

Vol. 60 • No. 6

June 2017

Microwave Journal

.com



horizon
house®

Founded in 1958

MVP
R&S
Signal
Generator

BETTER COMMUNICATION SOLUTIONS



Low PIM Couplers
IP67/68



Low PIM Attenuators
IP67/68

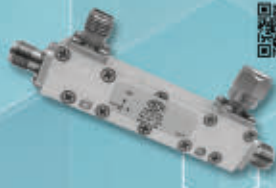
4.3/10.0



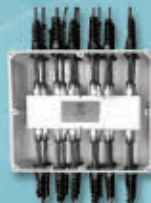
Low PIM Terminations
IP67/68



Power Divider/Combiner
MIL-DTL-23971 Available



Directional Couplers
MIL-DTL-15370 Available



Tower Top & D.A.S Equipment
IP67/68, NEMA & EN50155



Public Safety
Homeland Security



Satcom, mmWave
& Military



Aeronautical/Space
Transportation



AMER, EMEA
D.A.S



MECA 5G Products & Equipment

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

various mounting solutions. Since 1961 MECA Electronics (Microwave Equipment & Components of America) has served the RF/Microwave industry with equipment and passive components covering Hz to 40 GHz. MECA is a privately held ISO9001:2008 Certified, global designer and manufacturer for the communications industry with products manufactured in the United States of America. We stock products so that you do not need to.

Buy Online

Products in STOCK when you need them!



RFPartsOnDemand.com

MECA Electronics, Inc.
Microwave Equipment & Components of America

459 E. Main St., Denville, NJ 07834

Tel: 973-625-0661 • Fax: 973-625-9277 • Sales@e-MECA.com

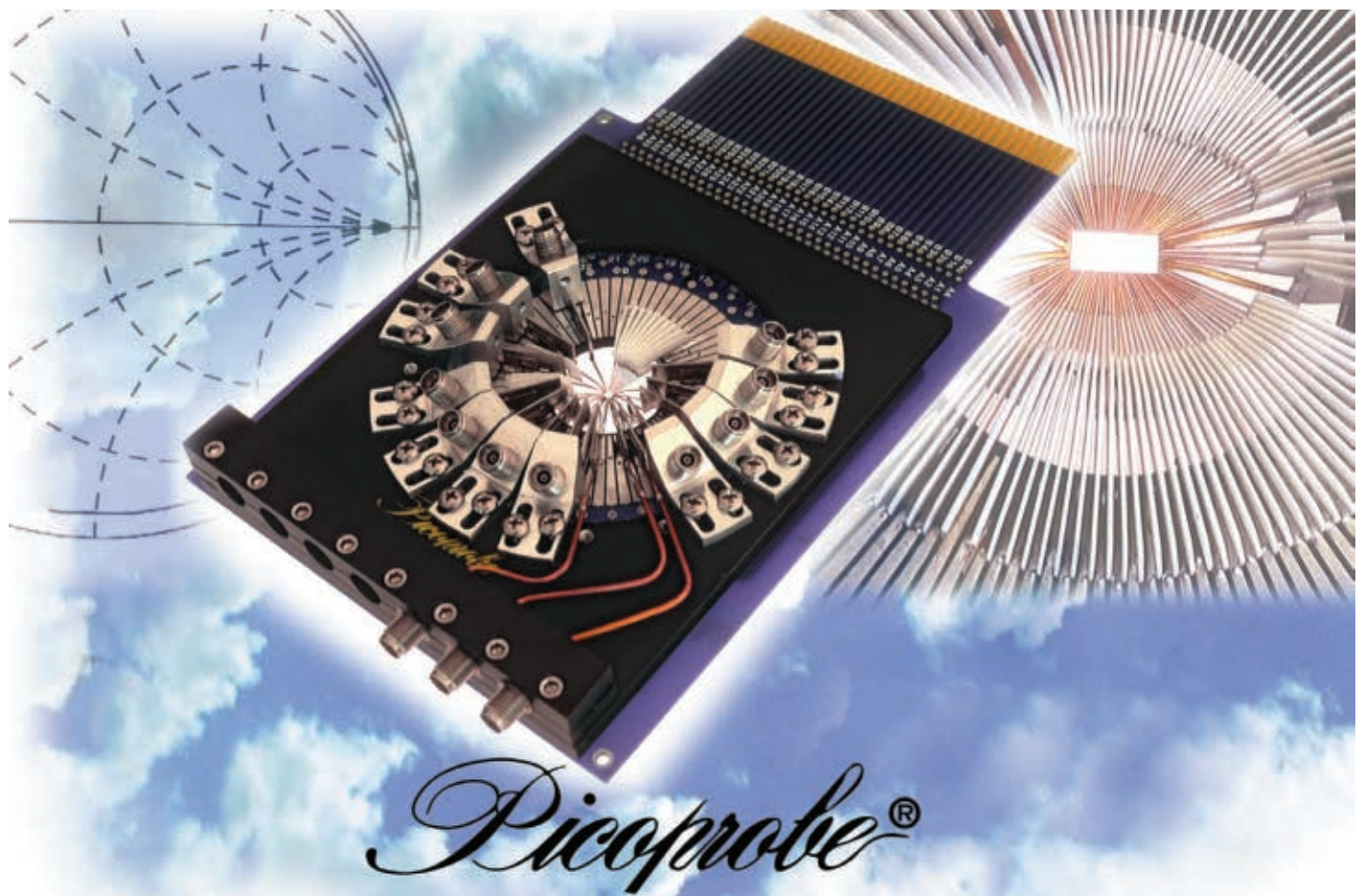


e-MECA.com
Since 1961



iBwave





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





POWER SPLITTERS/ COMBINERS

from **2 kHz to 40 GHz** as low as **89¢** ea. (qty. 1000)

NEW!

**THE WIDEST BANDWIDTH IN THE INDUSTRY
IN A SINGLE MODEL!**

EP2K1+ 2 to 26.5 GHz

EP2W1+ 0.5 to 9.5 GHz

EP2C+ 1.8 to 12.5 GHz


*The industry's largest selection includes **THOUSANDS** of models from 2 kHz to 40 GHz, with up to 300 W power handling, in coaxial, flat-pack, surface mount and rack mount housings for 50 and 75Ω systems.*

From 2-way through 48-way designs, with 0°, 90°, or 180° phase configurations, Mini-Circuits' power splitter/combiners offer a vast selection of features and capabilities to meet your needs from high power and low insertion loss to ultra-tiny LTCC units and much more.

Need to find the right models fast? Visit minicircuits.com and use Yoni2®!

It's our patented search engine that searches actual test data for the models that meet your specific requirements! You'll find test data, S-parameters, PCB layouts, pricing, real-time availability, and everything you need to make a smart decision fast!

All Mini-Circuits' catalog models are available off the shelf for immediate shipment, so check out our website today for delivery as soon as tomorrow!

 **RoHS Compliant**
Product availability is listed on our website.

 **Mini-Circuits®**



Communications & Power Industries

beverly microwave division

CPI Beverly Microwave Division

Who We Are

Did you know we are
**the world's largest manufacturer
of receiver protectors?**

Premier radar manufacturers depend
on our level of experience and our
advanced technology for supplying
components to integrate or update the
most complex radar systems.

See why
CPI Beverly Microwave Division is
recognized as the go-to supplier
for the world's premier
radar manufacturers.

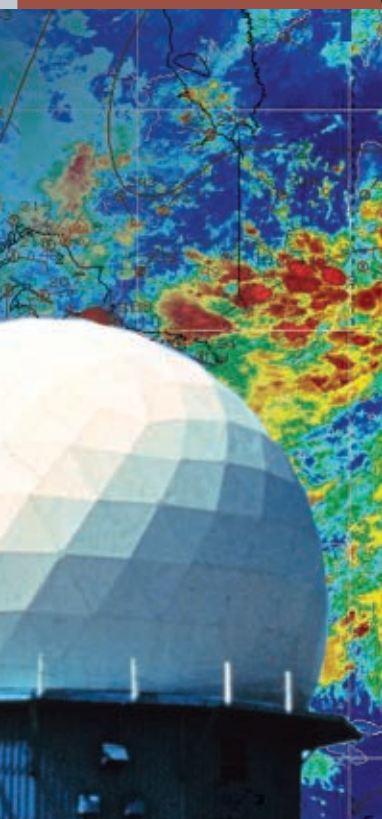
CPI BMD products are
often integral parts of
everyday life ...

**Our
components
are found
in most:**

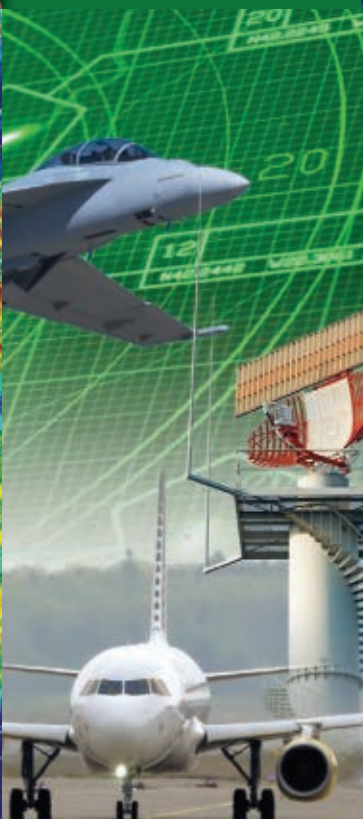
- Weather radar systems
- Air traffic control radars
- Cargo screening systems
- Particle accelerators
- Medical linear accelerators
- Unmanned aerial vehicles (UAV's)
- Ground based radar systems
- Missile seekers
- Naval radar systems
- Airborne radar and EW

Contact the radar experts at BMD to upgrade your system today at www.cpii.com/bmd

WEATHER RADAR



ATC RADAR



RADAR & EW



TEST & MEASUREMENT





Digitally-Tuned Bandpass Filters with Continuously Adjustable Bandwidth

- Adjustable Bandwidth
 - Adjustable Center Frequency
 - Suitable for LTE and WiFi testing
 - Custom Bandwidth Ranges and Center Frequency Ranges
- Made to Order**

Today's 4G wireless communication systems with carrier aggregation are predominantly using LTE signals modulated over several bandwidths, typically 5 MHz, 10 MHz, 15 MHz, 20 MHz and 40 MHz. Signals generally span from 700 MHz to 6000 MHz. Filtering is often required to reduce harmonics and improve dynamic range when testing LTE products. To replace the large number of fixed filters usually required, K&L has developed

and is now shipping a filtering system that can tune a bandpass filter anywhere in the 700 MHz to 6000 MHz range with continuously adjustable bandwidth. The system has software interfaces for automated testing corresponding to the two hardware interfaces (Ethernet and GPIB), as well as a convenient web-based user interface for devices such as smartphone, tablet and traditional computer.



ENABLING COMMUNICATION AND SIGNAL CONTROL

EXPANDING PCB Capabilities

*Advanced Embedded Component Technology
from Teledyne Labtech*

Complex RF Multi-layer PCBs

- Mixed Dielectric Multilayer PCB
- Embedded resistors, connector pins and capacitors
- Complex machined and laser cut structures
- Metal-cored PCB
- Embedded copper coin technology

Advantages

- Improved thermal management
- Increased performance
- Reduced size and costs

Applications

- Ground based and airborne - X-band AESA Radar
- Commercial airline - Ku/Ka Band antenna systems
- Satellite - Complex airborne antenna array
- Ground based - Ku/Ka Band mobile Satcom



**TELEDYNE
LABTECH LIMITED**
Everywhere you look

+44 (0) 1544 260093
TeledyneLabtech.com
labtechsales@teledyne.com



The Power of Consolidation

Cougar • Defence • Labtech
MEC • Microwave • Paradise Datacom

RF-LAMBDA

THE LEADER OF RF BROADBAND SOLUTIONS

Made in USA

BROADBAND SSPA SOLID STATE POWER AMPLIFIERS

WWW.RFLAMBDA.COM

0.1-22GHZ ULTRA BROADBAND SSPA

RFLUPA01M22GA
4W 0.1-22GHZ



RFLUPA0218GA
10W 2-18GHZ

EMC BENCHTOP POWER AMPLIFIER



140W 6-18GHZ
SOLID STATE BROADBAND

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

RFLUPA02G06GC
100W 2-6GHZ



RFLUPA0706GD
30W 0.7-6GHZ

6-18GHZ C, X, KU BAND



RFLUPA0618GC
25W 6-18GHZ



RFLUPA0811GA
50W 8-11GHZ



RFLUPA06G12GB
25W 6-12GHZ

18-50GHZ K, KA, V BAND



RFLUPA18G47GC
2W 18-47GHZ



RFLUPA27G34GB
15W 27-34GHZ



RFLUPA28G42GA
2W 28-42GHZ



RFLUPA32G38GB
8W 32-38GHZ

BENCHTOP RF MICROWAVE SYSTEM POWER AMPLIFIER



RAMP06G06GA - 30W 0.01-6GHZ



RAMP39G48GA - 4W 39-48GHZ



RAMP01G22GA - 8W 1-22GHZ



RAMP27G34GA - 8W 27-34GHZ

www.rflambda.com
sales@rflambda.com

1-888-976-8880
1-972-767-5998

San Diego, CA, US
Plano, TX, US
Ottawa, ONT, Canada





Cover Feature

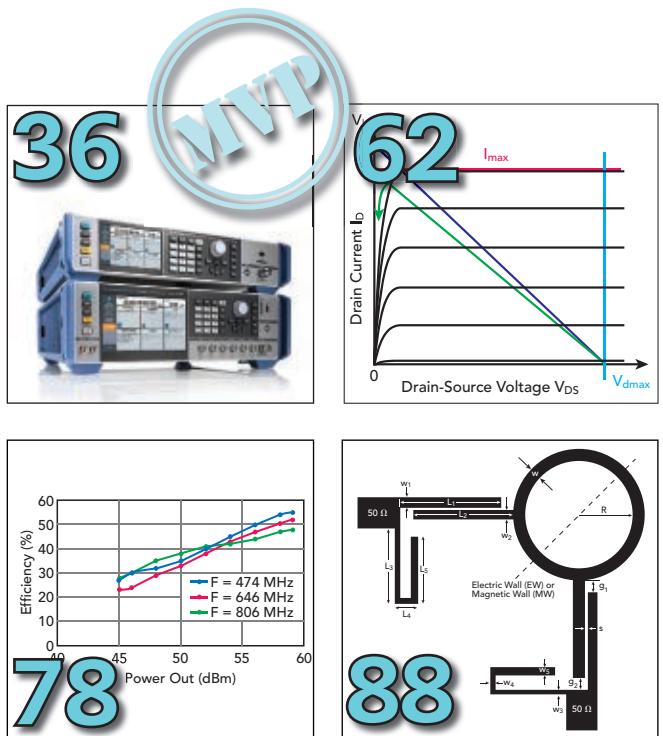
22 RFSoc Integrates RF Sampling Data Converters for 5G New Radio

Anthony Collins, Harpinder Matharu and Ehab Mohsen, Xilinx Inc.

MVP: Most Valuable Product

36 Redefining High-End RF and Microwave Signal Generation

Rohde & Schwarz



Technical Features

62 Network Synthesis and Power Amplifiers: So Much More than Impedance Matching

Gayle Collins, Nuvotronics

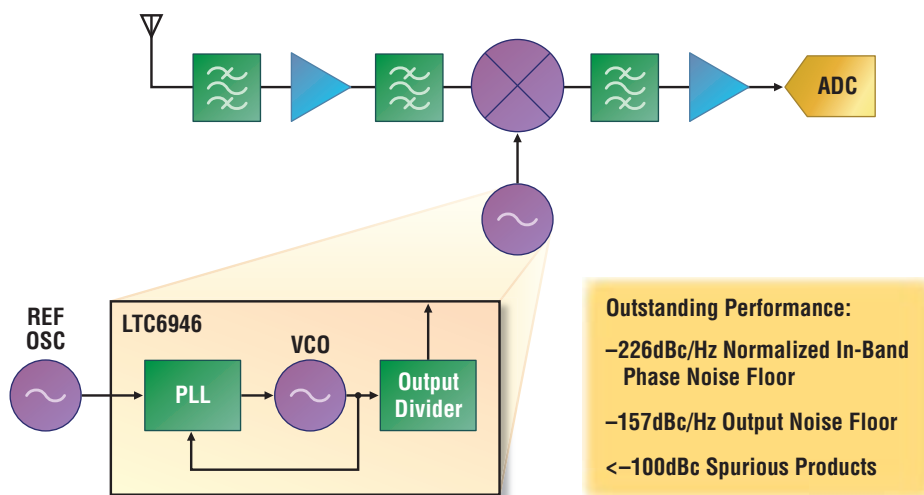
78 Ultra-Wideband Doherty Amplifier for Digital TV Transmitters

Bill Goumas and Peter Forth, Ampleon

88 Dual-Band Bandpass Filter with Multiple Controllable Transmission Zeros and Wide Stopband

Daotong Li, Yonghong Zhang, Jing Ai, Kaijun Song and Y. Fan, University of Electronic Science and Technology of China

The New Low in Frequency Synthesis



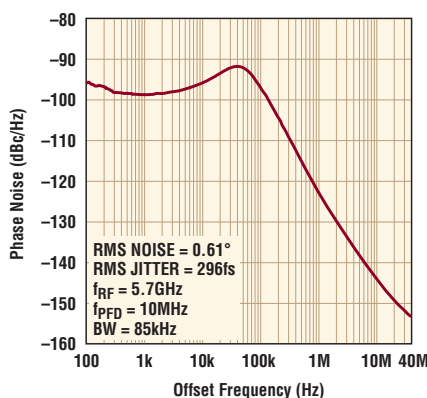
Low Noise and Spurious Levels, 375MHz to 6GHz Frequency Synthesizers

Our new ultralow noise, integer-N frequency synthesizers provide best-in-class phase noise and spurious performance. The LTC[®]6945 is a low noise, low 1/f corner PLL core for use with an external VCO while the LTC6946 is a complete frequency synthesizer including a low phase noise VCO. The free, easy-to-use PLLWizard[™] CAD tool quickly and accurately simulates synthesizer performance to ensure an optimal design. So, creating low noise designs without performance compromises is done without losing sleep.

▼ Features

- Low -226dBc/Hz Normalized In-Band Phase Noise Floor
- Industry's Lowest In-Band 1/f Noise Corner
- Spurious Levels <-100dBc
- High Current 11mA Output Charge Pump Minimizes Loop Compensation Thermal Noise
- Programmable Output Divider for Wide Operating Frequency Range

Closed-Loop Phase Noise



▼ Info & Free Samples

www.linear.com/product/LTC6946
1-800-4-LINEAR



LT, LTC, LTM, Linear Technology and the Linear logo are registered trademarks and PLLWizard is a trademark of Analog Devices, Inc. All other trademarks are the property of their respective owners.



NOW PART OF



Find your local sales office: www.linear.com/contact



Product Features

102 Small Size Synthesizer with Instrument Grade Performance

National Instruments

108 Multi-Gbps Modem Enables mmWave Fixed Wireless Access

Integrated Device Technology Inc.

Tech Briefs

112 Dual-Channel Mixer for 5G New Radio

Linear Technology, now part of Analog Devices, Inc.

114 Ultra-Low PIM Cavity Filters

MCV Microwave

114 39 GHz Tx/Rx ICs for 5G Phased Arrays

Anokiwave

Departments

17	Mark Your Calendar	116	Web and Video Update
18	Coming Events	118	New Products
43	Defense News	126	Book End
47	International Report	128	Advertising Index
51	Commercial Market	128	Sales Reps
54	Around the Circuit	130	Fabs and Labs

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 1143, Skokie, IL 60076 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.

©2017 by Horizon House Publications Inc.
Posted under Canadian international publications mail agreement #PM40612608

STAFF

Publisher: Carl Sheffres
Editor: Patrick Hindle
Technical Editor: Gary Lerude
Managing Editor: Jennifer DiMarco
Associate Technical Editor: Cliff Drubin
Copy Editor: Ashleigh West
Multimedia Staff Editor: Barbara Walsh
Contributing Editor: Janine Love
Consulting Editor: Harlan Howe, Jr.
Consulting Editor: Frank Bashore
Consulting Editor: David Vye
Consulting Editor: Raymond Pengelly
Electronic Marketing Manager:
 Chris Stanfa
Digital Content Production Specialist:
 Lauren Tully
Audience Development Manager:
 Carol Spach
Traffic Manager: Edward Kiessling
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. Bazy
President: Ivar Bazy
Vice President: Jared Bazy

EDITORIAL REVIEW BOARD

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

SUBSCRIPTION SERVICES

Send subscription inquiries and address changes to:
 Tel: (847) 291-5216
 e-mail: mwj@omeda.com



www.mwjournal.com

Printed in the USA

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.

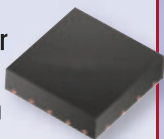
We provide many value-added services driven by customer requirements — because we know RF and microwave.

- 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



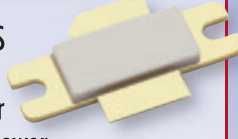
RF AMPLIFIERS

- 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



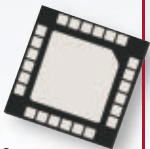
RF OSCILLATORS

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



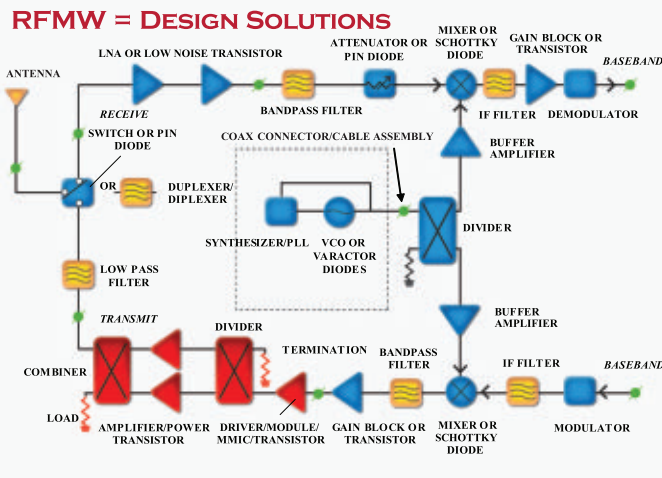
RF ATTENUATORS

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



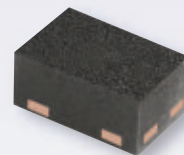
TEST & MEASUREMENT

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



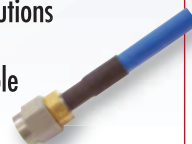
RF DIODES

- PIN
- Schottky
- Varactor
- Limiter
- Gunn



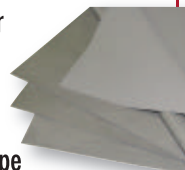
RF CABLE ASSEMBLIES

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



EMI / RFI

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



www.RFMW.com

Toll Free: 1-877-367-7369 • Fax: 1-408-414-1461

Canada 1-877-367-7369 • RFMW Mexico 1-408-414-1450 • RFMW Asia 65 6316 3389 • RFMW CO UK 44 1234 756012 • RFMW Italia 39 0774 359035
RFMW France 33 1 83 64 53 97 • RFMW Deutschland 49 8031 7969240 • RFMW Israel Ltd. 972 72 3322111 • RFMW Hong Kong Ltd. 852 2682 9330

LEARNING CENTER

MIMO Radars and Their Conventional Equivalents

Sponsored by: Rohde & Schwarz

6/14

Design Considerations and Tradeoffs for Microstrip, Coplanar and Stripline Structures at Millimeter Wave Frequencies

Sponsored by: Rogers

6/20

Getting to Know 5G: New Radio and the Race to Standardization

Sponsored by: National Instruments

6/27

Countering the UAS Challenge

Sponsored by: Rohde & Schwarz

6/28

Demystifying 5G-Numerology and Initial Access Concept for 5G NR

Sponsored by: Rohde & Schwarz

6/29

Web Survey

What RF IC technology are you designing in most?

Look for our multiple choice survey online at mwjournal.com

April Survey

For your application, which synthesizer spec most limits system performance?

Frequency coverage, resolution (36%)

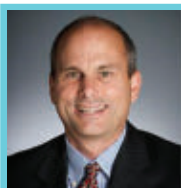
Phase noise, jitter (55%)

Spurs (0%)

Switching speed (9%)

Power dissipation (0%)

Size (0%)



5G Americas' president, **Chris Pearson**, discusses the organization's mission and member companies along with some of the major trends in 5G technology, spectrum allocation and regulation.

Executive Interviews

Jim Morgan, president and CEO of **SemiGen, Inc.**, describes the vision that started the company and how SemiGen's RF/microwave assembly services, portfolio of diodes and chip capacitors and responsive customer service are fueling growth.



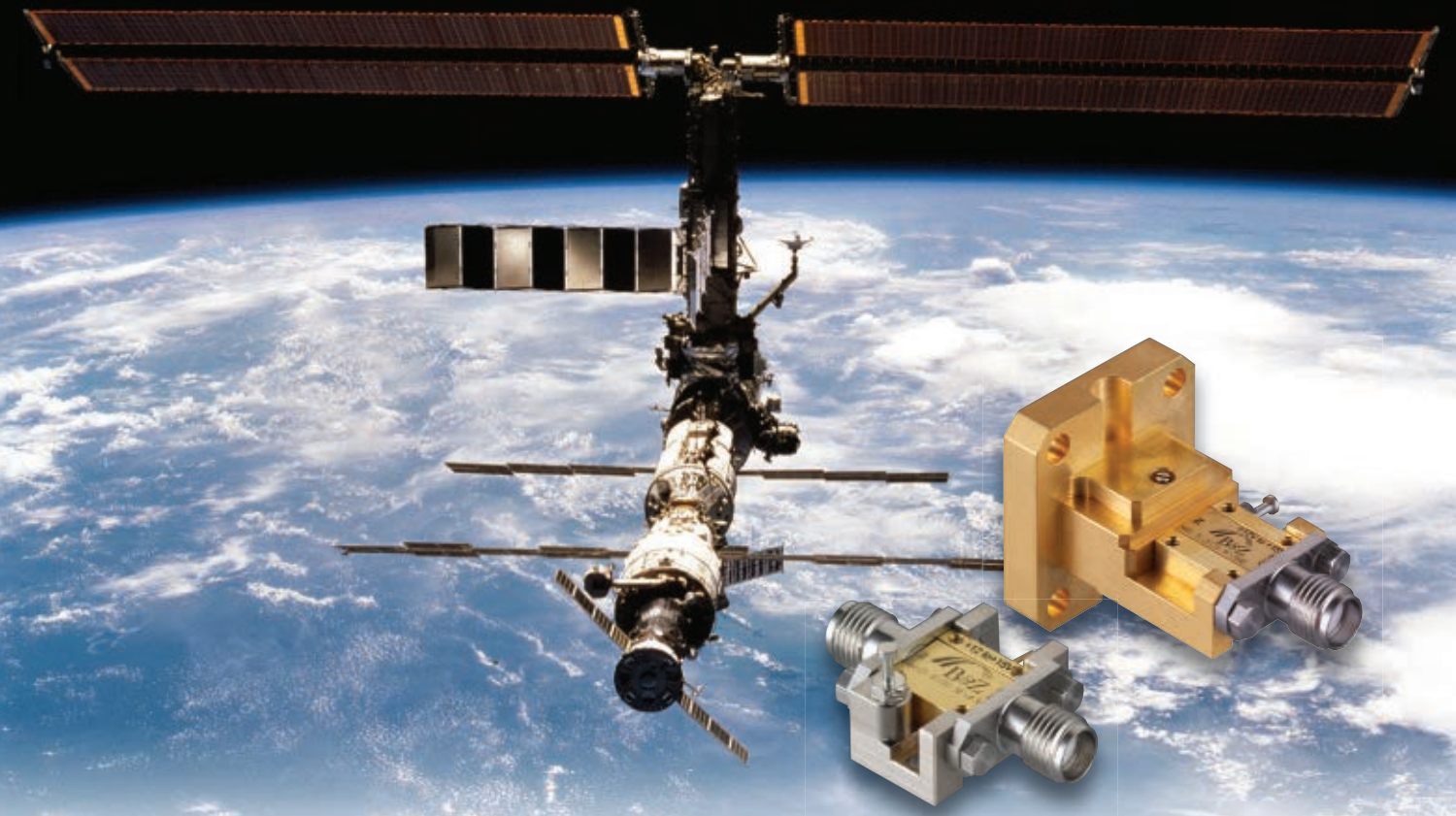
WHITE PAPERS



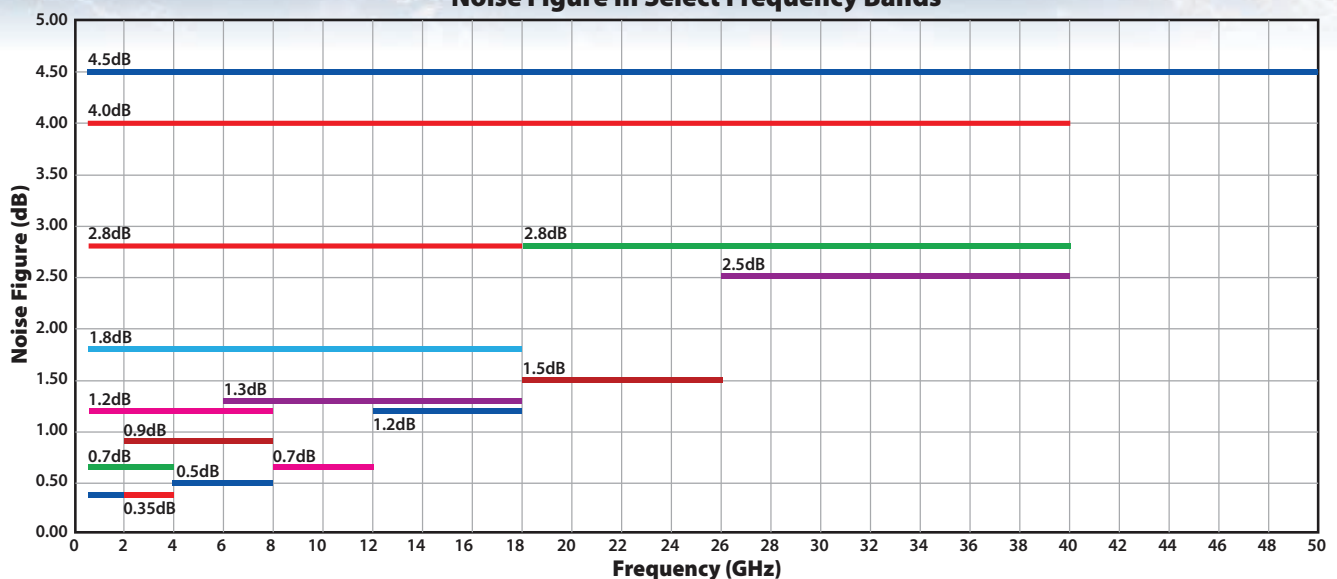
Catch Frequency Matters, the industry update from **Microwave Journal**, www.microwavejournal.com/FrequencyMatters

NEW

Has Amplifier Performance or Delivery Stalled Your Program?



Noise Figure In Select Frequency Bands





VCO's and Synthesizers

You Define It. We'll Design It.

Replacement Solutions for End-of-Life Parts. Custom Designs as Easy as 1-2-3.

Whether you need replacement parts or you have a new requirement for VCOs or synthesizers, Mini-Circuits is here to support you. Our engineers will work with you to find a solution from our extensive library of existing designs or develop a custom design to meet your needs, as easy as 1-2-3! Reach out to apps@minicircuits.com today, and see why so many customers trust Mini-Circuits as the industry's solid source.

- VCOs from 3 to 7000 MHz
- Synthesizers from 56 to 7800 MHz
- Thousands of Models in Stock
- Industry-leading design capability
- Reliable supply through the life of your system!





MARK YOUR CALENDAR

9-14

**IEEE AP-S/USNC-
URSI Symposium**
San Diego, Calif.



This year's IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting will include a wide range of technical sessions, workshops and short courses, as well as exhibits. It will also have a range of specific activities for students and young professionals. This meeting is intended

to be the premier international forum for the exchange of ideas on state-of-the-art research in antennas, propagation, electromagnetic engineering and radio science. Through a range of technical and social activities, it will provide the opportunity to interact with the world's leading experts in antennas and propagation from academia, industry and government. www.2017apsursi.org

TRAINING
11-12

**CST STUDIO SUITE - Signal Integrity
and Power Integrity Training**
Framingham, Mass.

18-19

**CST STUDIO SUITE - Microwave and
Antenna Training**
West Lafayette, Ind.



www.cst.com

25

**Technology and
Market Outlook for
Next Generation
MilSatComs**
Sponsored by:

ROHDE & SCHWARZ



25

**Call for Papers
Deadline**



Authors are invited to submit papers for presentation at RWW2018. All papers accepted will be published in a digest and included in IEEE Xplore. Radio & Wireless Week consists of five related conferences that focus on the intersection between wireless communication theory, systems, circuits and device technologies. This creates a unique forum for engineers to discuss various technologies for state-of-art wireless systems and their end-use applications.

www.radiowirelessweek.org

**SEPTEMBER
11-13**



**ED
CON**

2017

**Electronic Design Innovation
Conference & Exhibition**

**Hynes Convention
Center**
Boston, Mass.

**July 11:
Conference
materials due**

**Register now at
www.ediconusa.com**

FOR DETAILS, VISIT MWJOURNAL.COM/EVENTS

Coming Events

CALL FOR PAPERS

IEEE APMC 2017
June 20, 2017

RWW 2018
July 25, 2017

IEDM 2017
August 1, 2017

mwjournal.com

sensors
expo & conference

JUNE

Sensors Expo & Conference

June 27-29, 2017 • San Jose, Calif.
www.sensorexpo.com

MilSatCom USA

June 28-29, 2017 • Arlington, Va.
www.milsatcom-usa.com

JULY

IEEE AP-S/USNC-URSI Symposium

July 9-14, 2017 • San Diego, Calif.
www.2017apsursi.org



AUGUST

IEEE EMC + SIPI

August 7-11, 2017 • National Harbor, Md.
www.emc2017.emcss.org

Metamaterials 2017

August 28-Sept. 2, 2017 • Marseille, France
www.congress2017.metamorphose-vi.org

RFIT 2017

August 30-Sept. 1, 2017 • Seoul, South Korea
www.rfit2017.org



SEPTEMBER

EDI CON USA 2017

September 11-13, 2017 • Boston, Mass.
www.ediconusa.com

IEEE AUTOTESTCON

September 11-14, 2017 • Schaumburg, Ill.
www.autotestcon.com

MWC Americas 2017

September 12-14, 2017 • San Francisco, Calif.
www.mwcamericas.com



OCTOBER

EuMW 2017

October 8-13, 2017 • Nuremberg, Germany
www.eumweek.com

AMTA 2017

October 15-20, 2017 • Atlanta, Ga.
www.amta2017.org

IEEE CSIGS 2017

October 22-25, 2017 • Miami, Fla.
www.csigs.org

MILCOM 2017

October 23-25, 2017 • Baltimore, Md.
www.milcom.org

ITC/USA Conference

October 23-26, 2017 • Las Vegas, Nev.
www.telemetry.org

IME/China 2017

October 25-27, 2017 • Shanghai, China
www.imwexpo.com

Space Tech Expo Europe 2017

October 24-26, 2017 • Bremen, Germany
www.spacetecheurope.eu



NOVEMBER

Global MilSatCom 2017

November 7-9, 2017 • London, U.K.
www.globalmilsatcom.com

IEEE COMCAS 2017

November 13-15, 2017 • Tel Aviv, Israel
www.comcas.org

IEEE APMC 2017

November 13-16, 2017 • Kuala Lumpur, Malaysia
www.apmc2017.org

DECEMBER

IEDM 2017

December 4-6, 2017 • San Francisco, Calif.
www.ieee-iedm.org

ESC Silicon Valley

December 6-7, 2017 • San Jose, Calif.
www.escsiliconvalley.com/conference

IEEE IMaRC

December 11-13, 2017 • Ahmedabad, India
www.imarc-ieee.org



JANUARY 2018

Radio and Wireless Week

January 14-17, 2018 • Anaheim, Calif.
www.radiowirelessweek.org

DesignCon

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

PRODUCTS TO SOLUTIONS

RF Products

Ducommun has more than
50 years of experience
with the design, testing and
manufacturing of coaxial
switches and integrated systems.

Coaxial Switch

- DC to 8 GHz
- Low Insertion Loss
- High Isolation
- For use in Thermal Vacuum Chambers

Manually Controlled Switches

- DC to 22GHz
- Available in SPDT, DPDT, Multi-throw
- 200WCW
- Great for lab testing

Ultra Broadband Pin Diode Switches

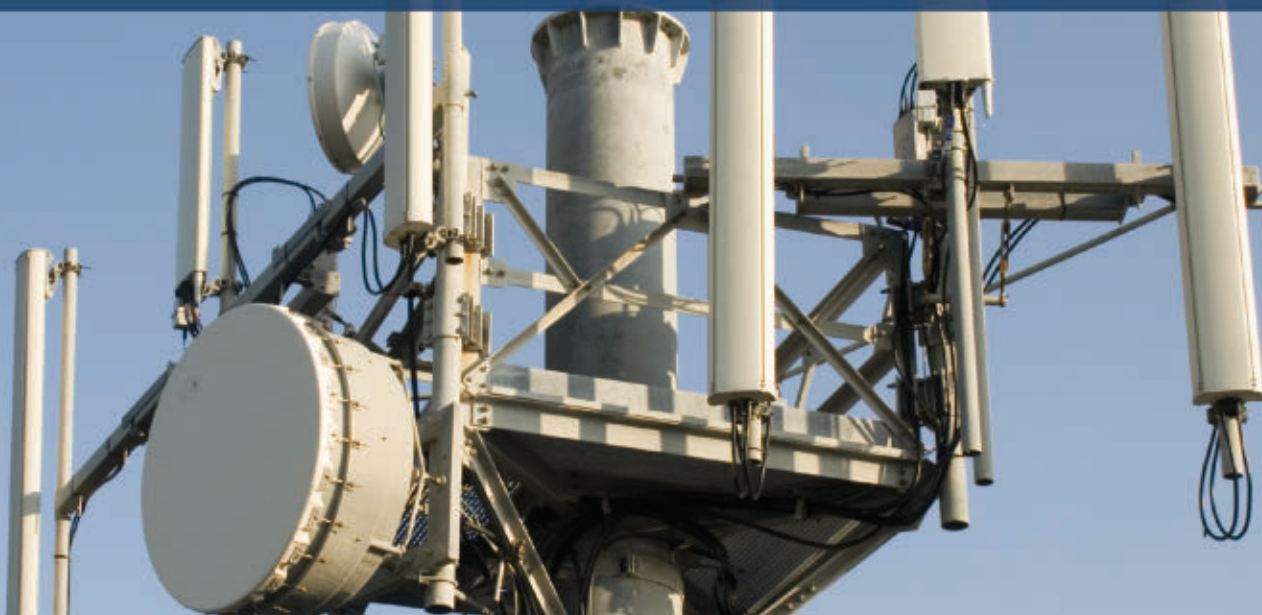
- SPST to SP8T
- Insertion Loss:
 - Reflective: 25dB min
 - Absorptive: 40dB min
- Complete solid state solution
- 0.30 GHz to 110GHz

For additional information,
contact our sales team at
310.513.7256 or
rfsales@ducommun.com

CONTACT US

INTEGRATED WIDEBAND RF TRANSCEIVERS

*Simplify Your System Design and
Standardize Your Radio Platform*



Analog Devices Simplifies Wireless System Design with RadioVerse™ Technology and Design Ecosystem

ADI recognizes the challenges associated with RF design and integration, and what it takes to bring a high performance radio solution to market quickly. The RadioVerse™ technology and design ecosystem gets our customers through the entire radio design process—from idea, to proof of concept, to production—as fast as possible. In addition to ADI's market-leading integrated transceiver technologies, RadioVerse offers a choice of evaluation options, software user guides, complete API, a standard serial peripheral interface (SPI), training, an active technical support community, and a growing ecosystem of industry-leading ODM partners.



Integrated Wideband RF Transceiver Product Series

Part Number	RF Tuning Range	Bandwidth	Channels	Interface	Power Consumption
AD9361	70 MHz to 6 GHz	56 MHz	2 Rx, 2 Tx	JESD207 CMOS/LVDS	<1.5 W
AD9363	325 MHz to 3.8 GHz	20 MHz	2 Rx, 2 Tx	JESD207 CMOS/LVDS	<1.5 W
AD9364	70 MHz to 6 GHz	56 MHz	1 Rx, 1 Tx	JESD207 CMOS/LVDS	<1.5 W
AD9371	300 MHz to 6 GHz	100 MHz Rx, 250 MHz Tx	2 Rx, 2 Tx, 2 ORx, 3 SnRx	6 Gbps JESD204B	<5 W



**LEARN MORE ABOUT ADI'S INTEGRATED
WIDEBAND RF TRANSCEIVERS**
www.richardsonrfpd.com/ADI-RadioVerse



ARE YOU 5G-READY?

**LET US BE YOUR ONE-STOP SHOP
FOR MMWAVE COMPONENTS & SUBASSEMBLIES.**



WWW.SAGEMILLIMETER.COM



MADE IN USA

www.sagemillimeter.com | 3043 Kashiwa Street, Torrance, CA 90505
T: 424-757-0168 | F: 424-757-0188 | sales@sagemillimeter.com

... ALSO INTRODUCING THE NEW SAGE STOCKROOM



WG to Coax Adapters



Balanced Mixers



Orthomode Transducers



Bulkhead Adapters



Sector Antennas



Faraday Isolators



Harmonic Mixers



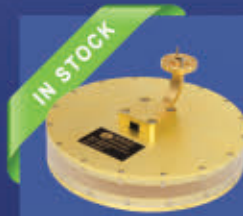
Power Dividers



Horn Antennas



Magic Tees



Omni Directional Antennas



Waveguide Terminations



Directional Couplers



Full-Band Attenuators



Taper Transitions

visit us
online
for more!

WWW.SAGEMILLIMETER.COM/STOCKROOM

Over 1,000 millimeterwave
components off-the-shelf,
in stock, and ready to ship
guaranteed in only 1-3 days.

SAGE
STOCKROOM

RFSoc Integrates RF Sampling Data Converters for 5G New Radio

Anthony Collins, Harpinder Matharu and Ehab Mohsen
Xilinx Inc., San Jose, Calif.

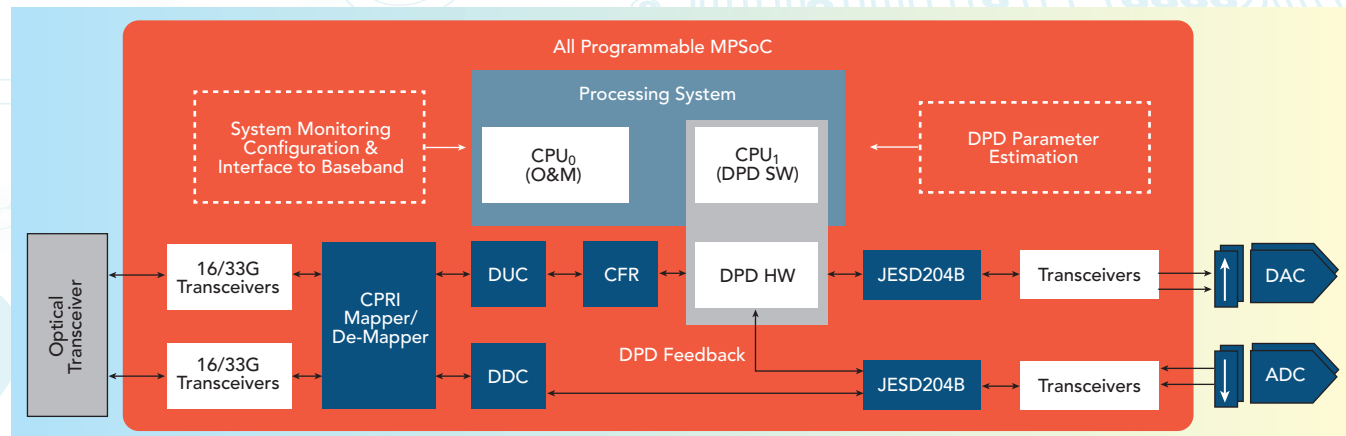
Fifth generation wireless access networks are expected to meet system and service requirements of new use cases and applications in 2020 and beyond. 5G new radio (NR) envisages providing 10 Gbps peak data rates per user, roughly 100x improvement over the fourth generation wireless access network. 4G LTE-Advanced Pro, also termed by some vendors as 4.5 to 4.9G, can achieve up to 1 Gbps peak data rates using wider bandwidths and carrier aggregation. Sustained data rate per user in

LTE-Advanced Pro typically ranges between 25 to 50 Mbps. 5G NR targets 100x improvement by pushing sustained data rate per user to 500 Mbps.

Significant increase in spectral efficiency and tapping into underutilized spectrum above 6 GHz are key enablers of multi-gigabit data rates for enhanced mobile broadband (eMBB). Massive MIMO, or large arrays of antennas, is the keystone technology for realizing this improvement. Massive MIMO adds spatial dimension in addition to

frequency and time to significantly boost spectral efficiency. The resulting signal-to-noise ratio (SNR) improvements brought about by the array gain and orthogonality of multiple beams means the same time and frequency allocations can be used by multiple users.

Time-division duplexing (TDD) bands with wider bandwidths, such as band 41 (2496 to 2690 MHz) and band 42 (3400 to 3600 MHz), are the prime candidates for massive MIMO deployments below 6 GHz bands. Tapping into underutilized centime-



▲ Fig. 1 All programmable MPSoC as a DFE platform.

COAXIAL AND WAVEGUIDE SWITCHES

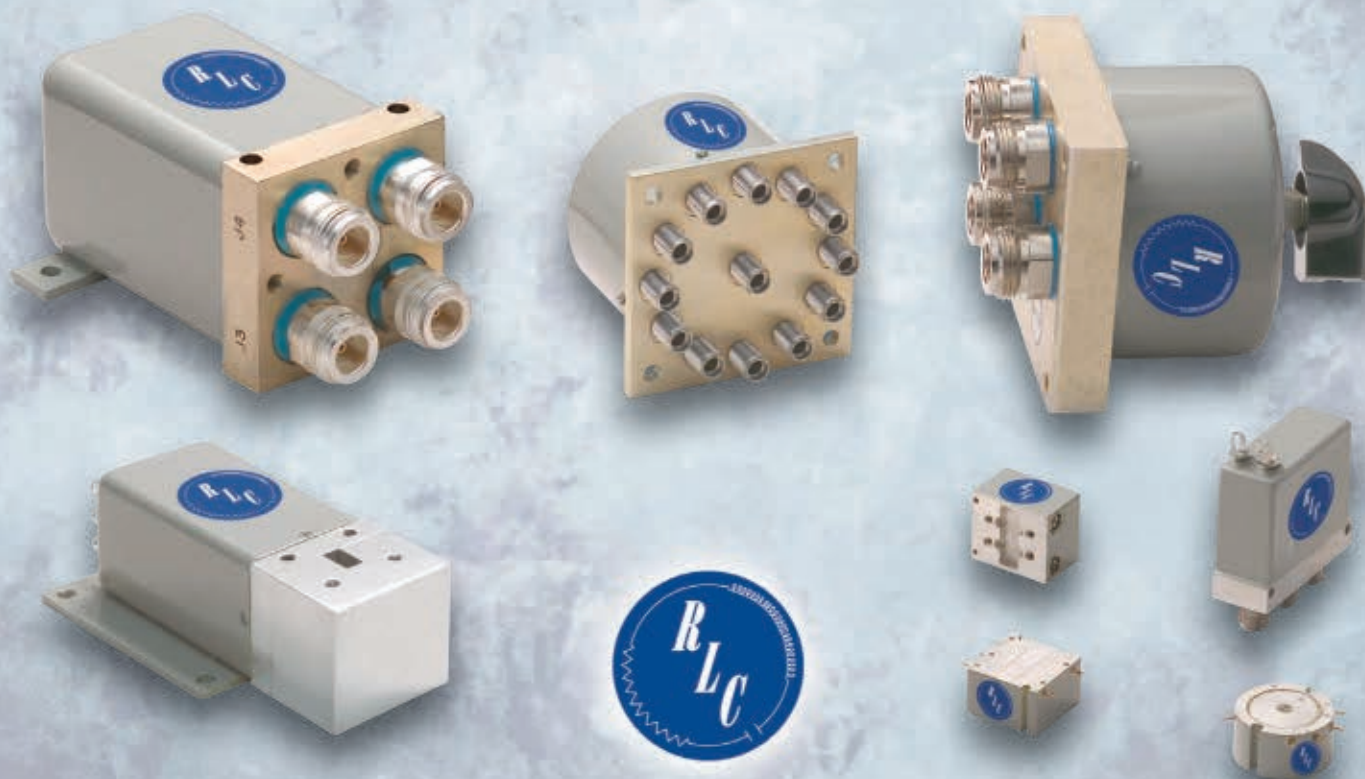
RLC has the exact solution you're looking for.

RLC Electronics manufactures a complete range of RF switches including coaxial in the frequency range from DC to 65 GHz and rectangular or double ridge waveguide. The operating modes on all designs are failsafe, latching and manual.

Control options are DC voltages as low as 5V, TTL, BCD, RS232, and RS422. All switches have excellent repeatability and lifetimes in excess of one million operations. Many types are QPL listed per MIL-DTL-3928.

- SPDT to SP12T
- Transfer
- Low VSWR
- High Isolation
- Low Insertion Loss
- High Power
- Low Passive Intermodulation
- Surface Mount Options

For more detailed information on coaxial and waveguide switches, 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.



Higher Performance at Lower Cost through Innovative Engineering



Agile
Microwave Technology Inc.



BROADBAND POWER AMPLIFIERS

- ▶ 2 – 18 GHz 8W, 10W and 15W
- ▶ 0.5 – 18 GHz 1W, 2W and 4W
- ▶ Compact Size
- ▶ Competitive Price & Fast Delivery



LNA with 5W Protection

- ▶ Broadband Performance to 20 GHz
- ▶ Low Noise Figure
- ▶ Medium Power up to 1W
- ▶ Hermetic Housing Option

**Contact us with your
custom requirements
and let us lower your
cost without sacrificing
performance or quality**

**516-931-1760
www.agilemwt.com
ISO 9001:2008 CERTIFIED**

CoverFeature

ter and millimeter wave bands, with large swaths of available bandwidth in frequencies such as 15, 28, 39 and 70 to 80 GHz, are critical components of 5G NR massive MIMO deployments above 6 GHz.

Total transmitted power by the full antenna array could typically range from 40 to 100 W, but power per antenna based on the number of antennas used in the array drops down to few hundreds of milliwatts. This allows use of low cost and lower precision analog components in the final stages of a typical RF line up. Instead of using active signal chains per antenna with fully digital beamforming, hybrid schemes are proposed, where a single active signal chain is shared by a set of antennas, with beamforming functionality performed partly in the digital domain and partly in the analog domain using phase shifters.

