered trademark of **Werlatone, Inc.**


Directional Couplers


0° Combiners/Dividers


90° Hybrid Couplers


180° Hybrid Combiners


Absorptive Filters

Semiconductors • First Response • Medical • In-Building • Military Comm and EW