The power, footprint and cost associated with deploying very high channel counts along with wider signal bandwidths are significant hurdles. Increased integration along with significant power reduction is required for commercial deployments. Integrating RF-class or RF sampling data converters into radio digital front-end system on chip (SoC) overcomes this hurdle by lowering power, footprint and cost of the total system.

IMPLEMENTING A VIABLE 5G NR WITH RF SoC

A 5G NR massive MIMO implementation requires a large number of active signal chains in the radio to connect to each antenna or a subset of antennas in the array. These active signal chains are traditionally comprised of data converters, filters, mixers and power amplifier or low noise amplifier, and can lead to significant increase in power, form factor and cost of the system. The large number of active signal chains in massive MIMO systems—for digital or hybrid beamforming—makes system power and footprint too high to realize commercially viable systems. The costs associated with moving data between the RF front-ends (RFFE) and the digital front-end (DFE) is one of the key challenges that must be resolved in 5G—at the software, hardware and system level.

A newly introduced SoC technology tackles this through device integration. The platform, based on a 16 nm FinFET silicon process, monolithically integrates RF-class analog technology into a multi-processor SoC (MPSoC) for a fully hardware and software programmable radio frequency system on a chip, or RFSoc. Based on an ARM-class processing subsystem merged with FPGA programmable logic, the architecture features 12-bit, 4 GSPS RF sampling analog to digital converters (ADC), and 14-bit, 6.4 GSPS direct RF digital to analog converters (DAC), along with optimized digital down-conversion and up-conversion signal processing.

The RFSoc is built on an all programmable MPSoC architecture, an established platform for radio DFE implementations. As shown in **Figure 1**, the base architecture can employ the ARM processing subsystem for O&M functionality, digital pre-distortion (DPD) and protocol software, while the FPGA fabric can be utilized for high performance data path functionality, control logic and high speed interfacing. Now with the integration of communication-grade RF sampling ADCs and DACs and the removal of multiple discrete components, RFSocs enable compact radio form factor with potential for embedding DFE functionality within or behind antenna arrays. The result is new levels of power efficiency, form factor reduction, shortened design cycles and design flexibility urgently needed for LTE-Advanced Pro, 5G active antenna systems and massive MIMO radios.

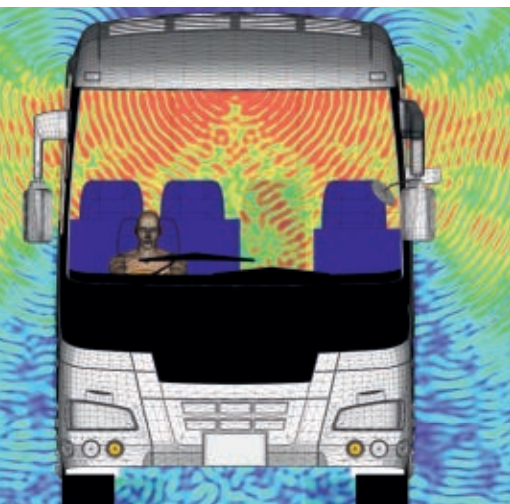
POWER REDUCTION

Figure 2 illustrates the high-power cost of moving data from a wideband (1 GHz) 2×2 RFFE into the DFE for processing using discrete RF sampling data converters. Even with integrated digital down-conversion (DDC) or digital up-conversion (DUC) in the data converters, large amounts of data still need to be sent to and from the DFE. The I/O power number shown for each quad transceiver (1 W per four lanes) includes the power associated with implementing JESD204B Protocol—on 16 nm MPSoC devices. In addition to interface power, the power con-



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 antenna development? You can read about how CST technology is used to simulate antenna performance at www.cst.com/antenna.

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.**



joins  **SIMULIA**

CERNEX, Inc.

RF, MICROWAVE & MILLIMETER-WAVE

COMPONENTS AND SUB-SYSTEMS

UP TO 325GHz

AMPLIFIERS UP TO 110GHz
FREQUENCY MULTIPLIERS/DIVIDERS
(UP TO 160GHz)

CONVERTERS UP TO 110GHz
ANTENNAS UP TO 220GHz

COUPLERS UP TO 220GHz
FERRITE PRODUCTS
(ISOLATORS/CIRCULATORS)
UP TO 160GHz

FILTERS/DIPLEXERS
SOURCES UP TO 160GHz

SWITCHES UP TO 160GHz
PHASESHIFTERS UP TO 160GHz

TRANSITIONS/ADAPTERS (UP TO 325GHz)
WAVEGUIDE PRODUCTS UP TO 325GHz

TERMINATIONS/LOADS UP TO 160GHz
MIXERS(UP TO 110GHz)

ATTENUATORS(UP TO 160GHz)
DETECTORS(UP TO 160GHz)

LIMITERS(UP TO 160GHz)
BLAS TEE (UP TO 100GHz)

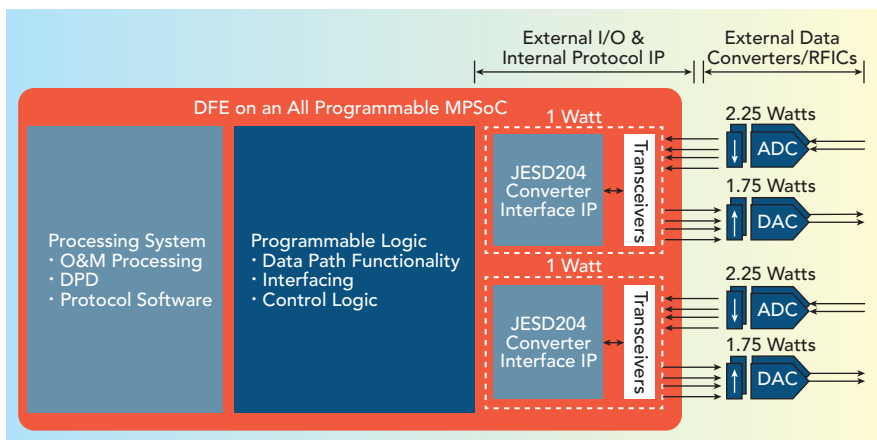
POWER COMBINERS/DIVIDERS EQUALIZERS

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

Cernex, Inc.
1710 Zanker Road, Suite 103
San Jose, CA 95112
Tel: (408) 541-9226
Fax: (408) 541-9229

www.cernex.com
cernex@cernex.com

CoverFeature

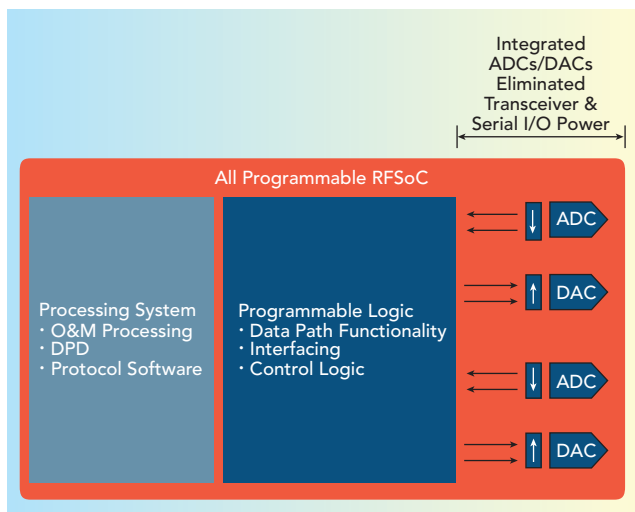


▲ Fig. 2 Radio DFE interfacing to external wideband data converters.

sumption of the discrete data converter components remains high. A typical single channel RF sampling ADC may consume ~2.25 W, and an RF sampling DAC ~1.75 W.

DFE signal processing, as shown in Figure 1, has leveraged the latest deep-submicron CMOS technologies to reduce power, while RF and other analog components have traditionally leveraged older-process technology. The older CMOS and even BiCMOS technology offered the required performance at the right costs for these predominately analog ("Big A") discrete components. However, the move to a more digitally dominated SoC ("Big D") means that it is now commercially viable to build data converters on the latest advanced CMOS technologies, allowing huge power and cost savings. Integration of these data converters is represented in **Figure 3**.

On the SoC device itself, the integration of the data converters eliminates the need for the JESD204B IP cores and use of the device's high speed serial transceivers. With the elimination of components, interfacing, IP and use of transceivers—as channel count increases so does system power reduction. Based on single channel RF data converters,



▲ Fig. 3 Elimination of RF component power and interface power.

elimination of all these factors results in 40 percent power reduction in a 4 Tx/4 Rx radio and over 50 percent power reduction for an 8 Tx/8 Rx system, as shown in **Table 1**.

SYSTEM FORM FACTOR REDUCTION

Radio form factor (size or volume) is a critical attribute for securing deployment in terms of rental fees, wind loading and compliance to the local government's regulations and restrictions. Reducing radio unit volume is an important system design criteria. Integrating RF-class data converters results in significant saving, as shown in **Figure 4**. Form factor reductions are proportional to the number of antennas in the system. PCB area savings can range from 40 percent and reach 75 percent. An example of an 8 Tx/8 Rx radio using quad channel ADC and DAC are shown in Figure 4.

TODAY'S
SMART DEVICES
DEMAND SMARTER
SEMICONDUCTOR
TEST SYSTEMS



NI's Semiconductor Test System (STS) meets the test needs of today and tomorrow by providing engineers with an open, software-centric platform based on PXI instrumentation, TestStand test management software, and LabVIEW code module development. With lab-grade measurement quality and production-grade performance, the STS accelerates RF and mixed-signal tests from the characterization bench to the production floor, which lowers test time and cost.

Prepare for the future at ni.com/smarter-test.

Target Simulation Systems

NSI-MI Technologies designs and manufactures specialized motion simulation systems to precisely simulate the movement of physical entities for use in virtual reality trainers and testers and for physical testing needs. We specialize in the areas of Aerospace and Defense enabling simulation for missiles, decoys and more.



www.NSI-MI.com
info@nsi-mi.com

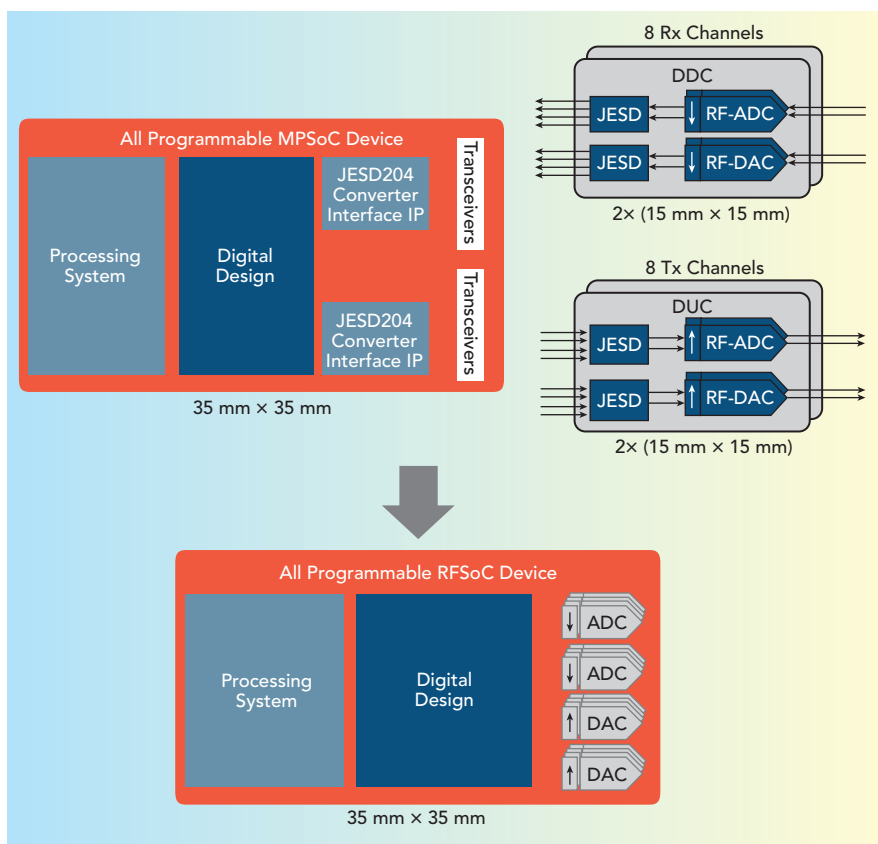
CoverFeature

SHORTENED DESIGN CYCLES AND ELIMINATING JESD204 INTERFACE

Beyond power and form factor benefits, elimination of discrete data converters shortens the design cycle in several ways. Because most modern converters currently use high speed serial interfaces from 12.5 to 25 Gbps based on the JESD204 protocol, design closure is impacted at the digital, analog

and system level. The JESD204 IP cores must be implemented in digital FPGA fabric, but arguably the more difficult task is ensuring a stable serial data link between the data converter and the radio's DFE. At 12.5 Gbps and up to 25 Gbps, signal distortion is a serious concern mostly due to running high line rates over low cost, lossy interconnect. Eliminating the DFE and RFFE interface removes this burden and

TABLE 1 POWER SAVINGS IN DIGITAL RADIO (WITH DPD) USING AN INTEGRATED SUBSYSTEM			
	4x4 100 MHz	4x4 200 MHz	8x8 100 MHz
Discrete Implementation			
Programmable Device	15 W	23 W	23 W
ADC/DAC Components	16 W	16 W	32 W
TOTAL POWER	31 W	39 W	55 W
Integrated RF-Analog			
Programmable Device + RF Subsystem	18 W	25 W	27 W
TOTAL POWER SAVINGS	41%	37%	51%



▲ Fig. 4 PCB area savings in 8 Tx/ 8 Rx radio.

Inmet & Weinschel

RF & Microwave Coaxial Component Solutions

DEFENSE • COMMERCIAL • INDUSTRIAL • SPACE



Attenuators and Terminations

DC to 50 GHz, power handling up to 1000W

Available with various connector options and Low PIM.

Bias Tees, DC Blocks and Power Dividers

Up to 50 GHz

Including broadband and high current bias tees, high voltage and broadband dc blocks and resistive or Wilkinson power dividers.

Gain Equalizers and Phase Shifters

DC to 40 GHz

Fixed and adjustable gain equalizers and manually adjustable phase shifters.

Adapters, Connectors and Accessories

DC to 65 GHz

Adapters with various connector configurations, Planar Crown® and Planar Blindmate® connector systems, dust caps, opens, shorts, open/short/loads and impedance matching pads.



API Technologies designs and manufactures high performance systems, subsystems, modules, and components for technically demanding RF, microwave, millimeter wave, electromagnetic, power, and security applications. API products are used by global defense, industrial, and commercial customers in the areas of commercial aerospace, wireless communications, medical, oil and gas, electronic warfare, C4ISR, missile defense, harsh environments, satellites, and space.

API Technologies is proud to offer Inmet and Weinschel brand components.

www.inmet.apitech.com | www.weinschel.apitech.com

reduces the number of board layers, complexity of routing the clocks on the PCB and synchronization of the communication links.

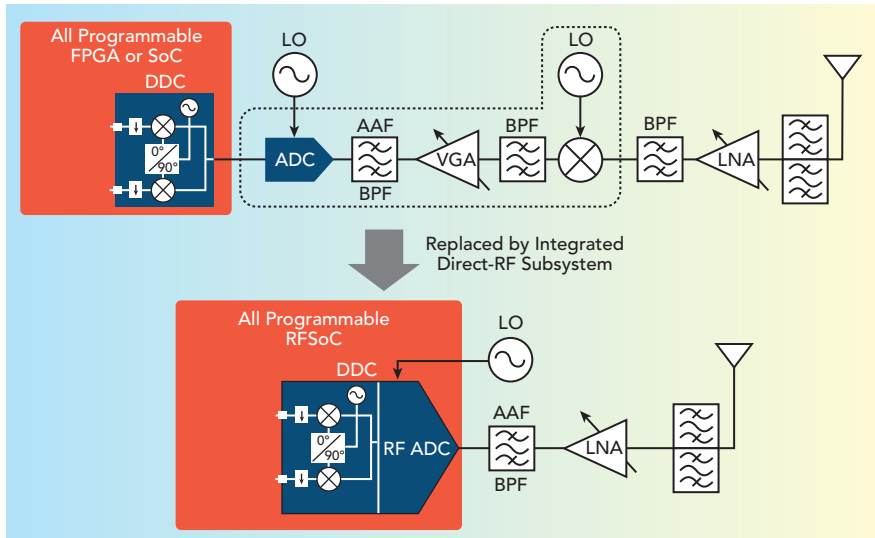
DESIGN FLEXIBILITY WITH RF SAMPLING ON 16 nm FinFET

Direct RF sampling DACs and RF sampling ADCs in the RFSoc elimi-

nate the need for intermediate frequency (IF) stage sampling for 5G Radios implemented in sub-6 GHz frequency bands, thereby reducing the complexity of the RFFE, as shown in **Figure 5**. Direct RF sampling, integrated with highly optimized RF digital signal processing engines (i.e., DDC and DUC) offers

a much more flexible approach to traditional analog frequency translation and filtering. The higher sample rates simplify the analog filtering requirements and allow a better trade-off between dynamic range (SNR) and signal bandwidth in the digital domain by decimating and filtering the ADC output to extract only the signal bandwidth of interest.¹ Implementing the signal conditioning in the digital domain also yields better performance and ease of use. Some of the traditional RF impairments in the IF approach are greatly reduced or eliminated (e.g., passband ripple, group delay variation, matching and local oscillator (LO) leakage issues).

With advanced CMOS technology, namely 16 nm FinFET, RF signal processing can be implemented in the digital domain with excellent power and cost efficiency. At 16 nm, the RF sampling solution in the RFSoc architecture delivers a flexible RF front-end while supporting wide bandwidths—up to 2 GHz—at a much lower power draw than required by analog technologies.



▲ Fig. 5 Comparison of superheterodyne and direct sampling receivers.

CUSTOM FREQUENCY SOURCE INSTRUMENTS

Superior Performance at a Lower Cost than Variable Low Noise Signal Generators



- ULN or Golden Phase Noise Performance
- Excellent Spectral Purity
- 1U to 8U, 19" Rack Mount Configurations
- Provides Only the Fixed Frequencies Needed
- Specify Number of Outputs and Levels
- Specify Connector Type and Locations on Panels
- Low Noise Power Supply and/or Voltage Regulators
- Any Many Other Customizing Options!

"Quietly the Best"



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

DEMONSTRATING ADC AND DAC PERFORMANCE

New digitally assisted techniques allowed designers to address the challenge of integrating state-of-the-art RF sampling converters using advanced CMOS technology.² By using very cost and power efficient 16 nm FinFET digital transistors, it is possible to add very sophisticated digital calibration to correct for any analog circuits impairments. This approach to implementing advanced RF sampling converters delivers large benefits in terms of power and area reduction. It also provides a platform technology that will scale with Moore's Law to 7 nm and beyond.

Results from a 16 nm FinFET test chip featuring the RFSoc's direct RF sampling converters show excellent performance, linearity and analog characteristics of a 6.8 GSPS RF DAC and 4 GSPS RF ADC—evaluated across process, temperature and power supply variation.² The built-in calibration and digitally assisted techniques deliver very consistent and stable performance across PVT.



5G Anritsu **READY**

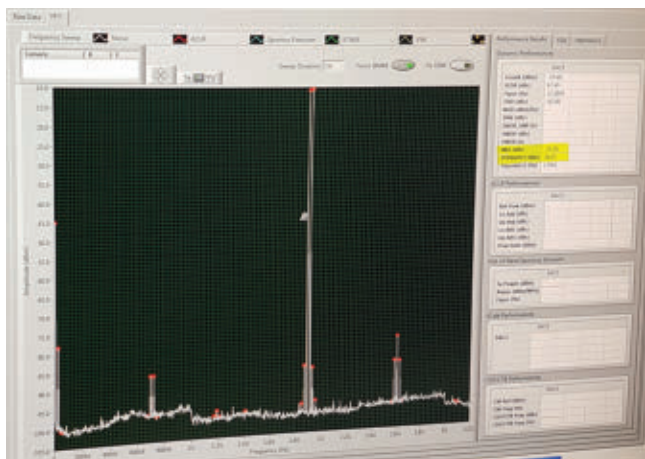
Testing solutions for today and tomorrow

5G networks will mean new features and technologies in support of a vast range of emerging applications and use cases. While exciting, these advancements also mean testing new technologies and network elements in ever-increasing combinations to ensure correct interoperability. Count on Anritsu to help you solve the unique testing challenges of 5G deployment.

Learn more and download our white paper, *Understanding 5G*: www.goanritsu.com/5GMWJ

1-800-ANRITSU
www.anritsu.com
© 2016 Anritsu Company

Anritsu
envision : ensure

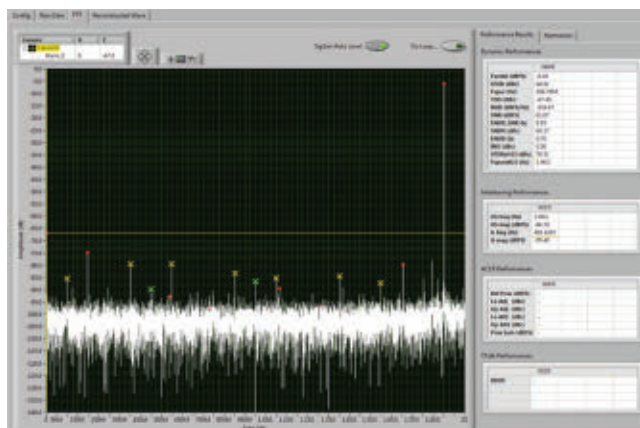


▲ Fig. 6 RF DAC generating two tones at 1.9 GHz separated by 20 MHz.

The output of the DAC generates two tones at a carrier frequency of approximately 1.9 GHz separated by 20 MHz, as shown in the output of the Rohde & Schwarz FSW Spectrum Analyzer in **Figure 6**. The 3rd order intermodulation illustrates the very high linearity of the DAC at approximately -75 dBc. This is within the first Nyquist zone, which extends up to 3.2 GHz. The 2nd and 3rd order

images folded back also show excellent performance of the DAC.

For the ADC, a high quality signal sourced by the Rohde & Schwarz SMW200A vector signal generator is used to synthesize both CW and modulated waveforms. Additional analog filtering by the signal source provides the signal purity required to evaluate the ADC. The captured data is analyzed using fast Fourier



▲ Fig. 7 FFT of a continuous wave tone sampled at 4 GS/s by the RF ADC.

transforms (FFT) implemented with LabView Software from National Instruments, as shown in **Figure 7**. The FFT of a -3 dBFS 1.9 GHz CW signal is sampled at 4 GSPS, and the plot shows the first Nyquist zone of the ADC. The 2nd and 3rd order distortion components are aliased into the first Nyquist zone as indicated by the red markers. Other distortion components shown are interleaving artifacts which are greatly suppressed using built-in calibration.

67 GHz Performance

FLEXIBLE, REPAIRABLE, AND SUSTAINABLE TEST CABLES

800 LB
Compression
Resistance

Vector
VNA

Brute
General Test

500 LB
Compression
Resistance

Type N to 1.85mm, Flexible, Repairable

VELOCITY
MICROWAVE

For a special offer visit:

www.velocitybygte.com/67GHz

866.409.0400



Up to 26.5 GHz
for Field
Repairable Cables



Repairable General
Purpose and VNA
Cables up to 67 GHz



Phase
Matched
Cables



Connector Gages: One
Gage for Male AND
Female Connectors



Torque
Wrenches

MEETING THE DESIGN CHALLENGES AND APPLICATION CONSTRAINTS FOR RFSOC

As with any complex SoC, there were tradeoffs and design choices made when developing the all programmable RFSOC. This ranged from meeting challenging power targets, to careful consideration of the constraints hardware designers face when realizing their end application, to providing a platform with the correct mix of optimized and programmable signal processing.

Power Density

With reduced form factor and significantly greater performance, 5G NRs face tough power density challenges and present a thermal engineering problem. The system is typically passively cooled with high operating ambient temperatures generated by the power amplifier and other components. In order for components to stay within their specified operating temperature range, they typically cannot dissipate more than 35 W before the thermal solution becomes complex and costly.

RCL Microwave, Inc.

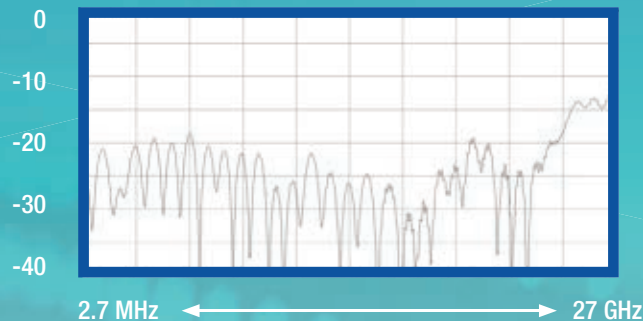
Your Only Source
For Broadband Dielectric Characterization



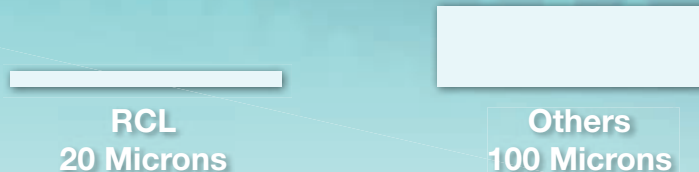
10,000 VS 1

Our test methods produce **10,000** data points.
Other test methods only produce **1** data point.

Extensive experience that gets results!



*Leading the industry in broadband dielectric characterization
with thin film capability to 20 microns*



Contact us for a free quote today!

877-387-6125

RCLMicrowave.com

While integrating RF sampling data converters greatly reduces the system power, it must also not significantly increase the power dissipation of the SoC. Ideally, the solution would be power neutral with the converter power being similar to the power dissipated by the external IO interfaces like JESD204B. This drove many of the design choices and techniques used in developing the RFSoc, including digitally assisted analog and interleaving to reduce the power consumption of the converters.

Practical Hardware Solutions

The RFSoc needed to meet key requirements like channel to channel RF isolation (which typically needs to be greater than 70 dB) and immunity to other sources of noise in what is a highly mixed signal environment. The SoC is a predominately digital (Big "D") device that supports external memory interfaces, along with system interfaces like 100GE and common public radio interface (CPRI). Through careful design and floor planning of the

SoC, along with package and PCB co-design, RFSocs can achieve very robust performance without costly PCB design rules or nonstandard manufacturing techniques.

Maximizing Flexibility

Traditional SoC implementation involves tradeoffs in functionality, cost and power consumption. Developing the RFSoc was no exception but benefited from significantly more degrees of freedom. Generic functionality like DDC was implemented in highly power efficient 16 nm FinFET logic; however, much of the application specific functionality can be efficiently implemented in the programmable logic. The RFSoc achieves a balance between dedicated hardened digital signal processing and user configurable high performance processing. The result is an all programmable platform for implementing a range of applications beyond just radio.

The choice of advanced CMOS technology like 16 nm FinFET is a key part of maintaining this flexibility to adapt to changing standards

and allow designers to react quickly to emerging requirements. The direct RF sampling moves the RF into the digital signal processing domain as soon as possible, where it can be processed very efficiently in the digital domain using advanced CMOS technology.

ALIGNED WITH 3GPP SPECIFICATION TIMELINES

The introduction of all programmable RFSocs is well aligned with 5G NR specification timelines. The draft of the 5G NR non-standalone specification (release 15) is targeted to be available by December 2017. The Standalone 5G NR portion of the release 15 specification is expected to be completed by June 2018. Non-standalone mode will use LTE as the control plane anchor. 5G NR control plane for standalone mode will be defined in the June 2018 release. The 3GPP industry workgroup is debating on the extent of the ultra-reliable low latency communication (URLLC) use case to be covered in release 15. Due to tight timelines for release 15, many facets of the URLLC use case are targeted in the 5G NR release 16 specification scheduled to be available by end of calendar year 2019.

SUMMARY

With all programmable RFSocs, the ability to leverage the same hardware to address diverse requirements and emerging standards will allow vendors to quickly react to new market opportunities by leveraging existing developments. In the case of 5G systems it is becoming clear that no one type of radio will address the diverse needs of next generation radio access networks (RAN) and so the number of different radio types is expected to increase significantly.³ ■

References

1. Boris Murmann, *IEEE Micro*, Volume: 26, Issue: 2, March-April 2006: "Digitally Assisted Analog Circuits."
2. While the test chip demonstrates a 6.8 GSPS DAC, All Programmable RFSoc specifications currently target 6.4 GSPS DAC performance.
3. "Final report on the METIS 5G System Concept and Technology Roadmap," METIS Deliverable D6.6, https://www.metis2020.com/wp-content/uploads/deliverables/METIS_D6.6_v1.pdf

Covering Your Spectrum

- Fixed Attenuators
- Variable Attenuators
- Terminations
- Power Dividers/Splitters
- RF Adapters
- DC Blocks
- RF Tuners
- DC to 50 GHz
- 1 Watt to 2000 Watts
- Custom Solutions

*Providing the highest quality and cost-competitive
Broadband RF and Microwave Products
in the Industry since 1989.*

Visit our new website with interactive catalog and online RFQ!

www.WeinschelAssociates.com

19212 Orbit Drive
Gaithersburg, MD 20879
Voice: 301.963.4630
Fax: 301.963.8640
RF@WeinschelAssociates.com



Test & Measurement

Public & Military Radios

Satellite Communication

Industrial, Scientific & Medical

Civil & Defense Radar

Diodes

The Trusted Name in High Performance RF

MACOM is committed to delivering industry-leading diode design and application-specific solutions for our customers worldwide.

MACOM design and application engineers are continuing our 65-year legacy and commitment of leadership with next-gen wideband RF solutions for mission-critical applications. Our expert RF team leverages the latest semiconductor technologies and state-of-the-art foundry processes to reach new levels of performance in bandwidth, power, packaging and reliability.

Only MACOM delivers:

Diode Support Services

- › Lot Approval offered: maintaining secured inventory at our factory
- › Product extensions / variants, custom design & development
- › Hi-Rel screening capabilities: space & JAN, JANTX, JANTXV, JANS-qualified RF & DC devices
- › Applications support: world-class experienced team available to support your critical requirements

Expansive Diode Product Portfolio

- › PINs, Schottkys, Varactors, Zeners, rectifiers, current regulators
- › Chip capacitors, attenuator pads, thin film resistors, spiral inductors
- › RF / Mw /mMW, DC general purpose solutions
- › Integrated diode products: switch modules, limiter modules, comb generators, driver modules

Patented Technologies

- › AlGaAs: high frequency switch portfolio up to 94 GHz
- › HMIC: high power diode & switch portfolio (0.1-20 GHz, 6.5W CW incident power)



Featuring:
MSS Family of Silicon
Schottky Mixer Diodes

MACOM™

Partners from RF to Light

Learn more at:

www.macom.com/diodes



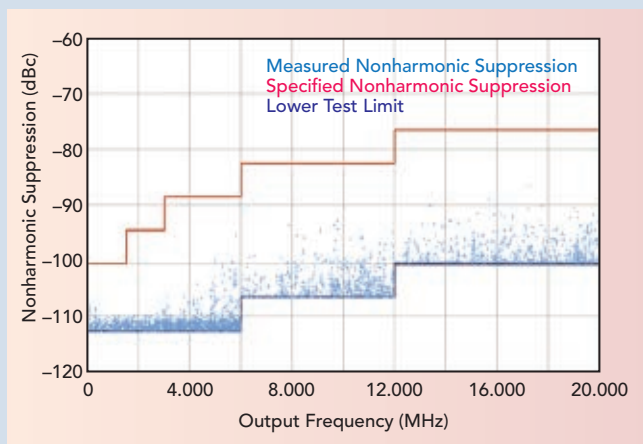
Most Valuable Product



Redefining High-End RF and Microwave Signal Generation

Rohde & Schwarz
Munich, Germany

In research and development, designers often push their designs almost beyond possible limits in order to attain utmost performance, and sometimes they do not initially know how far they need to go. In the test and verification phase, often an analog signal source is the first method of choice to prove the performance of a design. Ideally, it should not limit the design margins or test results but, in reality, it often does. For example, engineers testing state-of-the-art analog-to-digital (A/D) and digital-to-analog (D/A) converters seek the highest spurious-free dynamic range and the lowest broadband noise available, while radar engineers require the lowest possible phase noise. And in large test setups with long cabling, the output power of the signal source often seems too low.



▲ Fig. 1 Measured nonharmonic suppression of the R&S SMA100B with the R&S SMAB-B711 option.

When Rohde & Schwarz decided to develop a successor to its R&S SMA100A and R&S SMF100A high-end RF and microwave signal generators, the design engineers set themselves a simple yet very challenging goal: to deliver the best possible performance for each key parameter, without any compromises or the requirement for customers to make tough decisions. The result is the R&S SMA100B, which can deliver the cleanest signals at the highest output power without any compromise. The new microwave signal generator strongly benefits three key applications:

A/D AND D/A TESTING

Integrated A/D and D/A converters deliver higher clock rates and an effective number of bits (ENOB) with each generation. Testing their performance requires clock and test signal sources exceeding the spurious-free dynamic range of device under test (DUT). Clean clock signals provide the best spectral purity for a D/A converter's analog output signal. The new R&S SMA100B specifies nonharmonics < 100 dBc for a 1 GHz carrier frequency and < 80 dBc for a 10 GHz carrier frequency, an improvement of 10 to 18 dB over its predecessors. **Figure 1** shows actual measurement results that are significantly lower.

High sampling frequencies and high ENOB require a signal source with very low broadband noise. Clock signals with low wideband noise do not degrade the signal-to-noise ratio (SNR) of the sampled input signal of an A/D converter. With the R&S SMA100B, an optimized RF design and a new, all digital level control loop provide a typical broad-

What Advances Can You Make With Cobham?

COBHAM

The most important thing we build is trust

Innovative, Affordable MMIC Solutions

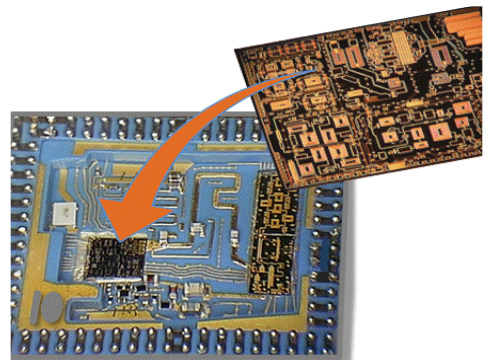
Cobham Advanced Electronic Solutions delivers high performance Radio Frequency (RF), microwave, and millimeter wave integrated Monolithic Microwave Integrated Circuit (MMIC) system on a chip (SoC) solutions for defense and aerospace applications. Creative MMIC products provide state-of-the-art alternatives for active electronically scanned array (AESA), radar, space, electronic warfare (EW), missile and missile defense, communications, and unmanned systems.

A leader in highly integrated MMIC products, Cobham offers true time delay units (TDU), transmit/receive integrated circuits (T/R IC), vector modulators, wide band ICs including low noise and power amplifiers, switches, limiters, and many others. Advanced manufacturing processes enable innovative, low cost and high volume module and package assembly solutions.

Cobham Advanced Electronic Solutions

Advance with Cobham at www.cobham.com/caes

CAES.BD@cobham.com • 417-231-5085



Most Valuable Product

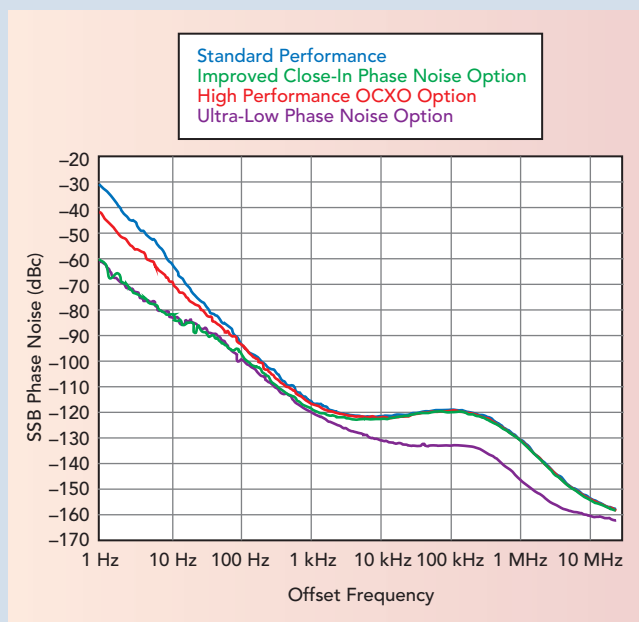
band noise of -160 dBc/Hz at 10 GHz carrier frequency, a value formerly achieved only by a few highly specialized signal sources.

Testing A/D converters often requires two signal sources: one for the DUT's clock and one for the analog signal. The microwave signal generator facilitates this by offering a high performance clock synthesizer option with ultra-low phase and broadband noise up to 6 GHz. The frequency of this additional synthesizer can be set independently of the main RF frequency. Sharing a common 1 GHz reference signal achieves very high phase stability between the output clock signal and the main synthesizer signal. To support single-ended and differential clock interfaces, the waveform, level and DC offset are programmable.

HIGH-END RADAR DESIGN

When designing and testing high-end radar systems, detection sensitivity is often limited by the phase noise of the RF signal source. The R&S SMA100B offers several low phase noise options to satisfy even the toughest requirements (see **Figure 2**). Close-in phase noise performance can be as low as -60 dBc/Hz (typical) at 1 Hz offset and 10 GHz carrier frequency. For applications requiring the lowest possible pedestal phase noise, the signal generator offers a dedicated YIG oscillator option that enables -132 dBc/Hz (typical) at 10 kHz to 100 kHz offsets and 10 GHz carrier frequency. The R&S SMA100B defines a new, unprecedented high-end class in phase noise performance.

When testing radar systems, fast and well-controlled RF pulses are essential. With 5 ns (typical) rise/fall time and >80 dB on/off ratio, the R&S SMA100B pulse modulator is suitable for all radar applications. Modern radar equipment must be tested



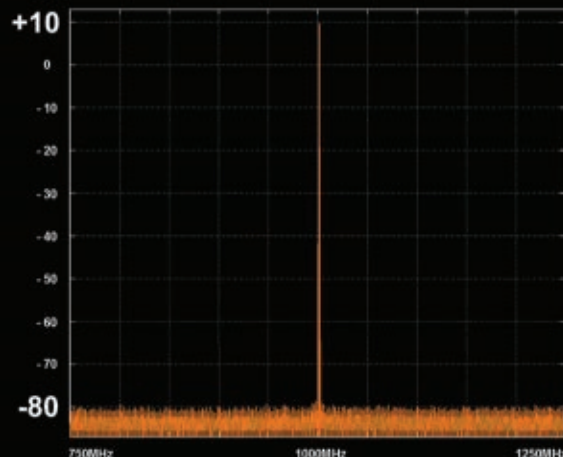
▲ Fig. 2 Measured single sideband phase noise performance of the R&S SMA100B at 10 GHz.

with leveled short pulses that have high level accuracy and level repeatability. The pulse modulator of the new R&S SMA100B has been designed for that. It can deliver leveled short pulses with high level accuracy and repeatability down to the nanosecond range.

HSX SERIES

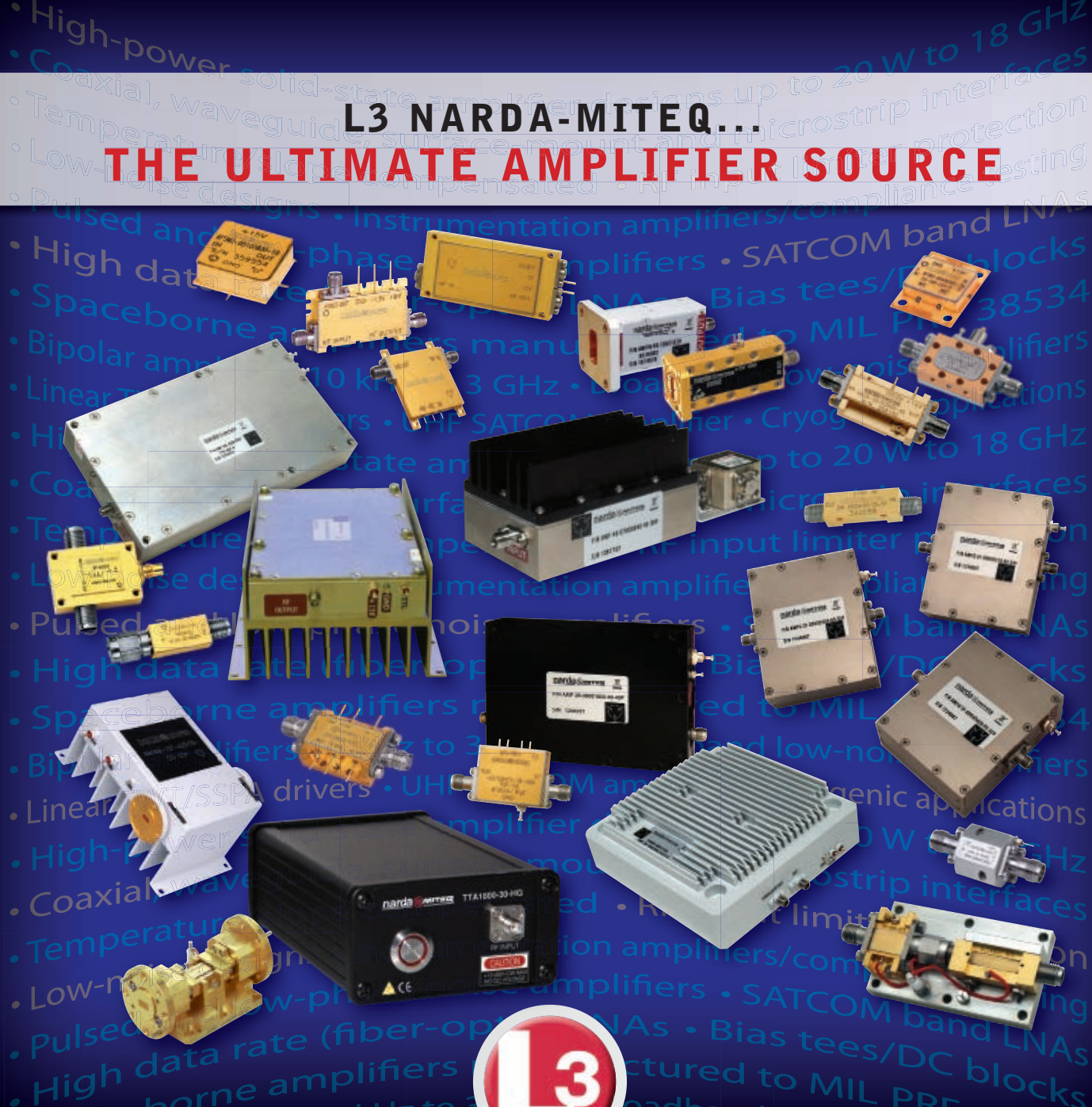
=

PURE SIGNAL GENERATION



- ▶ Up to 4x Independent, PHASE COHERENT Channels
- ▶ Broadband: 10MHz to 3GHz, 6GHz, 12GHz and >20GHz
- ▶ 10GHz Phase Noise: -123 dBc/Hz (10kHz offset)
- ▶ Spurious Response: < -80 dBc (-90 dBc typical)
- ▶ Dynamic Range: -110 dBm to $+20$ dBm

L3 NARDA-MITEQ... THE ULTIMATE AMPLIFIER SOURCE



narda  **MITEQ**

The Largest and Broadest Amplifier Selection

L3 Narda-MITEQ offers more amplifier solutions than any other company. With over 60 years of experience and an extensive, diversified amplifier design library, we can meet or exceed your specific requirements quickly. We are the proven source for standard and customized amplifier solutions, offering more than 10,000 catalog products. Providing everything from design to production, we are ready to meet your most complex challenges. When your next project demands an amplifier with a proven track record, count on L3 Narda-MITEQ – *your best resource for amplifier solutions.*

Learn more about all we have to offer by visiting us at nardamiteq.com or call us at (631) 231-1700.

Narda-MITEQ

  L3T.com

Most Valuable Product

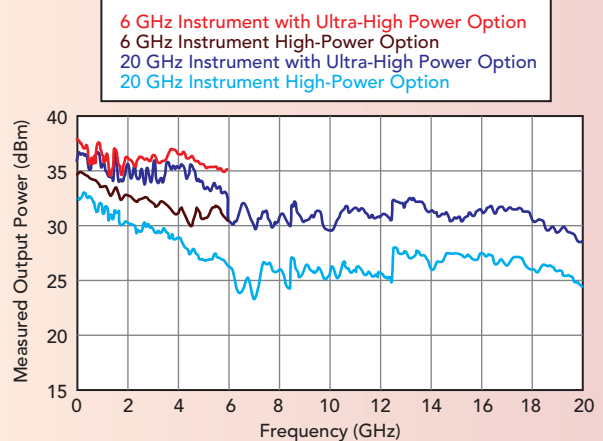
PRODUCTION MEASUREMENT OF MICROWAVE AMPLIFIERS

When testing high-power amplifiers, sufficient drive power is crucial. To satisfy cost-sensitive as well as highly demanding applications, the R&S SMA100B offers a three-stage output power option. A high output power option up to +35 dBm can be activated with an option key, even in the field. The factory fit ultra-high output power option offers power levels up to +38 dBm for the 6 GHz model (see **Figure 3**), a performance previously unavailable from any general-purpose signal generator on the market, according to Rohde & Schwarz.

In addition, due to built-in filters, a harmonics suppression of -65 dBc (typical) is available up to high-power levels for all output power options. With this combination of very high output power, low harmonics and extremely low wideband noise, the R&S SMA100B makes external amplifiers and filters unnecessary and saves the customer from using complicated and expensive test setups consisting of multiple boxes.

In a production environment, it is important to keep down-time caused by service needs or malfunction of the automatic test equipment (ATE) system to a minimum. For signal generators up to 6 GHz, an electronic solid-state step attenuator has therefore been a de-facto standard for more than a decade. The R&S SMA100B now carries this technology into the world of microwave signal generators, offering solid-state switching for all frequency options up to 20 GHz as standard, allowing very fast and wear-free level switching.

All these features fit into a compact 19 in, 2 HU housing saving rack space. All R&S SMA100B signal generators are



▲ Fig. 3 Measured maximum available output power of the R&S SMA100B.

equipped with a convenient touch display and an easy-to-use graphical user interface (GUI), which makes operating the instrument very easy. For benchtop operation, users can optionally select a 19 in, 3 HU housing with increased 7 in touch display.

VENDORVIEW

Rohde & Schwarz

Munich, Germany

+49 89 4129 12345

www.rohde-schwarz.com

Advanced Microwave, Inc.

MICROWAVE COMPONENTS & SYSTEMS

thin-film technology in very small, yet rugged, packages.

ONE STOP SHOP

AMPLIFIERS:

Frequency range of 0.1 to 40 GHz

LNA or Power

We also offer custom amplifiers including, but not limited to, Heatsink and Universal AC Input

UP/DOWN CONVERTERS:

Freq range 3 to 40 GHz

A complete remote converter system using a computer network control including I/OS, USB2, RS232, and Ethernet (RG45) optional



A complete package of any amplifier or converter which includes heatsink and 100 to 240 VAC input.

MILITARY ELECTRONICS:

Freq range: 0.1 to 40 GHz

for radar applications

- ▶ Pulse Modulators
- ▶ Threshold Detectors
- ▶ Detector Log Amplifiers
- ▶ remote sensing incl. I/OS, USB2, RS232, and Ethernet (RG45)

COMPONENTS:

Mixers 2.0 to 40 GHz

- ▶ Double/Triple Balanced
- ▶ IR Mixers
- ▶ IQ Modulators
- Limiters 0.1 to 40 GHz
- Detectors 0.01 to 40 GHz

CUSTOM products using AMI building blocks

Sunnyvale, CA 94089

www.advmic.com

Ph: 408-739-4214

sales@advmic.com

When it comes to power inductors,
we're spreading things a little thin



(actual height)

In fact, with hundreds of options under 1.2 mm high,
finding the perfect low-profile power inductor is no tall order!

Let's face it, thin is in. From smart phones and wearables to all types of portable devices, you face constant pressure to pack more performance into thinner packages.

To help, we continue to expand our line of mini, low-profile power inductors with footprints as small as 1.14 x 0.635 mm and maximum heights as low as 0.50 mm!

Select inductance values from 0.018 to

3300 μ H and current ratings up to 20 Amps.

Get the skinny on all our low-profile power inductors, including the new ultra-low loss XEL4012 Series with inductance values that have been fully optimized for high frequency applications over 5 MHz. Visit coilcraft.com/lowprofile today!



WWW.COILCRAFT.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

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, Inc. 4000 Via Pescador, Camarillo, CA 93012

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





BAE Develops Next-Gen Aircraft Threat Warning Solution

Developed to address the ever-changing and proliferating threat environment, the 3DAWS suite protects aircraft during complex, multi-threat engagement scenarios through a layered countermeasure defense, allowing aircrews to safely complete their missions. It not only maximizes the effectiveness of current flare and directable infrared countermeasure systems, but it also provides the necessary tracking capabilities for future soft- and hard-kill countermeasure solutions to damage or destroy incoming threats.

"With the rapidly evolving threat environment, any future threat detection system must address a first-encounter threat scenario and must do so by efficiently and smartly utilizing fielded and future countermeasure techniques," said Cheryl Paradis, director of Threat Management Solutions at BAE Systems. "Our new 3DAWS solution provides the capability to first make a definitive threat assessment—determining whether a track

Product suite designed to significantly increase aircraft survivability from advanced threats

is a false alarm or an incoming threat—and then quickly respond with the appropriate countermeasure."

At the heart of 3DAWS is BAE Systems' passively-cued, semi-active radio frequency 3D Tracker™ technology. Serving as an adjunct to the company's Common Missile Warning System or any future passive threat detection system, the 3D Tracker technology provides the third dimension to the system's detection process and allows for definitive threat assessment.

Built to be highly modular and with open architecture standards, the 3DAWS suite integrates with all existing U.S. Army aircraft, has the flexibility to work with fixed- and rotary-wing aircraft and can be tightly integrated with existing radar or laser warning systems, providing a third dimension to those passive systems.

World's Most Powerful Emulator of Radio-Signal Traffic Opens for Business

Though it resides in a mere 30 by 20 ft server room on the campus of the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Md., the Colosseum is capable of creating a much larger and critically important wireless world. If all goes as planned during DARPA's three-year Spectrum Collaboration Challenge (SC2), competitors vying for \$3.75 million in prize money will use the Colosseum as a world-unique testbed to create radically new paradigms

for using and managing access to the electromagnetic spectrum in both military and civilian domains.

"The Colosseum is the wireless research environment that we hope will catalyze the advent of autonomous, intelligent and—most importantly, collaborative—radio technology, which will be essential as the population of devices linking wirelessly to each other and to the Internet continues to grow exponentially," said SC2 Program Manager Paul Tilghman. Traditional wireless communications systems are defined by a specification—a document that is the product of years of study and debate, and prescribes precisely how a radio system will work and how, if at all, it will get along with other radios. "We are asking SC2 competitors to devise fundamentally new radio systems that can learn from each other in real-time, making the need for arduous radio specifications obsolete," Tilghman said.

On the surface, the Colosseum appears as a drab set of electronic racks. Yet it is a path-breaking testbed that can emulate tens of thousands of possible interactions among hundreds of wireless communication devices—including cell phones, military radios, IoT devices and a litany of others—operating simultaneously in a square-kilometer expanse. That is an area some 40x that of the Roman Colosseum's six acres. DARPA's Colosseum amounts to an artificial, high-fidelity holodeck that can simulate invisible, fast-as-light communication signals traversing, ricocheting, echoing and otherwise making their way from transmitters to receivers wherever they might be in a wide variety of simulated environments. Said Tilghman, "The Colosseum can make the radios believe they are operating in an open field, a dense city, a suburban shopping mall, a desert or any other scenario you can dream up."

Engineers at APL assembled the Colosseum with 128, two-antenna, software defined radio (SDR) units built by National Instruments (NI). Emulating electromagnetic waves from these radios traversing the physical world is no small task. To tackle this, APL partnered with NI to put 64 field programmable gate arrays (FPGAs) to the task. The FPGAs enable the Colosseum to make the SDRs behave as though they are operating in any of countless environments, each designed like an electromagnetic movie set.

By the numbers, the Colosseum testbed is a 256-by-256-channel RF channel emulator, which means it can



Source: BAE Systems

For More Information

Visit mwjournal.com for more defense news.

calculate and simulate in real-time more than 65,000 channel interactions among 256 wireless devices. Each simulated channel behaves as though it has a bandwidth (information content) of 100 MHz, which means the testbed supports 25.6 GHz of bandwidth in any instant. Moreover, each channel's transmission and reception frequency is tunable between 10 MHz (as in broadcast FM radio) and 6 GHz (as in Wi-Fi). The amount of digital RF data coursing through the Colosseum each second, more than 52 terabytes, exceeds the estimated amount of information contained in the entire print collection of the Library of Congress. In short, said Tilghman, "the Colosseum is a magnificent electronic arena and just what we need to discover how to eke more capacity from the frustratingly finite spectrum."

US Navy's Enterprise Air Surveillance Radar Completes Major Design Review

Raytheon Co. and the U.S. Navy recently conducted a Preliminary Design Review (PDR) for the new Enterprise Air Surveillance Radar (EASR), confirming system development is on track for delivery to the designated ship classes. The PDR fol-

lowed several milestones completed as planned on the development schedule, including the combined Systems Requirements and System Functional Reviews, and the Integrated Baseline Review.

EASR is the U.S. Navy's advanced radar for aircraft carriers and amphibious warfare ships, providing simultaneous anti-air warfare, anti-surface warfare and air traffic control mission capabilities. It delivers increased performance, higher reliability and sustainability and lower total ownership cost than the radars it replaces. EASR is the replacement for the Volume Search Radar for the CVN 78 class, and the AN/SPS-48 and AN/SPS-49 radar systems for numerous ship classes.

The PDR validated Raytheon's scaled design leveraging the AN/SPY-6(V) Air and Missile Defense Radar, configured into a rotating and a fixed face variant to match the missions of the multiple ship classes. EASR is built on Radar Modular Assembly (RMA) technology which has been matured through development—and recent test successes—of AN/SPY-6 for the DDG 51 Flight III destroyers. Each RMA is a self-contained radar in a 2 ft x 2 ft x 2 ft box. These individual radars can integrate together to form arrays of various sizes.

The commonality, in both hardware and software, with SPY-6 offers a host of advantages, including performance, availability and reliability, maintenance, training, logistics and lifecycle support.

WEST•BOND'S Latest Model 4KE: Now in ONE HEAD; Wedge Bonder / Au and Cu Ball Bonder

*Our exclusive triple convertible semi-automatic ultrasonic wire bonding machine:
The 4KE wedge-wedge and ball-wedge wire bonding machine, with
convertibility for either 45° or 90° feed, and ball bonding, all in ONE HEAD!.*



- 45° and 90° Wire Feed Convertibility
- Wire or Ribbon Bonding
- Cu or Au Ball-Wedge Bonding
- Throatless Chassis
- ESD Protection
- Adjustable Work Platform
- Orthogonal X, Y, and Z Axes

See West-Bond's latest Model 4KE and the 7312C at the
SEMICON West at Moscone Center, San Francisco, July 11-13, 2017

WEST•BOND, INC.

1551 S. Harris Court Anaheim, CA 92806

www.westbond.com

Ph. (714) 978-1551 Fax (714) 978-0431

e-mail: sales@westbond.com

Reactel, Incorporated

Reacting First to All Your Filter Needs.

**WORKING IN
TIGHT
SPACES?**



Actual Size



DISCRETE COMPONENT FILTERS

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

Our versatility is reflected in the variety of units we are providing for systems requiring small, lightweight, high-performance filters and multiplexers.

Small (profiles as low as 0.12"), lightweight and rugged enough to withstand the most demanding environments, these units are the perfect fit where small size and low weight are paramount.

Let our Engineers show you what we can do in tight spaces!



[Download a copy of our 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 • Follow us on Twitter: [@reacteljim](https://twitter.com/reacteljim)
Go online to www.reactel.com to download your Reactel catalog today.



@reacteljim

SIX DAYS

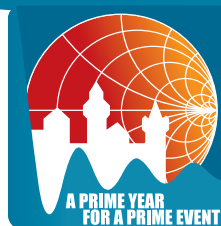


THREE CONFERENCES



ONE EXHIBITION

EUROPEAN MICROWAVE WEEK 2017
NÜRNBERG CONVENTION CENTER,
NUREMBERG, GERMANY
8TH - 13TH OCTOBER 2017



EUROPEAN MICROWAVE WEEK
NÜRNBERG CONVENTION CENTER
NUREMBERG, GERMANY
8TH-13TH OCTOBER 2017
www.eumweek.com

EUROPE'S PREMIER MICROWAVE, RF, WIRELESS AND RADAR EVENT

The Conferences (8th - 13th October 2017)

- European Microwave Integrated Circuits Conference (EuMIC) 9th - 10th October 2017
- European Microwave Conference (EuMC) 10th - 12th October 2017
- European Radar Conference (EuRAD) 11th - 13th October 2017
- Plus Workshops and Short Courses (From 8th October 2017)
- In addition, EuMW will include for the 8th year, the Defence, Security and Space Forum on 11th October 2017

DISCOUNTED CONFERENCE RATES

Discounted rates are available up to and including 8th September 2017.

Register NOW and SAVE!

Registration is available after this date and up to 13th October at the standard rate.

The FREE Exhibition (10th - 12th October 2017)

ENTRY TO THE EXHIBITION IS FREE! Register today to gain access to over 300 international exhibitors and take the opportunity of face-to-face interaction with those developing the future of microwave technology. The exhibition also features exhibitor demonstrations, industrial workshops and the annual European Microwave Week Microwave Application Seminars (MicroApps).

EuMA
European Microwave Association

Organised by:
horizon house

Official Publication:
Microwave Journal

Co-sponsored by:
IEEE

Co-sponsored by:
MTT-S

Supported by:
IET The Institution of Engineering and Technology

Supported by:
VDE ITG

EuMIC 2017
The 12th European Microwave Integrated Circuits Conference
Co-sponsored by:



47TH EUROPEAN MICROWAVE CONFERENCE 2017

The 47th European Microwave Conference
Co-sponsored by:



EuRAD 2017

The 14th European Radar Conference
Co-sponsored by:



Register online now as a delegate or visitor at: www.eumweek.com



Consortium Demonstrates Ultra-High Throughput Transmission Over Satellite

A European consortium consisting of the Fraunhofer Institute for Integrated Circuits IIS, WORK Microwave and Avanti Communications has completed highly successful over-the-air trials on Avanti HYLAS satellite capacity employing the latest DVB-S2X modulator and demodulator equipment. The demonstrations used wideband carriers exploiting full transponder bandwidth and outperforming the target throughput of more than 1 Gbps using a single communication carrier.

The technology demonstration was part of a development funded by the European Space Agency (ESA) under the ARTES Advanced Technology via the ultra-high throughput transmission through wideband Ka transponder contract.

“...exceptionally efficient use of spectrum.”

The experiments demonstrated a variety of carrier bandwidths and modulation schemes. This included closing the forward link with a 480 MHz carrier and successfully receiving and demodulating

this signal on the ground. The sustained throughput to a single end-user terminal was measured at 1.27 Gbps, leveraging from the DVB-S2X time slicing capability that allows the receiver to selectively skip and ignore parts of the incoming signal and thus save on processing power. DVB-S2X, as the latest satellite communication standard allows for, an exceptionally efficient use of spectrum.

Fraunhofer IIS developed a DVB-S2X receiver IP that was used for the technology demonstration, while WORK Microwave developed a high-performance wideband DVB-S2X modulator, which was used for the communication on the uplink. The FPGA-based, modular design of modulator and demodulator enables different products and throughput ranges, up to the maximum spectral efficiency supported by DVB-S2X on wideband carriers. U.K.-based Avanti Communications provided engineering support and HYLAS Ka-Band transponder capacity for the live demonstration.

“The successful demonstration of this next-generation technology confirms the innovation-led competitiveness of the European space industry and the capabilities of the European satellite fleet, as well as the importance of the ARTES Advanced Technology program to fund such developments,” said Nikolaos Topsisidis, the technical officer managing the activity on behalf of ESA.

Finland's First 5G Development Environment Opens to Businesses

The VTT Technical Research Centre of Finland, the University of Oulu and the Centria Polytechnic will take their 5G test environment to a new stage with the emphasis on vertical business use. There is already a large number of Finnish companies with whom 5G technology has been developed that will be tested in several application areas, with new solutions targeted for field trials during 2017.

In the 5GTN+ project, mostly funded by Tekes, future technology is applied to field testing even before commercial networks emerge. Thus, the opportunities offered by 5G technology will be utilized as early as possible, offering companies the opportunity to experiment with technology in their specific areas of application. The project, which focuses on seeking clear business benefits for partner companies, aims to strengthen the position of Finnish industry as a developer of new 5G technologies and applications.

“The 5G test environment supports corporate product development. Its benefits are reflected, for example, in high-speed and reliable connections, short delays, energy savings and connectivity,” said Project Manager Atso Hekkala from VTT.

“We provide the test network and related skills for everyone to use. We are also welcoming companies outside the project who are interested in taking advantage of new technology in their business among the first,” said Project Manager Olli Liinamaa from the University of Oulu.

...the opportunity to experiment with technology...

Infineon Joins 5G Automotive Association

In its continued efforts to contribute to the introduction of the 5G standard into the car, Infineon Technologies has joined the 5G Automotive Association (5GAA), which works to introduce new communication solutions, enabling connected automated driving and intelligent transport systems. As a leading semiconductor company for automobile electronics, cellular infrastructure and data security, Infineon provides key technologies required for 5G for the autonomous car and for electromobility.

Enhanced mobile broadband access at multi-gigabit speeds requires advanced semiconductor solutions. Infineon provides high-frequency components

InternationalReport

that receive, amplify and transmit data, as well as components for antenna tuning and switching. In addition to its broad portfolio of automotive electronics, Infineon supplies security chips that help secure the data communication inside a vehicle and with its external world.

"Secure communication with practically zero time delay is a critical requirement for the breakthrough of autonomous driving," said Peter Schiefer, president of the automotive division at Infineon. "In close cooperation with the car industry and IT, Infineon supports the communication solutions for the automated car with its cutting-edge semiconductors and with system and security expertise."

Broadband Forum Partners with SDN/NFV Industry Alliance in China

The Broadband Forum and SDN/NFV Industry Alliance have signed a Memorandum of Understanding to jointly set up an Open Broadband Laboratory Asia (OBLA) and promote the development of network transformation and cloud evolution.

Open Broadband Labs are a collaborative resource for the integration, staging and testing of open

source, commercial software, standards-based and vendor implementations where suppliers, integrators and operators can work together on new and coexisting solutions. The focus of Open Broadband Labs, such as OBLA, is acceleration of go-to-market and go-to-production for new services and applications, and the migration from existing broadband infrastructures to cloud-based ones introducing NFV and SDN technologies.

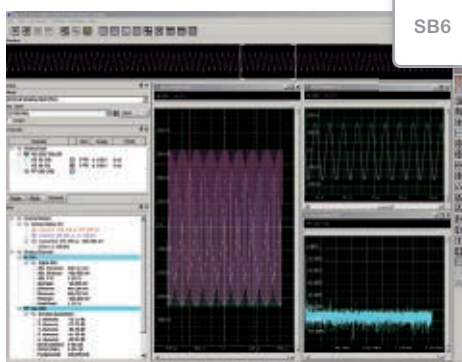
Under the agreement, the Forum will exclusively license the SDN/NFV Industry Alliance to undertake the construction of OBLA in China and to conduct conformance and interoperability testing, migration best practices, technical due diligence and training around the project. The SDN/NFV Industry Alliance will build and manage the OBLA, while the Forum will provide technical direction, testing methods, a standards framework and domain expertise. The aim of the project is to develop network cloud standards verification, testing, solution conformance and a proving ground for new services.

"This new lab facility is a strategic and natural evolution of the Forum's ongoing work on virtualization and cloud, with almost every project in our current scope now connected to these next-generation network technologies. We look forward to strengthening this work with the SDN/NFV Industry Alliance," said Broadband Forum Chairman Kevin Foster of BT.

Spectrum's new 16 bit Arbitrary Waveform Generator gives you complete control over signals

- 1, 2 or 4 channels
- PXIe x4 Gen2 Interface
- Streaming up to 1.4 GByte/s
- 1.25 GS/s with 400 MHz bandwidth
- up to ± 2.5 V into 50 Ω
- 4 GByte memory

Feature rich – Outstanding performance –
Easy to configure



SB6

SBench 6 –
powerful, flexible and
easy-to-use professional
instrumentation software

Outstanding Support ...

- Drivers for Windows and Linux, both 32 bit and 64 bit, included
- SDK's for LabVIEW®, MATLAB®, LabWindows/CVI®, C++, Delphi, .NET, Python, JAVA, ...
- Integrated marker outputs
- Sequence mode
- 2 years warranty
- Individually manufactured in Germany



40 GHz
(KBL-Series)

Precision 75Ω
(CBL-Series)

Precision 50Ω
(CBL-Series)

Armored
(APC-Series)

Ultra-Flexible
(ULC-Series)
Flexible
(FLC-Series)

NEW!
Spaghetti Cables
(SLC-Series)

Precision VNA
Cables
(VNAC-Series)

TEST CABLES *up to 40 GHz!*

Reliability You Can Trust... **\$68⁹⁵** from ea. (qty. 1-9)

Why do 10,000 customers trust Mini-Circuits test cables? Because they simply don't fail! Our test cables have been performance qualified to 20,000 flexures* and come backed by our 6-month product guarantee**, so you can be confident you're getting rugged construction, reliability, and repeatable performance you can depend on. Whether you're performing production

test, burn-in, over-temperature testing, hi-rel testing – you name it – chances are there's a Mini-Circuits test cable for your application in stock, ready for immediate shipment. Order some for your test setup at minicircuits.com today, and you'll quickly find that consistent long-term performance, less retesting and fewer false rejects really add up to bottom-line savings, test after test!

Model Family	Capabilities	Freq. (GHz)	Connectors†
KBL	Precision measurement, including phase, through 40 GHz	DC-40	2.92mm
CBL-75+	Precision 75Ω measurement for CATV and DOCSIS® 3.1	DC-18	N, F
CBL	All-purpose workhorse cables for highly-reliable, precision 50Ω measurement through 18 GHz	DC-18	SMA, N
APC	Crush resistant armored cable construction for production floors where heavy machinery is used	DC-18	N
ULC	Ultra-flexible construction, highly popular for lab and production test where tight bends are needed	DC-18	SMA
FLC	Flexible construction and wideband coverage for point to point radios, SatCom Systems through K-Band, and more!	DC-26	SMA
NEW! SLC	Super-flexible spaghetti cables with 0.047" diameter and 0.25" bend radius, ideal for environmental test chambers.	DC-18	SMA/SMP
VNAC	Precision VNA cables for test and measurement equipment through 40 GHz	DC-40	2.92mm

* All models except VNAC-2R1-K+

** Mini-Circuits will repair or replace your test cable at its option if the connector attachment fails within six months of shipment. This guarantee excludes cable or connector interface damage from misuse or abuse.

† Various connector options available upon request.

Contact apps@minicircuits.com to discuss your special requirements.



Ultra-Wideband
10 MHz to 13 GHz



Power Handling
up to 2W

Programmable ATTENUATORS

0 to 120dB 0.25dB Step 1 MHz to 13 GHz* from **\$395**

Features

- Models with attenuation range up to 30, 60, 63, 90, 95, 110 or 120 dB
- Choose from USB, Ethernet, RS232 and SPI control options
- Use our software or yours! User-friendly GUI and DLLs included[†]
- Sweep or hop attenuation levels
- Save and recall customized attenuation patterns
- Pocket-sized package, as small as 3.0 x 2.0 x 0.6"
- **Now** 16 unique models in stock, ready to ship!

* Specs may vary by model. See data sheets for specific model information.

[†] No drivers required. DLL objects for 32/64 bit Windows® environments using ActiveX® and .NET® frameworks.

Perfect for...

- Fading simulators
- Handover system evaluation
- Automated test equipment
- And MORE!

Visit minicircuits.com for detailed model specs, application notes, and more!
Place your order today and have them on your test bench as soon as tomorrow!



www.minicircuits.com/products/programmable_attenuators.shtml





Autonomous Vehicles and Safety Mandates Spur Increase in Automotive Radar Demand and Performance

The recent developments in autonomous vehicles and new “soft mandates” from safety agencies, such as Euro-NCAP, are raising requirements for enhanced resolution and 360-degree sensing. This will increase demand for automotive radars as well as bring about the introduction of new technologies, such as RF CMOS. This technology is used in the NXP Dolphin chipset that Hella will use in its fifth generation short range radars.

RF CMOS enables even greater integration of chipsets than current silicon germanium-based designs. It thus will allow the size of short range radars to be reduced even further, potentially enabling them to challenge the current market for ultrasonic sensors in high-end park assist applications.

In the meantime, radar resolutions are being improved by the current switch over to higher frequencies from 76 to 79 GHz and to the higher bandwidths enabled by these frequencies. Backed by learning algorithms and new modulation techniques, automotive radars will be more capable of identifying different targets. This raises the prospect of future radars recognizing pedestrians and even curb stones, as well as enhancing the robustness of detecting such targets and reducing false positive readings.

“This enhanced capability is what is required by autonomous vehicles, along with corner or surround radar concepts that provide redundant sensing, on top of cameras and lidars, and in adverse weather conditions,” said Kevin Mak, senior analyst at the Automotive Practice of Strategy Analytics. “But with this increase in performance comes the challenge of processing and transmitting larger rates of data, which can pose a dilemma on how auto makers design their vehicle architectures in the run-up towards autonomous vehicles,” Mak added.

Telco Cloud to Reach Critical Mass after 2020, Driven by 5G

Large-scale telco cloud deployments will reach global critical mass after 2020, in parallel with the deployment for 5G. This network generation will likely require a new core network to allow for advanced concepts, including network slicing and services geared toward different business verticals. Early 5G deployments, during which time there will not be an immediate need for a new telco core, will likely focus on enhanced mobile broadband.

“Although telcos are transforming their technology

and business platforms to become more agile and to evolve past their monolithic access-based business models, they are finding it much more challenging than anticipated,” said Dimitris Mavrakis, research director at ABI Research. “Software, cloud computing and open source are promising and will simplify operations, but in the short term, telcos are preferring to rely on their trusted vendors to continue this journey.”

AT&T, DT, Telefonica and Verizon are honing their strategies and planning their networks as shared platforms, rather than a mix of individual network appliances. This means that network resources will be virtualized, distributed and software controlled, leading to a much more agile network. This will allow the implementation of an “Untelco” strategy, selling tailored network resources to different verticals.

However, there are a few indications that end-to-end systems are still the end goal. For example, Telefonica O2 U.K. awarded an end-to-end contract to Nokia for a cloud-native packet core, something that would be a considerable challenge to implement in-house with a true vendor agnostic, common-off-the-shelf network. ABI Research expects many more end-to-end telco cloud contracts will be awarded in the years to come.

“Although a few open source projects are contributing valuable inputs toward the evolution of telco networks, there is also competition among open source projects, and the concept is also misunderstood and in some cases, misused by several industry players,” concludes Mavrakis. “The golden ratio is somewhere between end-to-end systems and open source components, if vendors provide open interfaces and flexibility to integrate third-party and smaller vendors.”

China, Japan and South Korea Lead Asian Smart City Initiative Deployments

Governments in China, Japan and South Korea lead the deployment of citizen-centric, smart city initiatives in Asia. Specific leading cities in China that continue to show accelerated adoption of smart energy solutions include Dalian, Hangzhou, Nanjing and Tianjin. The smart city programs improve overall quality of life, boost enterprise operational efficiencies and enhance the effectiveness of public safety and security, transportation, citizen engagement, catastrophe management and sustainability services.

“Asia’s demand for smart city solutions will heighten over the next five years with China, Japan and South Korea now accelerating adoptions of smart light, meter, building and transportation, as well as renewable energy programs,” says Raquel Artes, industry analyst at ABI Research. “All three countries possess strong wireless communication networks, which likely account for

CommercialMarket

the regions' ability to rapidly deploy many smart city initiatives in a timely and cost-efficient manner."

Estimates are that China smart meter installations will grow at a 21 percent CAGR to reach 349 million in 2020 through vendors like Itron, Echelon, Huawei, Holley Metering, Itron, Landis+Gyr and Sensus. The region also aims to have five million electric vehicles (EV) on the road by 2020. With Japan and South Korea targeting one million and 200,000 EVs, respectively, on the road by 2020. Key EV vendors include BAIC, BYD, Geely and Tesla, among others.

All three countries lead multi-applications smart card deployments that enable cashless payment for transportation, parking fees and toll road fees. Ridesharing programs are also gaining traction, as evident through car manufacturers like Hyundai deploying car sharing services in South Korea that utilize EV.

And while smart parking initiatives in Asia are still at a minimum, China acts as the region's catalyst. China Unicom, Huawei and the Shanghai government recently signed a strategic partnership to implement a smart parking solution in Shanghai International Tourism and Resorts Zone, which will deploy in a 4.5G NB-IoT based network. Smart parking enables parking operators and drivers to remotely check and locate available parking spaces in real-time. It, therefore, reduces labor requirements of parking operators, optimizes usage of parking

spaces and reduce public parking costs.

Japan also recently launched a smart catastrophe management program, which included an Emergency Warning System developed by NEC, to detect and issue a warning that will alert both the government and citizens of upcoming natural catastrophes and identify high-risk areas to promote quicker response times and resource dispatches.

Yet, despite significant smart city developments in China, Japan and South Korea, India and Indonesia are failing to keep pace. While both regions are deploying smart city projects designed to enhance public safety and reduce energy consumption, they struggle to lead in these market segments.

"India and Indonesia are lagging behind primarily due to a lack of infrastructure readiness," concludes Artes. "While there are vast opportunities for smart city vendors in India due to the governmental spearhead of wireless network and communications infrastructure development, the region is not fully capitalizing on those opportunities. This may soon change, as the government recently announced that it will develop 100 smart cities in the region as part of its Smart City program."

"Asia's demand for smart city solutions will heighten over the next five years..."



SEDI GaN: The Power Leader for Bringing Radar to Life

Part Number	Configuration	Frequency Range (GHz)	Min. Output Power (W)	Min. Power Gain (dB)
SGN1214-220H-R	Partially matched	1.2 - 1.4	220	17.4
SGN21-120H-R	Partially matched	1.7 - 2.5	125	14.5
SGN31-080H-R*	Partially matched	2.7 - 3.5	80	13.0
SGN2729-250H-R	50Ω matched	2.7 - 2.9	250	13.0
SGN2729-450H-R*	50Ω matched	2.7 - 2.9	450	13.0
SGN2729-600H-R	50Ω matched	2.7 - 2.9	600	12.8
SGN2731-500H-R	50Ω matched	2.7 - 3.1	480	11.8
SGN3135-100H-R*	Partially matched	3.1 - 3.5	100	12.5
SGN3035-150H-R	50Ω matched	3.0 - 3.5	150	12.8
SGN3135-500H-R*	50Ω matched	3.1 - 3.5	500	11.0
SGM6901VU*	50Ω matched	8.5 - 10.1	24	23.3
SGC8598-50A-R	50Ω matched	8.5 - 9.8	50	11.0
SGC8598-100A-R	50Ω matched	8.5 - 9.8	100	10.0
SGC8598-200A-R	50Ω matched	8.5 - 9.8	200	10.0
SGFCF2002S-D	Partially matched	Up to 3.5GHz	17@3GHz	27.4@3GHz
SGN350H-R	Unmatched	Up to 1.4GHz	350@900MHz	16.4@900MHz

*Under development

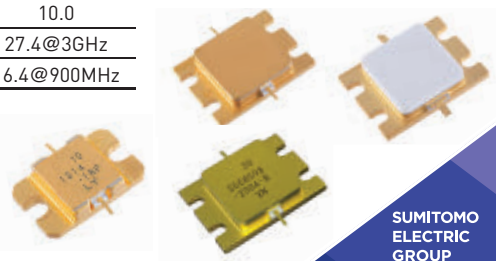
USA usaradar@sei-device.com
Europe mw_europe@sumielectric.com
Other globalradar@sei-device.com
Website www.sei-device.com or www.sedi.co.jp

Export of products in this list may be restricted under applicable US or Japanese law. Please inquire us through the e-mail addresses or websites above.

High Power:
X-band 200W,
S-band 600W

Easy to Use:
Fully/Partially Matched
to 50Ω

Proven Quality and
Reliability from the
Market Leader



**SUMITOMO
ELECTRIC
GROUP**

ATC Broadband SMT Capacitor Solutions

Reliable and Repeatable Broadband Performance

ATC's 520 and 530 Series family of Broadband Capacitors exhibit low insertion loss over multiple octaves of frequency spectrum, flat frequency response and excellent return loss. They are ideal for broadband DC blocking, coupling, bypassing, and feedback applications in optical communications systems and equipment using high-speed digital logic.

Attributes

- 0201 and 0402 EIA Case Sizes
- 16 KHz to 20 GHz
- Low Insertion Loss
- Voltage Ratings to 16 WVDC
- Unit-to-Unit Performance Repeatability
- RoHS Compliant Terminations
- Solderable SMT Terminations



ATC Series	EIA Size	Capacitance	Frequency Range	Insertion Loss	Voltage Rating
520 L	0402	10 nF	160 KHz to 16 GHz	1 dB max.	16 WVDC
530 L	0402	100 nF	16 KHz to 18 GHz	1 dB max.	16 WVDC
530 Z	0201	100 nF	16 KHz to 20 GHz	0.4 dB typ.	10 WVDC



AMERICAN

ATC North America
sales@atceramics.com

TECHNICAL

ATC Europe
saleseur@atceramics.com

CERAMICS

ATC Asia
sales@atceramics-asia.com



THE
ENGINEERS'
CHOICE®
ISO 9001 REGISTERED
COMPANY



THE ENGINEERS' CHOICE®

www.atceramics.com



Around the Circuit

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Analog Devices Inc. (ADI) announced the acquisition of **OneTree Microdevices Inc.**, a privately held company based in Santa Rosa, Calif. ADI is a leading supplier of mixed signal solutions for cable access ranging from data converters through clocking and control/power conditioning. With the acquisition of OneTree Microdevices' GaAs and GaN amplifier portfolio, which offers best-in-class linearity, output power and efficiency, ADI now supports the complete signal chain for next-generation cable access networks. Financial terms of the transaction were not disclosed.

Infinite Electronics Inc., a holding company for the Pasternack, Fairview Microwave and L-com brands, announced the acquisition of **Smiths Interconnect's Microwave Telecoms (SMT)** business from **Smiths Group plc**, a London based global technology company. SMT is comprised of the Kaelus, PolyPhaser, Transtector Systems and RadioWaves brands. Each of these companies provides a unique set of capabilities and product offerings deployed in critical communications networks worldwide, while also setting global standards through innovation and customer service. Collectively, SMT is committed to ensuring reliable communications network performance from the tower to the core.

Crane Co., a diversified manufacturer of highly engineered industrial products, announced that it has acquired **Westlock Controls** from **Emerson Electric Co.** for cash consideration of \$40 million. Westlock is a global leader in the manufacturing and sale of switchboxes, position transmitters and other solutions for networking, monitoring and controlling process valves. With primary operations located in Saddle Brook, N.J., Westlock had 2016 sales of approximately \$32 million. Crane is a diversified manufacturer of highly engineered industrial products. Founded in 1855, Crane provides products and solutions to customers in the hydrocarbon processing, petrochemical, chemical, power generation, unattended payment, automated merchandising, aerospace, electronics, transportation and other markets.

NEW STARTS

CORWIL Technology announced that is now offering its customers RF measurement capability up to 50 GHz. CORWIL Technology provides high quality and responsive semiconductor assembly and test services focusing on hi-rel, fast-turn and wafer processing markets. Founded in 1990 and based in Milpitas, Calif., CORWIL is the premier U.S. provider of full back-end assembly services and is a key partner with leading medical, military/aerospace and commercial semiconductor companies.

ACHIEVEMENTS

Microwave engineers at **RCL Microwave Inc.** in Apalachin, N.Y. have executed their first successful test and dielectric measurement of a thin, flexible 200 micron thick glass material using novel measurement fixtures and methods capable of broadband dielectric material characterization. The test was performed and successfully completed using unique broadband measurement fixtures and the phase difference method, which provides 10,000 data points from 1 MHz to 32 GHz. A 32 GHz broadband test fixture has been combined with the Phase Difference Dielectric Characterization Method to generate data across the entire frequency spectrum of interest.

Raytheon Co. and the **U.S. Navy** conducted the Preliminary Design Review (PDR) for the new Enterprise Air Surveillance Radar (EASR), confirming system development is on track for delivery to the designated ship classes. The PDR followed several EASR milestones completed as planned on the development schedule, including the Combined Systems Requirements and System Functional Reviews and the Integrated Baseline Review. EASR is the U.S. Navy's advanced radar for aircraft carriers and amphibious warfare ships, providing simultaneous anti-air warfare, anti-surface warfare and air traffic control mission capabilities. It delivers increased performance, higher reliability and sustainability and lower total ownership cost than the radars it replaces.

CONTRACTS

CACI International Inc. announced that it has been awarded \$349 million in previously unannounced awards on classified contracts with federal government customers. The awards were made during the company's first three quarters of fiscal year 2017, which ended March 31, 2017. For these contracts, CACI is delivering tailored information solutions and services to national-level agencies safeguarding our nation's security. CACI provides information solutions and services in support of national security missions and government transformation for intelligence, defense and federal civilian customers. CACI is a member of the Fortune 1000 Largest Companies, the Russell 2000 Index and the S&P Small-Cap600 Index. CACI's sustained commitment to ethics and integrity defines its corporate culture and drives its success.

Engility Holdings Inc. won the re-compete of the Systems and Software Assurance Services contract from **NASA's Goddard Space Flight Center**. Engility will help NASA's Independent Verification and Validation (IV&V) program support missions to explore Earth and the universe, including future moon and Mars expeditions. Under the IV&V contract, Engility's technical efforts will help NASA procure, develop, deploy and operate systems and software to meet exacting performance demands. By employing analytical techniques,

ULTRA-LOW PHASE NOISE PHASE LOCKED REFERENCE TRANSLATORS (OCXO)

Frequency Option	Reference Frequency In (MHz)	Frequency Out (MHz)	Phase Noise @ 100 Hz Offset dBc/Hz (Max)	Model Number
Programmable	1, 5, 10, 20, 50	1000	-110	LNFTP-1000-15
Fixed (Dual Output)	10	120 / 240	-125 / -130	LNFTD-10-120240-12
Fixed	10	1000	-110	LNFT-10-1000-15



Features

- Excellent Performance
- Models With:
 - Programmable Input Reference Frequency
 - Dual RF Output (Fundamental & X2)
 - Fixed Output Frequency

Applications

- Frequency Converters
- Synthesizer Reference Multipliers

Talk To Us About Your Custom Requirements.



Phone: (973) 881-8800 | Fax: (973) 881-8361

E-mail: sales@synergymw.com

Web: WWW.SYNERGYMWAVE.COM

Mail: 201 McLean Boulevard, Paterson, NJ 07504

Around the Circuit

security assessments and independent testing, Engility will add assurance that system software will operate safely, reliably and securely to achieve mission success.

BWX Technologies Inc. (BWXT) announced that the **U.S. Naval Nuclear Propulsion Program** exercised contract options in Q1 2017 with BWXT's subsidiary **Nuclear Fuel Services Inc.** (NFS) totaling approximately \$141.7 million for fuel manufacture, development activities and decommissioning work in support of the nation's nuclear submarines and aircraft carriers. NFS has been the sole manufacturer of nuclear fuel for the U.S. Navy's fleet of nuclear-powered aircraft carriers and submarines since 1964. The company employs a full-time workforce of approximately 1,000 people, including long-term contractors and security personnel.

Cubic Global Defense, a business unit of **Cubic Corp.**, announced it received a contract award worth more than \$35 million to continue supporting the British Army. The three-year contract allows Cubic to deliver services and repair to the Area Weapons Effects Simulator (AWES) at Salisbury Plain Training Area (SPTA) in the U.K. and at the British Army Training Unit Suffield (BATUS) in Alberta, Canada. AWES allows the British Army to conduct large-scale, force-on-force combat exercises with realistic, but simulated effects of direct fire, artillery, mortar fire, mines and air-delivered munitions as well as nuclear, biological and chemical weapons.

OSI Systems Inc. announced that its Security division has received a Foreign Military Sales (FMS) two-year contract extension from the **U.S. Department of Defense** valued at approximately \$23 million to provide training, service and logistics support for its Rapiscan® cargo and vehicle inspection systems. OSI Systems is a vertically integrated designer and manufacturer of specialized electronic systems and components for critical applications in the homeland security, healthcare, defense and aerospace industries. They combine more than 40 years of electronics engineering and manufacturing experience with offices and production facilities in more than a dozen countries to implement a strategy of expansion into selective end product markets.

Sparton Corp. and **Ultra Electronics USSI**, a subsidiary of **Ultra Electronics Holdings plc** (ULE), announced the award of subcontracts valued at \$17.4 million from their **ERAPSCO/SonobuoyTech Systems** joint venture. ERAPSCO/SonobuoyTech Systems will provide manufacturing subcontracts in the amount of \$11.2 million to Ultra Electronics USSI and \$6.2 million to Sparton De Leon Springs, LLC. Production will take place at Ultra Electronics USSI's Columbia City, Ind. facility and Sparton's De Leon Springs, Fla. facility. ERAPSCO/SonobuoyTech Systems were awarded multiple foreign contracts for the manufacture of passive and active sonobuoys in support of multiple underwater missions for detection, classification and localization of adversary submarines during peacetime and combat operations.

Comtech Telecommunications Corp. announced that during its third quarter of fiscal 2017, its Tempe, Ariz.-based subsidiary, **Comtech EF Data Corp.**, which is part of Comtech's Commercial Solutions segment, received a \$1.8 million contract award extension for additional Advanced Time Division Multiple Access (TDMA) Interface Processor (ATIP) production terminals and Engineering Support Services from the **Space and Naval Warfare Systems Command** (SPAWAR). The contract extension also included exercising options under an Engineering Support Services option to participate in integration and test activities to validate the U.S. Navy's planned PPPoE interface between the ATIP and Automated Digital Network System (ADNS).

Elbit Systems Ltd. has announced that it was awarded a contract to provide the **Israeli Ministry of Defense** (IMOD) with dozens of satellite-on-the-move (SOTM) systems. The contract is in an amount that is not material to Elbit Systems and will be performed over a two-year period. The ELSAT 2100 SOTM family of systems allows high data rate broadband capabilities to be available to land vehicles on the move. The systems can be installed on a variety of platforms and are unique in their small footprint and its advanced tracking capabilities, providing seamless communication even in difficult terrain.

PEOPLE



▲ Robert Bagheri

in the electronics industry. Before joining Telewave, Mr. Bagheri was founder, investor and chairman of a stealth start-up serving the wearables and mobile markets.



▲ Nick Doben

TechPlus Microwave Inc., a technology leader in the design and manufacture of RF and microwave filters, announced that **Nick Doben** has joined the company as senior program manager for aerospace, hi-rel and defense. With over 20 years of experience in the RF and microwave community, Doben will provide program management solutions and coordination in aerospace, defense and hi-rel.

Indium Corp. has named **Chris Nash** as product manager for PCB Assembly Materials. Nash is responsible for managing new solder paste product development, including strategy guidance and execution, directed to sales to the printed circuit board industry. In addition, he will provide solder paste product support, including leading marketing communications efforts, delivering field sales and technical team training and interfacing



AHEAD OF WHAT'S POSSIBLE™

ADI's RF & MICROWAVE PORTFOLIO INCLUDES 1,000+ RF ICs—AND THE SYSTEM EXPERTISE YOU NEED TO OPTIMIZE PERFORMANCE.

From wideband amplifiers and SOI switches to RF detectors and PLLs, our unrivaled DC through 100 GHz portfolio drives performance across the entire signal chain.

1,000+ WAYS TO DRIVE RF & MICROWAVE PERFORMANCE



DISCOVER ADI'S TOOLS AND RESOURCES, AND EXPLORE
THE INDUSTRY'S BROADEST RF IC PORTFOLIO

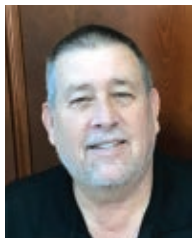
analog.com/RFMW



#ADIAhead

Around the Circuit

with manufacturing for increased customer support. Nash has worked for Indium Corporation for more than 10 years and has served in a number of roles, including inside sales, product management and global technical support. His most recent role was as new product development manager for PCBA.



▲ Paul White

Modelithics announced that **Paul White** has been named as the newest member of the Modelithics Board of Directors. White brings an extensive and impressive resumé of business and technical knowledge to the company, with over 35 years in the RF and microwave industry. White's early experience includes the engineering of low noise and high power solid state amplifier systems for next generation fire control radar systems, and in sales and marketing of a Hewlett Packard test and measurement product line. He then became a partner at Applied Engineering Consultants, selling microwave hardware and software into the defense and intelligence marketplace.

Ashleigh West has joined **Microwave Journal** as copy editor. Ms. West utilizes her specialized writing background to deliver polished editorial content in each



▲ Ashleigh West

print issue and for *Microwave Journal's* online content. Ms. West's monthly columns include the events calendar and marketing updates. She also produces the weekly Microwave Flash newsletter and the Military Microwaves monthly newsletter, and helps to co-manage *Microwave Journal's* social media presence across Facebook, Twitter and Instagram.

REP APPOINTMENTS

Ametherm announced that it has expanded its network of value-added representatives in the U.S. with the conclusion of a new agreement with **Unity Sales**. Effective immediately, Unity Sales is offering Ametherm's entire lineup of inrush current limiters and NTC thermistors in Ohio, Indiana, Michigan, Kentucky, Western Pennsylvania and West Virginia. Based in Fort Wayne, Ind.—with offices in all markets it serves—Unity Sales was founded in 2002 and provides cost-effective technology solutions to the transportation, medical, automotive, instrumentation, industrial, consumer and military/aerospace industries.

Anokiwave Inc., an innovative company providing highly integrated IC solutions for mmW markets and active antenna based solutions, announced that they have signed a representative agreement with **M-RF Co. Ltd.** in Japan. The agreement aligns with Anokiwave's goal to support new customers and opportunities for their

- VNA Test Assemblies
- Low Loss Cable Assemblies
- NMD Test Port Adapters
- Calibration Kits



Up to 67GHz



ARANCE ELECTRONICS
www.arance-rf.com



Tel: +86-25-58817997 Fax: +86-25-58072397
E-mail: sales@arance-rf.com; tech@arance-rf.com

Innovation That's Scalable.



Mercury offers a portfolio of RF and Microwave components that enable solutions at the block diagram level including:

- Amplifiers
- Detectors
- Ferrites
- Mixers
- Multipliers
- Noise products
- Switches
- VCOs



Visit mrcy.com/rfm and download our short-form catalog.



These components are designed to work together thus delivering lower technology risk. And all are manufactured in our scalable, world-class Advanced Microelectronics Centers.

Around the Circuit

highly-integrated Active Antenna Core IC solutions in Japan. M-RF Co. has specialized in high frequency components for 21 years and is focused on sales and technical service that matches leading high frequency component manufactures to customers in Japan.

RFuW Engineering Ltd., the industry's leading supplier of high-power, high reliability SMT RF limiters and switches, announced the appointment of **RFMW Ltd.** as the company's global distributor. RFMW offers customers worldwide sales coverage from their three pronged base of operations in the U.S., Asia and Europe. There are tremendous synergies created by the partnership between RFuW Engineering's uniquely positioned products and RFMW's broad set of customer relationships.

Southwest Antennas, an industry leader in rugged RF and microwave antennas and accessory product solutions, announced the appointment of **Aerocomm Technical Sales** as their new sales representative firm for the states of Arizona, Utah, New Mexico and Colorado. Aerocomm Technical Sales is based out of Phoenix, and will be representing the full line of Southwest Antennas products, including omni-directional and directional antennas, multi-port MIMO antenna products, RF coaxial gooseneck adapters, antenna mounts, filters and other RF and microwave accessories. For more information,

visit their website at www.aerocommsales.com, email sales@aerocommsales.com or call (602) 419-5422.

PLACES

NAI, a leading manufacturer of end-to-end connectivity solutions for high performance systems in industrial, telecom, data and medical industries, has announced the opening of its fourth plant in Hermosillo, Mexico, and the expansion of a current plant. The new 27,000 square foot Plant No. 4 operation is dedicated to the manufacture of copper cable assemblies and harnesses for their growing customer segments in medical device and equipment manufacturing and in industrial technology sectors. The new facility is located only two miles away from existing plant operations. Current production workers, engineers, quality control staff and management have transferred to the new facility.

Boeing has selected a site in Plano, Texas, for the headquarters of its new Global Services business unit, which will be operational in July. Boeing Global Services headquarters will be located in the Legacy West mixed-use development in West Plano. Global Services President and CEO Stan Deal, several of his leadership team members and some support staff will be located at the site, which will serve as a central hub for approximately 20,000 employees located around the globe. Boeing selected the greater Dallas area because it is centrally located within Boeing's U.S. footprint, has good proximity to major operations for commercial customers and defense partners and serves as a transportation hub that will allow the company to reach customers quickly and efficiently.

CETC

CHINA ELECTRONICS TECHNOLOGY INSTRUMENTS CO., LTD

Focus Measurement From China

Calibration Kits



High precision
reliability
performance
Broadband



More information on <http://www.ei41.com>

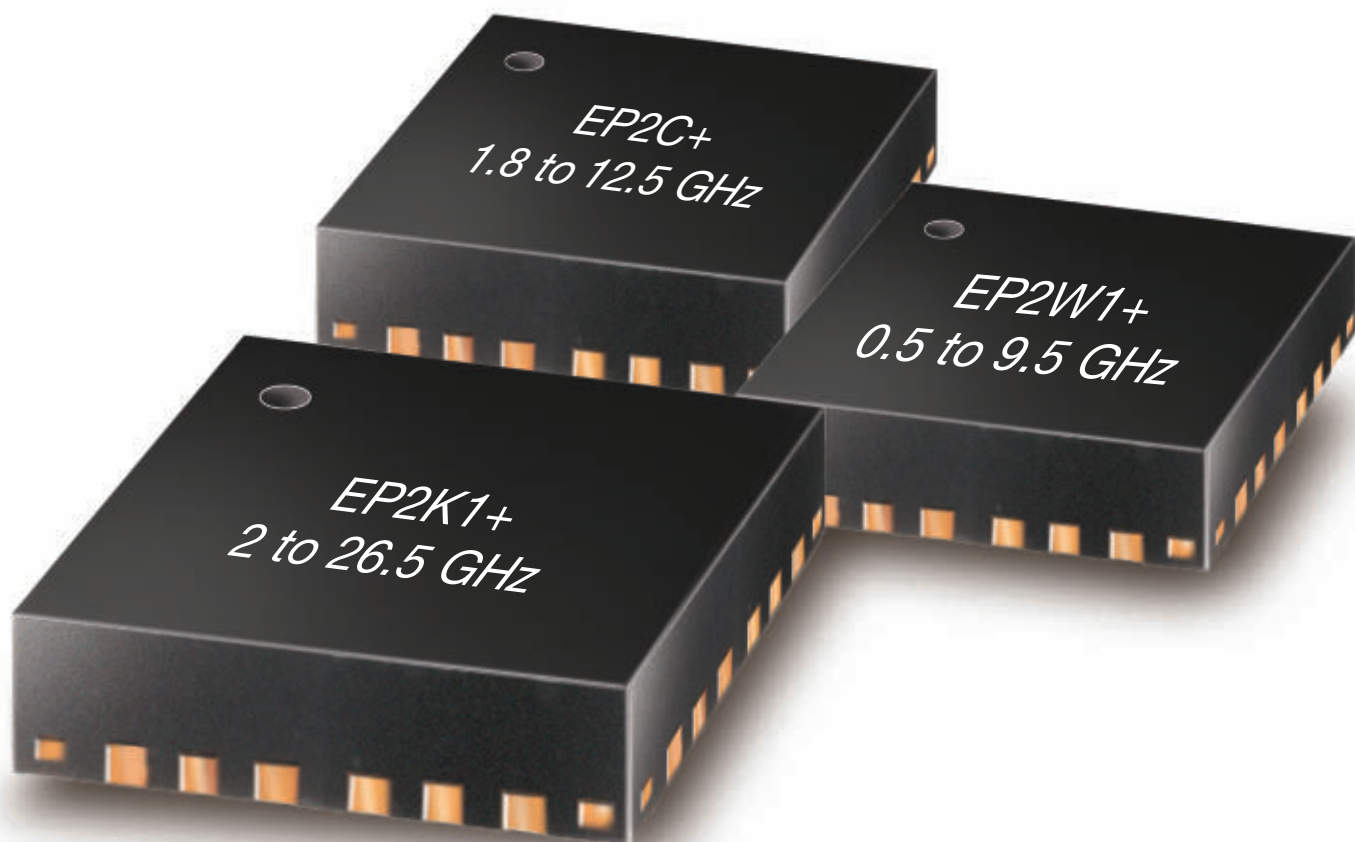
Please contact immediately

E-mail: dongjt@ei41.com Tel: +86053286896691

CETC

CHINA ELECTRONICS TECHNOLOGY INSTRUMENTS CO., LTD

Ultra-Wideband MMIC SPLITTER/COMBINERS



Single Unit Coverage as Wide as **2 to 26.5 GHz**

Models from **\$5⁵⁶**
ea. (qty. 1000)

THE WIDEST BANDWIDTH IN THE INDUSTRY IN A SINGLE MODEL!

Our new EP-series ultra-wideband MMIC splitter/combiners are perfect for wide-band systems like defense, instrumentation, and all cellular bands through LTE and WiFi. These models deliver consistent performance across the whole range, so you can reduce component counts on your bill of materials by using one part instead of many! They utilize GaAs IPD technology to achieve industry-leading performance, high power handling capability and efficient heat dissipation in a tiny device size, giving you a new level of capability and the flexibility to use them almost anywhere on your PCB! They're available off the shelf, so place your order on minicircuits.com today, and have them in hand as soon as tomorrow!

- Series coverage from 0.5 to 26.5 GHz
- Power handling up to 2.5W
- Insertion loss, 1.1 dB typ.
- Isolation, 20 dB typ.
- Low phase and amplitude unbalance
- DC passing up to 1.2A

 EP2K-Series, 4x4x1mm

 EP2W-Series, 5x5x1mm



Network Synthesis and Power Amplifiers: So Much More than Impedance Matching

Gayle Collins
Nuvotronics, Durham, N.C.

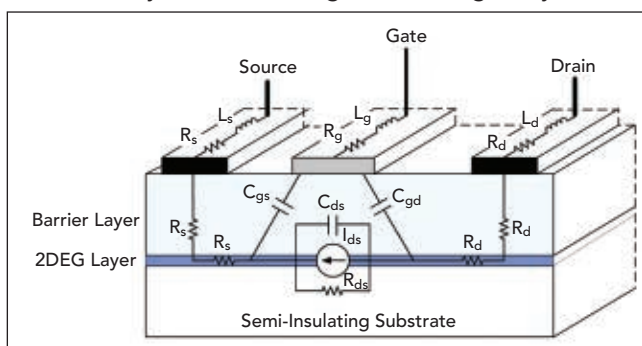
New materials and technologies are providing designers with the opportunity to produce solutions that could not be accomplished in the past, opening new avenues for innovative power amplifier (PA) design. The goal of every PA designer is to achieve the maximum performance from the transistor at hand; this is as true today as ever. Multi-standard requirements for wireless infrastructure are driving the need for broadband PAs capable of achieving performance across several bands. The requirement for power at ever-increasing frequencies is driving the development of n-dimensional power combiners and multiple-input-multiple-output systems (MIMO). The complexity of communication systems is driving a need to go beyond tra-

ditional approaches to impedance matching circuits and use such techniques as network synthesis.

Network synthesis requires an understanding of the components of a dynamically interacting system and designing a network that compels the desired performance. It is used widely in control, robotics and mechanical systems and is gaining renewed interest from the electrical engineering community, the field in which it originated. However, it has been somewhat neglected in the field of PA design: the output matching network is often considered to be just a passive circuit rather than part of a dynamic nonlinear system. Network synthesis provides a method of designing an interactive system, given a desired frequency or time domain response, with metrics such as power, efficiency and linearity. Such a system may include a passive or non-passive network that interacts with an active, often nonlinear device, the PA in this case. Let's begin with the motivation for why network synthesis techniques are needed for PA design, considering the behaviors of transistors in a few popular PA architectures.

MOTIVATION: PA DESIGN FOR DIFFERENT APPLICATIONS

In any approach to designing a PA, consideration must be given to how the active



▲ Fig. 1 Classic representation and small-signal model of an HFET/HEMT transistor, such as GaN.¹

Making the Connection in Handheld Solutions

***Available in
WR-10, WR-12, WR-15
&
Ext. WR-12 (56-94 GHz)**

***For measurements in:
5G, WiGig,
Auto Radar &
E-Band Backhaul**

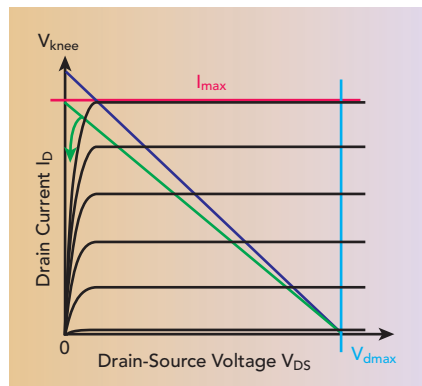


***No external I.O
source or
DC Power required**

**Introducing the first portable solution
for millimeter wave
spectrum analysis measurement.**

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



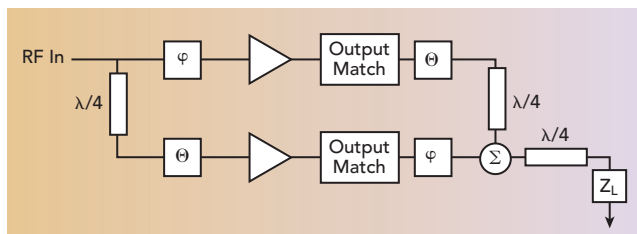


▲ Fig. 2 DC IV characteristics of a typical device.

device behaves in the intended environment. There are many approaches to PA design, including load modulation, envelope tracking, harmonic termination and design for a varying load. While these techniques all have a different approach to shaping the performance of the active device, it really is all about the interaction between the device and the driving point impedance that it “sees.” The HFET or HEMT device, typical of modern GaN RF power transistors, illustrates the active device (see **Figure 1**).

What is going on in the transistor? The driving point impedance defines the interaction of the voltage and current at the terminals of the device and determines the power and efficiency. In an ideal device, the maximum output power and maximum efficiency occur at the same driving point impedance. What prevents this in a real device? The answer is harmonics, which shape the time domain waveforms and give the ideal efficiencies of the different classes of PAs, but can also reduce the amount of power generated by the amplifier. The time domain waveforms are defined by the impedances presented to the device over frequency. The harmonics are generated by the clipping that occurs from the knee voltage in the device and at V_{dmax} (see **Figure 2**), where the voltage is limited.

The gate and drain voltages control how the charge flows in the channel of the transistor. By shaping these voltages with the driving point impedances, the behavior of the amplifier is shaped. Remember that the charge we are talking about is a combination of the mo-



▲ Fig. 3 Two-way Doherty PA.

bile charge in the channel and the stored charge. The mobile charge is resistive and the stored charge is reactive, so the mobile charge can be manipulated with the real part of the load and the reactive charge can be manipulated with the imaginary part of the load.

Doherty Amplifier Design

The Doherty principle² is an efficiency enhancement technique that relies on modulating the driving point impedance presented to a transistor using active load-pull techniques. The Doherty PA combines the outputs of two or more transistors that are offset by a quarter-wave transformer (see **Figure 3**). At low power, only the carrier amplifier is on, resulting in a greater efficiency than with a single transistor amplifier designed for full power. As the input power increases, the carrier amplifier is driven into saturation, and the peaking amplifier is driven on, changing the driving point impedance presented to the carrier amplifier, and hence its behavior. In an ideal Doherty PA design, the carrier amplifier's load is pulled from its maximum efficiency point to its maximum power point.

Under Doherty load modulation the current through the transistor changes, so the charge in the channel changes. The carrier device can be viewed as a current source until it reaches saturation, when its behavior becomes that of a voltage source. When the peaking device turns on, it also behaves as a current source until saturation. As the peaking device is driven to maximum power, the Doherty PA can be represented as a voltage source (carrier device) in parallel with a current source (peaking device).

Supply Modulation Amplifiers

In dynamic supply modulation schemes such as envelope tracking (ET), the supply voltage V_d is

varied to maintain high efficiency for all input power levels, by keeping the voltage swing at the maximum value of $V_d - V_{knee}$. Under drain modulation, the gate voltage is usually

kept constant, so C_{gs} stays roughly constant, and the voltage across the channel of the device changes with the voltages across C_{ds} and C_{gd} . As a result, two things happen: the charge on these capacitors will change, and generally the capacitance itself is voltage dependent and changes under supply modulation.³ Two effects are seen from this: The simple capacitance model is not good enough, because it is charge that is being manipulated by the drain modulation, so a fully charge-conservative model is desirable.^{4,5} Second, for GaN devices, the variation of C_{ds} with drain voltage is very small, making the GaN process attractive for drain modulated PAs; C_{ds} behaves more like a parallel-plate capacitor, making the simple approximation a good starting point. This is in contrast with LDMOS devices, where C_{ds} exhibits a large variation with drain voltage. The variation in C_{gd} with drain voltage is often minimized in PA technologies by the use of field plates. For the PA designer, the power transistor under drain supply modulation can be thought of as a current source with a bias-dependent output admittance. The impedance of the output match is chosen to give the best performance over the changing output admittance of the device.

PA Design for Varying Loads

In applications such as wireless power transfer, radar and heating, the loading of the PA varies. Both the real and imaginary parts of the load can vary over a large range. Load variation is often dealt with by switching devices or components in and out and can lead to transients in the system. The power transistor will then be presented with impedances on various time scales, increasing the design challenge for the PA designer.

These examples of PA architec-

NI AWR DESIGN ENVIRONMENT

SIMPLY SMARTER

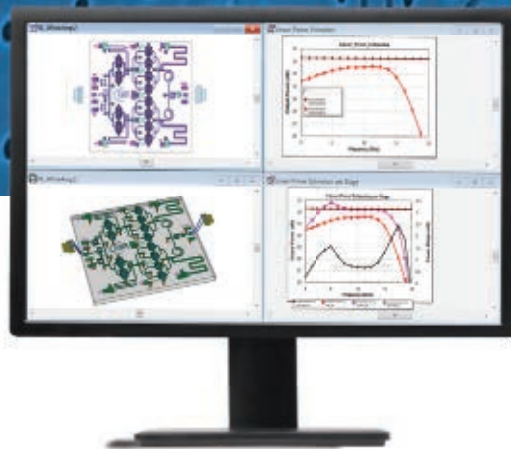
POWER AMPLIFIER DESIGN

NI AWR Design Environment is one platform integrating system, circuit, and electromagnetic analysis that provides robust harmonic-balance simulation for fast and accurate nonlinear analysis of power amplifiers. With highly accurate semiconductor device and circuit element models, load-pull analysis, and design automation, the software empowers amplifier designers to successfully bring their products to market.

Simply smarter amplifier design.

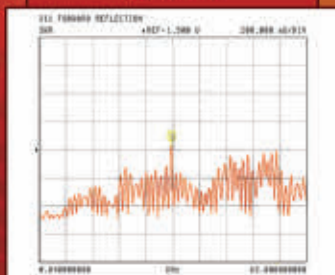


Learn more at awrcorp.com/amplifier

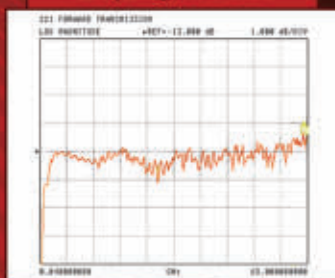


1-67 GHz Directional Couplers

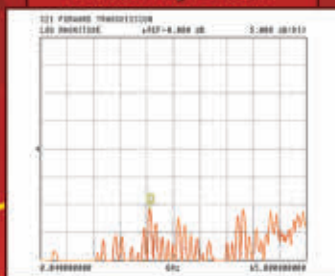
VSWR 1.6



Coupling +/- .7dB



Directivity >10dB



Our competitors dream about it.
Here at ETI, We
Design & Manufacture it!



Electromagnetic Technologies Industries, Inc.
50 Intervale Rd. Boonton, NJ 07005 U.S.A.
sales@etiworld.com • www.ETIworld.com



ISO 9001

Technical Feature

tures establish that the core of any PA design is the driving point impedance at the points of interaction of the active device and the network within which it is placed.

NETWORK SYNTHESIS

By reviewing some basics of network theory, we can see how to adopt and adapt these methods for the design of the impedance environment that will get the best out of the power transistor.

Network synthesis is the art of realizing a network, once the desired frequency response in the form of a transfer function or driving point impedance is known. The synthesis problem for electric networks was solved with Cauer's and Foster's theorems. The oldest and most widely used network synthesis procedures apply to two-element networks: LC, RC or RL. One of the starting points of network synthesis was Foster's reactance theorem,⁶ which provides the necessary and sufficient conditions for the class of all functions that can be realized as driving point impedances of one-port networks. Foster's theorem can be realized as the driving point impedance of a generalized network made up of shunt-series LC branches or series-parallel LC branches. The technique uses partial fraction expansion to decompose the desired rational function into inductance or capacitance. Next, the realization of a one-port network with a defined driving point impedance based on continuous fraction

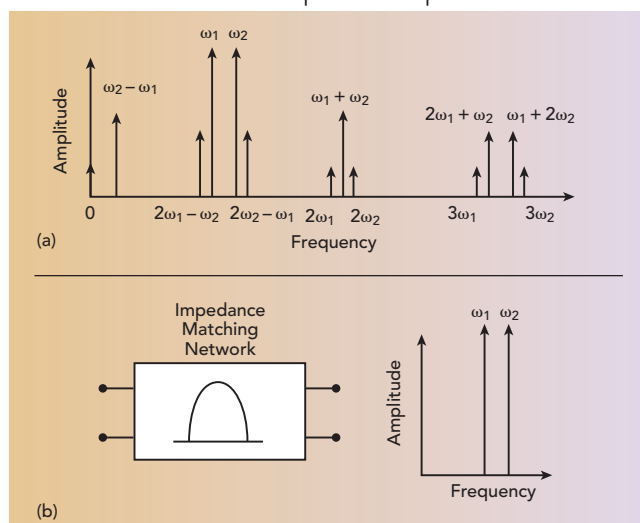
expansion was developed.⁷ The network synthesis theory was developed to include the positive real approach,⁸ driving point impedances synthesized as RLC networks⁹ and the insertion loss technique.¹⁰

Realization Techniques in Network Synthesis

The rapid development of techniques for the synthesis of two-port networks soon

followed. Bode developed a technique based on the image parameter method,¹¹ where the various sections of the network are defined as either bandpass or bandstop, and the filter sections are designed based on those specifications. This technique does not allow for the synthesis of an arbitrary frequency response but is useful in the design of simple structures.

Foster's LC one-port theorem was extended to LC two-ports, initially assuming a symmetrical network. Cauer demonstrated the validity of Foster's theorem for LC n-ports and showed that through linear transformations, all equivalent LC networks could be derived from one another. Belevitch¹² developed three methods for the synthesis of LTI reciprocal n-ports. The first consisted of the sequential extraction of reduced impedance matrices and was too cumbersome to be of much practical value, but it led to the proof that any positive real impedance or admittance matrix is realizable,^{13,14} showing that a complete n-port system can be formed with RLC elements and the ideal transformer. The initial development came as an extension of Darlington's method for one-ports, (i.e., the realization of a n-port as a reactive 2n-port with terminating resistors). This led to a formulation using scattering parameters and the scattering matrix for both reciprocal and nonreciprocal n-ports and, through this, solving the equivalence problem.¹⁴

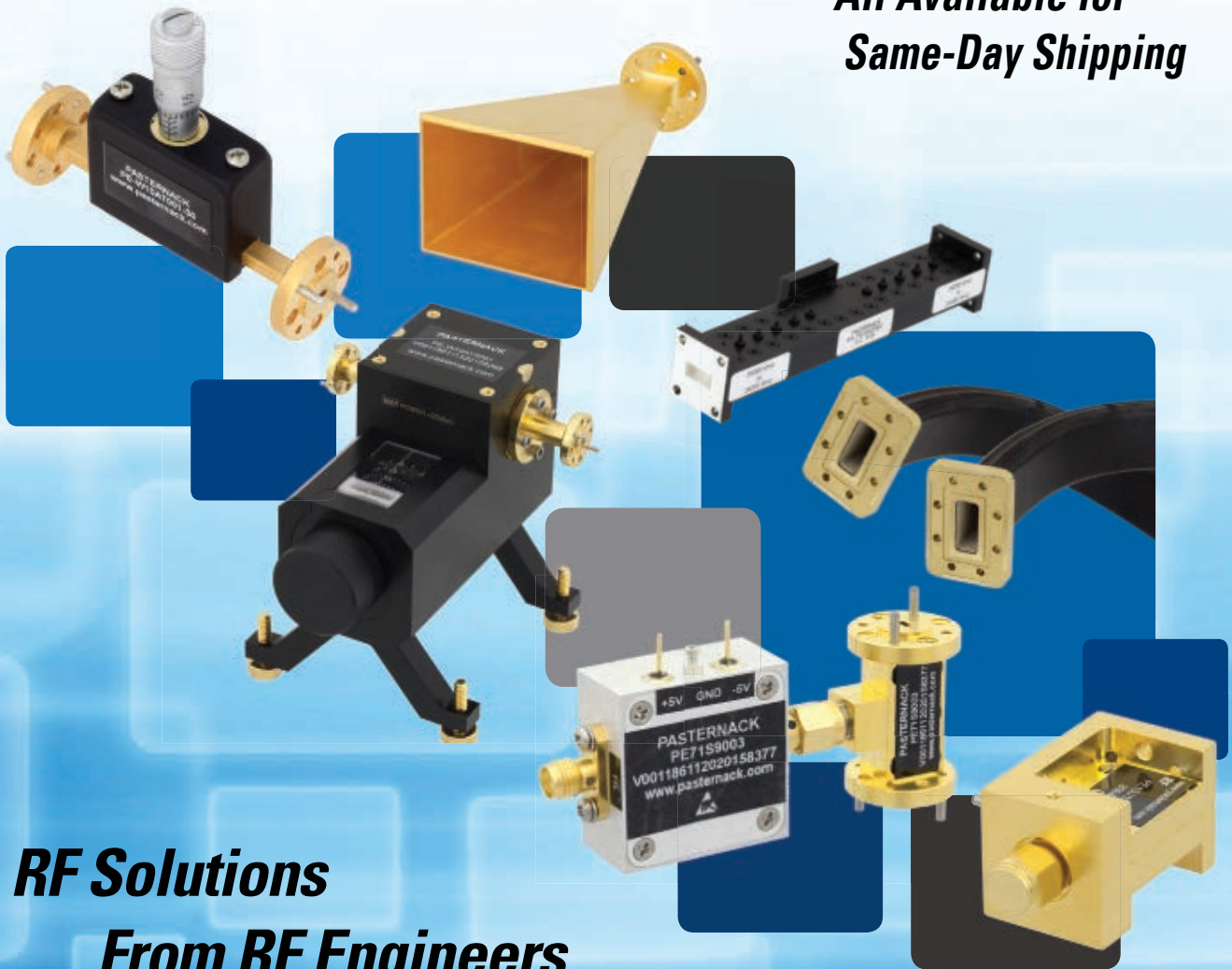


▲ Fig. 4 Distortion products generated by a transistor driven by a large two-tone input signal (a). The impedance matching network can be designed to minimize distortion (b).

Largest In-Stock Selection of

Waveguide Components

***All Available for
Same-Day Shipping***



***RF Solutions
From RF Engineers***

Pasternack's RF Engineering team has assembled the largest selection of in-stock and ready to ship waveguide components covering RF, microwave and millimeter-wave bands up to 110 GHz. With 20 different waveguide categories and over 500 designs including adapters, power amplifiers, detectors, bandpass filters, PIN diode switches, attenuators, horn antennas and more, Pasternack has the waveguide components you are looking for. Whether it's waveguide products or any of the other 40,000 in-stock components we carry, our Application Engineers stand ready to deliver solutions for all your RF project needs.

866.727.8376
visit pasternack.com today!

PE PASTERNAK®
THE ENGINEER'S RF SOURCE

In Stock
Capacitors
Reliable • Fast Turnarounds
• Competitive Pricing

HF/UHF
High Power Applications



- High Power Capacitors Case Sizes:
- Up to 25kV 2225
- High Current 3838
- TC = NPO / P90 6040
- Values: 1pF – 120,000pF 7676
- Custom Assemblies 1313

Available in Non-Magnetic Terminations

Custom Assemblies



- High Operating Voltage • High Reliability
- High Operating Current • High Q
- Extended Capacitance • Ultra-Low ESR
- Tighter Tolerances • Non-Magnetic

Typical Applications Field

- Medical Electronics • Inductive Heating
- AM/FM Broadcast

Typical assembly configurations are outlined by customer

Aerospace • Aviation • Military
Commercial • Medical
Telecommunications

- Unmatched customer service
- Modeling Available
- Design kits in stock
- Inventory programs

Call us today
631-425-0938
sales@passiveplus.com

www.PassivePlus.com

Technical Feature

WHY PA NETWORK SYNTHESIS?

PAs are designed with input and output matching networks that transform one impedance to another for performance, i.e., efficiency, power and gain. Additional requirements, such as bandwidth and linearity, can be improved with the deterministic design approach afforded by network synthesis. A single-stage PA design will have a two-port network on both the input and the output of the transistor and, with careful design, can mitigate the distortion. **Figure 4** shows the distortion products generated by the transistor in response to a large two-tone signal. If the impedance matching network is designed as a bandpass filter, the distortion products can be minimized. The output shown in **Figure 4** is for an ideal brickwall filter to illustrate the concept.

Bode-Fano Criterion

One important performance aspect is the bandwidth of the PA. The Smith chart gives a good match at a single frequency, but often a broadband design is required. The Bode-Fano criterion¹⁵ (see **Figure 5**) relates the quality of the match to the bandwidth of the match. The criterion shows that a perfect match is only possible if the bandwidth is a single frequency.

Cauer Networks

Let's explore some of the basic LC filter building blocks, beginning with Cauer. For the examples, lumped element filters will be used while acknowledging that these filters can be converted or extended to microstrip or waveguide. Cauer networks are ladder networks and can be expressed as a continued fraction. PA designers familiar with the Smith chart may be surprised that they have been using the continued fraction technique, albeit at a single frequency: the series elements are summed on the impedance circles and the shunt elements on the admittance circles. The difference between the Smith chart method and the network synthesis approach is that the network synthesis approach takes frequency into account.

Figure 6 shows the structure of a Cauer filter. The input impedance,

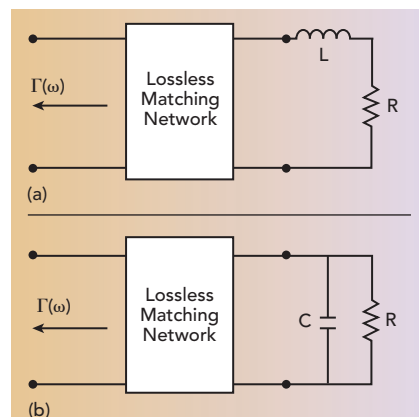


Fig. 5 Bode-Fano criterion for series LR (a) and parallel RC (b) networks.

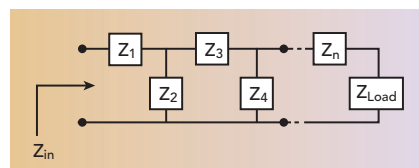


Fig. 6 Structure of a Cauer filter.

Z_{in} is calculated with a continued fraction:

$$Z_{in} = Z_1 + \frac{1}{Y_2 + \frac{1}{Z_3 + \frac{1}{Y_4 + \dots + Z_n + \frac{1}{Y_{Load}}}}} \quad (1)$$

Using the circuit in **Figure 7** as an example, the frequency domain function of the input impedance, $Z(s)_{in}$ is as follows, where $s = j\omega$:

$$Z(s) = \frac{a_3 s^3 + a_2 s^2 + a_1 s + a_0}{b_2 s^2 + b_1 s + b_0} \quad (2)$$

$$\frac{s^3 L_1 C_2 L_3 + s^2 L_1 C_2 R L + s(L_1 + L_3) + R L}{s^2 C_2 L_3 + s C_2 R L + 1}$$

Dividing the numerator by the denominator, beginning with the highest power, gives:

$$Z(s) = s L_1 + \frac{s L_3 + R L}{s^2 C_2 L_3 + s C_2 R L + 1} = s L_1 + \frac{1}{\frac{s^2 C_2 L_3 + s C_2 R L + 1}{s L_3 + R L}} \quad (3)$$

where the second term is inverted. Next, the division is carried out on the denominator of the second term, resulting in the final form of:

Forward Thinking

Introducing RO4730G3™ 94 V-0 Laminates: For Tomorrow's Wireless PCB Antennas

Rogers RO4730G3™ circuit laminates have been engineered for next-generation wireless PCB antennas, including in 4G and 5G cellular base stations and IoT networks.

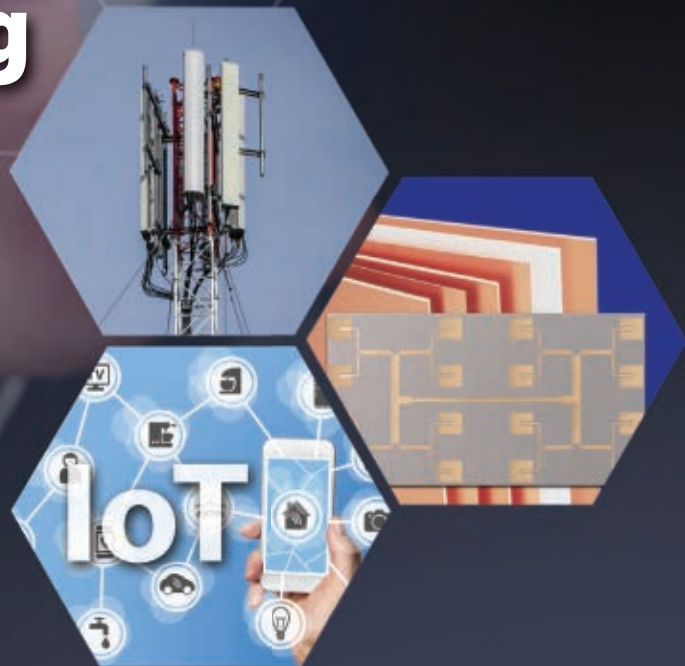
These low-loss, cost-effective circuit materials are lead-free process compatible and flame retardant. RO4730G3 laminates support broadband antenna designs with excellent PIM performance, outstanding dimensional stability and multilayer board design capability.

Built on the proven technology used in Rogers RO4000® thermoset resin/ceramic/woven glass materials, RO4730G3 94 V-0 laminates expand Rogers antenna grade product family, already the most popular for base station antennas.

**For tomorrow's PCB antennas today —
RO4730G3 Laminates**



Download the
**PIM and PCB
Antennas
Brochure**



MATERIAL	Dk	PIM*
RO4730G3 Ceramic Hydrocarbon	3.0	<-160 dBc
RO4700JXR™ Series Ceramic Hydrocarbon	2.55 to 3.0	<-160 dBc
RO4500™ Series Ceramic Hydrocarbon	3.3 to 3.5	<-157 dBc
AD Series™ PTFE	2.5 to 3.2	<-157 dBc

* On 0.060" (1.524mm) laminate



Advanced Connectivity Solutions

USA - AZ, tel. +1 480-961-1382

EUROPE - BELGIUM, tel. +32 9 235 3611

www.rogerscorp.com

PIN DIODE LIMITERS 1 WATT CW 1 - 40 GHz (Very High Frequency)

New



Many Models Available in Stock

- Very High frequency Wide Band
- 1 Watt CW Power Handling Capability
- Fast Response & Short Recovery Time (10 nsec typical)
- Hermetically Sealed Module

Typical Performance @ +25 Deg. C

MODEL	FREQ. RANGE (GHz)	MAXIMUM ¹ INSERTION LOSS (dB)	TYP LIM THRESHOLD (dBm)	MAX LEAKAGE ² @ 1W CW INPUT (dBm)
LP1-26A	1-26	3.5	+9	+20
LP2-26A	12-26	3.5	+9	+20
LP18-26A	18-26	3.0	+9	+19
LP18-40A	18-40	4.0	+9	+19
LP1-40A	1-40	4.5	+9	+20
LP2-40A	2-40	4.5	+9	+20
LP26-40A	26-40	4.0	+9	+19

Notes: 1. Insertion Loss and VSWR (2 : 1) tested at -10 dBm.

Notes: 2. Power rating derated to 20% @ +125 Deg. C.

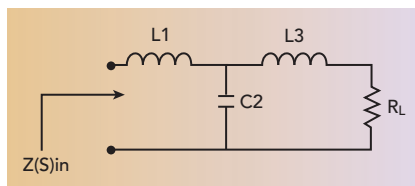
Other Products: Detectors, Amplifiers, Switches, Comb Generators, Impulse Generators, Multipliers, Integrated Subassemblies

Please call for Detailed Brochures

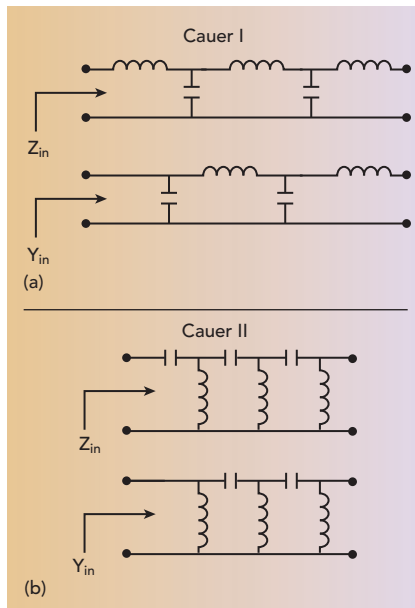


155 Baytech Drive, San Jose, CA 95134
Tel: (408) 941-8399 . Fax: (408) 941-8388
Email: Info@herotek.com
Website: www.herotek.com
Visa/Mastercard Accepted

Technical Feature



▲ Fig. 7 Example Cauer LC filter.



▲ Fig. 8 Cauer I (a) and Cauer II (b) networks, showing two topologies for each.

$$Z(s) = sL1 + \frac{1}{sC2 + \frac{1}{sL3 + RL}} \quad (4)$$

All rational functions can be formulated as a continued fraction by sequentially dividing and inverting the fraction. The two types of Cauer forms are shown in **Figure 8**, with two realizations of each. To realize a rational function, any of the four forms can be used provided the function meets the realizability conditions for the driving point immittance of a passive network: it must be positive real. This simply means that the function $Z(s)$ or $Y(s)$ is real for all real values of s and that the real part is greater or equal than zero when the real part of s is greater than or equal to zero. The Cauer I filter example of Figure 7 is a lowpass ladder network that is often used in the design of PAs.

Foster Networks

Foster networks are synthesized by the break down of the desired function of the driving point imm-

ittance of a passive network through partial fraction expansion. Foster I networks (see **Figure 9a**) provide open circuits to the transistor through series-parallel resonances and are realized from the partial fraction expansion of $Z(s)$, while Foster II networks (see **Figure 9b**) provide short circuits through the use of shunt-series resonant components and are realized from the partial fraction expansion of $Y(s)$.

The expression for the Foster I realization is:

$$Z(s)_{in} = \frac{s^2 + \frac{1}{C_1 L_1}}{\frac{s}{L_1}} + \frac{\frac{s}{C_2}}{s^2 + \frac{1}{C_2 L_2}} + \frac{\frac{s}{C_3}}{s^2 + \frac{1}{C_3 L_3}} + \dots + \frac{\frac{s}{C_n}}{s^2 + \frac{1}{C_n L_n}} \quad (5)$$

From this form, the locations of the short and the opens of the network can be found by inspection. The first element is a short at $\omega = 1/\sqrt{L_1 C_1}$, and the parallel elements are opens at $\omega = 1/\sqrt{L_i C_i}$.

The Foster II realization is:

$$Y(s)_{in} = \frac{s^2 + \frac{1}{C_1 L_1}}{\frac{s}{C_1}} + \frac{\frac{s}{L_2}}{s^2 + \frac{1}{C_2 L_2}} + \frac{\frac{s}{L_3}}{s^2 + \frac{1}{C_3 L_3}} + \dots + \frac{\frac{s}{L_n}}{s^2 + \frac{1}{C_n L_n}} \quad (6)$$

This form also allows identifying the locations of the short and open circuits of the network by inspection. The first element is an open at $\omega = 1/\sqrt{L_1 C_1}$, and the series elements are shorts at $\omega = 1/\sqrt{L_i C_i}$.

The different realizations can be combined to realize any given driving point immittance function.

Multipoint Network Synthesis

The Cauer continued fraction expansions are useful for synthesizing a two-element one-port network, given a desired driving point im-

RF-LAMBDA

THE LEADER OF RF BROADBAND SOLUTIONS

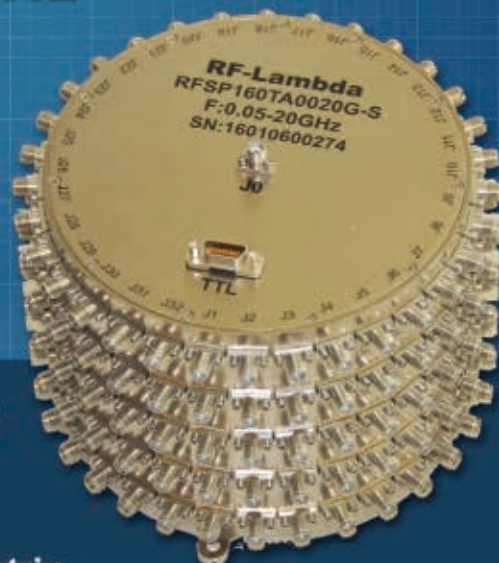
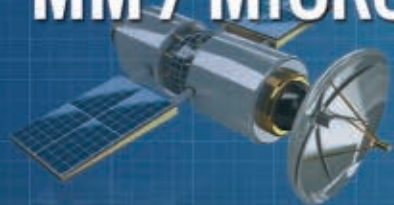
WWW.RFLAMBDA.COM

ITAR & ISO9000
Registered Manufacture



Thousand
in stock

RF SWITCHES MM / MICROWAVE DC-50GHz



160 CHANNELS
mm/Microwave

0.05-20GHz

Filter Bank Switch Matrix

For Phase Array Radar Application Satellite communication.



PN: RFSP32TA5M43G

SP32T SWITCH 0.5-43.5GHz



PN: RFSP16TA5M43G

SP16T SWITCH 0.5-43.5GHz

www.rflambda.com
sales@rflambda.com

1-888-976-8880
1-972-767-5998

Plano, TX, US
San Diego, CA, US
Ottawa, ONT, Canada



mittance function. The extension of the continued fraction expansion to a transfer function matrix is applied to two-element multiport networks with a specified driving point immittance matrix.¹⁶ The $n \times n$ driving point impedance matrix that describes an LC, RC or RL n -port network is a symmetric and positive real matrix. The partial fraction expansion of an RC driving point impedance matrix is in the form:

$$Z_{RC} = A_{\infty} + \frac{A_0}{s} + \sum_{i=1}^m \frac{A_i}{s + a_i} \quad (7)$$

If $T_{RC}(s)$ is defined as

$$T_{RC}(s) = \sum_{i=1}^m \frac{A_i}{s + a_i} \quad (8)$$

then

$$T_{RC}(s) = Z_{RC} - A_{\infty} - \frac{A_0}{s} \quad (9)$$

The impedance matrix, $T_{RC}(s)$ can be obtained from Equation 9 and expanded in the Caue matrix form.¹⁶ From this, the elements of the network can be determined.

MIMO DOHERTY PA DESIGN

We illustrate the network synthesis approach to PA design using an N-way Doherty PA (DPA).¹⁷ A DPA is usually realized by designing a match to 50Ω for each amplifier, and using phase offsets and quarter-wave transformers to obtain the required load modulation. The MIMO approach to the synthesis of the load modulation presents the output network in a generalized form (see **Figure 10**).

For a general n -dimensional system of amplifiers, where the carrier amplifiers are numbered 1 to m , the peaking amplifiers numbered $m+1$ to n and the load is the $n+1$ th node L , the output network is represented by an $n+1 \times n+1$

Invisipin®

ULTRA Hi RF - Compliant Connector



INFINITELY CONFIGURABLE • INDIVIDUALLY SOLDERABLE • HI COMPLIANCE RANGE

Specifications

- > 50 GHz Bandwidth @1 dB
- 20 mΩ C-Res (typical)
- Up to 4 Amps

Configurations

- 0.23mm to 0.64mm diameter pins
- Pitches from 0.4mm to >1mm



(Coaxial Configuration)

*Available in tape and reel (machine placeable) or fully integrated into custom products.

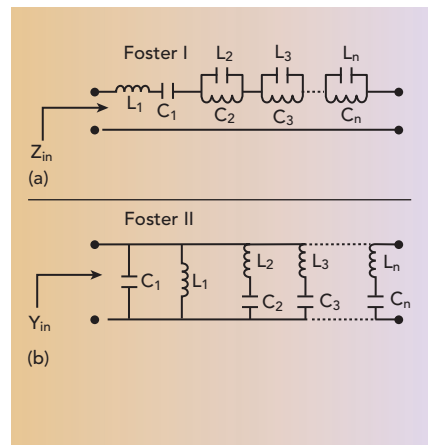
R&D
Interconnect Solutions®

www.RDIS.com/MJ

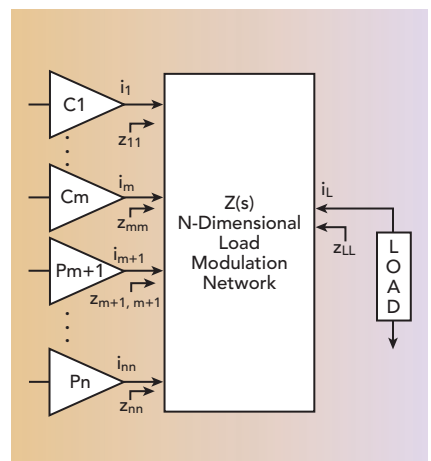
MJ@RDIS.com

610-443-2299

©2015 R&D Interconnect Solutions. All rights reserved. R&D Interconnect Solutions, Invisipin, and RDIS.com are trademarks of R&D Interconnect Solutions.



▲ Fig. 9 Foster I (a) and Foster II (b) networks.



▲ Fig. 10 MIMO Doherty PA.



Powering the Wireless Revolution



Skyworks 5G White Paper is Now Available!

5G in Perspective - A Pragmatic Guide to What's Next

To download, please visit www.skyworksinc.com/5G

matrix of frequency-dependent impedances or transfer functions. In this impedance matrix, the diagonal terms are the impedances presented to each individual amplifier when it is on and the others are off. The off-diagonal terms represent the load modulation from the other amplifiers as they switch on. The synthesis of the combining network is then cast in

terms of the complex driving point impedance and the load modulation, or Doherty action. The first matrix in Equation 10 describes the driving point impedances of each amplifier, and the second matrix is the load modulation matrix that describes the interactions between the amplifiers. The impedances are complex frequency-dependent transfer functions.

$$\begin{matrix} Z_{Cmod} \\ Z_{Pmod} \\ Z_{Lmod} \end{matrix} = \begin{bmatrix} Z_{CC} & 0 & 0 \\ 0 & Z_{PP} & 0 \\ 0 & 0 & Z_{LL} \end{bmatrix} + \begin{bmatrix} 0 & \frac{1}{i_C} Z_{CP} & \frac{1}{i_C} Z_{CL} \\ \frac{1}{i_P} Z_{PC} & 0 & \frac{1}{i_P} Z_{PL} \\ \frac{1}{i_L} Z_{LC} & \frac{1}{i_L} Z_{LP} & 0 \end{bmatrix} \begin{bmatrix} i_C \\ i_P \\ i_L \end{bmatrix} \quad (10)$$

Here, C indicates the carrier amplifiers, P the peaking, L denotes the load node(s), ii indicates the driving point impedances and ij the cross impedances. This results in a generalized approach for DPA synthesis.

The driving point impedances for the carrier amplifiers are chosen to give the maximum efficiency in back-off. The modulation impedances are designed to modify the load of the amplifiers to give the desired efficiency and power during drive-up. This formulation of the modulation matrix is symmetrical, which reduces the number of equations to be solved by half. This is a powerful construct and can be modified to account for active load and phase modulation. The effectiveness of the load modulation on the complete PA can be optimized using this matrix approach, to maximize the efficiency of the PA at a prescribed back-off power, for example. The frequency response of the diagonal terms of the impedance matrix determine the bandwidth of the DPA. With the impedances in the matrix represented by transfer functions, the amplitude and phase are shaped to achieve the desired frequency response, enabling an approach to wide bandwidth DPA design.

SUMMARY

PA systems are made up of dynamically interacting components, whether they are standard class A amplifiers, voltage supply modulated architectures or systems with intentional or unintentional load modulation. PA design requires

FASTER, QUIETER, SMALLER SIGNAL SOURCES QUICKSYN SYNTHESIZERS

Design smaller and more efficiently with National Instruments QuickSyn synthesizers. The revolutionary phase-refining technology used in QuickSyn synthesizers enables blazing fast switching speeds, very low spurious and phase noise performance, wide frequency range, and small footprint.

ni-microwavecomponents.com/quicksyn



QuickSyn Lite Synthesizer



© 2016 National Instruments. All rights reserved.



Plug, test, smile

When it comes to test and measurement, SUCOFLEX® 526V and SUCOFLEX® 526S assemblies guarantee the highest level of satisfaction. Thanks to their unique cable and connector design, they deliver best-in-class phase and amplitude stability with flexure, movement, temperature and tensile stress in combination with outstanding return and insertion loss up to 26.5 GHz.

For more positive facts: › smile.hubersuhner.com



a network to compel the desired performance, and the driving point impedances are at the core of this design. As PA systems grow more complex, there is an increasing interest in network synthesis techniques. A general review of network synthesis has been presented, demonstrating historical highlights of the development of this important field from early beginnings to a current application.

There are many more insights that can be found in the references for the interested reader, such as Carlin and Youla's work on n-port synthesis¹⁸ and Fano on broadband matching networks.¹⁴ Carlin's short article on unconventional circuit theory also contains a feast of references.¹⁹ ■

References

1. J. Wood, private communication (2015).
2. W. H. Doherty, "A New High Efficiency Power Amplifier for Modulated Waves,"

- Proc. IRE, Vol. 24, pp. 1163–1182, 1936.
3. G. F. Collins, et. al., "C-Band and X-Band Class F, F⁻¹ GaN MMIC PA Design for Envelope Tracking Systems," *EuMW*, 2015.
4. J. Wood, "Microwave Bytes: Conservatively Speaking," *IEEE Microwave Magazine*, Vol. 15, No. 7, pp. 110–115, November/December 2014.
5. G. F. Collins, J. Wood, B. Woods, "Challenges of Power Amplifier Design for Envelope Tracking Applications," 2015 Topical Conference on Power Amplifiers for Wireless and Radio Applications (PAWR), San Diego, January 2015.
6. R. M. Foster, "A Reactance Theorem," *Bell Syst. Tech. J.*, Vol. 3, No. 2, pp. 259–267, April 1924.
7. S. Darlington, "A Survey of Network Realization Techniques," *IRE Trans. On Circuit Theory*, Vol. CT-2, pp. 291–297, December 1955.
8. O. Brune, "Synthesis of a Finite Two-Terminal Network whose Driving-Point Impedance is a Prescribed Function of Frequency," *Doctoral Thesis, MIT*, 1931.
9. R. Bott and R. J. Duffin, "Impedance Synthesis without Use of Transformers," *Journal of Applied Physics*, Vol. 20, p. 816, 1949.
10. S. Darlington, "Synthesis of Reactive 4-poles which Produce Prescribed Insertion Loss Characteristics," *J. Math. Phys.*, Vol. 18, No. 4, pp. 257–353, September 1939.
11. H. W. Bode, "A General Theory of Electric Wave Filters," *Bell Syst. Tech. J.*, Vol. 14, No. 2, pp. 211–214, April 1935.
12. V. Belevitch, "Summary of the History of Circuit Theory" *Proc IRE*, Vol. 50, No. 5, pp. 848–855, May 1962.
13. M. Bayard, "Synthese des Rⁿseaux Passifs a un Nombre Quelconque de Paires de Bornes Connaissant Leurs Matrices d'Impedance ou d'Admittance," *Bulletin, Societe Francaise des Electriciens*, 9, 6 series, September 1949.
14. Y. Oono, "Application of Scattering Matrices to the Synthesis of n Ports," *IRE Trans. Circuit Theory*, Vol. 3, No. 2, pp. 111–120, June 1956.
15. R.M. Fano, "Theoretical Limitations on the Broadband Matching of Arbitrary Impedances," *J. Franklin Inst.*, pp. 139–154, February 1950.
16. C. J. Cooke and L. S. Smith, "A Multi-Port Network Synthesis using a Matrix Continued Fraction," *International J. Electronics*, Vol. 43, No. 5, pp. 449–459, 1977.
17. G. Collins, "A Generalized MIMO Design Technique for Broadband Doherty Power Amplifiers Based on Complex Network Synthesis Methods," *INMMIC*, Dublin, 2012.
18. D.C. Youla, et. al., "Bounded Real Scattering Matrices and Foundations of Linear Passive Network Theory," *IRE Trans. on Circuit Theory*, Vol. 6, pp. 102–124, March 1959.
19. H. J. Carlin, "Unconventional Network Theory" *IEEE Trans. Circuit Theory*, Vol. 11 pp. 324–326, September 1964.

Look To Norden For Your 5G And Automotive Radar Test Components

Frequency Multipliers

- Frequency Outputs up to 110 GHz
- Multiplication Factors 2x, 3x, 4x, 12x and Higher
- High and Adjustable Output Power
- Custom Designs can Include Low Phase Noise and Bypass Switching



Frequency Converters

- Frequency Bands 500 MHz to 110 GHz
- Down and Up Converters
- Transceivers
- Low Noise Converters



Ka, V, E, and W Band Amplifiers

- Wide Band & Narrow Band
- Low Noise Amplifiers
- Integrated Assemblies Include Limiters, Switches and Detection Circuits
- 26 - 40GHz Norden Part Number NP2640G30N-P28S is Recommended in 5G Test Set Application Notes



Norden is the leader in providing test components for the 5G millimeter-wave spectrum around the frequencies of 28, 38, 60 and 73 GHz and the automotive radar 76-81 GHz Band. Norden Frequency Converters are used to extend the frequency range include frequency multiplication, filtering, and power amplification.



For more information on these products go to:

www.nordengroup.com call **530.642.9123 x1#**

or email: **Sales1@nordengroup.com**

UP TO 100 Watt AMPLIFIERS

NOW! 100 kHz to 26.5 GHz



\$995
from ea. qty. (1-9)

High-powered performance across wide frequency ranges. Mini-Circuits' class A/AB linear amplifiers have set a standard for wideband high-power performance throughout the RF and microwave industry. Rugged and reliable, they feature over-voltage and over-temperature protections and can withstand opens and shorts at the output! Available with or without heat sinks, they're perfect for demanding test lab environments and for integrating directly into customer assemblies. With standard models covering frequencies from 100 kHz up to 26.5 GHz, chances are we have a solution for your needs in stock. Place your order on minicircuits.com today for delivery as soon as tomorrow! Need a custom model? Give us a call and talk to our engineers about your special requirements!

Model	Frequency (MHz)	Gain (dB)	Pout@ Comp.		\$ Price* (Qty. 1-9)
			1 dB (W)	3 dB (W)	
ZVM-273HP+	13000-26500	14.5	0.5	0.5	2195
ZVE-3W-83+	2000-8000	35	2	3	1424.95
ZVE-3W-183+	5900-18000	35	2	3	1424.95
ZHL-4W-422+	500-4200	25	3	4	1160
ZHL-5W-422+	500-4200	25	3	5	1670
ZHL-5W-2G+	800-2000	45	5	5	995
ZHL-10W-2G+	800-2000	43	10	12	1395
• ZHL-16W-43+	1800-4000	45	12	16	1595
• ZHL-20W-13+	20-1000	50	13	20	1470
• ZHL-20W-13SW+	20-1000	50	13	20	1595
LZY-22+	0.1-200	43	16	30	1595
ZHL-30W-262+	2300-2550	50	20	32	1995
ZHL-30W-252+	700-2500	50	25	40	2995
LZY-2+	500-1000	47	32	38	2195
LZY-1+	20-512	42	50	50	1995
• ZHL-50W-52+	50-500	50	63	63	1395
• ZHL-100W-52+	50-500	50	63	79	1995
• ZHL-100W-GAN+	20-500	42	79	100	2845
NEW! ZHL-100W-272+	700-2700	48	79	100	7995
ZHL-100W-13+	800-1000	50	79	100	2395
ZHL-100W-352+	3000-3500	50	100	100	3595
ZHL-100W-43+	3500-4000	50	100	100	3595

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

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

*Price Includes Heatsink



Ultra-Wideband Doherty Amplifier for Digital TV Transmitters

Bill Goumas and Peter Forth

Ampleon, Nijmegen, The Netherlands and Smithfield, R.I.

A proof of concept LDMOS ultra-wideband Doherty (UWD) amplifier enables fractional bandwidths greater than 50 percent. It covers a frequency band from 470 to 803 MHz with peak power greater than 750 W, digital video broadcasting-terrestrial (DVB-T) power greater than 115 W and efficiencies of 38 to 47 percent. Predistortion capability is demonstrated by satisfying the digital TV linearity requirement of -38 dBc with a commercial DVB-T exciter. The impact of the UWD amplifier on transmitter operating cost is presented.

The standard for terrestrial digital video broadcasting, DVB-T, was set in 1997 and put into use in 1998 for the transmission of digital terrestrial television. It provides an advanced method of transmission compared to the previous analog format used before 1998. The entire TV signal has a bandwidth of about 6 MHz. Typical TV broadcast transmitters produce 1 to 10 kW of average power. DVB-T is an orthogonal frequency division multiplexing (OFDM) signal which contains carriers that are approximately 4 kHz apart. This signal has a high crest factor (or peak-to-average power ratio) of around 13 dB. High peak power creates design challenges, such as determining the size and shape of RF components suitable for short voltage peaks.

It has been empirically determined that a power amplifier that compresses a DVB-T signal to a crest factor of 8 dB can still be effectively linearized with digital predistortion (DPD). For characterizing a power amplifier for a DVB-T application, 8 dB is the approximate peak-to-average ratio (PAR) that is typically used when considering peak power re-

quirements. Predistortion is used almost exclusively in the broadcast transmitter market. Design goals typically achieve -35 dBc shoulders at a 4.3 MHz offset. A block diagram of the signal chain is shown in **Figure 1**.

Transmitting UHF digital TV signals¹ is typically accomplished through the use of wideband push-pull class AB power amplifiers.² As such, the achieved average efficiency is limited to 25 to 30 percent.^{2,3} Due to the very high output power levels involved, where the average power is typically 0.5 to 30 kW, maximizing broadcast efficiency is extremely important in reducing electricity use and the overall operating cost. The broadcast industry is looking for high efficiency alternatives to their current RF power amplifier blocks. Although various high efficiency architectures exist to provide wide RF bandwidth along with high efficiency,^{2,3} such as envelope tracking and envelope elimination and restoration, application to broadcast transmitters is complicated and costly due to the very high output powers involved. Doherty amplification² is a cost-effective technique that is widely used in cellular base station transmitters;

World's First Commercially Available mmW 5G 39 GHz Active Antenna ICs

AWMF-0123 and AWMF-0125 39-GHz Quad Core ICs

Enable low cost hybrid beam forming
for multi-antenna arrays with high energy efficiency
and low latency beam steering™

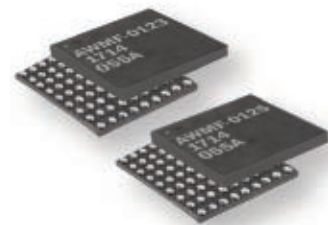
Supports 4 antennas

37.1 - 40 GHz operation

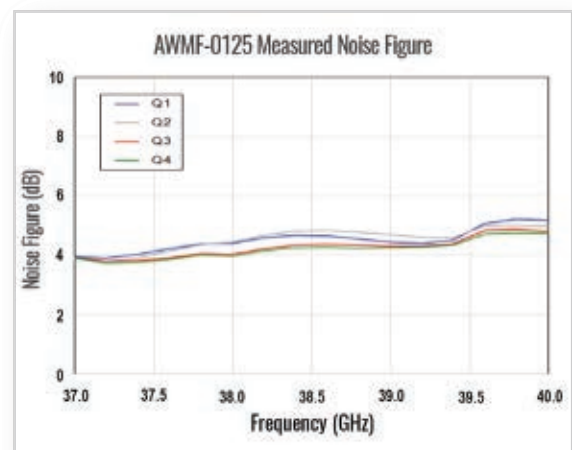
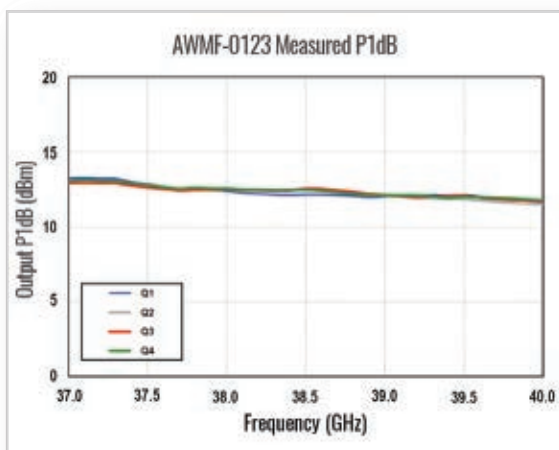
+12 dBm Tx OP1dB

5.0 dB Rx NF

5-bit amplitude/phase control



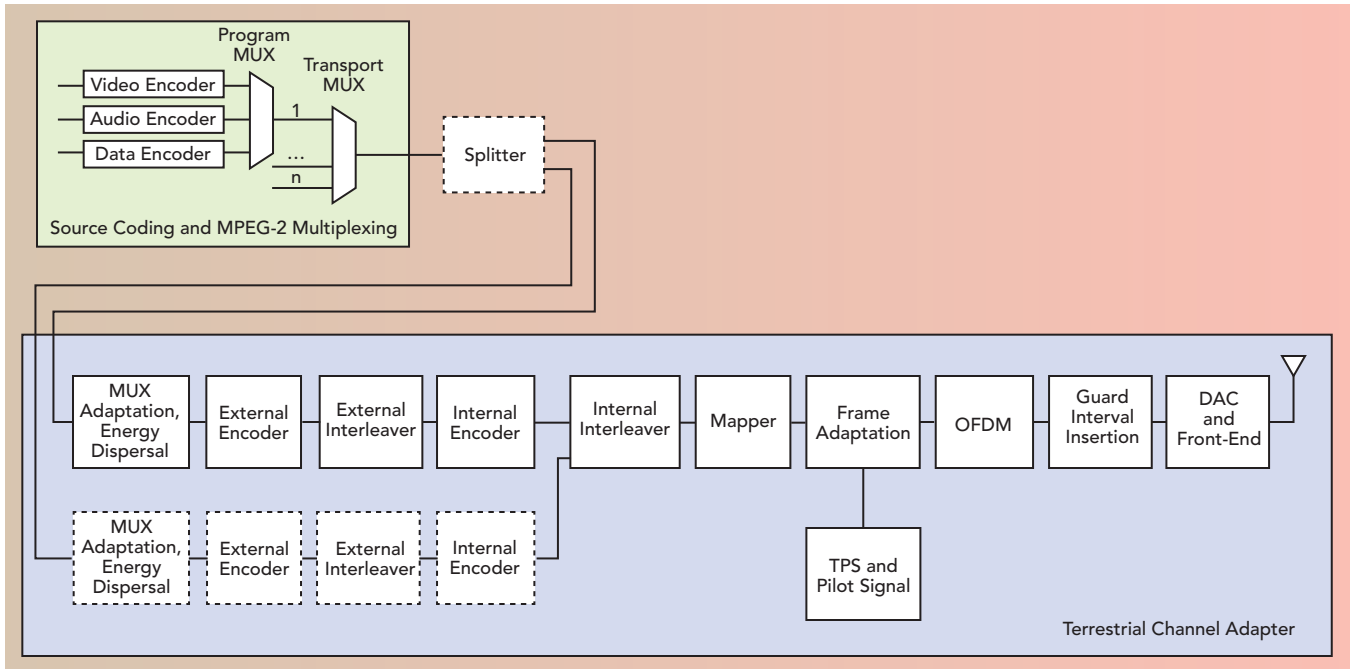
WLCS package
for planar antenna arrays



mmW Si
Core ICs

Active Antenna
ASICs

mmW
Front End ICs

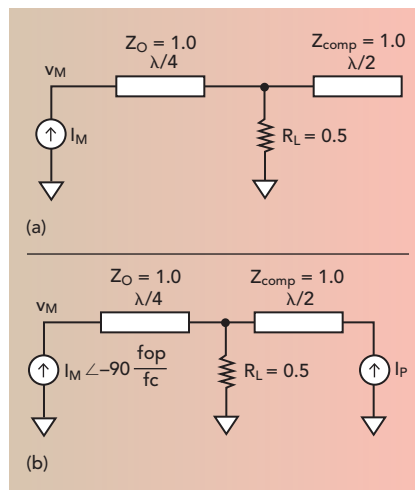


▲ Fig. 1 DVB-T transmit signal chain.

however, high-power Doherty amplifiers are notorious for having narrow RF bandwidth, typically 5 to 10 percent fractional.⁴ The solution to this problem is a wideband Doherty amplifier—greater than 30 percent fractional bandwidth.

WIDEBAND DOHERTY AMPLIFIERS

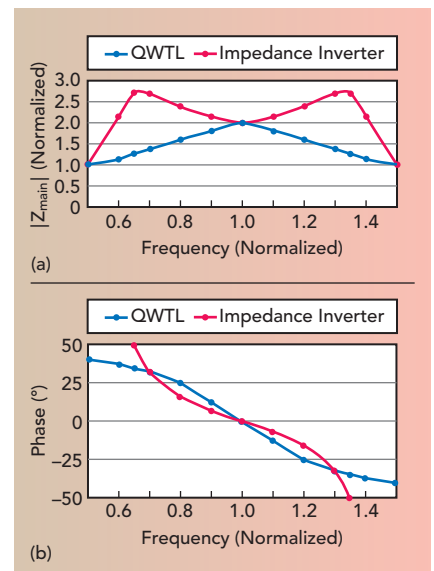
Although there have recently been a number of wideband Doherty amplifier techniques presented in the literature,³⁻⁶ most are inherently low power and require complex input signal conditioning, such as dual input drive and drain voltage control. This article addresses the needs of broadcast transmitters by presenting a simple but effective design technique that allows the development of wideband Doherty amplifiers with up to 60 percent fractional bandwidth that are suited for high-power levels. The approach presented here is verified with a 115 W (750 W peak) power Doherty amplifier covering the entire broadcast frequency band with average efficiencies of 38 to 47 percent while maintaining a minimum output PAR of 8 dB.⁷ This is achieved using standard 50 V LDMOS technology without any added costs or increased complexity. The amplifier circuit described here can be used as a building block



▲ Fig. 2 Wideband impedance inverter (a) and connection of the peaking amplifier to the impedance inverter (b).

for achieving power up to multi-kW levels by combining similar amplifier stages.

Factors affecting the bandwidth of the Doherty power amplifier (DPA) are quite well known and documented. It was shown by Qureshi, et al.,⁴ that by (1) compensating the output capacitance of the PA devices in a wideband fashion and (2) interchanging the position of the power combiner and impedance transformation, it is possible to increase DPA bandwidth significantly. Overall bandwidth is still limited, however, by the bandwidth of the impedance inverter, which for a $\lambda/4$



▲ Fig. 3 Magnitude (a) and phase (b) of the normalized impedance seen at the device end of the wideband impedance inverter.

transmission line (QWTL) impedance inverter is 28 percent, using a 10 percent relative efficiency drop condition at the band edges.^{3,4} In order to address the bandwidth requirements of the broadcast industry, the techniques presented by Qureshi, et al., are extended using a wideband impedance inverter to achieve a fractional RF bandwidth greater than 50 percent.

A very wideband impedance inverter can be created by adding an

World's First mmW Commercially Available 5G Phased Array Active Antenna

AWMF-0129 28-GHz Phased Array Innovator Kit

Demonstrating planar antenna and analog RF beamforming
with high power efficiency and low latency beam steering™
for OTA link and channel measurements

27.5 - 30 GHz operation

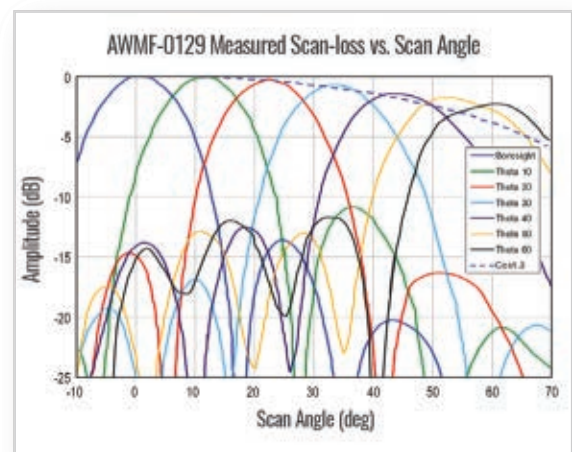
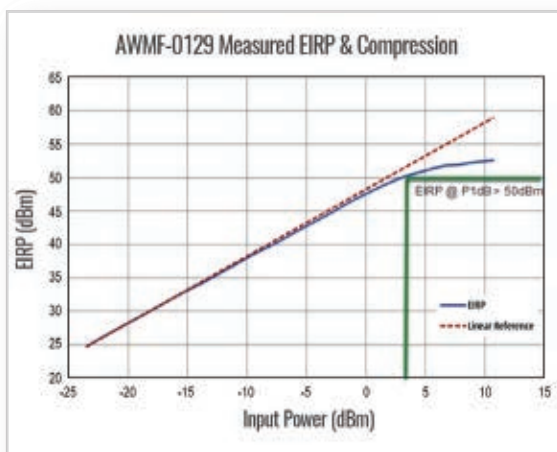
>50 dBm Tx EIRP

>-7 dB/K G/T Rx sensitivity

+/- 60° 2D electronic beam scan

Programmable beam width and taper

Scalable for hybrid beamforming MU-MIMO



mmW Si
Core ICs

Active Antenna
ASICs

mmW
Front End ICs

open circuited half-wave line ($\lambda/2$) to the load end of the QWTL, as shown in **Figure 2a**. The resulting loading conditions for this DPA are shown in the **Figure 3** compared to a DPA based on a conventional QWTL impedance inverter. Figure 3 shows that the addition of the $\lambda/2$ line results in a much wider load modulation bandwidth. This circuit structure also helps to flatten the efficiency bandwidth in practical designs. The related achievable efficiency bandwidth is estimated to be more than 60 percent. This compares to approximately 25 percent fractional bandwidth for a simple QWTL inverter. The peaking device is connected to the open end of the $\lambda/2$ compensation line without any loss in functionality at the back-off power level, as shown in **Figure 2b**. The impedance of the compensation line must be chosen to be equal to the optimum load impedance of the peaking device. If the proper input phase relations are enforced, there is no bandwidth restriction on the wideband DPA under full power conditions (assuming the use of ideal PA devices).

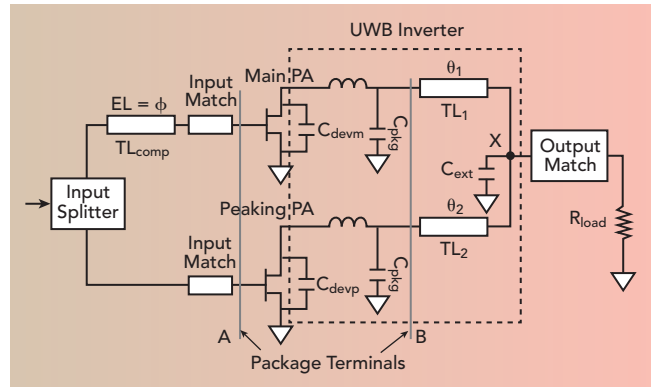
UWD DESIGN

The analysis has so far considered ideal PA devices without any output capacitance. Practical devices, however, do have significant output capacitance along with package parasitics. It has been shown that these

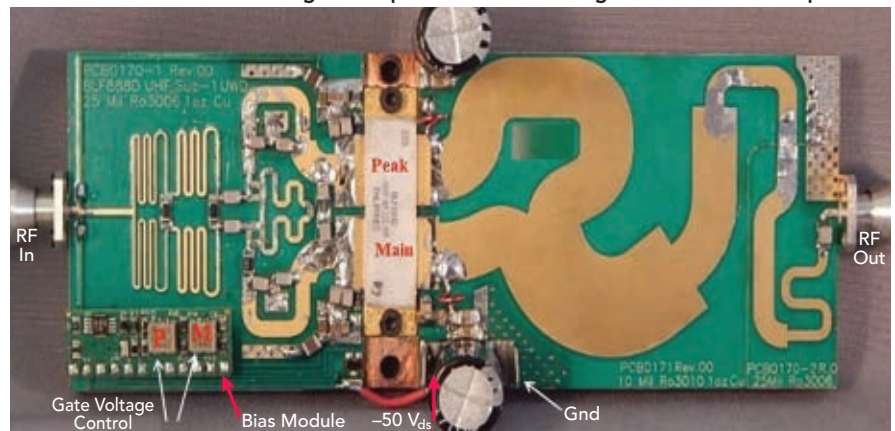
can be compensated in a wideband manner by absorbing them in the impedance inverter.^{3,4} Note that in this design, in order to absorb all parasitics in the "artificial" transmission line, the addition of external capacitors is still required (see **Figure 4**).

An Ampleon (formerly NXP) BLF888D high voltage LDMOS device is used to demonstrate this concept. These devices provide wide bandwidth in combination with high-power and excellent ruggedness. A schematic of the wideband impedance inverter and wideband output capacitance

compensation network is shown in **Figure 4**. The DPA is matched from the combining point impedance (1.25Ω in this case) to 50Ω using a wideband multi-segment impedance transformer.⁸ The circuit is fabricated using standard Rogers 3000 series PCB material (see **Figure 5**).

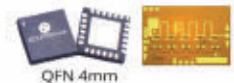


▲ Fig. 4 Simplified schematic diagram of the UWD amplifier.



▲ Fig. 5 Assembled UWD amplifier.

Get **maximum** performance and **minimal** noise figure with Eclipse broadband LNA MMIC's.



	Frequency Range	Gain	Noise Figure	P1dB	Psat	OIP3	Bias Supply	
Model Number	GHz	dB Typ.	dB Typ.	dBm Typ.	dBm Typ.	dBm Typ.	V/mA	Package
EMD1710	2.0 - 20	12.5	2.0	+18.5	+19.0	+28.0	5/83	QFN 4mm
EMD1715	DC - 20	14.5	1.8	+20.5	+23.5	+28.0	5/103	QFN 4mm
EMD1725-D	DC - 40	15.0	3.5	+20.5	+23.0	+33.0	8/108	DIE

Eclipse Microdevices EMD1710 and EMD1715 are ideal for applications that require a typical noise figure as low as 2.0 dB across the DC- 20 GHz band, while requiring only 83mA/103mA from a +5V supply. The EMD1725-D has a typical noise figure of 3.5dB to 40 GHz. The EMD1700 series are available in 4mm QFN packages and bare die (1725-D only).

www.eclipsemdi.com
 408.526.1100
 Let's talk shop.



COMMUNICATION

Passive Intermodulation Test Solutions

High-speed data transmission in today's global mobile communication networks demands high efficiency of network infrastructure – and passive intermodulation (PIM) can cause serious interferences.

As a global leader of RF connectivity solutions, Rosenberg has a strong expertise in manufacturing of Low-PIM components as well as PIM T&M solutions – rack and portable desktop analyzers, adaptors and test cables for various applications:

- R&D, test labs and calibration
- Production lines
- Low-weight PIM site analyzers for multi-function on-site tests, less than 15 kg

www.rosenberger.com/pia

Rosenberger

Broadest Selection of In-Stock RF Switches



PIN Diode



Waveguide



USB Controlled



Electromechanical



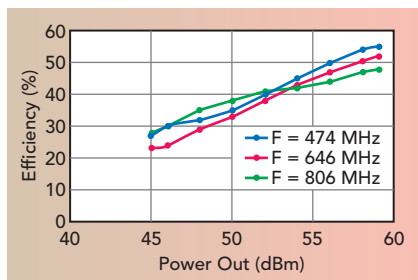
Surface Mount

- Coaxial, Waveguide and Surface Mount options available
- SPST thru SP12T and Transfer configurations
- Frequencies from 10 MHz to 110 GHz
- All in-stock and ship same-day



Fairview Microwave
RF COMPONENTS ON DEMAND. *Done!*

Technical Feature

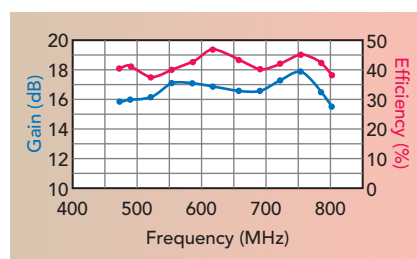


▲ Fig. 6 UWD amplifier pulsed RF efficiency vs. output power.

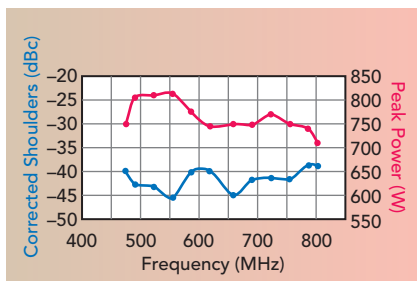
To achieve maximum peak power, the output power of both devices is combined in phase at the power combining node (node X in Figure 4). It can also be deduced from Figure 2a that these phase relationships can be achieved by adding a $\lambda/4$ transmission line in front of the main device combined with an in-phase power splitter, as shown in Figure 4. Note that for the $\lambda/4$ transmission line to work properly as a phase compensator, it is important that the inputs of the PA devices are reasonably matched; otherwise, reflections from the PA devices will disrupt the actual phase relationships at the gates and, thus, at the PA outputs. Broadcast amplifiers, when aiming for a flat gain versus frequency response, however, are typically designed with high reflection losses (approximately -2 dB) at lower frequencies to compensate for the 6 dB/octave gain slope inherent in LDMOS PA devices. For this reason, it is essential to use an input splitter that isolates the PA devices from each other over the desired bandwidth, to minimize the impact of input reflections. The use of a two-stage Wilkinson power divider⁹ with a $\lambda/4$ transmission line in front of the main device keeps the phase error below 5° over the desired bandwidth and achieves the required isolation.

MEASUREMENTS

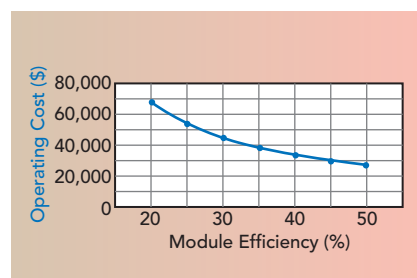
The prototype UWD amplifier shown in Figure 5 was measured using pulsed RF, with a pulse width of 100 μ s and 10 percent duty cycle and DVB-T signals. In order to measure the performance of the UWD amplifier with the modulated signals, a commercially available DVB-T exciter was used. The measured pulsed RF efficiency (see Figure 6) shows the capability of the UWD amplifier



▲ Fig. 7 UWD amplifier gain and efficiency vs. frequency at 115 W average output power.



▲ Fig. 8 Corrected shoulders of the UWD amplifier with 115 W average output power, using a commercial DVB-T exciter. Peak output power is also shown.

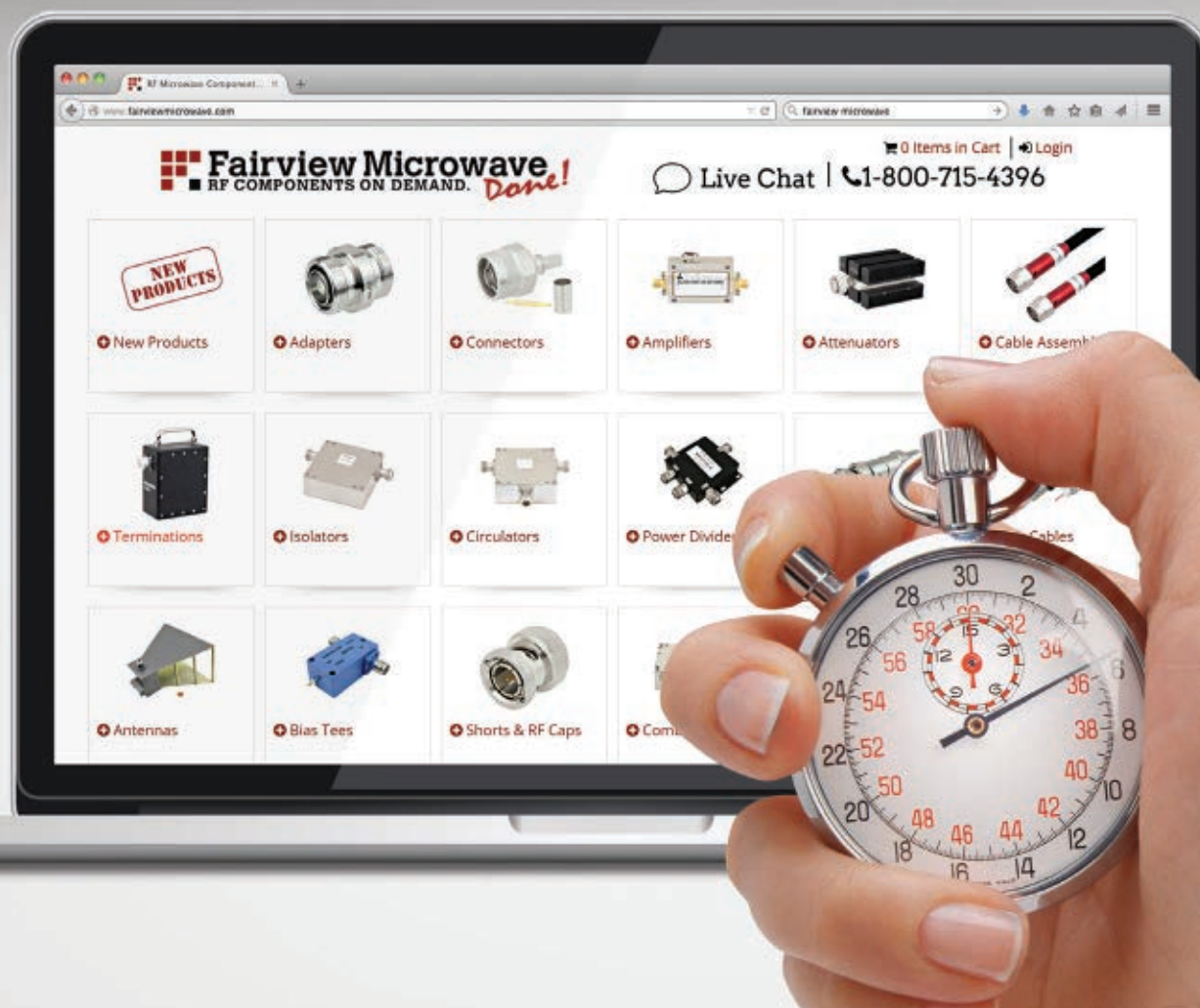


▲ Fig. 9 Transmitter operating cost per year vs. module efficiency, assuming 10 kW transmit power, 1 dB combining loss, 90 percent AC to DC power conversion efficiency and \$0.11/kWh.

to maintain high efficiency at back-off power levels over a wide range of frequencies. Measured pulsed RF efficiencies versus frequency are shown in Figure 7, demonstrating average efficiencies ranging from 38 to 47 percent over the desired UHF band.

Note that the input PAR of the DVB-T signal is 9.5 dB and the PA is allowed to compress at most by 1.5 dB, so the resulting PAR at the output of the PA is always more than 8 dB over the desired band. All efficiency, gain and power measurements are performed under these constraints. Predistortion is also performed using the same DVB-T exciter. As shown in Figure 8, the UWD amplifier meets the -38 dBc linearity requirement for broadcast over the entire 470 to 803 MHz band.

The Right RF Parts. Right Away.



We're RF On Demand, with over one million RF and microwave components in stock and ready to ship. You can count on us to stock the RF parts you need and reliably ship them when you need them. Add Fairview Microwave to your team and consider it done.

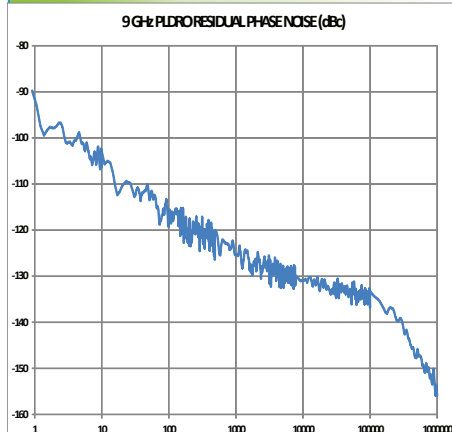
fairviewmicrowave.com
1.800.715.4396

 **Fairview Microwave**
RF COMPONENTS ON DEMAND. *Done!*



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

Technical Feature

OPERATING COST BENEFIT

Power usage is a big concern for the TV operator. The benefit of the UWD and its efficiency improvement compared to conventional class AB operation is significant. **Figure 9** shows the impact of efficiency on operating cost, where the efficiency shown is at the 150 W UWD amplifier module level. Implementation of the 150 W UWD amplifier reduces the operating cost of a 10 kW transmitter by approximately \$25,000 per year.

SUMMARY

A design approach for the realization of high-power wideband Doherty amplifiers exhibits 50 to 60 percent fractional bandwidth. This is enabled through the use of a wideband impedance inverter along with a wideband capacitance compensation and matching strategy. The key achievement, and the importance to the industry, is that these results are achieved using standard 50 V LDMOS devices along with an easy-to-implement passive input splitter. The approach enables low cost efficient high-power wideband amplifier implementations and simple system integrations.

A UWD prototype amplifier covering the entire UHF TV band (470 to 803 MHz) achieved an average efficiency of 38 to 47 percent (for $P_{avg} = 115$ W), while maintaining a peak power capability greater than 750 W over the entire band. It offers 15 to 20 percent more efficiency than the currently used wideband class AB power amplifiers in today's broadcast transmitter systems.^{10,11} This is the best demonstrated bandwidth for a DPA. An operating cost estimate shows the potential for a \$25,000 reduction in annual operating costs for a 10 kW transmitter.

Since this proof of concept development, Ampleon has made considerable progress in increasing UWD amplifier power levels, with the recent focus on the 470 to 608 MHz range and development of a 150 W average DVB-T stage which uses a new LDMOS device. The focus on 470 to 608 MHz is driven by migration of the upper end of the UHF TV band in the U.S. to mobile wireless applications. The latest UWD amplifier in this frequency range has achieved 47 percent efficiency with less than -38 dBc shoulders. ■

ACKNOWLEDGMENT

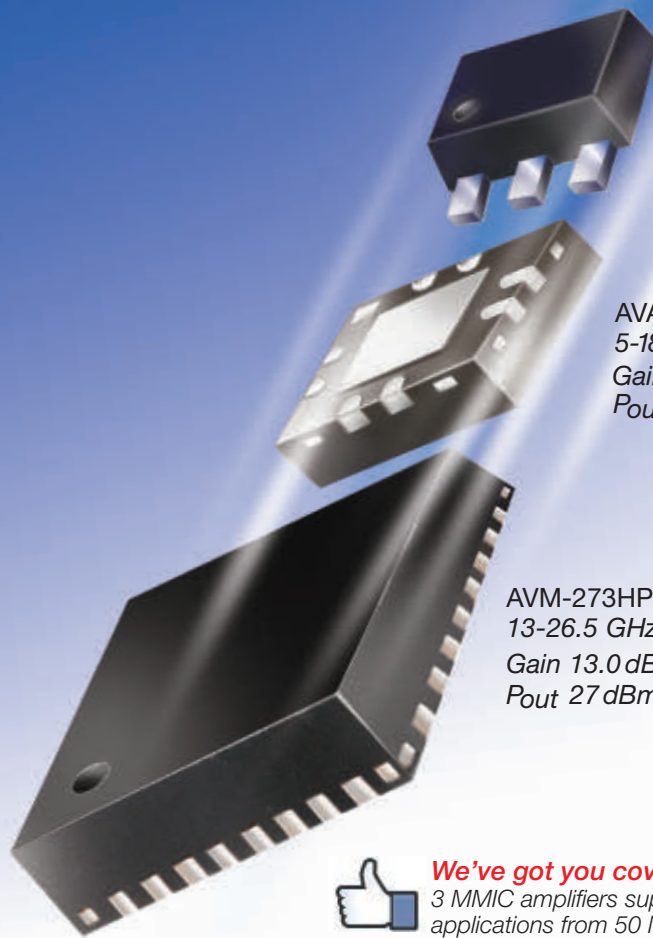
The authors wish to acknowledge our colleagues J.H. Qureshi, W. Sneijders, R. Keenan, L.C.N. de Vreede and F. van Rijs for the initial design.⁷

References

1. "ETSI EN 300 744 V1.6.1 (2009-01) Digital Video Broadcasting (DVB), ETSI, 01/2009," Web. www.etsi.org/deliver/etsi_en/300700_300799/300744/01.06.01_60/en_300744v010601p.pdf.
2. S. C. Cripps, *RF Power Amplifier for Wireless Communication*, Artech House, 2006.
3. J.H. Qureshi, *High Efficiency RF Power Amplifier Architectures*, Doctoral Thesis, TUdelft, July 2012.
4. J. H. Qureshi, L. Nan, E. Neo, F. V. Rijs, I. Blednov and L. de Vreede, "A Wide-Band 20 W LDMOS Doherty Power Amplifier," *IEEE MTT-S International Microwave Symposium Digest*, May 2010, pp. 1504-1507.
5. D. Gusstafsson, C. M. Andersson and C. Fager, "A Novel Wideband and Reconfigurable High Average Efficiency Power Amplifier," *IEEE MTT-S International Microwave Symposium Digest*, June 2012.
6. C. M. Andersson, D. Gustafsson, J.C. Cahuana, R. HeUberg and C. Fager, "A 1-3 GHz Digitally Controlled Dual-RF Input Power Amplifier Design Based on a Doherty-Outphasing Continuum Analysis," *IEEE Transactions on Microwave Theory & Techniques*, Vol. 61, No. 10, October 2013, pp. 3743-3752.
7. J.H. Qureshi, W. Sneijders, R. Keenan, L.C.N. de Vreede and F. van Rijs "A 700-W Peak Ultra-Wideband Broadcast Doherty Amplifier," *IEEE MTT-S International Microwave Symposium Digest*, June 2014, pp. 1-4.
8. R.W. Klopfenstein, "A Transmission Line Taper of Improved Design", *Proceedings of the IRE*, Vol. 44, No. 1, January 1956, pp. 31-35.
9. B. S. Cohn, "A Class of Broadband Three-Power TEM-Mode Hybrids," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 16, No. 2, February 1968, pp. 110-116.
10. "BLF888A/BLF888B High Power UHF Transistor (NXP Semiconductor)," www.mouser.com/ProductDetail/NXP-Semiconductors/BLF888A112/?qs=5XzWkq3%2FTOr3Fxn35KN8w%3D%3D, www.mouser.com/ProductDetail/NXP-Semiconductors/BLF888B112/?qs=vbj%2FKoHZRAgWMN0Y2Riy8g%3D%3D.
11. "MRFE6VP8600H High Power UHF Transistor (NXP Semiconductors)," www.nxp.com/assets/documents/data/en/brochures/BR1607.pdf.

MMIC AMPLIFIERS

50 MHz to 26.5 GHz



PHA-1+ \$199
0.05-6 GHz ea. (qty. 20)
Gain 13.5 dB
P_{out} 22 dBm

AVA-183A+ \$795
5-18 GHz ea. (qty. 20)
Gain 14.0 dB
P_{out} 19 dBm

AVM-273HPK+ \$3690
13-26.5 GHz ea. (qty. 10)
Gain 13.0 dB
P_{out} 27 dBm



We've got you covered!

3 MMIC amplifiers support the whole gamut of applications from 50 MHz all the way up to 26.5 GHz!

Mini-Circuits' AVM-273HPK+ wideband microwave MMIC amplifier supports applications from 13 to 26.5 GHz with up to 0.5W output power, 13 dB gain, ± 1 dB gain flatness and 58 dB reverse isolation. The amplifier comes supplied with a voltage sequencing and DC control module providing reverse voltage protection in one tiny package to simplify your circuit design. This model is an ideal buffer amplifier for P2P radios, military EW and radar, DBS, VSAT and more!

The AVA-183A+ delivers 14 dB gain with excellent gain flatness (± 1.0 dB) from 5 to 18 GHz, 38 dB isolation, and 19 dBm power handling. It is unconditionally stable and an ideal LO driver amplifier. Internal DC blocks, bias tee, and microwave coupling capacitor simplify external circuits, minimizing your design time.

The PHA-1+ uses E-PHEMT technology to offer ultra-high dynamic range, low noise, and excellent IP3 performance, making it ideal for LTE, and TD-SCDMA. Good input and output return loss across almost 7 octaves extend its use to CATV, wireless LANs, and base station infrastructure.

Visit minicircuits.com for full specs, performance curves, and free data! These models are in stock and ready to ship today!

**FREE X-Parameters-Based
Non-Linear Simulation Models for ADS**



<http://www.modelithics.com/mvp/Mini-Circuits.asp>



Dual-Band Bandpass Filter with Multiple Controllable Transmission Zeroes and Wide Stopband

Daotong Li, Yonghong Zhang, Jing Ai, Kaijun Song and Y. Fan
University of Electronic Science and Technology of China, Chengdu, China

A dual-band bandpass filter with multiple controllable transmission zeroes (TZ) and wide stopband performance is based on a single quadruple-mode circular ring resonator (Q-CRR). The two passbands are generated by using degenerate modes. After installing two parallel-coupled feed line sections on a ring at the two ports with 90 degrees separation and two open-ended tri-section stepped-impedance resonators (OT-SIR) loaded on the I/O ports, eight TZs are produced in the stopband. By tuning the length and the impedance ratio of the OT-SIR and the length of the parallel-coupled feed lines, the locations of the TZs are adjusted. Measured results show good agreement with simulation.

Dual-band bandpass filters (BPF) with good selectivity and wide stopbands are highly desired in modern dual-band wireless communication systems.^{1,2} Various design approaches have been used. Microstrip ring resonators have been employed in microwave circuits such as filters, mixers and oscillators.^{3,4} A dual-band ring resonator bandpass filter, can be realized by using co-existing degenerate orthogonal modes.^{5,6} Due to their compact size, high-Q factors and sharp rejection skirts, ring resonators have been comprehensively analyzed. Two dissimilar ring resonators with different resonant frequencies can be used to achieve dual-band passband performance, although the stopband is narrow and the size is relatively large.⁷⁻⁹ Dual-band BPFs have been designed using multilayer structures; however, a complex feed is usually required.^{9,10} Huang et al.,¹¹ describe a dual-band bandpass filter using stepped-impedance ring resonators with an adjustable first- and second-order resonator; however, there is only a single transmission pole in the second

passband, while the isolation between the two passbands and the suppression of the stopband are not good because there are only three TZs. Dual-band BPFs using ring resonators loaded by open-circuited stubs do not have sharp rejection skirts and good rejection in the stopband because there are only two TZs.¹²⁻¹⁵ Luo et al.,^{5,6} report on a class of dual-mode dual-band ring resonator BPFs using microwave C-sections, but these structures need many perturbation elements to be installed along the ring. Chiou et al.,¹⁶ describe a dual-band bandpass filter with four TZs based on a signal ring resonator, however, the upper stopband is narrow and this structure also needs many perturbation elements installed along the ring. Dual-band BPFs using a single rectangular ring resonator exhibit poor out-of-band rejection and selectivity.¹⁷

In this article, we describe a dual-band BPF using a single Q-CRR. After installing two coupled-line sections at the two excitation ports, two transmission poles are generated in each passband. With a two-port excitation angle of 90 degrees, parallel-coupled

WIN. Because not everyone can do this.

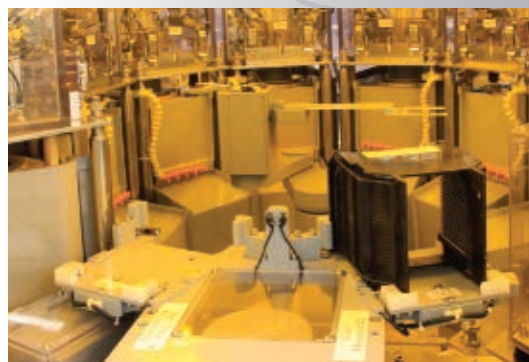
A wider set of solutions

A broader spectrum of possibilities

WIN Semiconductors delivers technology solutions that cover applications from DC to 100GHz and beyond. As the innovation leader in compound semiconductors, WIN serves a wide range of rapidly growing markets with unmatched manufacturing scale and unique capabilities to help design engineers solve problems - fast.

Integrated Technology Platforms

- I HBT with E/D pHEMT
- I High performance pHEMT with E/D logic
- I 0.1 μm - 0.5 μm pHEMT plus P/N ESD diodes
- I 3 metal PIN MMIC and high voltage IPD



Advanced Chip Integration

- I Moisture rugged
- I Cu pillar bump/flip chip
- I RF isolated through-wafer connections
- I Wafer scale package

With an expansive technology portfolio, rapid turn times, and unrivaled manufacturing scale, WIN enables market leading products with a seamless move to high volume production.

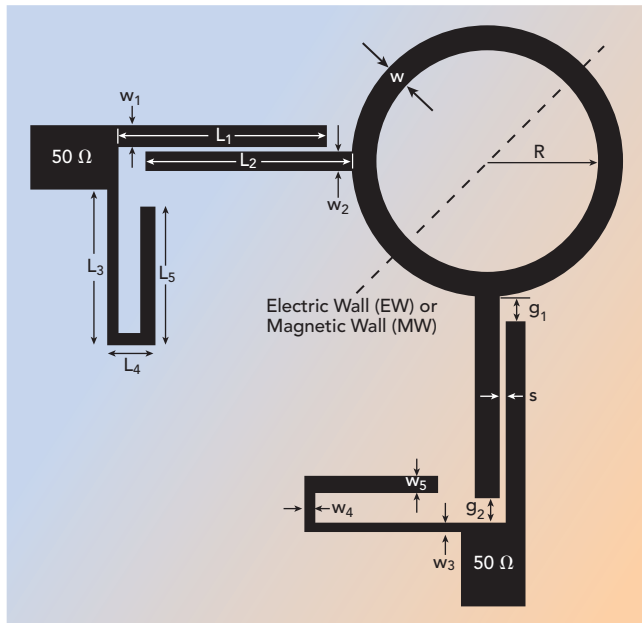
How can WIN help you today?

Contact WIN today, and see how we can help you reduce size, improve performance and reach the next level of innovation.

With technology, manufacturing scale and support services unmatched in the industry, you'll see why partnering with us is a win-win.

TechnicalFeature

feed lines and OT-SIRs at the I/O ports, eight control-lable TZs are generated and provide a good isolation and a wide upper stopband. By tuning the length and the impedance ratios of the OT-SIRs, TZ locations are adjusted, extending the upper stopband.



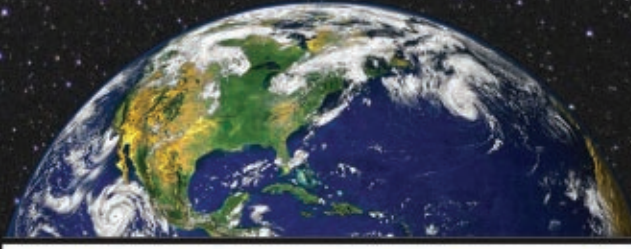
▲ Fig. 1 Configuration of a dual-band bandpass filter using a single Q-CRR.

Out of This World Quality.

Substrates for Demanding Applications

Surface Finish to 0.000001" max.

Lapping
Polishing
Filled Via Planarity
Wafer Dicing
Laser Machining
Specialty Processes



CENTERLINE TECHNOLOGIES

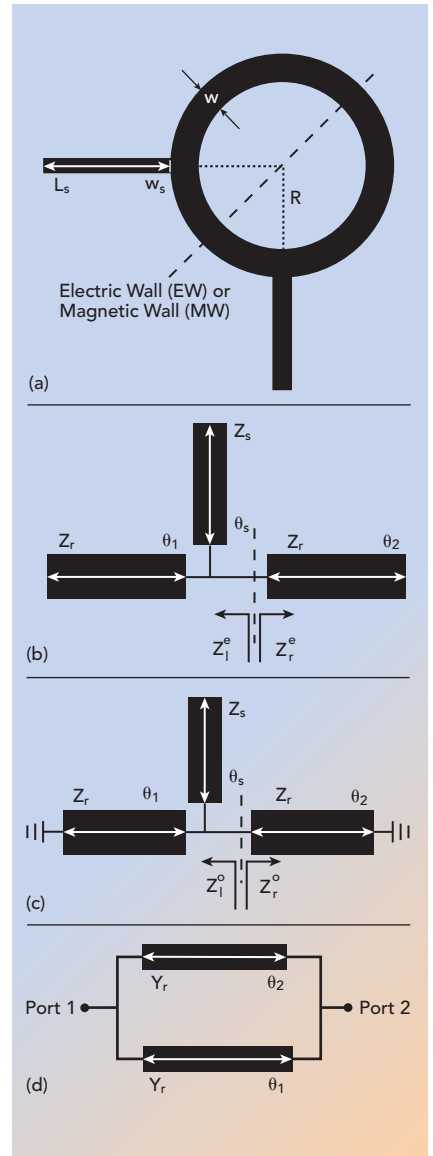
www.centerlinetech-usa.com/MWJFeb

FILTER DESIGN

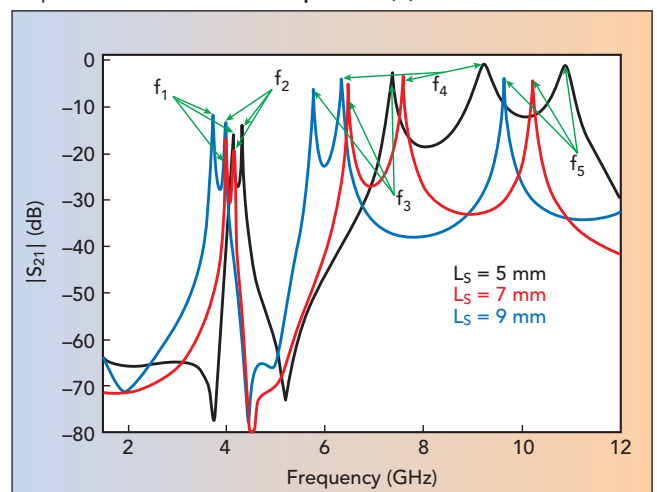
Figure 1 shows the filter configuration. It consists of a quadruple-mode circular ring resonator (Q-CRR) connected to parallel-coupled feed lines and OT-SIRs loaded at the input/output (I/O) ports.

Q-CRR

The Q-CRR (see **Figure 2a**) consists of a circular ring resonator with two orthogonally separated open-ended stubs, where R , w and w_s are the radius and the widths of the circular ring and open stubs, respectively. The operating mechanism is discussed by using even and odd mode analysis because of the resonator's even symmetrical structure. The even and odd mode equivalent circuits are shown in **Figures 2b** and **2c**. Z_s and θ_s are the characteristic impedance and



▲ Fig. 2 Q-CRR layout (a), even mode equivalent circuit (b), odd mode equivalent circuit (c), circuit for obtaining TZ frequencies (d).



▲ Fig. 3 Simulated transmission response of the Q-CRR with different line length (L_s) under loose coupling.



Planar Monolithics Industries, Inc.

High Power Limiters

PMI offers a variety of high power limiters covering the 0.01 to 18 GHz frequency range for military and industrial applications. PMI's limiters offer low loss, high speed along with low leakage levels and high peak power handling. More available at http://www.pmi-rf.com/Products/limiters/limiters_features.htm

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

Model: LM-10M2D5G-100CW-1KWP-SFF

<http://www.pmi-rf.com/Products/limiters/LM-10M2D5G-100CW-1KWP-SFF.htm>

Frequency	0.01 to 2.5 GHz
Insertion Loss	0.5 dB Typ - Measured 1.09 dB
VSWR	1.3:1 Max (@ -10 dBm input) Measured Input: 1.28:1, Output: 1.22:1
Input Power	100 watts CW Max, 1 kW peak (1% duty cycle, 1 µs Max pulse width)
Recovery Time	1 µs Max - Measured 100 ns
Maximum Flat Leakage	13 dBm Max
Operating Temperature	-55 °C to +85 °C



Package Size: **1.86" x 0.65" x 0.38"**
Connectors: **SMA Female**

Model: LM-1G2G-4CW-1KWP-SMF

<http://www.pmi-rf.com/Products/limiters/LM-1G2G-4CW-1KWP-SMF.htm>

Frequency	1.0 to 2.0 GHz
Insertion Loss	0.7 dB Max - Measured 0.65 dB
VSWR	2.0:1 Max (@ -10 dBm input) Measured 1.54:1
Input Power	4 Watts CW Max, 1 kW peak (1% duty cycle, 1 µs Max pulse width)
Recovery Time	1 µs Max - Measured 100 ns
Maximum Flat Leakage	16 dBm Max (40 mW) - Measured 15.35 dBm
Operating Temperature	-55 °C to +85 °C



Package Size: **1.0" x 0.75" x 0.38"**
Connectors: **SMA Female**

Model: LM-6D7G7D9G-30W-SFF

<http://www.pmi-rf.com/Products/limiters/LM-6D7G7D9G-30W-SFF.htm>

Frequency	6.7 to 7.9 GHz
Insertion Loss	1.1 dB Max - Measured 0.96 dB
VSWR	1.5:1 Max (@ -20 dBm input) Measured 1.38:1
Input Power	30 Watts CW Max
Recovery Time	10 µs Max - Measured 70 ns
Maximum Flat Leakage	18 dBm Max at Input Power of 30 W CW Measured 7.05 dBm
Operating Temperature	-40 °C to +85 °C



Package Size: **1.0" x 0.65" x 0.38"**
Connectors: **SMA Female**

Model: LM-6G18G-15-10W-SFF

<http://www.pmi-rf.com/Products/limiters/LM-6G18G-15-10W-SFF.htm>

Frequency	6.0 to 18.0 GHz
Insertion Loss	2.5 dB Typ @ 0 dBm - Measured 1.71 dB
VSWR	1.8:1 Typ - Measured 1.69:1
Input Power	10 Watts CW Max
Recovery Time	Measured 12.2 ns
Maximum Flat Leakage	+15 dBm Typ
Operating Temperature	-55 °C to +85 °C



Package Size: **1.0" X 1.0" X 0.5"**
Connectors: **SMA Female**

West Coast Operation:

4921 Robert J. Mathews Pkwy, Suite 1
El Dorado Hills, CA 95762 USA
Tel: 916-542-1401, Fax: 916-265-2597

East Coast Operation:

7311-F Grove Road
Frederick, MD 21704 USA
Tel: 301-662-5019, Fax: 301-662-1731

sales@pmi-rf.com • www.pmi-rf.com
ISO9001-2008 REGISTERED

PRODUCTS TO SOLUTIONS

MMW Amplifiers

Ducommun has more than 50 years of experience with the design, testing and manufacturing of standard and custom millimeter wave amplifiers.



• High Power, Single DC power supply/
internal sequential biasing



32 to 36 GHz Power Amplifier

- AHP-34043530-01
- Gain: 30 dB (Min)
- Gain Flatness: ± 2.0 dB (Max)
- P-1dB: 34 dBm (Typ), 33 dBm (Min)

• Ka-Band GaN Amplifier



27-31 GHz, 8 W GaN Power Amplifier

- Model AHP-29043925-G1
- Gain: 25 dB (Typ), 23 dB (Min)
- Psat: 39 dBm (Typ), 38 dBm (Min)
- 22% Power-Added Efficiency

For additional information,
contact our sales team at
310.513.7256 or
rfsales@ducommun.com

CONTACT US

Technical Feature

the electrical length of the loaded open-circuited stub on the ring. Z_l and Z_r represent the two oppositely oriented input impedances at the same position. The input impedances with superscript "e" and "o" are the even and odd mode impedances, respectively. According to transmission line theory and the odd-even mode analysis method, the resonant frequencies under even and odd mode excitation satisfy¹⁸

$$Z_l^e + Z_r^e = 0 \quad (1)$$

$$Z_l^o + Z_r^o = 0 \quad (2)$$

where

$$Z_r^e = -\frac{jZ_2}{\tan\theta_2},$$

$$Z_l^e = \frac{jZ_s Z_r \tan\theta_s}{Z_r - Z_s \tan\theta_s \tan\theta_1},$$

$$Z_r^o = jZ_r \tan\theta_2,$$

$$Z_l^o = \frac{jZ_s Z_r \tan\theta_s \tan\theta_1}{Z_s \tan\theta_s + Z_r \tan\theta_1}$$

Due to transverse interference between the two signal paths from one port to the other port, some TZs are generated.¹⁹ Figure 2d is the equivalent circuit. The TZ frequencies are obtained by applying $Y_{21} = Y_{12} = 0$, where the admittance matrices are calculated by adding upper and lower Y-parameters of the two paths connected in shunt between ports 1 and 2. The calculated results are expressed by

$$\sin\theta_1 + \sin\theta_2 = 0 \quad (3)$$

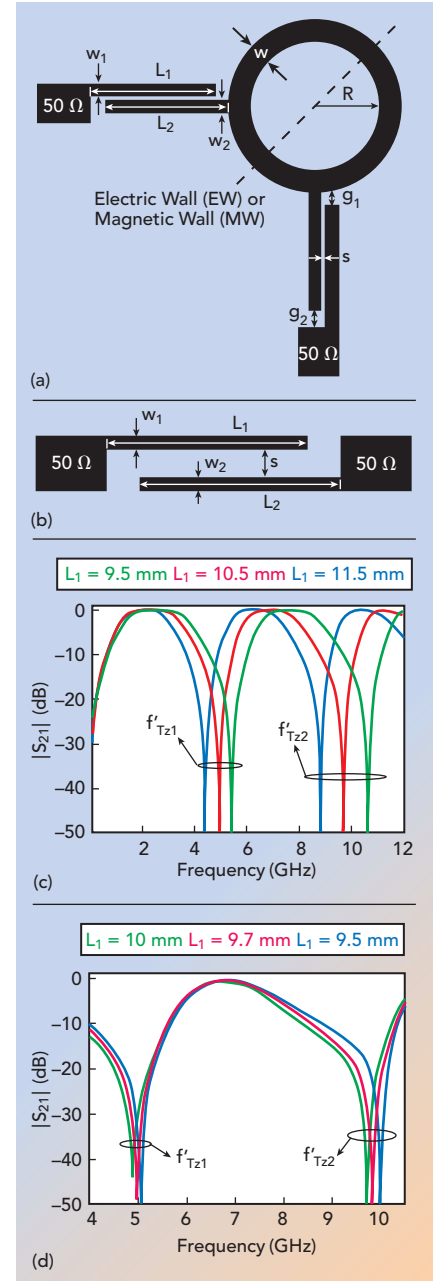
where $\theta_2 = 3\theta_1$; so, the TZs appear at $\theta_1 = (2n-1) \times 90^\circ$, $n = 1, 2, 3, \dots$

Figure 3 shows the frequency responses of the Q-CRR with loose coupling for various values of L_5 . It can be seen that all the resonant frequencies become smaller as L_5 increases. The first two resonant frequencies, f_1 and f_2 , split from each other as L_5 increases, while the third and fourth resonances, f_3 and f_4 , move closer to each other and thus form a second passband. The fifth resonance f_5 is the first spurious frequency.

Parallel-Coupled Feed Lines

Figure 4a shows the layout of Q-CRR dual-band BPF fed by the parallel-coupled feed lines. L_1 , w_1 and L_2 , w_2 are the length and width of the parallel-coupled feed line connecting with input/output ports and the loaded open stub on the circular ring resonator, respectively, while s is the gap between the two coupled lines.

To examine their characteristics, the parallel-coupled feed line struc-

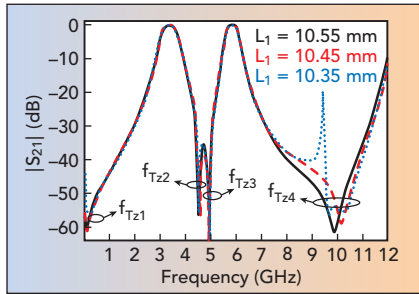


▲ Fig. 4 Q-CRR layout (a), parallel-coupled feed line (b), simulated $|S_{21}|$ for the parallel-coupled feed lines using three values of L_1 in the case of $L_1 = L_2$ and $w_1 = w_2$ (c), variation of TZs vs. length of L_1 (d).



How do you go from a brilliant idea to a multi-million dollar business? You find the right partner to help you bring your vision to life. What can Avnet's global expertise do for your products?

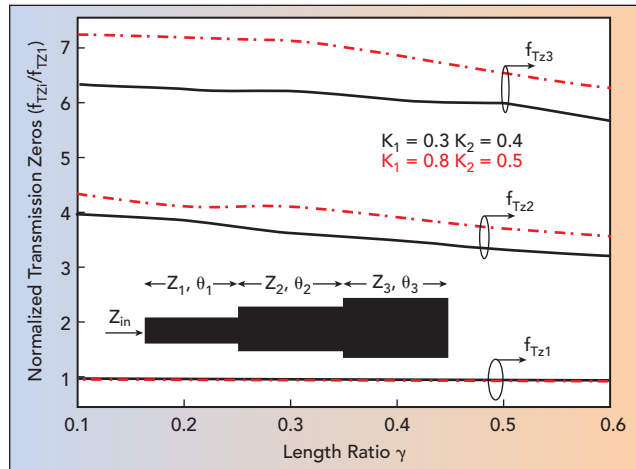
Find out at avnet.com



▲ Fig. 5 Simulated $|S_{21}|$ for the Q-CRR fed by the parallel-coupled feed line vs. length of L_1 .

ture shown in **Figure 4b** is simulated with three different values of L_1 . The results are shown in **Figure 4c**. When $L_1 = L_2$ and $w_1 = w_2$, the TZs are distributed in the stopband. The TZs shift lower in frequency when the length of L_1 increases. The transmission zero f_{TZ2} is changed significantly by altering the length of L_1 while leaving the length of L_2 unchanged (see **Figure 4d**), while f_{TZ1} varies slightly.

The effect of these overlaps is seen when the circular ring resonator and the parallel-coupled lines are used together. **Figure 5** shows the simulated results of the Q-CRR fed by the parallel-coupled feed lines with three different lengths of L_1 . The TZ overlap shown in Figure 5 causes suppression of the fifth resonant frequency in Figure 3, and produces sharper rejections at cut-off regions, further extending the upper stopband.



▲ Fig. 6 Location of transmission zeroes vs. length ratio γ and different impedance ratios K_1 and K_2 .

TZs Introduced By Stub-loaded OT-SIR

Figure 6 shows the OT-SIR consisting of three sections. The impedance ratios (K_1 , K_2) and the length ratios (α , γ , ζ) are defined respectively as $K_1 = Z_1/Z_2$, $K_2 = Z_1/Z_3$, and $\alpha = \theta_1/(\theta_1+\theta_2+\theta_3)$, $\gamma = \theta_2/(\theta_1+\theta_2+\theta_3)$, $\zeta = \theta_3/(\theta_1+\theta_2+\theta_3)$. The input impedance of the OT-SIR is

$$Z_{in} = Z_1 \frac{Z_L + jZ_1 \tan \theta_1}{Z_1 + jZ_L \tan \theta_1} \quad (4)$$

where

$$Z_L = Z_2 \frac{jK_2 \tan \theta_2 \tan \theta_3 - jK_1}{K_2 \tan \theta_3 + K_1 \tan \theta_2}$$

when the $Z_{in} = 0$, the first three TZs of the OT-SIR are obtained.

To verify the design concept, a resonator is simulated on a substrate with relative dielectric constant of 3.5 and thickness of 0.508 mm. Two microstrip lines with 50Ω characteristic impedance are utilized to feed the OT-SIR. The length is fixed at 19.5 mm, corresponding to $\lambda_g/2$ at the fundamental resonant frequency, where the λ_g is guided

wavelength, while the length ratios $\alpha = \zeta$. **Figure 6** shows the simulated result of normalized TZs f_{TZi}/f_{TZ1} ($i = 1, 2, 3$) versus the length ratio γ under the condition of ($K_1 = 0.3$, $K_2 = 0.4$) and ($K_1 = 0.8$, $K_2 = 0.5$). The gaps between the first three TZs are tuned by altering the impedance ratios K_1 and K_2 and the length ratio γ . The adjustment of K_1 can be used to enlarge the spans between the first three TZs, for example, as the K_1 increases, the spacings between the first three TZs decrease. Similarly, the spans between the three TZs become smaller when the impedance ratio K_2 is enlarged. It is also apparent that the spans between the first three TZs decrease when

VISIT US AT BOOTH 1156



6-8 JUNE 2017 - HAWAII

ERZIA
www.erzia.com

Space / Aerospace / Military / Laboratory



MW and MMW amplifiers and integrated assemblies

Up to 100 GHz. High degree of customization.

ERZIA HQ, Josefina de la Maza 4, 39012 Santander, Spain
sales.rf@erzia.com Tel: +34 942 29 13 42

ERZIA, 2001 L Street NW, Suite 500, Washington, DC 20036
sales.rf@erzia.com Tel: +1 202-495-3479

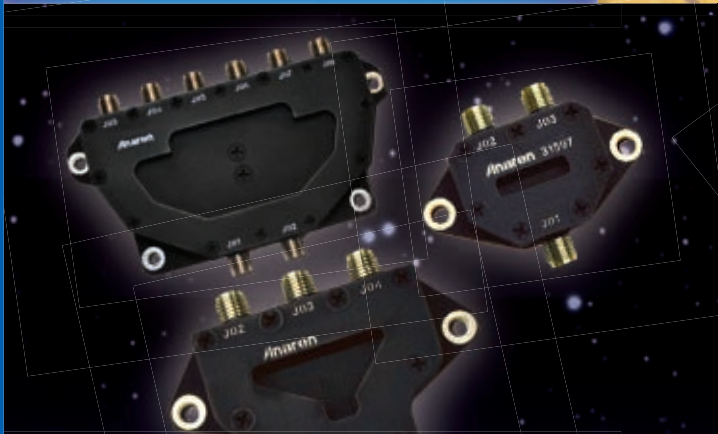


Anaren Precision Etched Ceramics (APECS) — offering thin-film tolerances & performance, at a thick-film price

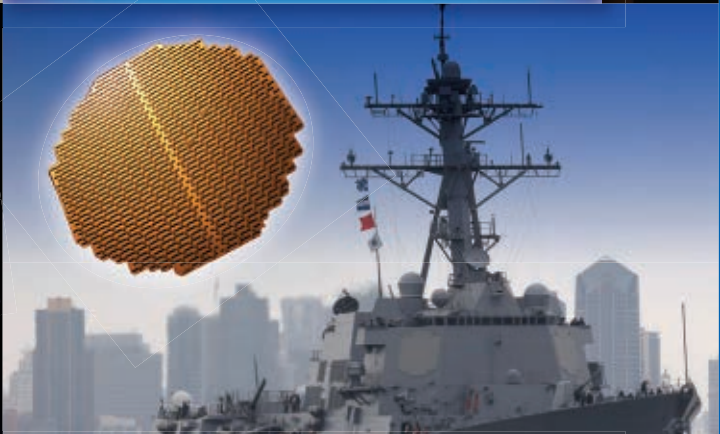


Space/Mil-grade Xinger® couplers — proven in Mars missions & ready for tough terrestrial settings, too

1st on genuine Xinger-brand components!
1 billion Xinger components sold!



Space-qualified couplers & power dividers — high-rel, lightweight & low-power for today's satellite applications



RF solutions for next-gen AESAs — including manifolds, T/R modules & beam-formers for air, sea, and land platforms

Isn't it time to put Anaren innovations like these to work for you?

Fast-approaching our 50th anniversary — and this year celebrating our 1 billionth Xinger®-brand coupler sold! — today's Anaren continues to drive innovative, best-in-class RF technology for the world's most demanding space, defense, wireless, and consumer electronics customers.

- > **Our Space & Defense Group** offers a fast-growing range of passive and active solutions, including multichip modules, IMAs, and custom solutions for today's digital radars. Exciting, new PCB and ceramic substrates and multilayer packaging techniques. And a growing line-up of space-grade components and high-temperature modules.
- > **Our Wireless Group** continues to reinvent the passive components category. From new, Femto-sized and mil-grade Xinger®-brand SMTs. To subminiature baluns and couplers for consumer products. To our growing family of Anaren Integrated Radio (AIR) modules and other solutions for the wireless IoT.

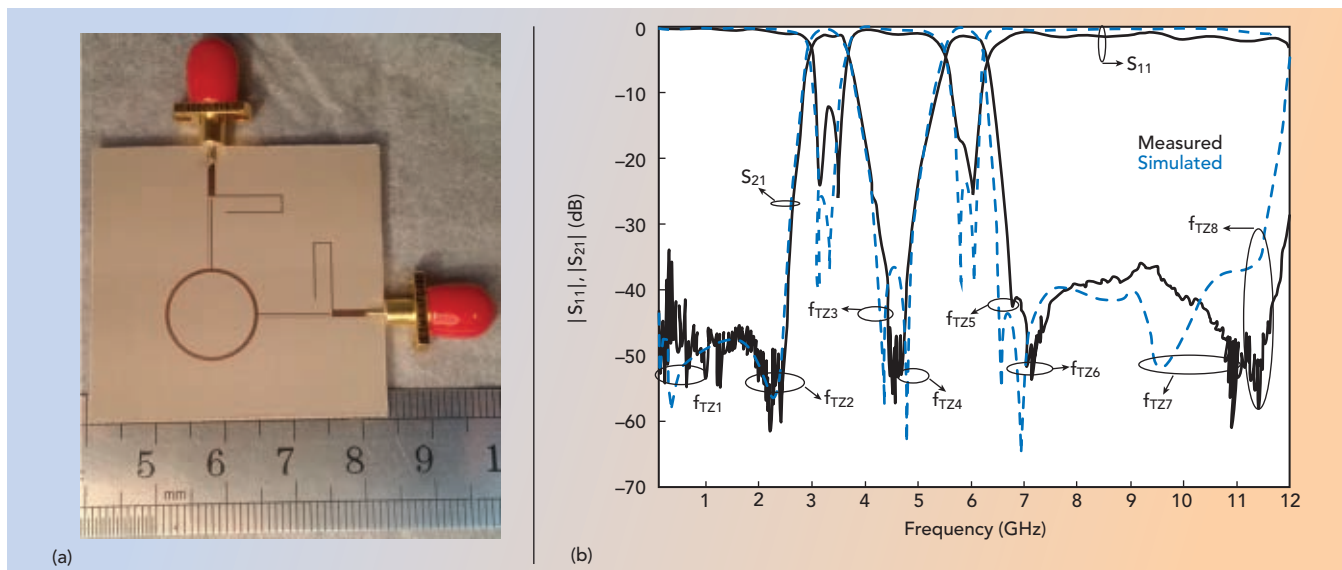
To learn more about how today's Anaren can make you more competitive tomorrow — visit www.anaren.com or email us at sales@anaren.com today!



Anaren®

What'll we think of next?®

800-411-6596 > www.anaren.com



▲ Fig. 7 Fabricated dual-band BPF (a), with simulated vs. measured results (b).


the length ratio γ increases. The relationship of the spans between the first three TZs and the length ratios α and ζ can also be seen by using the same method. Changes in the length ratio ζ have similar effects as changes in the length ratio γ , while the spans between the first three TZs become larger as the length ra-

tio α increases. So, the location of the TZs can be adjusted by tuning the impedance ratios (K_1 , K_2) and the length ratios (α , γ , ζ), which improves selectivity and rejection in the stopband.

EXPERIMENTAL RESULTS

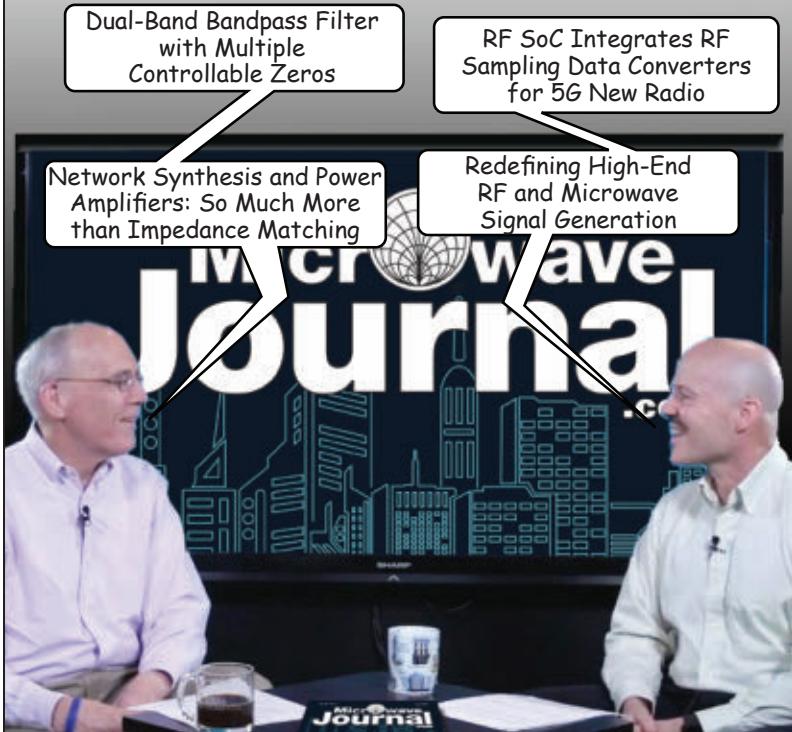
The dual-band BPF with mul-

tiple controllable TZs is fabricated on Taconic RF-35 substrate with relative dielectric constant of $\epsilon_r=3.5$ and thickness of $h=0.508$ mm. The dimensions are $L_1=10.26$ mm, $L_2=10.4$ mm, $L_3=10$ mm, $L_4=2.74$ mm, $w_1=0.12$ mm, $w_2=0.24$ mm, $w_3=0.24$ mm, $w_4=0.26$ mm, $w=0.6$ mm, $g_1=0.49$ mm, $g_2=0.3$



Frequency Matters.

www.mwjjournal.com/freqmatters



Dual-Band Bandpass Filter with Multiple Controllable Zeros

RF SoC Integrates RF Sampling Data Converters for 5G New Radio


Network Synthesis and Power Amplifiers: So Much More than Impedance Matching

Redefining High-End RF and Microwave Signal Generation


Catch up on the latest industry news with the bi-weekly video update

Frequency Matters

from
Microwave Journal



Sponsored By



AHEAD OF WHAT'S POSSIBLE™

ACCELERATE

Your High Frequency Designs with
The Modelithics® COMPLETE Library
of Scalable, Parasitic Simulation Models
for Passive and Active Devices

Modelithics Models are:

- Measurement-based
- Equivalent circuit models
- Thoroughly documented

Modelithics Models offer:

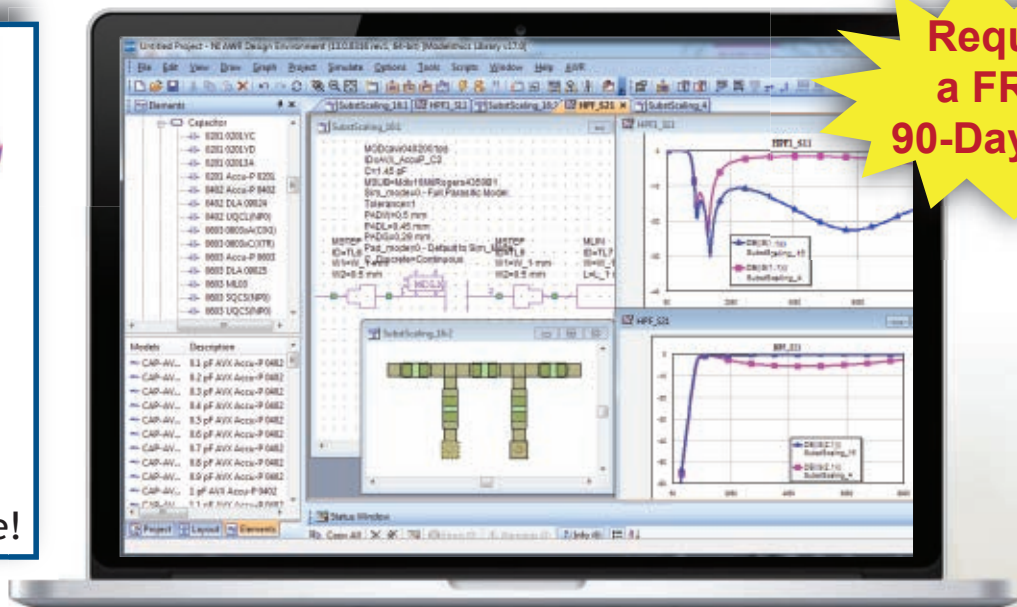
- Substrate and pad scaling
- Part value scaling
- EM co-sim compatibility

...and more!

AVX-Modelithics Models for:
Capacitors, Inductors, Resistors, Attenuators,
Hybrid & Bi-directional Couplers and Diplexers



Accu-P
Accu-L
COG
DLA09
DLA11
SQ, UQ
CP0402
DB0603
Many more!



**Request
a FREE
90-Day Trial**

FREE 90-day trial of ALL Modelithics
models for AVX components

www.Modelithics.com/MVP/AVX



INTRODUCING

Microwave Journal's New Video Library



Educational and demo
videos organized by:

Applications

Products

Events

Companies

Visit and bookmark
videos.microwavejournal.com

**Sponsored video programs
are available**



Frequency Matters.

Technical Feature

TABLE 1
COMPARISON OF DUAL-BAND BANDPASS FILTERS

Reference	Number of TZs	Isolation (dB)	Substrate ϵ_r/h	Size (mm ²)	Center Frequency (GHz)	Fractional Bandwidth (%)	Insertion Loss (dB)
5	4	15	10.8/1.27	13 × 13	2.38/4.87	6.7/8	2/2
9	3	27	10.2/0.635	25 × 20	5.2/5.8	6/5.6	2.5/2.76
10	4	20	10.2/0.635	36 × 36	1.1/1.86	7.7/5.9	1.07/1.1
11	3	17	3/0.76	14 × 14	2.4/5.2	6/6	3.2/3.4
12	2	15	3.5/0.508	15 × 15	3.46/5.2	2.8/2.1	1.8/2
14	5	40	2.45/1	31.6 × 25	1.5/2.44	8.24/7.27	1.12/1.37
15	0	25	2.5/1	30 × 30.5	1.8/2.36	2.22/1.7	2.5/2.5
15	3	50	2.5/1	30 × 49	2/2.76	7.5/5.43	2.5/3
15	1	20	2.5/1	30 × 29.1	1.8/2.36	2.22/1.7	2.3/2.7
17	3	32	10.8/1.27	19.1 × 19.1	2.3/4	8.6/7.5	0.65/1
20	3	40	9.8/1.19	Unknown	1.38/2.55	18.7/8.9	0.73/1.5
This Work	8	48	3.5/0.508	24.6 × 24.6	3.5/5.8	20/11.5	1/1.4

mm, $s = 0.21$ mm and $R = 6.75$ mm. A photograph of the filter is shown in **Figure 7a**. It is measured with a Keysight 8757D network analyzer. Simulated and measured frequency responses are compared in **Figure 7b**. Good agreement is achieved. The measured minimum insertion loss is 1 dB in the first passband and 1.4 dB in the second passband. The 3 dB fractional bandwidths are 20 percent and 11.5 percent, respectively. Passband return losses are larger than 13.6 dB in the first passband and 18 dB in the second passband. Eight TZs are generated at 0.32, 2.31, 4.32, 4.75, 6.73, 7.12, 10.92 and 11.44 GHz, respectively. The TZs located at 0.32, 4.32 and 10.92 GHz are generated by the parallel-coupled feed lines, the TZs of 2.31, 6.73 and 11.44 GHz are generated by the OT-SIR and the others are achieved through transverse interference of the Q-CRR. With the aid of additional controllable TZs provided by the parallel-coupled feed line section and the loaded OT-SIR, the fifth resonance located in the upper stopband is fully suppressed. Meanwhile, the span of the upper stopband is also enlarged. In the measured upper stopband response, 20 dB rejection in the frequency range of 6.5 to 12.25 GHz is obtained. **Table 1** shows some reported performance of dual-band BPFs in recent years for comparison. Selectivity, suppression in the stop-

band and the width of the stopband are improved through this work.

CONCLUSION

A dual-band BPF with multiple controllable TZs using a single Q-CRR and a pair of OT-SIRs is presented. Two TZs are placed between the two passbands and six TZs are created in the stopband which results in a good selectivity and a wide upper stopband. Two transmission poles are generated in each passband after installing two parallel-coupled-line sections at the two excitation ports. The spurious frequency at the fifth resonance of the resonator is suppressed by an additional zero from the parallel-coupled-line section. When the TZs generated by the Q-CRR are combined with the TZs introduced by the stub-loaded OT-SIR and parallel-coupled feed lines, performance in the upper stopband is improved.

ACKNOWLEDGMENT

This work is partially supported by the R&S program for science and technology innovation, partially by National Key Scientific Instrument and Equipment Development Projects (Grant No. 2013YQ200503), partially by the National Natural Science Foundation of China (Grant No: 61271026) and partially by the Program for New Century Excellent Talents in University (Grant No: NCET-11-0066). ■

6 GHz Signal Generators

... the choice is yours !

Choosing the right signal generator is now easy — the SG386 RF Signal Generator from SRS performs like the Agilent N5181A, but sells for a fraction of the price!

The SG386 is loaded with features including a rich suite of modulation functions, computer interfaces, and optional square wave clock outputs and analog I/Q inputs.

It comes with a standard OCXO timebase that has very low aging characteristics and excellent frequency stability. And the SG386 has extremely low phase noise making it ideal in the most challenging applications.



**SRS
SG386**

- DC to 6 GHz range
- ± 0.002 ppm stability
- -116 dBc/Hz phase noise
(1 GHz, 20 kHz offset)

\$5,900



**Agilent
N5181A-506**

- 100 kHz to 6 GHz range
- ± 1 ppm stability
- -118 dBc/Hz phase noise
(1 GHz, 20 kHz offset)

\$16,373



SG386 ... DC to 6 GHz

\$5,900

- 2 GHz, 4 GHz & 6 GHz models
- AM, FM, Φ M, PM & sweeps
- Excellent phase noise
- Standard OCXO timebase
- Rubidium timebase (opt.)
- Square wave clock outputs (opt.)
- I/Q modulation inputs (opt.)
- GPIB, Ethernet & RS-232

DemoDirect

Free 30 day evaluation
Call (408)744-9040



FEATURED

WHITE PAPERS

The information you need, from industry experts








Check out these new online Technical Papers featured at **MWJournal.com**



Frequency Matters.

TechnicalFeature

References

1. H. W. Deng, Y. J. Zhao, Y. Fu, X. J. Zhou and Y. Y. Liu, "Compact and High Selectivity Dual-Mode Dual-Band Microstrip BPF with QWR and SLR," *Microwave and Optical Technology Letters*, Vol. 54, No. 12, December 2012, pp. 2702-2705.
2. S. Yang, L. Lin, J. Z. Chen, K. Deng and C. H. Liang, "Design of Compact Dual-Band Bandpass Filter Using Dual-Mode Stepped-Impedance Stub Resonators," *Electronics Letters*, Vol. 50, No. 8, April 2014, pp. 611-613.
3. I. Wolff, "Microstrip Bandpass Filter Using Degenerate Modes of a Microstrip Ring Resonator," *Electronics Letters*, Vol. 8, No. 12, June 1972, pp. 302-303.
4. K. Chang and L. H. Hsieh, *Microwave Ring Circuits and Related Structures*, Wiley, New York, 2004.
5. S. Luo, L. Zhu and S. Sun, "A Dual-Band Ring-Resonator Bandpass Filter Based on Two Pairs of Degenerate Modes," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 58, No. 12, December 2010, pp. 3427-3432.
6. S. Luo and L. Zhu, "A Novel Dual-Mode Dual-Band Bandpass Filter Based on a Single Ring Resonator," *IEEE Microwave and Wireless Components Letters*, Vol. 19, No. 8, August 2009, pp. 497-499.
7. J. X. Chen, T. Y. Yum, J. L. Li and Q. Xue, "Dual-Mode Dual-Band Bandpass Filter Using Stacked-Loop Structure," *IEEE Microwave and Wireless Components Letters*, Vol. 16, No. 9, September 2006, pp. 502-504.
8. X. Y. Zhang and Q. Xue, "Novel Dual-Mode Dual-Band Filters Using Coplanar-Waveguide-Fed Ring Resonators," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 55, No. 10, October 2007, pp. 2183-2190.
9. E. E. Djoumessi and K. Wu, "Multilayer Dual-Mode Dual-Bandpass Filter," *IEEE Microwave and Wireless Components Letters*, Vol. 19, No. 1, January 2009, pp. 21-23.
10. J. W. Baik, L. Zhu and Y. S. Kim, "Dual-Mode Dual-Band Bandpass Filter Using Balun Structure for Single Substrate Configuration," *IEEE Microwave and Wireless Components Letters*, Vol. 20, No. 11, November 2010, pp. 613-615.
11. T. H. Huang, H. J. Chen, C. S. Chang, L. S. Chen, Y. H. Wang and M. P. Houng, "A Novel Compact Ring Dual-Mode Filter with Adjustable Second-Passband for Dual-Band Applications," *IEEE Microwave and Wireless Components Letters*, Vol. 16, No. 6, June 2006, pp. 360-362.
12. K. D. Xu, Y. H. Zhang, Y. Fan Y, J. L. W. Li, W. T. Joines and Q. H. Liu, "Planar Dual- and Tri-Band Bandpass Filters Using Single Improved Ring Resonator and Simple Feed Scheme," *Microwave and Optical Technology Letters*, Vol. 56, No. 3, March 2014, pp. 574-577.
13. J. P. Wang, L. Wang, Y. X. Guo, Y. X. Wang and D. G. Fang, "Miniaturized Dual-Mode Bandpass Filter with Controllable Harmonic Response for Dual-Band Applications," *Journal of Electromagnetic Waves and Applications*, Vol. 23, No. 11-12, January 2009, pp. 1525-1533.
14. S. J. Sun, T. Su, K. Deng, B. Wu and C. H. Liang, "Shorted-Ended Stepped-Impedance Dual-Resonance Resonator and its Application to Bandpass Filters," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 61, No. 9, September 2013, pp. 3209-3215.
15. S. Fu, B. Wu, J. Chen, S. J. Sun and C. H. Liang, "Novel Second-Order Dual-Mode Dual-Band Filters Using Capacitance Loaded Square Loop Resonator," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 60, No. 3, March 2012, pp. 477-483.
16. Y. C. Chiou, C. Y. Wu and J. T. Kuo, "New Miniaturized Dual-Mode Dual-Band Ring Resonator Bandpass Filter With Microwave C-Sections," *IEEE Microwave and Wireless Components Letters*, Vol. 20, No. 2, February 2010, pp. 67-69.
17. S. Sun, "A Dual-Band Bandpass Filter Using a Single Dual-Mode Ring Resonator," *IEEE Microwave and Wireless Components Letters*, Vol. 21, No. 6, June 2011, pp. 298-300.
18. S. Sun and L. Zhu, "Wideband Microstrip Ring Resonator Bandpass Filters Under Multiple Resonances," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 55, No. 10, October 2007, pp. 2176-2182.
19. R. Gomez-Garcia, M. Sanchez-Renedo, B. Jarry, J. Lintignat and B. Barelaud, "A Class of Microwave Transversal Signal-Interference Dual-Passband Planar Filters," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 19, No. 3, March 2009, pp. 158-160.



CERAMIC FILTERS

LOW PASS BANDPASS HIGH PASS DIPLEXERS

99¢

Covering DC to 18.3 GHz from ea. qty. 3000

Over 195 models as small as 0.06 x 0.03"! 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. Supporting a wide range of applications with high stop band rejection and low pass band insertion loss in tiny packages, they're a perfect fit for your system requirements. Visit minicircuits.com for comprehensive data sheets, PCB layouts, free high-accuracy simulation models, and everything you need to choose the model for your needs. Order direct from our web store, and have them in your hands as soon as tomorrow!

Now available in small-quantity reels at no extra charge:

Standard counts of 20, 50, 100, 200, 500, 1000 or 3000.

Save time, money, and inventory space!

Wild Card Filter Kits, KWC-LHP, only \$98



- Choose any 8 LFCN or HFCN models
- Receive 5 of each model
- A total of 40 filters for a great value
- Order your KWC-LHP Filter Kit TODAY!

RoHS compliant U.S. Patents 7,760,485 and 6,943,646

Free, High-Accuracy Simulation Models for ADS



www.modelithics.com/mvp/Mini-Circuits.asp





Small Size Synthesizer with Instrument-Grade Performance

National Instruments
Santa Clara, Calif.

With the availability of low-cost integrated phase-locked loop (PLL) ICs, many families of miniature and low-cost frequency synthesizers are available. However, integrated and embedded test systems have always faced challenges in utilizing these new offerings. The conditions that small, portable applications face—especially those within the military and aerospace markets—are not limited to environmental factors such as flightline location, elevated temperature and vibration. The RF setting presents additional challenges because of load impedance uncertainties due to switches, varied lengths of transmission lines and other effects that degrade embedded systems testing and measurement accuracies. Miniature frequency synthesizers typically do not have closed-loop automatic level control (ALC), which mitigates the impact of an uncertain output impedance. While small synthesizers may have partial coverage at RF frequencies, imposing demands such as extended low frequency coverage or calibrated amplitude modulation (AM) makes miniature synthesizers impractical for embedded test

requirements in many instances. Consequently, engineers are forced to either use benchtop synthesizers or develop internal designs, which increases the size, power consumption, cost and development time, and decreases the portability and flexibility of test systems.

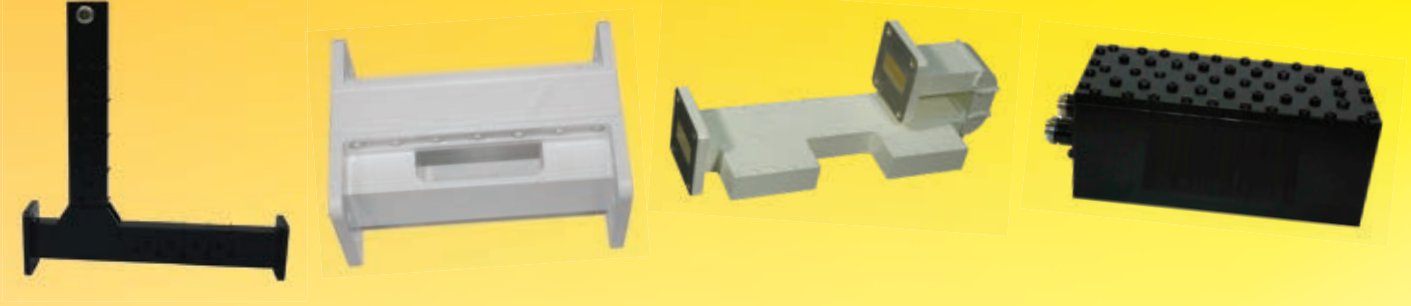
To address these demands, National Instruments is introducing the QuickSyn X, the industry's smallest, fast switching, full-function frequency generator. The QuickSyn X provides closed-loop ALC, extended low frequency coverage, calibrated AM and low power consumption, as well as being compact and low cost—without compromising any key performance metrics such as phase noise and frequency switching speed.

EXPANDED FREQUENCY RANGE

QuickSyn X covers from 250 kHz to 20 GHz and does so without compromising any of its key performance metrics, including harmonic performance. **Figure 1** shows the frequency coverage and output power; the synthesizer provides more than 20 dB output power control across its frequency range.

Your source for RF & Microwave Filters covering 5 Hz to 50 GHz

- RF & Microwave (Discrete Element, Cavity, Waveguide and High Power Filters)
Specializing in OEM Custom Design and Program Development
- Satcom (C, X, Ku, K and Ka band)
- Broadcast (DTV, FM, STL/BAS, MF, HF & VHF)
- Wireless (LTE, GSM, EGSM, PCS, UMTS, BRS-EBS)



COMPONENTS

In Stock, Ready to ship

Low PIM Couplers



Low PIM Power Dividers



Terminations



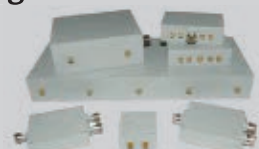
Attenuators



Isolators & Circulators



High Power Combiners



Competitive pricing, Exceptional Quality, Short Lead Times
Contact our experienced staff to discuss your requirements
Committed to Excellence for 50 Years!



MFC

Microwave Filter Company, Inc.

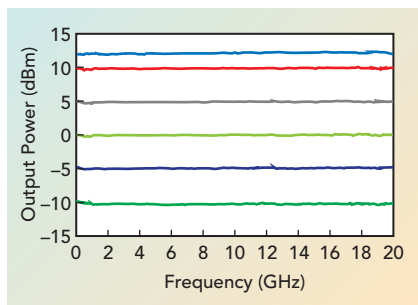
Call (800) 448-1666

Email: mfcsales@microwavefilter.com

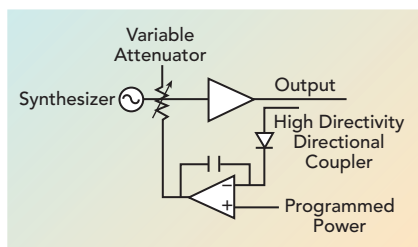
Visit our web site: www.microwavefilter.com

ISO 9001:2008 Certified





▲ Fig. 1 Leveled output power across the QuickSyn X's frequency range from 250 kHz to 20 GHz.

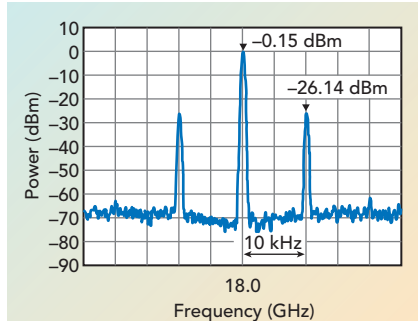


▲ Fig. 2 Simplified block diagram of the QuickSyn X's ALC implementation.

CLOSED-LOOP POWER CONTROL

Closed-loop ALC was one of the most requested features, and the QuickSyn X allows both open-loop and closed-loop ALC. When fast frequency switching is desired, the unit can be placed in an open-loop mode; when more power control accuracy is desired or when the output power must be insensitive to varying load impedance, the closed-loop ALC can be used. **Figure 2** shows a simplified block diagram of the ALC implementation in the QuickSyn X. The forward power is measured at the coupled port of a high-directivity directional coupler using a precision detector. This measurement is compared to the power programmed by the user, and an error signal is applied to a variable attenuator that adjusts the output power to compensate for any difference. Because of the high directivity of the directional coupler, the power delivered to the output is insensitive to load impedance variation.

The closed-loop ALC amplitude control is greater than 10 dB, which is not possible with many small synthesizers. Also, by using an external attenuator module that allows for attenuation adjustment in 10 dB steps, the closed-loop ALC range of the QuickSyn X can be extended to



▲ Fig. 3 Spectrum of an 18 GHz carrier with 10 percent AM.

a broad dynamic range from -100 to +10 dBm.

The synthesizer offers the power accuracy of closed-loop ALC when the carrier is being modulated. This is achieved using the conventional standard instrument protocol of the power search function. Using power search, carriers modulated with AM, pulse modulation or frequency modulation (FM) have the same power accuracy as with closed-loop ALC, without the closed-loop ALC conflicting with the modulation.

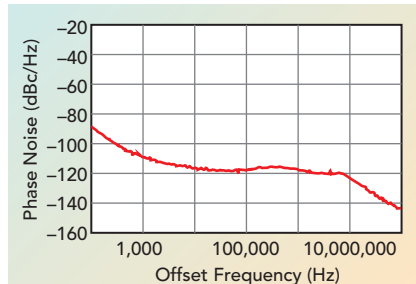
INSTRUMENT-GRADE AM

Instrument-grade or calibrated AM can be critical for many use cases. QuickSyn X offers calibrated AM across its entire frequency range and a large power control range. **Figure 3** shows an 18 GHz carrier with a power level of 0 dBm, modulated with 10 percent AM. A carrier-to-sideband level of -26.14 dB is observed, which reflects an AM index of 9.86 percent and an error from the programmed value of 1.4 percent.

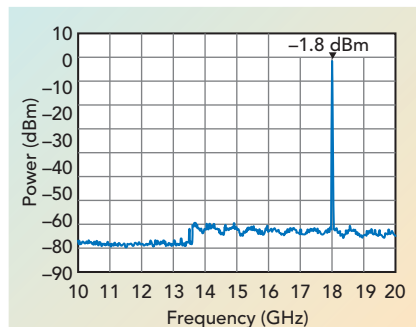
Instrument-grade pulse modulation is one of QuickSyn X's extended features, with a typical on-off ratio of 80 dB across the frequency range. The synthesizer provides multiple modes of FM and phase modulation, and each modulation may be used individually or in combination with any other modulation format. For example, pulse modulation may be combined with FM.

SPECTRAL PURITY, FAST FREQUENCY SWITCHING

QuickSyn X provides both fast frequency switching and low phase noise (see **Figure 4**). The typical phase noise at 10 kHz offset is bet-



▲ Fig. 4 Phase noise of a 20 GHz output signal.



▲ Fig. 5 Spurious-free dynamic range of the QuickSyn X.

ter than -116 dBc/Hz. QuickSyn's phase refining technology, which is based on fundamental VCOs up to 20 GHz, enables phase noise performance that is normally achieved with YIG technology and without the penalty of slow-tuning YIGs. In many cases, QuickSyn synthesizers have better phase noise than YIG-based synthesizers.

Using advanced direct digital synthesis spur-reduction technology, a frequency resolution of 0.001 Hz is achieved without incurring elevated spurs. A wide loop bandwidth makes the unit insensitive to microphonic effects. **Figure 5** shows the spurious-free dynamic range of the QuickSyn X, with the synthesizer generating a CW signal at 18 GHz and the output measured with a spectrum analyzer from 10 to 20 GHz. Spurious emissions are better than -65 dBc. Due to the difficulty measuring spurious levels below this level, the spurious levels of the QuickSyn X are verified during manufacturing test at -60 dBc.

Good harmonic performance is achieved through harmonic filtering. At an output power of +10 dBm, the QuickSyn X's harmonic levels below 100 MHz are roughly -30 dBc; above 100 MHz, harmonic

IMS 2017
04 - 09 Jun., 2017
Booth #1349



1.0mm
series

RF.Microwave Coaxial Connector & Cable Assembly



Joint Design Manufacturing 

Various Test Cables 



Multi Coax 



- **1.0mm Connector**
DC to 110GHz; VSWR≤1.2
- **1.85mm Connector**
DC to 67GHz; VSWR≤1.2
- **2.4mm Connector**
DC to 50GHz; VSWR≤1.2
- **2.92mm Connector**
DC to 40GHz; VSWR≤1.15
- **3.5mm Connector**
DC to 34GHz; VSWR≤1.15



Frontlynk Technologies Inc.

www.frontlynk.com

Tel: +886-6-356-2626

Fax: +886-6-356-6268

E-mail: info@frontlynk.com



MCV
MICROWAVE



LTE Frequency Band	728 - 746 MHz
Insertion Loss	0.3~1.2 dB max (25°C) 0.5~1.5 dB max (Full Temp.)
Return Loss	20 dB min
Rejection@ Rx Band	up to 100 dB min
Power Handling, Sea level at ambient temperature, COM port 50 ohm loaded	50W~200W CW max 400W ~1500W Peak max
LTE Frequency Band	698 - 716 MHz
Insertion Loss	0.3~1.2 dB max (25°C) 0.5~1.5 dB max (Full Temp.)
Return Loss	20 dB min
Rejection@ Tx Band	up to 95 dB min
IMD in RX band, COM port (2 CW tones +43 dBm each)	156 dBc typ., 153 dBc min., 163 dBc available

QUICK-TURN

CUSTOM PROTOTYPE RF/MICROWAVE FILTERS & ANTENNAS

ULTRA-LOW PIM 153dBc or 163dBc
CO-LOCATION BAND MITIGATION
ULTRA-NARROW BAND (~0.03%BW)
ULTRA-WIDE BAND (10GHz BW)

PRODUCTS

LTE Small Cell TMA/Combiner/Multiplexer DAS Solutions
Ultra-Low PIM Duplexers from 450 MHz to 2.7 GHz
Miniature Bandpass, Band Reject, Highpass, Lowpass Filters
Ultra-high Q Dielectric Resonators and Meta Materials
Narrow Band and Broad Band Antennas and Filters

Call for a FREE Engineering Consultation

858.450.0468

mcv-microwave.com

ProductFeature

performance is typically better than -40 dBc.

The synthesizer offers list mode operation, where the power and frequency can be incremented between consecutive measurements in any sequence, achieving extremely fast 200 μ s switching times. The list mode is also available with external trigger control.

The QuickSyn X synthesizer uses a highly stable internal oven-controlled crystal oscillator (OCXO), factory calibrated to a GPS standard to ensure the accuracy of the synthesized signal. The internal oscillator frequency can be adjusted for aging and temperature variation. The unit provides a 10 MHz reference output, and the internal OCXO can be locked to an external reference.

COMMUNICATIONS

The QuickSyn X supports multiple communication modes, including SPI, USB, Ethernet, GPIB and RS232. Like all QuickSyn synthesizers, it can also be controlled via a USB-based virtual-instrument graphical-user interface. The QuickSyn X family is capable of being controlled using the most-used standard commands for programmable instruments (SCPI), since many legacy systems with aging frequency synthesizers are supported by SCPI programming platforms. This compatibility reduces the time and cost of integrating the latest synthesizer technology with SCPI software platforms.

CONCLUSION

The QuickSyn X gives system engineers tremendous versatility and flexibility by providing powerful capabilities in a small, light and power-efficient package, including closed-loop ALC and without compromising excellent phase noise and fast frequency switching. Measuring only 2 in \times 7 in \times 5 in, the QuickSyn X is a highly capable synthesizer on its own or a versatile building block in test and measurement systems for military and commercial applications.



National Instruments
Santa Clara, Calif.

www.ni-microwavecomponents.com



Where can we take you next

Over 100 high performance standard products—and growing.

For more than a decade, we've been focused on providing military and aerospace designers proven GaAs and GaN solutions to their biggest signal chain challenges.

Visit our website and learn about our commitment to quickly getting you wherever you're headed next.

CustomMMIC.com





Multi-Gbps Modem Enables mmWave Fixed Wireless Access

Integrated Device Technology Inc.
San Jose, Calif.

As mobile operators continue to trial various technologies, it seems clear that 5G deployments will begin with fixed broadband wireless access in the millimeter wave (mmWave) band. This is driven by the large amount of spectrum available in both licensed and unlicensed bands, and the maturity of technologies that facilitate mmWave solutions. The combination of advanced wireless signal processing technology and the extensive spectrum available increases the bandwidth capacity of infrastructure networks that will offer the end user an immediate increase in data rate. This increase in capacity benefits operators by generating additional revenue from new business models built around various 5G use cases, such as virtual reality, real-time distributed ultra-high definition gaming and tactile internet for remote surgery.

FIXED BROADBAND ACCESS

Operators today offer fixed wireless access via fiber, DSL, cable, wireless and satellite media, which have data rates between a few and 100s of megabits per second (Mbps), depending on the location and the access technology. For example, xDSL offers data rates in the range of 100s of Mbps. However, the services are geographically challenged and cannot uniformly guarantee the required quality of service or through-

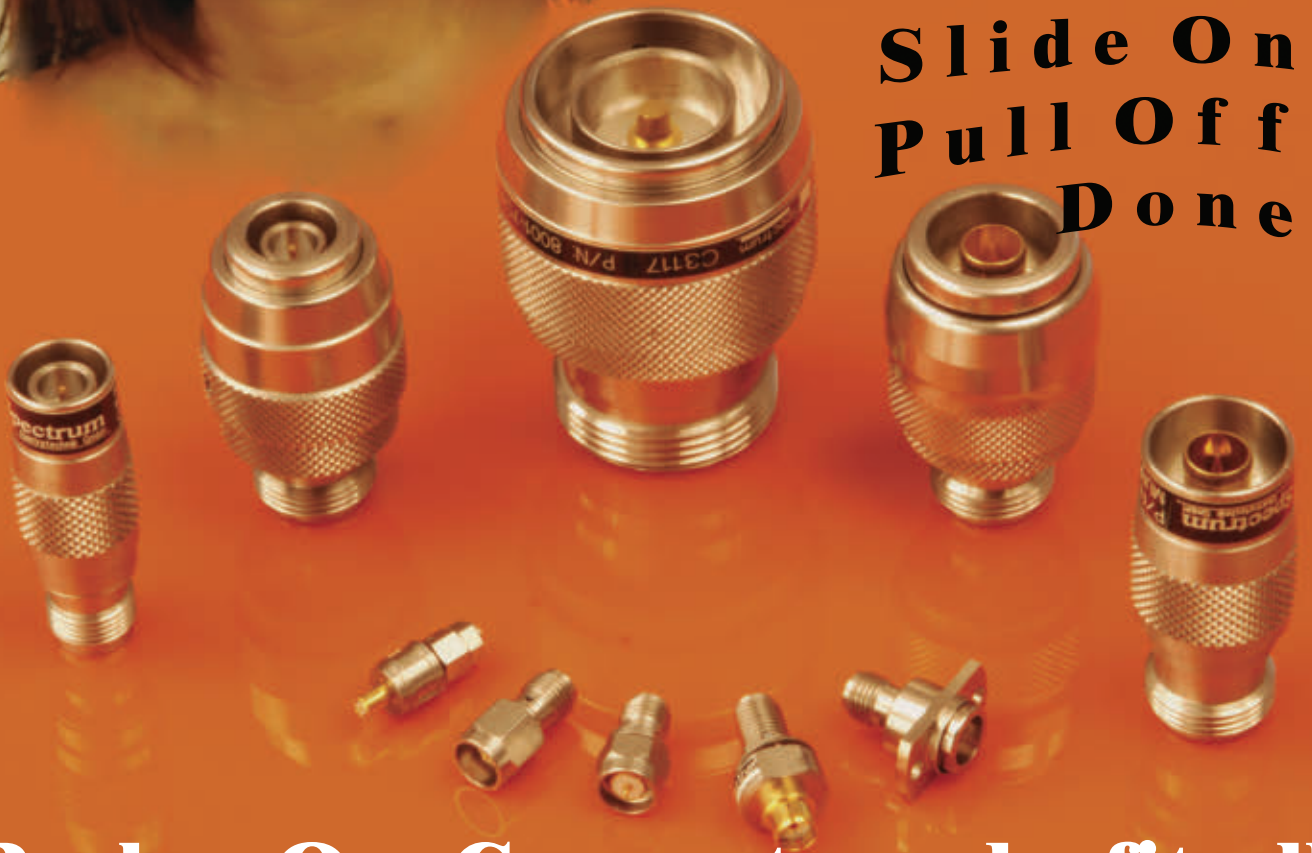
put over distance in both urban and suburban areas. Satellite access technology, on the other hand, has the potential to cover remote areas and is able to reach 100s of Mbps, based on the DVB-S2x specification. However, due to the inherent delay in geostationary earth orbit (GEO) satellite networks, this type of fixed access service will always have limitations. Among all the available technologies, an end-to-end fiber network offers multi-gigabit fixed access to the user today. A fiber network's biggest hurdle is delivery of that fiber access to the end user. In communities where fiber is nonexistent, it can be time-consuming and costly to deploy, resulting in operators experiencing long delays in realizing a return on their investments. In most cases, the fiber is never seen at the end user's location; the fiber based link is terminated at a central hub, and the "last mile" access is provided by either xDSL or wireless.

During the last several years, wireless technologies and spectrum allocation have seen radical changes. In particular, the availability of mmWave spectrum from 26 to 90 GHz has opened significant opportunity to deliver multi-gigabit wireless access to the user. For example, in July 2016, the FCC opened up around 3.85 GHz of licensed spectrum between 27.5 and 40 GHz (i.e., 27.5 to 28.35, 37 to 38.6 and 38.6 to 40 GHz). The FCC also added 7 GHz of

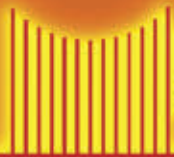


**Are you still Threading?
Torquing? Untorquing?
Unthreading?**

**Never ever heard of
P u s h - O n s ?
S l i d e O n !
P u l l O f f !
D o n e !**



**Push - On Connectors do fit all
standard SMA, N, TNC, 7/16**



Spectrum
Elektrotechnik GmbH

when Quality is needed

80905 Munich, Germany

Telephone: +49-89-3548-040

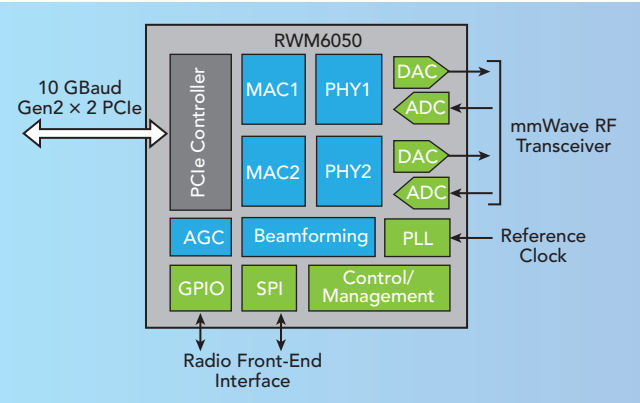
WWW.SPECTRUM-ET.COM

P.O. Box 450533

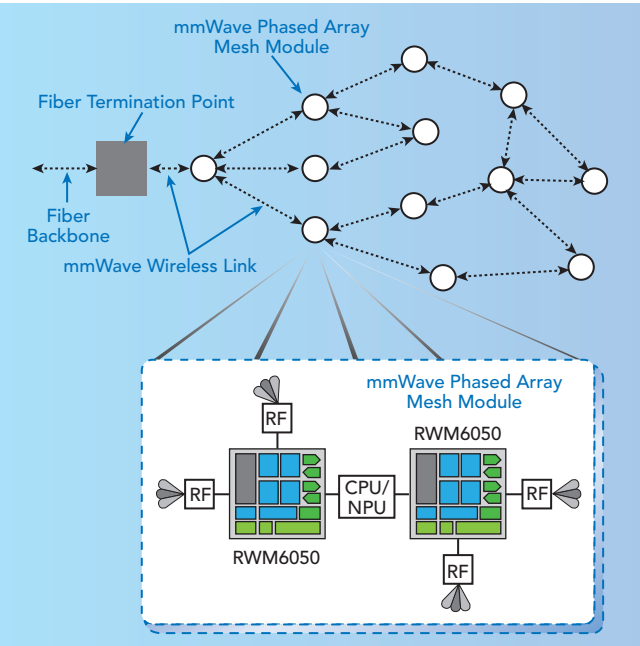
Facsimile: +49-89-3548-0490

Email: sales@spectrum-et.com

TABLE 1					
27.85 of U.S. SPECTRUM ALLOCATED by FCC					
	Ka-Band		V-Band	E-Band	
Designated Band (GHz)	27.5 to 28.35	37 to 40	57 to 71	71 to 76	81 to 86
Spectrum (GHz)	0.85	3	14	5	5



▲ Fig. 1 IDT mmWave modem block diagram.



▲ Fig. 2 Mesh network example for fixed wireless broadband access.

spectrum in the unlicensed V-Band (64 to 71 GHz) to the existing unlicensed V-Band spectrum (57 to 66 GHz). Ten GHz of spectrum is available in the lightly licensed E-Band (71 to 76 and 81 to 86 GHz). In total, this provides nearly 28 GHz for radio access technologies (see **Table 1**).

The access to spectrum is an important first step to enable wireless technology as a solution for fixed access networks. The second “wave”

or step is the significant technology advancement in antenna design and wireless communications protocols, based on beamforming and phased arrays for mmWave channels. Lastly, fueled by an industry-driven ecosystem and standardization bodies such as Wi-Fi Certified WiGig, IEEE 802.11, ETSI ISG mWT and 3GPP, there have been considerable improvements in signal processing techniques that have created opportunities for commercially feasible mmWave solutions.

mmWAVE MODEM

IDT recently introduced mmWave-based wireless modem technology to address the emerging fixed broadband wireless market (see **Figure 1**). The solution closes the last mile gap for 5G and offers a true multi-gigabit wireless fiber experience for the end user. The modem technology offers a range of innovative features such as beamforming, channelization and flexible medium access control schemes. With these features, operators and network equipment manufacturers can take advantage of the large wireless spectrum available in the mmWave band and offer real-

time 5G services in an interference limited environment, expected in the unlicensed band. The solution is equally applicable to the licensed mmWave bands (e.g., Ka-Band) and can enable multi-gigabit solutions based on higher order modulation and strong forward error correction (FEC) schemes such 64-QAM and low-density parity-check (LDPC) encoding, respectively.

Operators benefit from a simplified deployment model enabled by a range of network topologies offered by the solution. For example, the dual modem architecture with support for time-division duplex (TDD) and frequency-division duplex (FDD) allows operators to deploy fully redundant wireless fixed broadband access for home and enterprise users in both mesh and hub-spoke architectures. With support for beamforming with phased-array antennas, operators can design a scalable sectorized cell architecture of varying sizes, as the number of users grow over time. **Figure 2** illustrates an example topology of a multi-gigabit fixed wireless broadband access mesh network based on the mmWave solution.

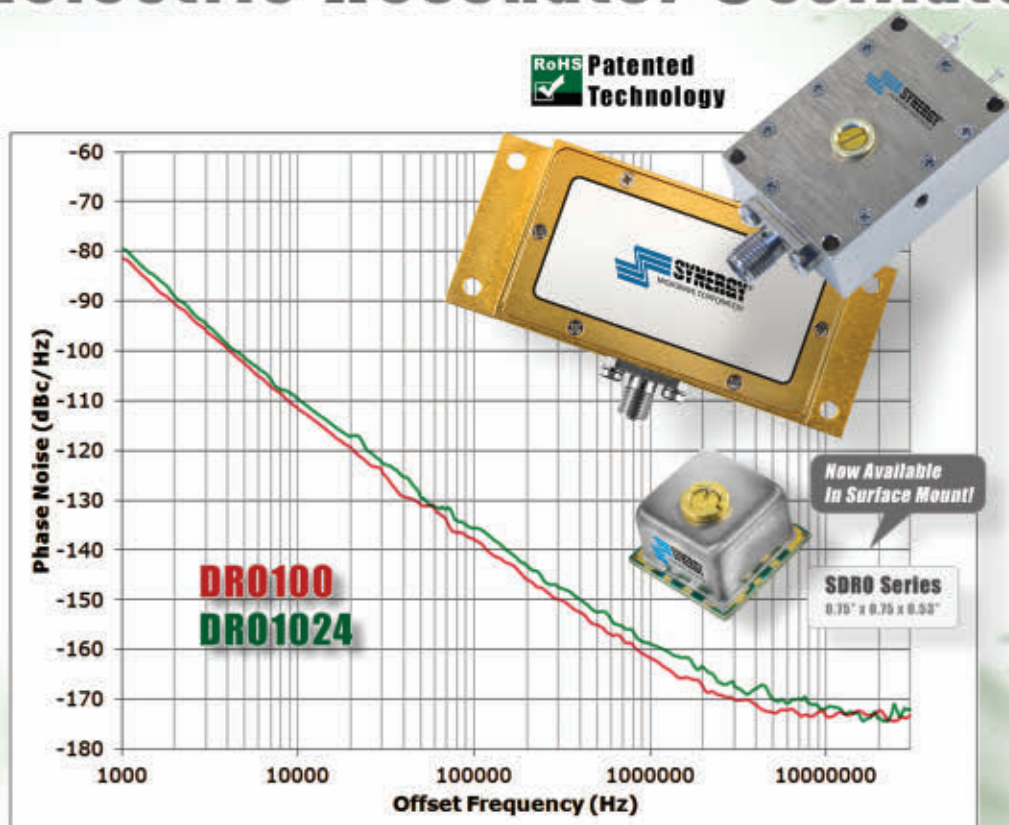
Deploying multi-gigabit speeds to the last mile needs to be practical and profitable. The greatest advantage both operators and network equipment manufacturers will experience is the speed and low cost to deploy a RapidWave-based module. A chipset including the RapidWave modem paired with a mmWave phased-array front-end provides critical functionality, including digital beam alignment and sub-channelization, that accelerates the deployment and simplifies frequency planning, even in densely distributed networks.

Nearly 28 GHz of new mmWave spectrum, algorithm and antenna technology advancements and standardization have enabled new innovations, such as the RapidWave modem, that will fuel the 5G vision of multi-gigabit fixed broadband wireless access.

Integrated Device Technology Inc.
San Jose, Calif.
www.idt.com

Exceptional Phase Noise Performance Dielectric Resonator Oscillator

RoHS Patented
Technology

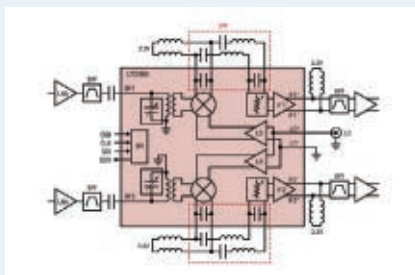


Model	Frequency (GHz)	Tuning Voltage (VDC)	DC Bias (VDC)	Typical Phase Noise @ 10 kHz (dBc/Hz)
Surface Mount Models				
SDRO1000-8	10	1 - 15	+8 @ 25 mA	-107
SDRO1024-8	10.24	1 - 15	+8 @ 25 mA	-111
SDRO1250-8	12.50	1 - 15	+8 @ 25 mA	-105
Connectorized Models				
DRO100	10	1 - 15	+7 - 10 @ 70 mA	-111
DRO1024	10.24	1 - 15	+7 - 10 @ 70 mA	-109

Talk To Us About Your Custom Requirements.



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



Linear Technology's LTC5566 is a wideband, high dynamic range, dual-channel mixer with programmable variable gain IF amplifiers. The LTC5566's input frequency range covers 300 MHz to 6 GHz, optimized and characterized at the 4G and emerging 5G bands (i.e., 3.6 and 4.5 GHz). To meet 5G sub-6 GHz requirements, the signal chain bandwidth is 400 MHz.

The LTC5566 is built on an active, double balanced mixer core with no conversion loss and excellent port-to-port isolation, which reduces external RF filtering requirements. Each mixer input contains an integrated wideband balun transformer, enabling a simple single-ended interface. Using the SPI or parallel

pins, the mixers' inputs can be digitally tuned for optimum return loss over several wide, overlapping frequency bands, ranging from 1.3 to 5.3 GHz.

The mixer has high dynamic range, with an input 1 dB compression point of +11.5 dBm and an input IP3 of +25.5 dBm at 3.6 GHz. Up to 5.8 GHz, the input IP3 remains greater than +24 dBm. The device's integrated IF amplifier provides a maximum conversion gain of 12 dB, and each channel's gain can be independently programmed from -3.5 to 12 dB in 0.5 dB steps using the on-chip SPI bus. The LTC5566 has 50 dB channel-to-channel isolation up to 3.6 GHz and 40 dB at 4.5 GHz. Both channels exhibit very

low phase shift over the full 15.5 dB attenuation range, a critical parameter for MIMO receivers.

The LTC5566 operates from a single 3.3 V supply, drawing a nominal 384 mA with both channels on. A low power mode is available, reducing the supply current to 294 mA with a slight decrease in IP3 performance.

The mixer is rated for -40°C to +105°C case temperature operation and is offered in a 5 mm x 5 mm 32-lead plastic QFN package.

VENDORVIEW

Linear Technology Corp., now part of Analog Devices, Inc.
Milpitas, Calif.
www.linear.com

It's finally here...

The Signal Integrity Journal

Covering SI, PI, EMC/EMI



**From the
Publishers of
Microwave Journal**

www.signalintegrityjournal.com

RF-LAMBDA

THE LEADER OF RF BROADBAND SOLUTIONS

ITAR & ISO9000
Registered Manufacture



PIN DIODE, GaAs AND GaN CONTROL PRODUCTS

SWITCH IN PIN DIODE, GaAs AND GaN TECHNOLOGY UP TO 67GHz



PN: RFSP4TA5M43G
FULL BAND 0.05-43.5GHz SP4T
SWITCH 50NS SPEED



PN: RFSP2TRDC18G
HIGH POWER 10W DC-18GHz HOT
SWITCHABLE SP2T SWITCH



PN: RFSP2TR5M06G
HIGH POWER 100W DC-6GHz HOT
SWITCHABLE SP2T SWITCH



PN: RFSP8TA0018G
HIGH IP3 500DBM 0.02-18GHz
SP8T PIN DIODE SWITCH



PN: RFPST1826N6
DIGITAL CONTROL PHASE SHIFTER 360
DEGREE 64 STEP 18-26GHz

DIGITAL AND VOLTAGE CONTROL PHASE SHIFTER UP TO 40GHz



PN: RFPST0618N6
DIGITAL CONTROL PHASE SHIFTER
360 DEGREE 64 STEP 6-18GHz



PN: RVPT0818GBC
VOLTAGE CONTROL PHASE
SHIFTER 360 DEGREE 8-18GHz



PN: RVPT0408GBC
VOLTAGE CONTROL PHASE
SHIFTER 360 DEGREE 4-8GHz

DIGITAL AND VOLTAGE CONTROL ATTENUATOR UP TO 50GHz



PN: RFDAT0040G5A
DIGITAL STEP ATTENUATOR
0.1-40GHz 5 BITS 31dB



PN: RFVAT0218A30
VOLTAGE CONTROL ATTENUATOR
2-18GHz 30dB IP3 500DBM



PN: RFVAT0050A17V
VOLTAGE CONTROL ATTENUATOR
0.01-50GHz 17dB



PN: RFDAT0018G8A
DIGITAL STEP ATTENUATOR 0.1-18GHz
8 BITS 128dB IP3 500DBM

www.rflambda.com
sales@rflambda.com

1-888-976-8880
1-972-767-5998

Plano, TX, US
San Diego, CA, US
Ottawa, ONT, Canada





Ultra-Low PIM Cavity Filters

MCV Microwave has developed a line of ultra-low passive inter-modulation (PIM) cavity filters and multiplexers covering frequency bands from 250 MHz to 6 GHz. The typical PIM performance in production is -163 dBc measured with two CW tones, each at 43 dBm. An even lower PIM filter with a maximum of -168 dBc is available, if requested. The filter line has low passband insertion loss, high-power handling and, for multiplexers, high isolation between bands.

These high-power, low PIM filters are suitable for use in small cells, tower-mounted amplifiers, combiners, multiplexers, DAS systems and PIM test benches. To il-

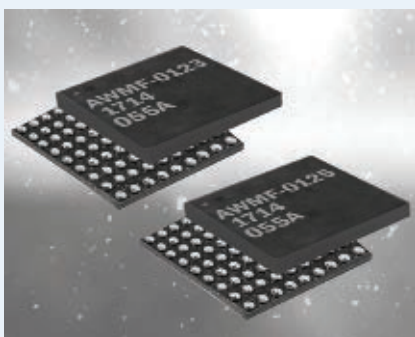
lustrate the typical performance, MCV Microwave's 700 MHz high band duplexer design covers the 728 to 757 MHz transmit and 776 to 787 MHz receive bands. Insertion loss is 1.2 dB maximum at room temperature and less than 1.5 dB over the operating temperature range of -40°C to +85°C. Return loss is better than 20 dB. Transmit signal rejection in the receive band is 100 dB minimum, and receive signal rejection in the transmit band is 95 dB minimum. Two-tone IMD performance is -168 dBc maximum and -163 dBc typical. Maximum power handling is 200 W CW and 1500 W peak. This duplexer measures 282 mm x 190 mm x 55 mm.

Low PIM series PBCC cavity filters, PBCCD dielectric resonator loaded cavity filters, PRCC notch filters, PMCC combiners and multiplexers can be ordered in standard and miniature sizes, and custom requirements are welcome. MCV Microwave designs and manufactures their products with precision and practicality, employing a robust design approach with high yields to guarantee competitive pricing and on-time delivery. MCV is vertically integrated, with proprietary, in-house ultra-high Q dielectric resonators and 3D electromagnetic modeling.

VENDORVIEW

MCV Microwave
San Diego, Calif.

www.mcv-microwave.com



39 GHz Tx/Rx ICs for 5G Phased Arrays

Expanding its family of Ka-Band beamforming ICs for 5G, Anokiwave has introduced 39 GHz transmit (Tx) and receive (Rx) ICs that complement their 28 GHz offering. Operating from 37.1 to 40 GHz, the AWMF-0123 and AWMF-0125 "quad core chips" support four radiating elements, with 5-bit phase and 5-bit gain beam steering at each antenna element. The AWMF-0123/5 ICs offer adjustable Tx output power, with a 1 dB compression point of +12 dBm and a 5.0 dB Rx noise figure. The ICs are assembled in a 3.7 mm x 3.7 mm wafer level chip scale pack-

ages (WLCSP) for low inductance, flip chip integration in a 39 GHz planar phased array. The devices have ESD protection on all pins and are biased with +1.8 V.

The focus of 5G millimeter wave development is currently at 28 and 39 GHz, two bands garnering the most investment by operators and network equipment manufacturers. Working with Ball Aerospace, Anokiwave recently announced the availability of a 64 element, 28 GHz active electronically scanned array using their Tx and Rx beam steering ICs. The AWMF-0129 is the first commercially available array, developed to

aid operators and equipment manufacturers quickly prototype and evaluate the 28 GHz spectrum for 5G use. The AWMF-0129 achieves 50 dBm EIRP and offers users real-time active beam steering, timing control and choice of waveforms.

Anokiwave has been developing silicon ICs for microwave and millimeter wave systems since 1999. Their products are used in radar, satellite communications and wireless infrastructure.

VENDORVIEW

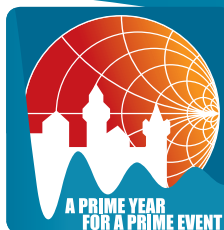
Anokiwave
San Diego, Calif.
www.anokiwave.com

SIX DAYS

THREE CONFERENCES

ONE EXHIBITION

EUROPEAN MICROWAVE WEEK 2017
NÜRNBERG CONVENTION CENTER,
NUREMBERG, GERMANY
8TH - 13TH OCTOBER 2017



**EUROPEAN
MICROWAVE WEEK**
NÜRNBERG CONVENTION CENTER
NUREMBERG, GERMANY
8TH-13TH OCTOBER 2017
www.eumweek.com

EUROPEAN MICROWAVE WEEK 2017 REGISTRATION INFORMATION

EUROPE'S PREMIER MICROWAVE, RF, WIRELESS AND RADAR EVENT



REGISTER ONLINE AT:
www.eumweek.com

EuMA
European Microwave Association

Organised by:
**horizon
house**

Official Publication:
**Microwave
Journal**

Co-sponsored by:
IEEE

Co-sponsored by:
MTT-S

Supported by:
IET The Institution of
Engineering and Technology

Supported by:
**VDE
ITG**

**EuMIC
2017**
The 12th European Microwave
Integrated Circuits Conference
Co-sponsored by:



47TH EUROPEAN MICROWAVE CONFERENCE 2017
The 47th European Microwave Conference
Co-sponsored by:



**EURAD
2017**
The 14th European Radar Conference
Co-sponsored by:





EUROPEAN MICROWAVE WEEK 2017

THE ONLY EUROPEAN EVENT DEDICATED TO THE MICROWAVE AND RF INDUSTRY

The EuMW 2017 team are excited to return to Nuremberg, a uniquely fascinating European city, full of medieval charm. Bringing industry and academia together, European Microwave Week 2017 is a SIX day event, including THREE cutting edge conferences and ONE exciting trade and technology exhibition featuring leading players from across the globe. Concentrating on the needs of engineers, the event showcases the latest trends and developments that are widening the field of applied microwaves. It also offers you the opportunity for face-to-face interaction with those driving the future of microwave technology.

EuMW 2017 will see an estimated 1,700 - 2,000 conference delegates, over 4,000 visitors and in excess of 300 international exhibitors (inc. Asia & US).

REGISTRATION TO THE EXHIBITION IS FREE!

Pivotal to the week is the European Microwave Exhibition, which offers YOU the opportunity to see, first hand, the latest technological developments from global leaders in microwave technology.

The exhibition will provide an unrivalled opportunity for visitors to view and ask questions related to the latest products, components and materials from our extensive selection of international exhibitors. It will also feature exhibitor demonstrations, Industrial Workshops and the annual European Microwave Week Microwave Application Seminars (MicroApps).

- **International Companies** - meet the industry's biggest names and network on a global scale
- **Cutting-edge Technology** - exhibitors showcase the latest product innovations, offer hands-on demonstrations and provide the opportunity to talk technical with the experts
- **Technical Workshops** - get first hand technical advice and guidance from some of the industry's leading innovators

BE THERE

Exhibition Dates

Tuesday 10th October

Wednesday 11th October

Thursday 12th October

Opening Times

09:30 - 18:00

09:30 - 17:30

09:30 - 16:30

FAST TRACK BADGE RETRIEVAL

Entrance to the Exhibition is **FREE** and attending couldn't be easier.

VISITORS

Registering for the Exhibition

- Register as an Exhibition Visitor online at www.eumweek.com
- Receive a confirmation email with barcode
- Bring your barcode with you to the Exhibition
- Go to the Fast Track Check In Desk and print out your visitor badge
- Alternatively, you can register onsite at the self service terminals during the Exhibition

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



EUROPEAN MICROWAVE WEEK 2017 THE CONFERENCES

Don't miss Europe's premier microwave conference event. The 2017 week consists of three conferences and associated workshops:

- European Microwave Integrated Circuits Conference (EuMIC) 9th - 10th October 2017
- European Microwave Conference (EuMC) 10th - 12th October 2017
- European Radar Conference (EuRAD) 11th - 13th October 2017
- Plus Workshops and Short Courses (From 8th October 2017)
- In addition, EuMW 2017 will include for the 8th year, the Defence, Security and Space Forum on 11th October 2017

The three conferences specifically target ground breaking innovation in microwave research through a call for papers explicitly inviting the submission of presentations on the latest trends in the field, driven by industry roadmaps. The result is three superb conferences created from the very best papers. For a detailed description of the conferences, workshops and short courses please visit www.eumweek.com. The full conference programme can be downloaded from there.

FAST TRACK BADGE RETRIEVAL

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

CONFERENCE PRICES

There are TWO different rates available for the EuMW conferences:

- **ADVANCE DISCOUNTED RATE** – for all registrations up to and including 8th September
- **STANDARD RATE** – for all registrations made after 8th September

Please see the Conference Registration Rates table on the back page for complete pricing information.

All payments must be in € Euro – cards will be debited in € Euro.

Online registration is open now, up to and during the event until 13th October 2017

DELEGATES

Registering for the Conference

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

- | | |
|--|---|
| - Saturday 7th October (16:00 - 19:00) | - Sunday 8th October (07:30 - 17:00) |
| - Monday 9th October (07:30 - 17:00) | - Tuesday 10th October (07:30 - 17:00) |
| - Wednesday 11th October (07:30 - 17:00) | - Thursday 12th October (07:30 - 17:00) |
| - Friday 13th October (07:30 - 10:00) | |

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

CONFERENCE REGISTRATION INFORMATION

EUROPEAN MICROWAVE WEEK 2017, 8th - 13th October, Nuremberg, Germany

Register Online at www.eumweek.com

ONLINE registration is open from 1st June 2017 up to and during the event until 13th October 2017.

ONSITE registration is open from 16:00 on 7th October 2017.

ADVANCE DISCOUNTED RATE (up to and including 8th September) STANDARD RATE (from 9th September & Onsite).

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

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

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

Reduced Rates for the conferences are also offered if you are a Student/Senior (Full-time students 30 years or younger and Seniors 65 or older as of 13th October 2017).

The fees shown below are invoiced in the name and on behalf of the European Microwave Association. EuMA's supplies of attendance fees in respect of the European Microwave Week 2017 are exempted from German VAT under Article 4 no. 22a German VAT Act.

ADVANCE REGISTRATION CONFERENCE FEES (UP TO AND INCLUDING 8TH SEPT.)

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

STANDARD REGISTRATION CONFERENCE FEES (FROM 9TH SEPT. AND ONSITE)

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

WORKSHOP AND SHORT COURSE FEES (ONE STANDARD RATE THROUGHOUT)

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

Other Items

STATE RECEPTION – 11TH OCT 2017

Tickets for the State Reception are free, but are limited. They are available for delegates on a first-come, first-served basis.

Proceedings on USB Stick

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

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

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

Partner Programme and Social Events

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

EUROPEAN MICROWAVE WEEK WORKSHOPS & SHORT COURSES

SUNDAY 8th October		
Half Day	SS-01	EuMC
Full Day	WS-01	EuMC
Full Day	WS-02	EuMC/EuMIC
Full Day	WS-03	EuMC
Full Day	WS-04	EuMC
Full Day	WS-05	EuMC/EuMIC
Full Day	WS-06	EuMC/EuMIC
Full Day	WS-07	EuMC
Full Day	WS-08	EuMC/EuMIC
Full Day	WS-09	EuMC/EuMIC
Full Day	WS-10	EuMC
Full Day	WS-11	EuMC
Half Day	WS-12	EuMC
Full Day	WS-13	EuMC
Half Day	WS-14	EuMC
Half Day	WS-15	EuMC

MONDAY 9th October		
Full Day	WM-01	EuMC
Full Day	WM-02	EuMC
Full Day	WM-03	EuMC
Half Day	WM-04	EuMC
Half Day	WM-05	EuMC
Half Day	WM-06	EuMC
Half Day	WM-07	EuMC
Full Day	WM-08	EuMC

TUESDAY 10th October		
Full Day	WTu-01	EuMC/EuMIC

WEDNESDAY 11th October		
Half Day	SW-01	EuMC/EuRAD
Half Day	WW-01	EuMC
Half Day	WW-02	EuMIC/EuRAD
Half Day	WW-03	EuMC/EuMIC

THURSDAY 12th October		
Half Day	WTh-01	EuMC/EuRAD
Full Day	WTh-02	EuRAD
Full Day	WTh-03	EuMC/EuMIC

FRIDAY 13th October		
Full Day	SF-01	EuRAD
Half Day	SF-02	EuMC/EuRAD
Half Day	SF-03	EuRAD
Full Day	WF-01	EuRAD
Half Day	WF-02	EuMC
Half Day	WF-03	EuMC/EuRAD
Half Day	WF-04	EuRAD
Full Day	WF-05	EuMC
Full Day	WF-06	EuMC/EuRAD
Half Day	WF-07	EuMC/EuRAD
Half Day	WF-08	EuMC/EuRAD

SPECIAL FORUMS & SESSIONS

Date	Time	Title	Location	No. of Days	Fee	
Wednesday 11th October	08:30 - 18:30	Defence, Security & Space Forum	St. Petersburg	1	€ 20 for delegates (those registered for EuMC, EuMIC or EuRAD)	€ 60 for all others (those not registered for a conference)
Monday 9th - Wednesday 11th October	08:30 - 17:50	European Microwave Student School	Neu Delhi	3	€ 40	
Monday 9th - Wednesday 11th October	08:30 - 17:50	European Microwave Doctoral School	Singapur	3	€ 80	

SIX DAYS

THREE CONFERENCES

ONE EXHIBITION

EUROPEAN MICROWAVE WEEK 2017
NÜRNBERG CONVENTION CENTER,
NUREMBERG, GERMANY
8TH - 13TH OCTOBER 2017



**EUROPEAN
MICROWAVE WEEK**
NÜRNBERG CONVENTION CENTER
NUREMBERG, GERMANY
8TH-13TH OCTOBER 2017
www.eumweek.com

EUROPE'S PREMIER MICROWAVE, RF, WIRELESS AND RADAR EVENT

THE EUROPEAN MICROWAVE EXHIBITION (10TH - 12TH OCTOBER 2017)

- 8,000 sqm of gross exhibition space
 - 4,000 Attendees
- 1,700 - 2,000 Conference delegates
- In excess of 300 international exhibitors
(including Asia-Pacific, the US, and Europe)

EuMA
European Microwave Association

Organised by:
**horizon
house**

Official Publication:
**Microwave
Journal**

Co-sponsored by:
IEEE

Co-sponsored by:
MTT-S

Supported by:
IET
The Institution of
Engineering and Technology

Supported by:
**VDE
ITG**

**EuMIC
2017**
The 12th European Microwave
Integrated Circuits Conference
Co-sponsored by:
**ELECTRON
DEVICES
SOCIETY**

**47TH EUROPEAN
MICROWAVE CONFERENCE 2017**
The 47th European Microwave Conference
Co-sponsored by:
EurAAP

**EURAD
2017**
The 14th European Radar Conference
Co-sponsored by:
EurAAP **IEEE**

INTERESTED IN EXHIBITING?

For International Sales:

Richard Vaughan, International Sales Manager
E: rvaughan@horizonhouse.co.uk
Tel: +44 20 7596 8742

For US Sales:

Alyssa Connell, Event Coordinator
E: aconnell@mwjournal.com
Tel: +1 781 619 1930

OR VISIT: www.eumweek.com

Web and Video Update

New Website Look

Ciao Wireless is proud to announce a new website look that is modern, informative and responsive. The latest web update features a new look, mobile device support and improved navigation throughout the website. You can easily browse through the company's various applications to find a solution for your project. The website also features an option to download catalog sections or the company's entire catalog.

Ciao Wireless Inc.

www.ciaowireless.com



Introducing MyCST

VENDORVIEW

With the introduction of MyCST, users will be able to customize their experience of the CST website. CST STUDIO SUITE® is used across a wide range of industries and markets, and CST provides webinars, workshops and articles for all of them. Users can now select what kinds of CST events they want to be notified about, manage their event registrations, view past webinars and save interesting CST articles for future reference. Try it out for yourself today on the CST Website.

Computer Simulation Technology

www.cst.com



New and Improved

K&L Microwave's website provides information and tools to speed the identification and specification of custom design solutions from the full range of company products. The latest update features mobile device support and introduction of the AB series of printed band-pass filters on the Filter Wizard® design tool. K&L is part of the Microwave Products Group, a premier global supplier of mission/system-critical engineered electronic components and subsystems. Research capabilities, access data sheets, submit quote requests and download catalog sections.

K&L Microwave

www.klmicrowave.com



New Website Details

Norden Millimeter released their updated website detailing "Who We Are and What We Do". Norden designs and manufactures products 500 MHz to 110 GHz including amplifiers, frequency multipliers, frequency converters, transceivers, switched filters and custom integrated assemblies. Product application areas cover military, commercial, scientific, microwave test equipment, ultra-secure communication systems, ELINT, RADAR and airborne. The website provides information on Norden's "State of The Art Microwave and Millimeter Wave Products" and related test data.

Norden Millimeter

www.nordengroup.com



New Product Finder

VENDORVIEW

SPINNER has released a new online product catalog with a dedicated web address: products.spinner-catalog.com. It clearly presents each product with the relevant data, a description, images, drawings and downloads. A search function with a suggestion list leads straight to the information on any desired product. Products can be easily added to a comprehensive comparison list. The content automatically adjusts to the screen resolution of the user's device.

SPINNER GmbH

www.products.spinner-group.com



New Video

For quick and easy microwave path alignment, see Sunsight Instruments' revolutionary end to end patent-pending Path Alignment Kit. Huge labor and project time savings, you save a lot of time on tower, reduce climber fatigue and do more links per day than you can using traditional methods—which all need to find signal first. The company aligns path in minutes using extremely accurate GPS position data—no signal, power or frequency needed, can do with or without ODU/radio installed.

Sunsight Instruments

www.sunsight.com/index.php/microwave-path-alignment



Join the High-Frequency, High-Speed Revolution!

EDICON is coming! EDICON is coming!

ED CON 2017

Electronic Design **Innovation** Conference & Exhibition

September 11-13, 2017

HYNES CONVENTION CENTER • BOSTON, MA

Where RF, microwave, EMC/EMI, signal integrity, and power integrity engineers meet for networking, product demonstrations, training and learning.

Featuring:

- Exhibition of Industry-Leading Vendors
- High-Speed Demonstration Zone
- Speed Training in Frequency Matters Theater
- In-Depth Short Courses
- Hands-On Workshops
- Peer-Reviewed Technical Sessions
- Panels on Latest Technologies
- Keynotes and Plenary Session
- Outstanding Paper Awards
- Luxury Coach Busing from Boston Area
- Family Fun Program

Organized by

Official Publications



@ediconusa

#ediconusa

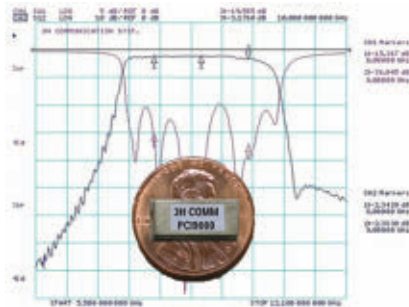
REGISTER NOW
www.EDICONUSA.com

NEW PRODUCTS

FOR MORE NEW PRODUCTS, VISIT WWW.MWJOURNAL.COM/BUYERSGUIDE
FEATURING **VENDORVIEW** STOREFRONTS

COMPONENTS

Pico Series Bandpass Filter



3H's new X-Band, miniature, leadless, SMT, Pico filter offers low passband insertion loss of < 3.5 dB with a VSWR 2.0:1. The filter size is 0.43 in x 0.28 in x 0.15 in. The filter is manufactured for automated assembly processes and is designed to meet Mil-Std-202 conditions.

3H Communication Systems
www.3hcommunicationsystems.com

Broadband Absorptive PIN Diode Switch

Ampical's SW12A003 SP12T 2 to 18 GHz broadband absorptive PIN diode switch features low insertion loss, low VSWR, high isolation and fast switching speed. Input ports



are terminated in 50 Ω when switched in the isolation (off) state. All RF ports incorporate DC blocks. An on-board TTL-compatible driver

provides convenient logic control. Additional frequency ranges, configurations and features are available upon request. Hermetic seal, MIL and hi-rel screening are available on request.

Ampical
www.ampical.com

RF Switches



Dow-Key Microwave is a leading manufacturer of RF switches offering an extensive line of SPDT and DPDT (Transfer) switches for a wide

range of RF and microwave applications. Designed with one to five million life cycles, the break-before-make coaxial switches operate from DC to 40 GHz, offer latching or fail-safe actuators while including a variety of control options. Standard coil voltages of 12, 24 and 28 V are available and may also be designed to include RoHS compliance.

Dow-Key Microwave Corp.
www.dowkey.com

SPDT 40 GHz Switch - DK1 Series



The DK1 series features K connectors and a frequency range of DC to 40 GHz. This series is available with fail-safe, latching self-cut-off or pulse latching functions. At frequency between 32 to 40 GHz, it is rated to perform at: VSWR at 2:1, ILO at 1.0 dB, ISO at 50 dB and switching time of 15 ms max at extreme temperatures of -35°C to +85°C. This SPDT is designed in accordance to MIL-DTL-3928 (Testing and Operation Modes).

Ducommun
www.ducommun.com

Coaxial Voltage Variable Attenuators



Fairview Microwave Inc., a supplier of on-demand microwave and RF components, has introduced a new line of voltage variable attenuators (VVA) that offer up to 60 dB of attenuation across a broad range of frequencies from 400 MHz to 18 GHz. These voltage variable attenuators are frequently used in applications such as electronic warfare, instrumentation, point-to-point and point-to-multipoint radios, fiber optic and broadband telecom, microwave radio and VSAT, military radios, radar, ECM, SATCOM and sensors and R&D.

Fairview Microwave Inc.
www.fairviewmicrowave.com

High Power Limiters



High power limiters feature 200 W CW, 10 to 500 MHz, frequency range down to very low

frequency (10 MHz), low insertion loss and VSWR, 200 W CW and 1000 W peak, (1 microsec pulse width) power handling capability, built-in DC block at input and output and a hermetically sealed module.

Herotek
www.herotek.com

SPDT Reflective RF Switches



IDT has introduced a new family of high performance single-pole, double throw reflective RF switches in compact 2 mm x 2 mm packages. The F2972 and F2976 operate from 5 MHz to 10 GHz,

offering an industry-leading mix of low-insertion loss, high isolation, low distortion and

high-power handling. Specified for use in either 50 or 75 ohm systems, the switches offer versatility for a wide range of applications, including BTS wireless communications equipment, DOCSIS 3.1 CATV applications, drones and general purpose consumer products.

Integrated Device Technology
www.idt.com

Low PIM Termination Brackets



MECA offers mounting brackets for their full line of Low PIM Terminations. From 10 through 250 W models in all

connector styles/configurations, designed for in-building, tower top or desktop configurations. Available in various weatherproof IP 67 standard, IP68 available. Made in the U.S. with a 36 month warranty.

MECA Electronics Inc.
www.e-MECA.com

Wideband Double Balanced MMIC Mixer Die, Level 15, 5 to 21.5 GHz



Mini-Circuits' MDB-24H-D+ is a wideband, double-balanced, level 15 MMIC Mixer die with an IF bandwidth from DC to 5 GHz and LO/RF bandwidth from 5 to 21.5 GHz, supporting a wide range of applications

including satellite up and down converters, defense radar, VSAT and more. This model provides low conversion loss (6.9 to 10.3 dB), 44 dB L-I isolation, 28 dB L-R isolation and good input/output return loss over its full frequency range without the need for external matching components.

Mini-Circuits
www.minicircuits.com

Ultra-Wideband, Coaxial 2-Way 0° Splitter/Combiner, 500 to 8500 MHz



Mini-Circuits' ZX10-2-852+ is a wideband coaxial 2-way, 0° splitter combiner covering over eight octaves from 500 to 8500

MHz. This model handles up to 2.5 W RF input power with low insertion loss (from 1.1 to 3.0 dB), 1.4:1 typical VSWR, 0.2 dB amplitude unbalance, 3° phase unbalance and DC passing up to 0.4A. It comes housed in a compact case (0.74 x 0.90 x 0.54) featuring rugged, unibody construction for high reliability and excellent survivability and SMA connectors at all ports.

Mini-Circuits
www.minicircuits.com

PRECISION ATTENUATORS

2 W to 100 W



DC-50 GHz from \$29⁹⁵ ea. (1-49)

Customers trust Mini-Circuits BW-family precision fixed attenuators for accuracy, reliability, and repeatability. Now, we've expanded your choices by adding the BW-V series, covering even more applications from DC up to 50 GHz! With fixed attenuation values from 3 to 20 dB, these new, ultra-wideband models feature 2.4mm connectors and provide outstanding attenuation accuracy, excellent VSWR, and RF power handling up to 1W. Our full "BW" family of fixed precision attenuators now includes over 70 models with attenuation values ranging from 1 to 50 dB and power handling from 1 to 100W to meet your requirements with performance you can count on.

Visit minicircuits.com for free data, curves, quantity pricing, designer kits, and everything you need to find the right BW attenuator for your needs. All models are available off the shelf for delivery as soon as tomorrow!

 RoHS compliant



Exhibition Space is Filling Up Fast. Book Your Booth Today!



2017

Electronic Design Innovation
Conference & Exhibition

Where high frequency meets high speed.

September 11-13

**Hynes Convention Center
Boston, MA**

Join the Growing List of Exhibitors:

AEM
AmpliTech, Inc.
Analog Devices
Anritsu
ANSYS
Applied Thin-Film Products
AR RF/Microwave Instrumentation
B & Z Technologies
Barry Industries, Inc.
Berkeley Nucleonics
Cadence Design Systems
Cernex & Cernex Wave
Copper Mountain Technologies
CST-Computer Simulation Technology AG
dBm Corp, INC
EMSCAN
GEIB Refining Corp
Gowanda Electronics
Holzworth Instrumentation
Innovative Integration
Integra Technologies
International Manufacturing Services, Inc.
IW Microwave Product Division
Laser Services Inc

Liberty Test Equipment
Lighthouse Technical Sales
MACOM Technology Solutions Inc
Maury Microwave
MCV Microwave
Mician Inc
Microwave Communications Laboratories,
MCLI
Microwave Development Laboratories
Millitech
Mitsubishi Electric US
MOSIS
National Instruments
Ophir RF Inc
Orban Microwave
PA&E
Passive Plus Inc.
Piconics Inc.
Planar Monolithics Industries, Inc
PPG Aerospace-Cuming Microwave
Princeton Technology Corp
Reactel Inc.
Relcomm Technologies
RF-Lambda

Rogers Corp.
Rohde & Schwarz
SemiGen Inc.
SignalCore Inc
Smith's Microwave Subsystems
Sonnet Software
Southwest Microwave, Inc.
TDK- LAMBDA Americas HP Division
TechPlus Microwave, Inc.
TECOM Industries
Teledyne Labtech
Teledyne LeCroy
Teledyne Microwave Solutions
Teledyne Relays
Times Microwave Systems
TRAK Microwave
Transline Technology Inc.
TTE Filters
T-Tech Inc.
UltraSource, Inc
Weinschel Associates
Wenzel Assoc.
WestBond

Contact your MWJ Sales Representative

EDICONUSA.com

Host Sponsor



AHEAD OF WHAT'S POSSIBLE™

Diamond Sponsor



Gold Sponsors



Organized By



CABLES & CONNECTORS

Compact Waveguide Rotary Joint



MDL introduced its new compact waveguide rotary joint series. Model 28RU199 WR-28 "U" style with mounting flange. Frequency range is 34 to 36 GHz, VSWR 1.30:1 max, WOW 1.05 max, insertion loss 0.30 dB max, over 360° rotation. It can be pressurized. Let the company's designers know how you need yours optimized and customized. Model styles "U", "I", "L", "F" are currently available in WR-22, WR-28, WR-34, WR-42, WR-51.

Microwave Development Laboratories Inc.
www.mdlab.com

Precision Compression Mount Connector Line



SV's top selling solderless precision compression mount connector line is now available with screws. SV's solderless high frequency RF install fast, easy and without damaging the PCB board. SV offers cost effective coaxial PCB mount SMA, 2.92 mm and 2.4 mm connector series. Additionally, SV can customize a PCB footprint design for your application using its latest simulation technology. These are all readily stocked through distribution.

SV Microwave
www.svmicro.com

AMPLIFIERS

Single Band Amplifiers



AR's new 20S6G18A and 40S6G18B are self-contained, air-cooled, broadband, class A solid-state amplifiers designed for applications where instantaneous bandwidth, high gain

and linearity are required. The Model 20S6G18A, when used with a sweep generator, will provide a minimum of 20 W of RF output power instantaneously from 6 to 18 GHz, while the 40S version delivers 40 W. These instruments are suitable for radiated immunity testing, TWTA replacements and EW applications.

AR RF/Microwave Instrumentation
www.arworld.us

Wideband Low Phase Noise Amplifier

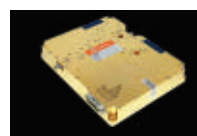


Custom MMIC, a leading developer of performance driven monolithic integrated circuits (MMIC), has added a new category to their rapidly ex-

panding standard product offerings. Custom MMIC's new GaAs MMIC low phase noise amplifier family offers previously unattained phase noise performance. Phase noise is a critical requirement which defines the performance level of most radars and communications systems. The five product family achieves phase noise performance as low as -165 dBc/Hz at 10 kHz offset.

Custom MMIC
www.custommmic.com

GaAs Hybrid SSPA Module



Exodus Advanced Communications announced the release of their best in class SSPA model

AMP3060—a 32 to 40 GHz, 10 W GaAs hybrid SSPA module. It provides 10 W CW Psat over the full bandwidth 4 dB peak to peak flatness. This amplifier is designed for any application that requires wide band coverage such as EMI/RFI, Ka-Band radar, EW and high-power millimeter testing.

Exodus Advanced Communications
www.exoduscomm.com

130 W, 3.8 to 4.2 GHz, GaN/SiC Transistor



Designed for low C-Band applications, this high-power GaN-on-SiC HEMT transistor supplies 145 W of typical peak pulsed output power at 50 V drain bias, with 14 dB of

gain and 57 percent of efficiency at 100 us-2 percent pulse conditions.

Integra Technologies
www.integratech.com

TECHPLUS
MICROWAVE Inc.

HIGHEST QUALITY FILTERS
FOR ANY
APPLICATION OR ENVIRONMENT

COMMERCIAL * MILITARY *
SPACE * PUBLIC SAFETY

WWW.TECHPLUSMICROWAVE.COM
916-672-6356

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

Waveguide and Coaxial Switches

We offer Switches for any application:
HI-REL, MILITARY, COMMERCIAL.

From design to delivery, all under one roof.
Offering the Finest in Microwave Switches Since 1974.

The only bright spot to golf!

Sector Microwave Ind., Inc.
[631] 242-2300 Phone [631] 242-6158 Fax
www.SectorMicrowave.com

SAVE THE DATE!



2018

Electronic Design Innovation Conference

电子设计创新大会

BACK TO BEIJING!

March 20-22, 2018

China National Convention Center

Host Sponsor:



Diamond Sponsor:



Corporate Sponsor:



Organized by:



Reserve your Booth now for best location!

EDICONCHINA.com

Low Phase Noise Amplifiers



Pasternack, a leading provider of RF, microwave and millimeter wave products, has released a new line of low phase noise amplifiers that incorporate GaAs HBT MMIC semi-

conductor technology to deliver ultra-low phase noise performance over a wide dynamic range. These amplifiers can be used to help optimize the sensitivity and dynamic range of higher performing test, radar and communication receiver designs where performance is dependent on how effectively the smallest and largest signal levels can be processed.

Pasternack
www.pasternack.com

ANTENNAS

Dual Polarized Antenna Horn Assembly



For communication and radar applications, SAGE Millimeter has released a new full band, dual polarized horn antenna as-

sembly. Model SAR-5037531530-15-S1-DP covers the frequency range of 50 to 75 GHz and features an integrated orthomode transducer (OMT) that provides high port isolation and cross-polarization cancellation. Features include high isolation, low insertion loss, full band performance and dual polarization.

SAGE Millimeter
www.sagemillimeter.com

SOURCES

RF Signal Generator



DS Instruments introduces the SG6000F, a harmonic-filtered version of the popular SG6000 compact and economical RF signal generator covering 25 MHz to 6 GHz. Output power is adjustable

and pre-calibrated to +10 dBm. Harmonic levels are now -30 dBc across the entire instrument output range. The USB serial port requires no drivers or API, only simple text commands.

DS Instruments
www.ds instruments.com

OCXO + Rubidium Ruggedized Frequency Source



Wenzel Associates offers the QRB Sync Series products, which includes a low noise OCXO coupled with a very stable disciplined rubidium oscillator and combined within a small ruggedized housing. This combination offers exceptional phase noise performance as well as excellent stability. There are many options to choose from, depending on the application, including HF and VHF frequencies from 10 to 500 MHz as well as low g-sensitivity and internal vibration isolation.

Wenzel Associates
www.wenzel.com/model/ocxorubidium-assemblies

TEST & MEASUREMENT

Phase Noise Testing Solution



The Model 7330 is a compact integrated phase noise testing solution offering an indispensable set of measurement functions for evaluating signal sources ranging from 5 MHz to 33 GHz. Fully turnkey, compact and broadband with both additive and residual measurements. This instrument is capable of measuring some of the most difficult devices such as unstable free-running VCO or pulsed amplifiers.

Berkeley Nucleonics
www.berkeleynucleonics.com

XMC I/O Module



The XA-160M is an XMC I/O module featuring two 16-bit, 160 MSPS A/D channels and two 16-bit, 600 MSPS DAC channels designed for high speed stimulus-response, ultrasound and servo control applications. It provides an extremely economical solution for real-time, FPGA-accelerated stimulus-response applications such as RADAR, LIDAR, optical servo or medical scanning. When mated with one of the company's rugged, embedded PCs, the XA-160M becomes an autonomous, self-booting instrument with dual, 10 GbE connectivity—perfect for distributed instrumentation.

Innovative Integrations
www.innovative-dsp.com

High Performance Broadband Antennas & Accessories

Commercial ▪ Military ▪ Law Enforcement
Homeland Security ▪ Broadcast Video
UAV / Robotics ▪ Oil & Gas ▪ M2M / IoT

southwestantennas.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:

- AVOZ-D2-B: for production testing attenuators
- 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
- AVRQ-5-B: for optocoupler CMTI tests

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



RF Amplifiers, Isolators and Circulators from 20MHz to 40GHz

- Super low noise RF amplifiers
- Broadband low noise amplifiers
- Input PIN diode protected low noise amplifiers
- General purpose gain block amplifiers
- High power RF amplifiers and broadband power amplifiers



- RF isolators and circulators
- High power coaxial and waveguide terminations
- High power coaxial attenuators
- PIN diode power limiters
- Active up and down converters

Wentek Microwave Corporation
138 W Pomona Ave, Monrovia, CA 91016
Phone: (626) 305-6666, Fax: (626) 602-3101
Email: sales@wentek.com Website: www.wentek.com

REGISTER NOW



IEEE COMCAS 2017

International Conference on Microwaves, Communications, Antennas and Electronic Systems

David Intercontinental Hotel ■ 13-15 November 2017 ■ Tel Aviv, Israel



3 Day International Professional IEEE Conference

2 Day Technical Exhibition

The International IEEE COMCAS 2017 continues the tradition of providing a multidisciplinary forum for the exchange of ideas, research results, and industry experience in the areas of microwaves, communications and sensors, antennas, biomedical systems, RF/MW devices and circuits, signal processing and imaging, radar and electronic systems engineering. It includes a technical program, industry exhibits, and invited talks by international experts in key topical areas.

Among the Keynote speakers at the Plenary session: Prof. Avram Bar-Cohen, Raytheon, on "Gen3 Embedded Cooling for High Power RF Components", Prof. Col. Barry L. Shoop, Westpoint NY, US Army, IEEE President 2016 on: "Innovation as an Ecosystem" and Mr. Israel Lupa, General Manager Radar Systems Division, IAI/Elta Israel on "Radar Technology: From PESA to digital AESA".

We are all going to be there!

With over 200 professional lectures, 48 sessions in a 3 days conference, participants from 38 countries and exhibitors from more than 90 industrial companies.

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: Amir Boag, Stephen B. Weinstein, Caleb Fulton, Oren Eliezer, Lance M. Kaplan, Aleks Dyskin, Reuven Shavit, Ofer Barnea

For further information please visit: **www.comcas.org**

*The official language of the Conference is English.



Conference Secretariat: ORTRA LTD. Tel: +972 - 3 - 6384444 Fax: +972 - 3 - 6384455 E-mail: comcas@ieee.org



IoT Technical Challenges and Solutions

Arpan Pal and
Balamuralidhar
Purushothaman

The mention of the IoT may warrant a roll of the eyes by the RF/microwave community. We have heard about it ad nauseam, usually oversimplified in catch phrases such as "connecting everything to everything." Unless we are working on an IoT application, we may not appreciate the complexity of the ecosystem required to make the IoT work. It is much more than a Zigbee or LoRa wireless connection from a battery-powered sensor. An IoT system design includes communications, computing, storage, mobility, security, privacy, data analytics and, most importantly, it must provide a return on investment for the ecosystem players and users. As authors Arpan Pal and Bal-

amuralidhar Purushothaman write, "The challenges with IoT go beyond making and connecting devices that work. The integrated product and services need to work seamlessly, almost invisible to an end user." They quote Mark Weiser, from a 1991 article published in *Scientific American*: "We need machines that fit the human environment instead of forcing humans to enter theirs."

With this fragmentation of the IoT, the authors seek to integrate the multiple dimensions of a successful implementation. In seven, very readable chapters, they provide an overview of the IoT today (Chapter 1), the scalability of networks and computing (Chapter 2), security and privacy (Chapter 3), sensor informatics (Chapter 4), mobile sensing (Chapter 5), analytics as a service (Chapter 6), the requirements for a realistic IoT deployment today and future IoT technologies (Chapter 7). Chapter 4 is perhaps the most interesting, as the authors claim that sensor informatics are the main driving force for success-

fully creating a value-add business model. Although the book is technical, the reader does not need a technical background, simply an interest in the IoT.

Pal and Purushothaman are both principal scientists with Tata Consultancy Services. Pal is the head of the Kolkata Innovation Lab, and Purushothaman leads the Bangalore Innovation Lab. Both received Ph.D. degrees from Aalborg University in Denmark.

To order the book:

Published by Artech House
www.artechhouse.com
ISBN: 978-1-63081-111-2
204 pages
\$119, Print
\$119, eBook

OUR HOTTEST NEW BOOKS IN MICROWAVE DESIGN



High-Speed Circuit Board Signal Integrity, Second Edition

Stephen C. Thierauf

Hardcover • Approx. 320 pp. • 2017
ISBN: 978-1-60807-977-3
\$169 / £135



A Practical Guide to EMC Engineering

Levent Sevgi

Hardcover • Approx. 324 pp. • 2017
ISBN: 978-1-63081-383-3
\$159 / £127



Reflectionless Filters

Matthew A. Morgan

Hardcover • 280 pp. • 2017
ISBN: 978-1-63081-327-7
\$139 / £111

US: Call 1-800-225-9977 (in the U.S. or Canada),
or 1-781-769-9750, ext. 4030

Fax 1-781-769-6334

E-mail to: artech@ArtechHouse.com

UK: Call +44 (0)20 7596 8750

Fax +44 (0)20 7630-0166

E-mail artech-uk@ArtechHouse.com

For complete descriptions and to order, visit

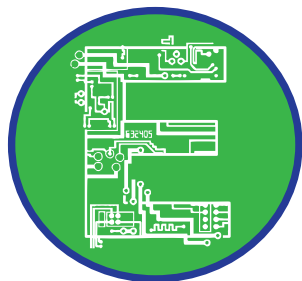
ArtechHouse.com

All orders plus shipping/handling and applicable taxes.



ARTECH HOUSE
BOSTON | LONDON

685 Canton Street, Norwood, MA 02062 USA
16 Sussex Street, London SW1V 4RW UK



LEARNING CENTER

Presented by: 

June Short Course Webinars

Technical Education Training 6/14
**MIMO Radars and
Their Conventional Equivalents**
Sponsored by: Rohde & Schwarz

Technical Education Training 6/20
**Design Considerations and Tradeoffs for
Microstrip, Coplanar and Stripline Structures at
Millimeter-Wave Frequencies**
Sponsored by: Rogers

Technical Education Training 6/27
**Getting to Know 5G: New Radio and
the Race to Standardization**
Sponsored by: National Instruments

Technical Education Training 6/28
Countering the UAS Challenge
Sponsored by: Rohde & Schwarz

Technical Education Training 6/29
**Demystifying 5G—Numerology and Initial Access
Concept for 5G NR**
Sponsored by: Rohde & Schwarz

Signal Integrity Journal's Webinar 6/21
New Connectors for High-Speed Applications
Sponsored by: CST
www.signalintegrityjournal.com

Past Webinars On Demand



**Groundbreaking 1800 W with 65 V
LDMOS Technology**

Sponsored by:  

Presented by: Franck Nicholls, RF Industrial Product Line
Manager, NXP Semiconductors

microwavejournal.com/events/1630

**Secure or Not Secure? Analysis of IP
Security Mechanisms in IoT and
Mobile Devices**

Sponsored by: 

Presented by: Christian Hof, Senior Product Manager,
Test and Measurement Division, Rohde & Schwarz, Munich
and Meik Kottkamp, Principal Technology Manager, Test and
Measurement Division, Rohde & Schwarz, Munich

microwavejournal.com/events/1583



RF and Microwave Filters

Sponsored by: 

Presented by: Dr. Bob Froelich

microwavejournal.com/events/1631

**Recent Radar and Phased-Array
Breakthroughs**

Sponsored by: 

Presented by: Dr. Eli Brookner

microwavejournal.com/events/1633



Register to attend at mwjournal.com/webinars

AdvertisingIndex

Advertiser	Page No.	Advertiser	Page No.	Advertiser	Page No.
Advanced Microwave, Inc.	40	Fairview Microwave	84, 85	R&D Interconnect Solutions.....	72
Advanced Switch Technology.....	120	Frontlynk Technologies Inc.	105	RCL Microwave, Inc.	33
Agile Microwave Technology Inc.....	24	GGB Industries, Inc.	3	Reactel, Incorporated.....	45
American Technical Ceramics	53	Herotek, Inc.	70	RF-Lambda.....	9, 71, 113
Analog Devices	57	Holworth Instrumentation	38	RFMW, Ltd.....	13
Anaren Microwave.....	95	Huber + Suhner AG.....	75	Richardson RFPD	19
Anokiwave	79, 81	IEEE COMCAS 2017	125	RLC Electronics, Inc.	23
Anritsu Company.....	31	K&L Microwave, Inc.....	7	Rogers Corporation.....	69
API Technologies.....	29	KR Electronics, Inc.....	122	Rohde & Schwarz GmbH.....	COV 3
Arance Electronics.....	58	L-3 Narda-MITEQ.....	39	Rosenberger	83
Artech House	126	Linear Technology Corporation.....	11	Sage Millimeter, Inc.....	20-21
Avnet, Inc.	93	MACOM	35	Sector Microwave Industries, Inc.	122
Avtech Electrosystems	124	Master Bond Inc.....	120	Skyworks Solutions, Inc.	73
B&Z Technologies, LLC	15	MCV Microwave.....	106	Southwest Antennas.....	124
Centerline Technologies.....	90	MECA Electronics, Inc.....	COV 2	Spectrum Elektrotechnik GmbH.....	109
Cernex, Inc.	26	Mercury Systems, Inc.....	59	Spectrum Systemwicklung Microelectronic GmbH	48
China Electronics Technology Instruments Co., LTD.....	60	Microwave Filter Company, Inc.....	103	Stanford Research Systems.....	99
Ciao Wireless, Inc.....	42	Microwave Journal	96, 98, 100, 112, 127	Sumitomo Electric USA Inc.	52
Cobham Advanced Electronic Solutions	37	Mini-Circuits	4-5, 16, 49, 50, 61, 77, 87, 101, 119, 129	Synergy Microwave Corporation.....	55, 111
Coilcraft.....	41	Modelithics, Inc.	97	TechPlus Microwave, Inc.....	122
CPI Beverly Microwave Division	6	National Instruments.....	27, 65	Teledyne Labtech Limited.....	8
CST of America, Inc.....	25	Nexyn Corporation	86	Velocity Microwave.....	32
Custom MMIC	107	NI Microwave Components	74	VIDA Products Inc.....	120
Ducommun Labarge Technologies, Inc.....	18, 92	Norden Millimeter Inc.	76	Weinschel Associates.....	34
Eclipse Microwave	82	NSI - MI Technologies	28	Wenteq Microwave Corporation.....	124
EDI CON China 2018	123	OML Inc.....	63	Wenzel Associates, Inc.	30
EDI CON USA 2017	117, 121	Passive Plus, Inc.....	68	Werlatone, Inc.....	COV 4
ERZIA Technologies S.L.	94	Pasternack	67	West Bond Inc.....	44
ET Industries	66	Planar Monolithics Industries, Inc.	91	WIN Semiconductors Corp.....	89
EuMW 2017	46, 115				

Sales Representatives



Frequency Matters.

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) 619-1942
FAX: (781) 769-5037
cboyd@mwjournal.com

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

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

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

China

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

Shanghai
Linda Li
ACT International
Tel: 86-21-62511200
lindal@actintl.com.hk

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

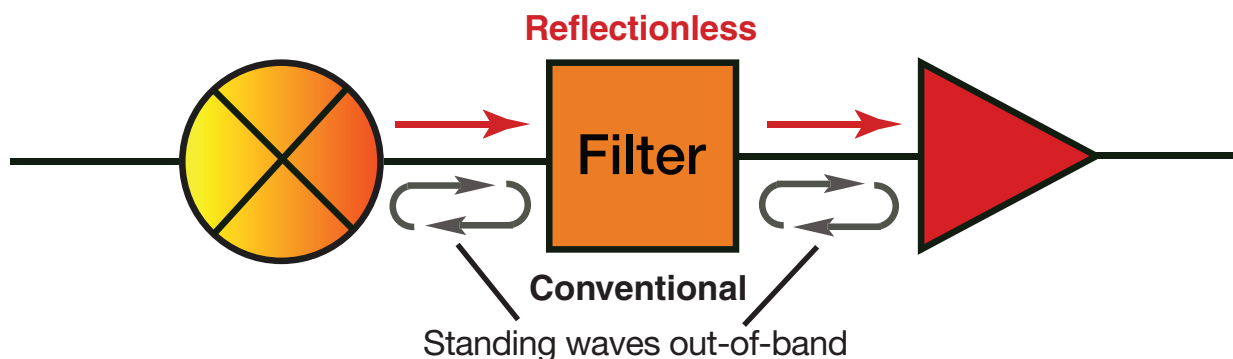
Hong Kong, Taiwan, Singapore

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

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

Revolutionary **ABSORPTIVE/REFLECTIONLESS** **FILTERS**

Now! DC to 30 GHz!



Stop Signal Reflections Dead in Their Tracks!

\$6⁹⁵
ea. (qty. 1000)

Mini-Circuits is proud to bring the industry a revolutionary breakthrough in the longstanding problem of signal reflections when embedding filters in RF systems. Whereas conventional filters are fully reflective in the stopband, our new X-series reflectionless filters are matched to 50Ω in the passband, stopband and transition band, eliminating intermods, ripples and other problems caused by reflections in the signal chain. They're perfect for pairing with non-linear devices such as mixers and multipliers, significantly reducing unwanted signals generated due to non-linearity and increasing system dynamic range by eliminating matching attenuators². They'll change the way you think about using filters in your design!

Jump on the bandwagon, and place your order online today for delivery as soon as tomorrow. Need a custom design? Call us to talk to our engineers about a reflectionless filter for your system requirements.

- ✓ High pass, low pass and band pass models
- ✓ Patented design eliminates in-band spurs
- ✓ Absorbs stopband signal power rather than reflecting it
- ✓ Good impedance match in passband stopband and transition
- ✓ Intrinsically Cascadable³
- ✓ Passbands from DC – to 30 GHz⁴

Available in Tiny QFN Packages and Die Form!



Tiny 2x2mm

3x3mm

Bare Die Form

Protected by U.S. Patent No. 8,392,495 and Chinese Patent No. ZL201080014266.I. Patent applications 14/724976 (U.S.) and PCT/USIS/33118 (PCT) pending.

¹ Small quantity samples available, \$9.95 ea. (qty. 20)

² See application note AN-75-007 on our website

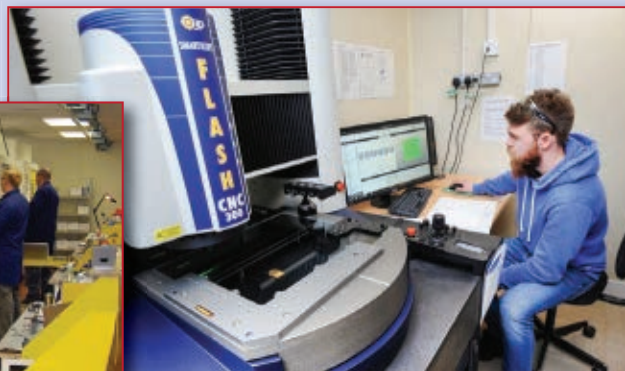
³ See application note AN-75-008 on our website

⁴ Defined to 3 dB cutoff point



FAB\$ and LAB\$

Flann Microwave—Rural Location, Global Player



Suppliers, customers and partners of Flann Microwave will be aware of the company's location in Bodmin, Cornwall—the U.K.'s most south westerly peninsular. However, the company's origins lie closer to London than Land's End, as Flann was founded in Kingston upon Thames, Surrey in 1956 by engineer Bernard Fleming, who took his experience in radar and combined it with his passion for innovation and insight into the potential of waveguide technology.

Since then, the company has grown to secure a global reputation for innovation and the production of precision microwave and millimeter wave passive waveguide components, sub-assemblies, calibration kits and instrumentation to 500 GHz.

In 1970, Fleming relocated the business to a new, purpose-built headquarters and engineering facility in Cornwall—a picturesque county renowned for agriculture, craggy cliffs and sandy beaches, but more associated with waves than waveguides. The move necessitated that all of the key capabilities be brought "in-house," to make them vertically integrated and more self-contained. With a workforce that is currently 66 strong, the company exports more than 80 percent of production.

The facility provides the latest engineering, production and test capabilities. 3D finite element electromagnetic simulators are used, together with mode matching design software, enabling the transfer of 3D models direct to the CAD office where the parts are mechanically designed. Full 3D models are then transferred electronically to the machine shop and the parts are machined on one of seven CNC mills or two CNC lathes, or manually by an experienced technician.

The facility is equipped with a full suite of the plating and surface finishing processes needed for microwave devices including Gold, Silver, Copper, Tin, Nickel and Chromate, as well as RoHS conversion coatings for Aluminum.

RF testing of products is a priority. Flann has vector network analyzer capability in-house from 500 MHz to 500 GHz, and it works with National Measurement Institutions around the world to improve the traceability of RF measurements. The company is working toward achieving ISO 17025 recognition.

Over the last 60 years, Flann has been at the forefront of innovation, playing a major role in landmark projects such as equipping the Goonhilly Earth Station, which received the first live transatlantic television broadcasts from the United States in 1962, with Flann still supporting the facility today. Another is the 10-year National Air Traffic Services (NATS) project, completed in 2013, involving the manufacture, installation and test of precision waveguide equipment to upgrade or replace all of the U.K.'s main 23 radar stations.

At the very heart of the business and its workforce is a spirit of innovation, commitment to engineering expertise, attention to detail and customer service, which has been the foundation for Flann's success. It has an ongoing policy of maintaining the highest standards and continuing to invest, both in innovation and its workforce—15 percent of whom are in the R&D team.

The company is committed to finding and developing talented new employees. For instance, in the last six years it has trained and employed six apprentices, with three more recruited recently. Flann works closely with the materials laboratory at the University of Plymouth and has strong links with Exeter University, where the company is currently sponsoring a PhD student researching metamaterial antennas for 5G backhaul.

As a family-owned company Flann is a rarity, especially in the U.K. Although it has a rich past, it is also planning on a bright and prosperous future with the security of a succession plan in place and a determination to continue to be a pioneering force in the future.

Whatever your DUT, they will characterize it.

Network analyzers from Rohde & Schwarz lead in technology and ease of use — in all classes, for any application.

www.rohde-schwarz.com/ad/nwa

Mobile

R&S®ZVH: Cable and antenna analyzers for rough field use. Specifically designed for installing and maintaining antenna systems.

Universal

R&S®ZVL: A network and spectrum analyzer in one, battery operable, 50 Ω or 75 Ω .

Efficient

R&S®ZNB and R&S®ZNC: Instruments up to 40 GHz with high measurement speed and wide dynamic range for the lab and in production. Largest touchscreen on the market for intuitive, easy operation.

Demanding

R&S®ZVA and R&S®ZVT: High-end network analyzers for demanding measurements on mixers and amplifiers incl. non-linear S-parameters. For up to 500 GHz, with up to 8 test ports and 4 independent generators.



ROHDE & SCHWARZ

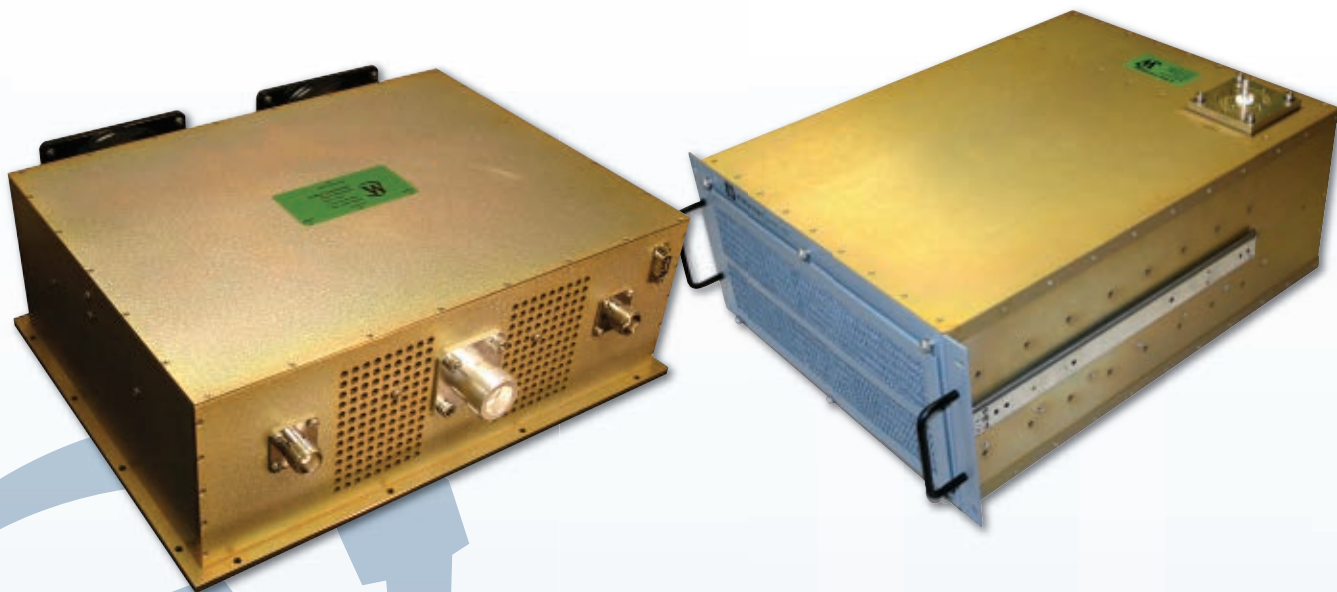


WERLATONE®

WE ARE HIGH POWER

Big Stuff! High Power RF Combiners

- Power Levels to 20 kW CW
- Low Insertion Loss
- Send Us Your Specs!
- Isolated & Non-Isolated Designs
- Rack Mount, Drawer Mount, Radial Type
- Coherent and Non-Coherent Combining



Combiners/Dividers

Model	Type	Frequency (MHz)	Power (W CW)	Insertion Loss (dB)	VSWR	Isolation (dB)	Size (Inches)
D8230	4-Way	1-30	2,500	0.2	1.15:1	30	10.5 x 5.4 x 1.28
D8265	2-Way	1-50	5,000	0.3	1.25:1	20	15.5 x 11.75 x 5.25
D2076	2-Way	1.5-30	3,000	0.1	1.25:1	22	7 x 3.75 x 2.62
D5807	4-Way	1.5-30	4,000	0.25	1.20:1	25	13 x 11 x 3.7
D2075	2-Way	1.5-30	6,000	0.2	1.25:1	20	15.5 x 11.75 x 5.25
D8969	2-Way	1.5-30	12,500	0.2	1.25:1	20	17 x 17 x 8
D6139	4-Way	1.5-32	5,000	0.25	1.25:1	20	13 x 11 x 5
D6774	4-Way	1.5-32	20,000	0.3	1.20:1	20	21 x 17.25 x 11
D6846	6-Way	1.5-30	4,000	0.35	1.35:1	20	3U, 19" Rack
D8421	8-Way	1.5-30	12,000	0.3	1.30:1	20	22.5 x 19.5 x 8.75
D7685	4-Way	2-100	2,500	0.5	1.30:1	20	15 x 13 x 5.5
D10454	2-Way	3-50	5,000	0.5	1.30:1	20	15.5 x 11.75 x 5.25
D9221	4-Way	20-130	10,000	0.3	1.25:1	20	14.75 x 12 x 5
D2786	4-Way	20-150	4,000	0.5	1.35:1	20	18 x 17 x 5
D6078	2-Way	100-500	2,000	0.25	1.20:1	20	13 x 7 x 2.25
H7521	2-Way (180°)	200-400	2,500	0.3	1.30:1	20	15 x 10 x 2
D7502	2-Way	400-1000	2,500	0.25	1.20:1	NI*	9.4 x 3.4 x 1.25

*NI = No Isolating Terminations

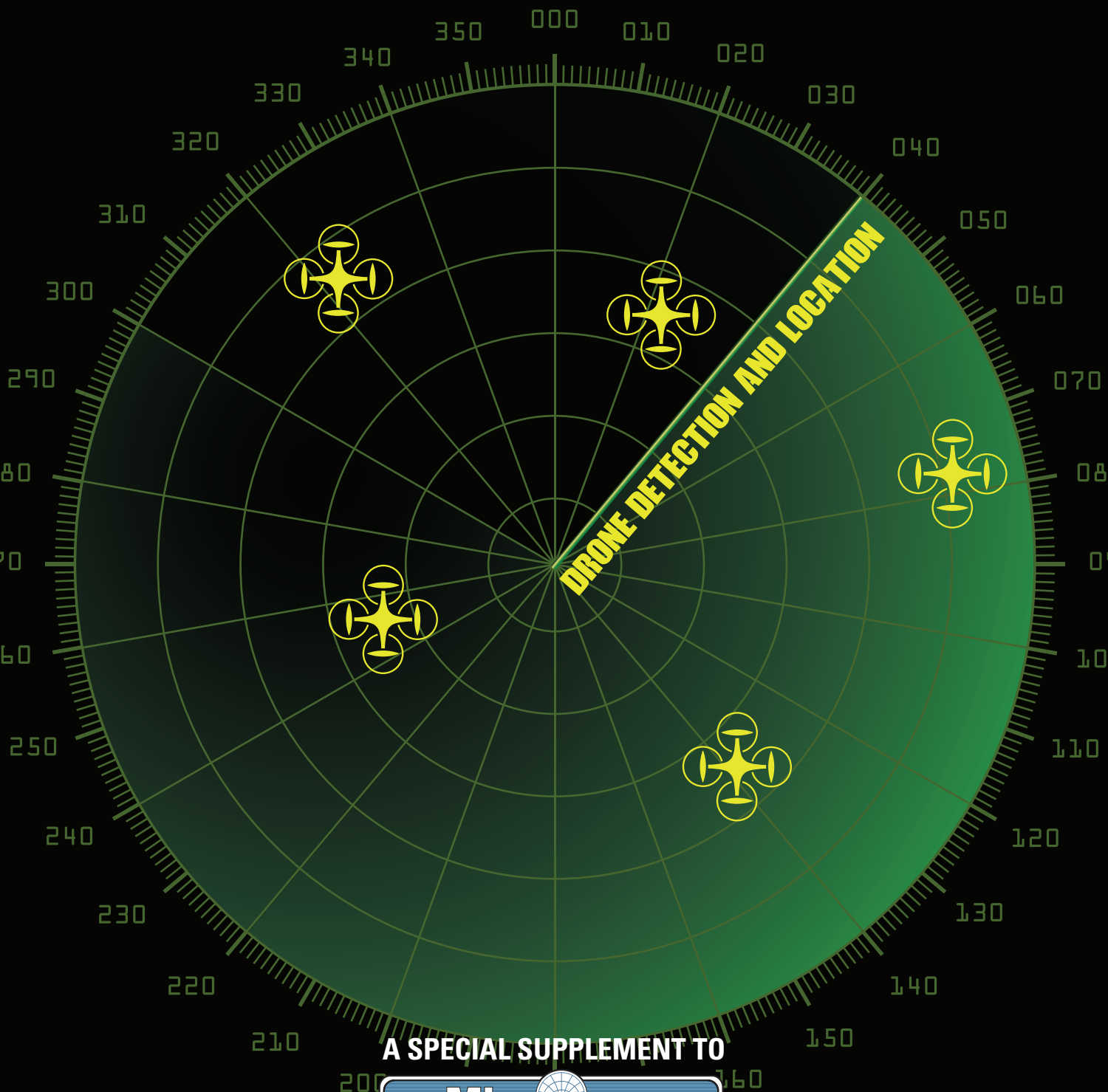
Werlatone, Inc.

17 Jon Barrett Road
Patterson, NY 12563
T 845 278 2220
F 845 278 3440
sales@werlatone.com
www.werlatone.com

AEROSPACE AND DEFENSE

ELECTRONICS

2-0-1-7



A SPECIAL SUPPLEMENT TO

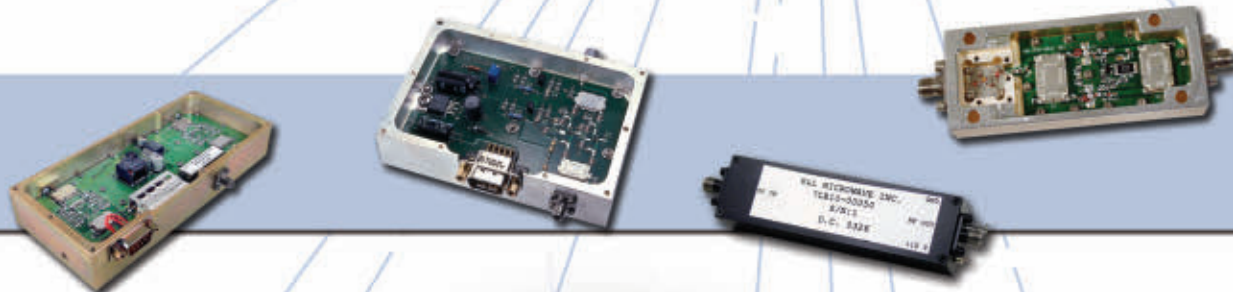
Microwave
Journal

Get Where You're Going with...



K&L's pre-filtered GPS LNA's

- Covers L1, L2, L5 and combinations
- Gains available 16 to 40 dB
- Low Noise Figure - Typically 1.8 dB or less
- Available with or without internal limiter
- Rugged design for harsh military environments
- Other frequencies available

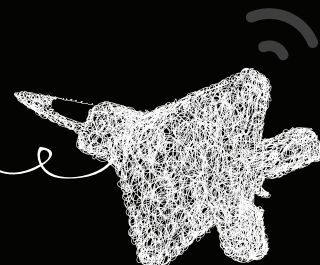


ENABLING COMMUNICATION AND SIGNAL CONTROL

www.klmicrowave.com • www.klfilterwizard.com • 410-749-2424 • sales@klmicrowave.com • [f](#) [in](#) [g+](#)

**We love
knotty
problems**

QORVO
all around you

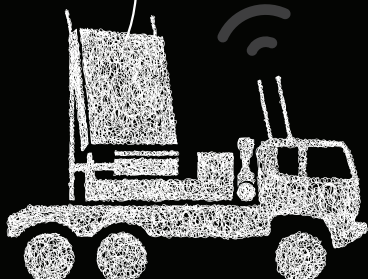


RF challenges got
you in a twist?
Bring it.

Qorvo is your smart RF partner for building solutions that protect from today's complex EW threats. As requirements for effective electronics warfare RF capabilities increase, our differentiation, our passion, will serve you well.

Smartner™ up.

QORVO and ALL AROUND YOU are registered trademarks of Qorvo, Inc. in the U.S. and in other countries. SMARTNER is a claimed trademark of Qorvo, Inc.



Say hello to a smarter partnership at qorvo.com/smartner

Cover Feature

6 Drone Detection and Location Systems

Edited by Patrick Hindle, Microwave Journal Editor

8 RF Drone Detection and Location System Challenges and Solutions

Darren McCarthy, Rohde & Schwarz

16 RF Techniques for Detection, Classification and Location of Commercial Drones

I.C. Tillman, Keysight Technologies

20 Detection of UAV's Based on Their RF Emissions

Aaronia AG

Technical Features

26 Solid-State PAs Battle TWTAs for ECM Systems

Rick Montgomery and Patrick Courtney, Qorvo

32 5 W, Ku-Band GaAs T/R MMIC with Switch Topology

Ye Yuan, Yong Fan, Ziqiang Yang and Haodong Lin, University of Electronic Science and Technology of China

Product Features

42 Optimizing ASIC Designs for SWaP

GLOBALFOUNDRIES

46 Noise Injection Loop Test Translator for Satcom Systems

AtlanTecRF

48 Selecting the Best Fan-Out for Military Radio Testing

JFW Industries Inc.

Tech Briefs

54 MANET/MIMO Sector Antennas Support High Data Rates

Southwest Antennas

54 High Performance GaAs and GaN From a DoD Trusted Supplier

BAE Systems

55 100 MHz OCXO Reference for LEO Satellites

Bliley Technologies

Company Showcase

56 Descriptions of company literature and products

Staff

Publisher: Carl Sheffres

Editor: Patrick Hindle

Technical Editor: Gary Lerude

Managing Editor: Jennifer DiMarco

Associate Technical Editor: Cliff Drubin

Copy Editor: Ashleigh West

Multimedia Staff Editor: Barbara Walsh

Contributing Editor: Janine Love

Consulting Editor: Harlan Howe, Jr.

Consulting Editor: Frank Bashore

Consulting Editor: Raymond Pengelly

Electronic Marketing Manager:

Chris Stanfa

Digital Content Production Specialist:

Lauren Tully

Audience Development Manager: Carol Spach

Traffic Manager: Edward Kiessling

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. Bazy

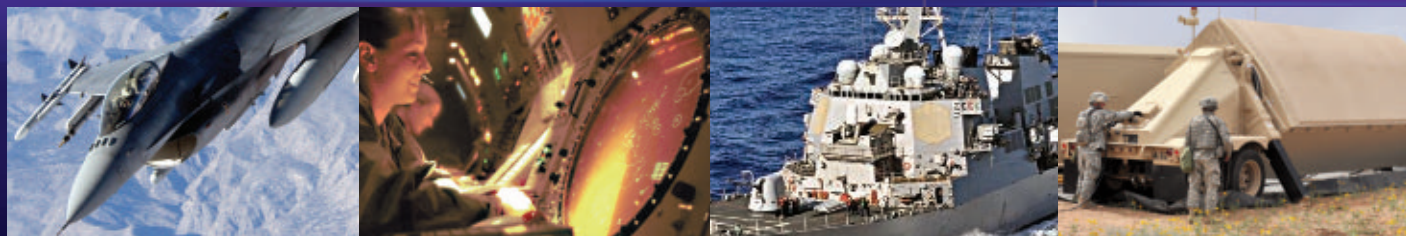
President: Ivar Bazy

Vice President: Jared Bazy



Enabling wideband frequency agility

**GaN and GaAs Solid-State Power Amplifiers
for Multi-Function, Radar and EW System Design**



Whether your application is narrowband, wideband or ultra-wideband, operating in pulsed or CW mode, CTT's power amplifiers are an especially attractive choice for new multi-function frequency-agile systems that effectively conserve weight, space and power consumption.

The characteristics of the portion of the electromagnetic spectrum selected for any of these particular system designs are undoubtedly the most important to the end user, as it has the greatest impact on the type of information required and received.

Engineered specifically to meet the stringent requirements imposed by many modern system designs, CTT's family of GaN and GaAs-based solid-state power amplifiers excel in a wide range of applications.

CTT has delivered production quantities of amplifiers with power levels from 10 through 200 Watts – and higher – for a variety of multi-function, radar and EW applications.

- AMDR • Shipboard Radar • AESA Radar
- VLO/FLO Threats • New Land Radar • EW • UAVs

More than thirty 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

- NEW GaN and GaAs Models
- Radar Bands up to 400W
- EW Bands up to 200W
- Pulse and CW
- Solid-State Microwave Power Modules
- Rack-Mount Configurations

❖ Low-Noise Amplifiers

❖ Up and Downconverters

❖ Subsystems

❖ Custom Engineered Options



USA-based thin-film microwave production facility

CTT INC.

Invited Paper
With Contributions From:
Rohde & Schwarz
Keysight Technologies
Aeronia AG

Drone Detection and Location Systems

Edited by Patrick Hindle
Microwave Journal Editor



Radio-controlled commercial drones have quickly caught the attention of consumers and entrepreneurs who have created many new and emerging commercial uses. From videography to inspection of crops and infrastructure to delivery of goods, drone technology has become both a pastime for the hobbyist and an essential tool for the business entrepreneur. With many commercial applications and millions of hobbyists flying drones, the commercial sales of drones is expected to reach nearly \$10B globally by 2025 according to some reports.

However, with widely publicized incidents, such as a drone landing on the White House garden and near hits with landing planes at airports, the detection, location and mitigation of the possible threats posed by consumer drones presents a new challenge for securing critical or private facilities, infrastructure, public venues and even borders.

There have been about 600 drone incidents that have been recorded by the U.S. Federal

Aviation Administration over the previous six months. Civilian-operated UAVs are a problem that is getting worse—on April 17 of this year, a British Airways flight making its final approach to London's Heathrow Airport was reported to have struck a UAV. Two months earlier, another plane that had just departed from Heathrow Airport had a near collision with a UAV.

The UAVs that landed in front of German Chancellor Angela Merkel in September 2013 and on the roof of Japanese Prime Minister Shinzo Abe's office in April 2015 were flown by protestors trying to prove a point. But in the future, such UAV's could carry explosives, bio or chemical weapons to perform terrorist attacks. They can also be used to transport illegal items such as drugs, or used to jam radio signals, like GPS or Wi-Fi, interrupting service. Given these concerns, market forecasts for drone detection systems are estimated to grow to about \$16B by 2022 according to ASD reports.

Drone radio controls (RC) typically operate in one of three different parts of the spectrum



Welcome to our Satellite Office

**With hundreds of space missions under our belt,
Coilcraft CPS is well positioned for all your aerospace applications**

Space is no place for commercial-grade components. That's why leading aerospace companies rely on Coilcraft CPS for proven RF and power magnetics featuring:

- Custom termination plating including Sn/Pb and Gold
- Extended temperature ranges (-55°C to +300°C)
- Vibration testing to 80 G / shock testing to 1000 G
- Low outgassing to NASA specifications

We also offer comprehensive product testing and validation services in accordance with MIL-STD-981 and EEE-INST-002, as well as custom screening to your electrical and physical specifications.

Learn more about how our deep space experience can help your design take flight. Call or visit **coilcraft-cps.com** today!



* Coilcraft CPS parts are available with or without ITAR compliance.

800.981.0363 847.639.6400 www.coilcraft-cps.com

TABLE 1

TYPICAL FREQUENCY BANDS FOR DRONE RADIO CONTROL
(Courtesy of Keysight Technologies)

Band Name	Start Frequency	Stop Frequency	Power Limitation
UHF Short Range Device	433.05 MHz	434.79 MHz	≤ 10 mW ERP
ISM 2.4 GHz	2.4 GHz	2.4835 GHz	≤ 100 mW EIRP
ISM 5.8 GHz	5.725 GHz	5.85 GHz	≤ 100 mW EIRP

ERP – Effective Radiated Power

EIRP – Equivalent Isotropic Radiated Power

reserved for remote control devices shown in **Table 1**. These bands can be very crowded—especially the 2.4 GHz ISM where most commercial Wi-Fi, Bluetooth and IoT (i.e., ZigBee, Z-Wave, LoRa) systems operate. Signals operating in these bands are loosely regulated, using random access rules rather than a controlled time or frequency division access scheme. Thus, there are a large number of signals occurring across the 80 MHz of the 2.4 GHz ISM band. The SRD and 5.8 GHz ISM bands are not as active, but given time they are bound to become the most populated.

Microwave Journal gathered the following three contributed pieces from Rohde & Schwarz, Keysight Technologies and Aeronia AG about RF drone detection and location systems, including the challenges to drone detection, advantages and disadvantages of these systems and some information about their systems. While there are many companies developing these systems, we chose these three leading test & measurement companies to contribute their approaches and views as experts in the area of spectrum monitoring.

RF Drone Detection and Location System Challenges and Solutions

Darren McCarthy
Rohde & Schwarz
Beaverton, Ore.



Stopping a drone from flying is not a trivial task and no single solution is a panacea. Visual and sound detection can be subject to impaired performance and errors from environmental interference. Radars may not detect drones with a small form factor and Electro/Optical (EO) sensors may not work in adverse weather conditions such as rain or fog. Even RF detection would not be effective alone on a pre-programmed drone using GPS waypoints for guidance. The presence of a radio link is necessary for RF detection. However,

a RF detection system is a key trigger point for most of the consumer drone technologies in use and has a distinct advantage of speed of detection versus other technologies.

To be effective, RF detection systems must provide a high level of sensitivity, give an early warning and not create false alarms. A complete countermeasure system also requires a safe, reliable means of stopping the threat. An RF detection system can be a useful part of the complete workflow for a system that includes other sensor technologies.

One of the critical shortcomings of protection systems has been the integrated workflow between the detection system and the immediate interaction between the detection and countermeasures systems to attain a high level of success.

Figure 1 gives a workflow for consideration and forms the framework for the design challenges of detecting possible threats from drones. In this article, we will focus on the detection and location drones controlled by RF links, and the need for interoperability and customization as technology advances.

Situational Awareness: Detection, Classification and Geolocation

While no universal standard exists for the remote con-

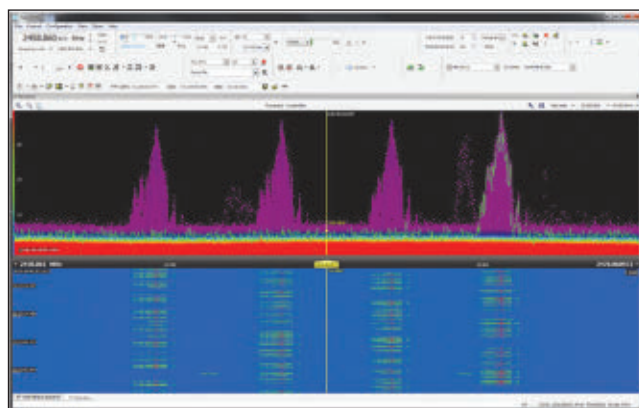
trol of drones, the majority of drone technologies are radio controlled and emit an uplink (controller to device) and downlink telemetry or video signal back to the user. The RF detection system has a distinct advantage for the detection of a radio controlled drone—time!

The RF link establishment between the controller and the drone gives the RF detection system a substantial advantage in assessing the threat situation.

While most operate in the unlicensed ISM bands at 2.4 or 5.8 GHz, other frequency bands are also used including 433 MHz and 4.3 GHz. Some of the older frequencies used by radio controlled devices include 27, 35, 40.68 and 72 MHz, which could also offer an extended range of control to several kilometers. The ability to track and detect possible devices requires a broadband antenna and receiver system capable of monitoring all the critical bands of interest on the hunt for possible threats. Further, since these ISM bands and devices operate with very low power (~100 mW) and in the presence of oth-



▲ Fig. 1 Framework for drone location and detection systems.



▲ Fig. 2 Example of FHSS technology used for a 2.4 GHz drone.

Working at the cutting edge of technology

Signal generation, analysis and phase noise test for demanding requirements

When working at the cutting edge of technology, you shouldn't waste your time with inferior tools. Rely on measuring instruments evolved in the spirit of innovation and based on industry-leading expertise.

Instruments like the R&S®SMW200A vector signal generator, the R&S®FSW signal and spectrum analyzer and the R&S®FSWP phase noise tester. Each is at the crest of today's possibilities.

See for yourself at

www.rohde-schwarz.com/ad/highend



ROHDE & SCHWARZ

HIGH RANGE DRONE DETECTION SYSTEM



RF Detection System with
24/7 recording and automatic
signal-classification in real-time



High Range, 5km and more

Detects the UAV & Operator

Passive & Fully Automatic

Optional Countermeasures

Phone: +49 6556 93033
Mail: mail@aaronia.de
Web: www.aaronia.com

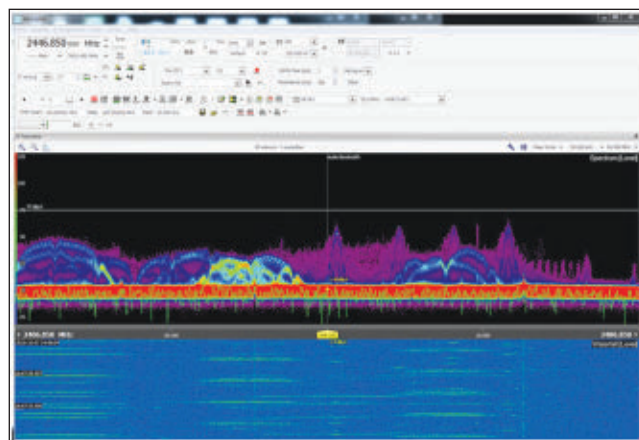
MADE IN GERMANY

AEROSPACE AND DEFENSE ELECTRONICS COVER FEATURE

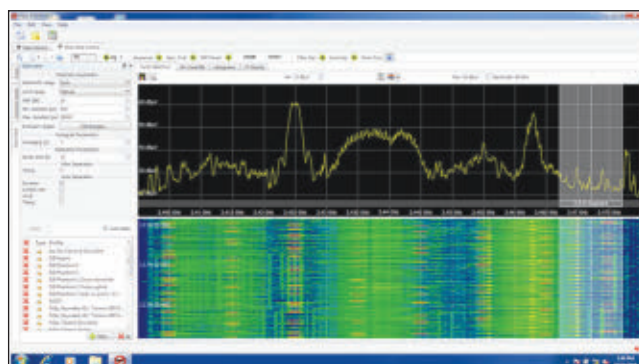
er legitimate RF uses with similar technologies, like WLAN, the high sensitivity to see signals at distance ranges and discern legitimate versus unauthorized threats requires operation expertise in signal analysis and automatic detection is required.

Figure 2 shows an example of a drone using FHSS technology in the 2.4 GHz ISM band. In the upper display, the RF spectrum shows the signal persistency on a temperature scale which is the presence of a signal over a period of time that is channelized into four frequency channels. The lower display shows the spectrogram, or waterfall, of the same signal over time with the color scale representing amplitude. A detailed analysis of this signal will show that this signal is hopping between the different RF spectrum channels with a specific burst duration, channel sequence or hopping pattern, and at a specific hopping rate (~ 100 hops/s). From this display, the clean spectrum and lack of other signals makes it easy to recognize the pattern of this FHSS drone, similar to what one might find in a lab or controlled environment.

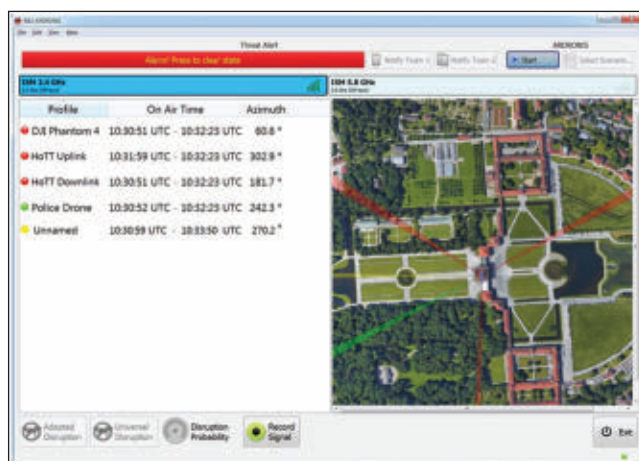
Consider the environment represented in **Figure 3**. This now becomes a little less obvious to a system operator when in the typical environment of crowded ISM band technologies. The presence of multiple WLAN access points and user terminals, Bluetooth technologies and IoT devices, can all be present in the same spectrum and



▲ Fig. 3 A drone signal in the presence of normal traffic from Wireless LAN.



▲ Fig. 4 A multi-threat environment with multiple drones (uplink and downlink) identified (lower left).



▲ Fig. 5 Example Geo-location of drone threats and a "friendly" drone Interoperability and Future-Proof.

the FHSS drone can be lost in the view. Also, keep in mind that some drones utilize WLAN signals for control or downlink video, so deeper inspection and decoding of WLAN signals is warranted to detect motion.

To reliably detect a drone signal, automatic classification is essential. A human operator cannot be expected to understand and assess all signals in all

Reactel, Incorporated

Reacting First to All Your Filter Needs.

**Let our Engineers show you
what we can do in tight spaces!**

High Performance, Rugged Packaging, Small Size and Weight

Great things *can* come in small packages. Reactel filters are ideally suited for the demanding environments that unmanned vehicles encounter.

Many manufacturers rely on Reactel to provide units which are:

- High performance
- Lightweight
- Low profile

Contact a Reactel engineer with your filter or multiplexer requirements. We can create a unit which will be the perfect fit for your applications.



*Reactel is happy to introduce our Filter RFQ App
available for Apple and Android devices.*

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



frequency bands in a timely manner. A simple threshold-based RF alarm signal, available on many basic spectrum monitoring systems, can lead to false alarms whenever a signal threshold is detected. The automatic classification system must recognize the expected environment and be able to look for the transmission system for classifying the signature, of an expected threat from a library of known drone signals. Time is

the biggest advantage of an RF detection system during the link establishment, and this advantage must be used to improve situational awareness.

The multi-drone environment must also be considered. There may be situations where a "friendly" drone (white list) would be used for perimeter monitoring, police investigation or crowd observation. The individual identification of known "friendly" signals must

be assessed against the environment. This presents the opportunity where a drone threat (black list) may coexist with a white list asset. This leads to the question of how many threats are expected in an environment.

There is a complex challenge to rapidly classifying signals in a multi-threat environment (see **Figure 4**), especially considering the complexity of separating the signatures of multiple commercial drones using FHSS, WLAN and Bluetooth technologies operating on the same frequency band, and others that might operate on other frequency bands. Not only is this a challenge during the signal classification process, but it must also be noted that not all direction finding technologies perform geolocation equally in a multi-signal environment. This is especially true with direction finding technologies that are not able to distinguish multiple signals at the same time on the same frequency, but emanating from different angles of arrival.

The selection of direction finding technologies must also consider the ability of the system to geolocate threats that are occurring at the same time and on the same frequencies, as well as the ability to operate over the entire expected operational band. It is important that behind the technology of the system, these threats can be presented to the user in a clear manner for them to be able to act upon the threat. **Figure 5** gives an example of four drones being detected at the same time and the angle of arrival of each of the threats and the friendly police drone.

RF detection systems play an essential part of a drone defense system; however, there are drone technologies that can operate based on a GPS, or other GNSS technologies, waypoint system that do not emit an RF signature. In this case, sole reliance on an RF detection system would be inadequate protection for high-valued targets.

The complete solution must consider other technologies that can work in concert to complement the advantages and overcome the disadvantages of sole technologies reliance. Therefore, an open system interface that can enable any of these other technologies to "tip" the defensive system is important. Alarms or tipping of other systems should also consider visual or acoustic methods as well as text messaging (SMS) to predefined groups of mobile phones or as an XML message via an IP network.

As drone technologies continue to advance, new RF interfaces continue to be incorporated into these commercial

Introducing the New Gallium Nitride (GaN) Amplifier for X Band Radar



Model BMC928958-1000

1000 Watts, X-Band,
Solid State Power Amplifier Module

- ECCN-3A999 (Non-ITAR Classification)
- High Output Power Dynamic Range
- RF Input & Output Sample Detectors
- Pulse Width and Duty Factor Protection
- Thermal and Load VSWR Protection
- Optional Digital Interface for Control & Status Monitoring

COMTECH PST proudly introduces a new Gallium Nitride (GaN) amplifier for applications in the X-Band weather radar market.

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 100kW.



X-Band Transmitter
TWT replacement

**NEW
8kW
SSPA**

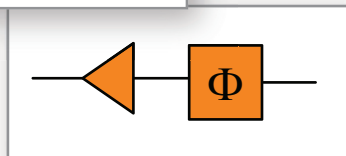
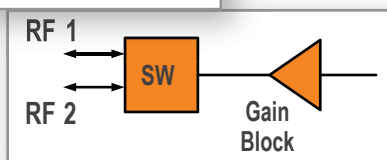
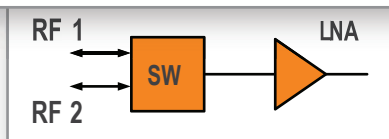
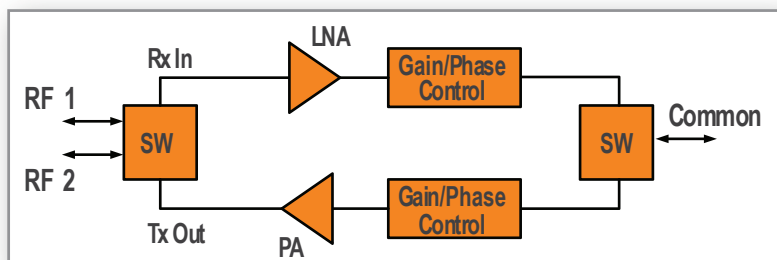
Contact us today with your requirements and specs...we'll meet your needs and exceed your expectations.

Comtech...simply more.



105 Baylis Road, Melville, NY 11747 • Tel: (631) 777-8900
Fax: (631) 777-8877 • www.comtechpst.com • sales@comtechpst.com

Introducing flexible mmW multi-function silicon ICs for active gain and phase control with duplex switching



AWMF-0117 Ku-band Single Channel IC

10.5 - 16 GHz; Switched Tx/Rx Duplex
+12 dBm Tx OP1dB/24 dB Tx Gain
3.0 dB Rx NF/30 dB Rx Gain
6-bit amplitude/phase control
2.5 x 2.5 mm package

AWMF-0116 Ka-band Single Channel IC

26 - 30 GHz; Switched Tx/Rx Duplex
+12 dBm Tx OP1dB/18 dB Tx Gain
5.0 dB Rx NF/24 dB Rx Gain
6-bit amplitude/phase control
2.5 x 2.5 mm package

**Enabling a wide range of system functions for
mmWave communication and sensing applications**

mmW Si
Core ICs

Active Antenna
ASICs

mmW
Front End ICs

devices. It is important for the detection system to have a scalable approach to extend and incorporate new RF signatures as they become available. A database is only good against known threats. Continued vigilance against the new advances in RF interfaces is essential, and the ability to augment the protection system to the latest threats remains imperative.

An example system is the R&S® ARDRONIS technology (see **Figure 6**), which has already demonstrated itself as acceptable for the highest levels of security. At the G7 Economic Summit held in Elmau Castle, Germany and again during U.S. President Barack Obama's visit to the Hanover Trade Fair in 2016, the system's underlying technologies were used to secure the sites

Cover your bases with KRYTAR



KRYTAR, Inc., founded in 1975, specializes in the design and manufacturing of ultra-broadband microwave components and test equipment for both commercial and military applications.

Products cover the DC to 67 GHz frequency range and are designed for a wide range of applications including:

- ☐ Test Equipment
- ☐ Simulation Systems
- ☐ SATCOM & SOTM
- ☐ Jammers for Radar & IEDs
- ☐ Radar Systems
- ☐ EW: ECM, ECCM & ESM

KRYTAR has a commitment to technical excellence and customer satisfaction.



KRYTAR®

www.krytar.com

1288 Anvilwood Avenue • Sunnyvale, CA 94089

Toll FREE: +1.877.734.5999 • FAX: +1.408.734.3017 • E-mail: sales@krytar.com

These principles form the basis for the steady growth that has earned KRYTAR an enviable reputation in the microwave community.

Cover your bases. Contact KRYTAR today for more information.

MIL-Qualified RF, Microwave & mmW Components

- ☐ Directional Couplers to 67 GHz
- ☐ **NEW! 3 dB 90° Hybrid Couplers to 44 GHz**
- ☐ **NEW! 3 dB 180° Hybrid Couplers to 40 GHz**
- ☐ Beamforming Networks to 18 GHz
- ☐ Power Dividers to 45 GHz
- ☐ Detectors to 40 GHz
- ☐ Custom Applications



▲ Fig. 6 Rohde & Schwarz's R&S® ARDRONIS-D radio monitoring solution combines detection, classification and geolocation in a single, portable, highly reliable system. from unauthorized, remote controlled drones.

The R&S® ARDRONIS automatic radio-controlled drone classification solution is a comprehensive solution with specialized capabilities for detecting, classifying, geolocating, recording and disrupting the remote control link to a drone. The solution is optimized for countering the threats arising from radio controlled (RC) drones. Through successful trials, deployments with key customers, involvement in protecting various important and public events as well as VIP persons, R&S® ARDRONIS has proven to be an effective technical approach.

R&S® ARDRONIS is a reliable approach to effectively detect and monitor drone activity and achieve early warning capability. It meets the challenge of identifying the direction of operators by finding the direction of active remote controls and drones. Effective countermeasures can be deployed in time to counter and prevent a radio controlled drone from entering a defined area by disrupting the radio communications link. The capabilities and key functionalities of R&S® ARDRONIS include classification, geolocation and countermeasures for threats imposed by radio-controlled drones.

Summary

There are many considerations to the challenges of the potential threats presented by drones. The widespread use of commercially available drones heeds warning to an increased need for vigilance these threats may possess for potential high-valued targets and critical sites.

The depth of the solution obviously needs to be weighed against the possibilities of the threat and the poten-

POWER + PROWESS



Highest Power Density 700 W L-Band RF LDMOS Transistor

As the largest and most-deployed provider of RF power technology, NXP offers its industry-leading technology, design and manufacturing prowess to the aerospace and defense electronics industry. Our portfolio includes the new AFV10700H/HS Airfast™ RF Power LDMOS transistor: 1030-1090 MHz, 700 W PEAK, 50 V.

Our RF power products are proven rugged and reliable in the harshest environments. US manufacturing and a 15-year product longevity warranty ensures long term security of supply. NXP's dedicated support team of aerospace and defense systems and applications experts will back you up every step of the way. Talk to us.



**LEARN MORE ABOUT THE
NEW NXP AFV10700H/HS**
www.richardsonrfpd.com/AFV10700H



Your Global Source for RF, Wireless, Energy & Power Technologies
www.richardsonrfpd.com | 800.737.6937 | 630.262.6800

tial of the threat to change over time. RF detection systems have a distinct advantage of reaction time along with a high probability of use. The actions and workflow of how to respond to a threat must play into how components of a defensive system can complement their actions for a complete solution.

The careful consideration of the type of RF detection system must also consider the need to be able to sift through the myriad of RF signals in a dense spectrum environment and simultaneously reduce the false alarm rate. One needs to be able to tell the difference between a Wi-Fi signal someone turns on for their own personal hotspot and the Wi-Fi signal of a drone. As new signals appear and technology advances, skilled users should be able to define their own threats to be included in the classification database, or a service level agreement to renew and keep the database current with technology should be made available.

Geolocation technology needs to be carefully considered and technology assessment should be performed against an anticipated scenario. Choosing a direction finding technology that is blind to a multi-threat environment could have disastrous consequences.

RF Techniques for Detection, Classification and Location of Commercial Drones

I.C. Tillman
Keysight Technologies
Santa Rosa, Calif.



An effective drone detection system monitors all three of the bands, 433 MHz SRD and 2.4 or 5.8 GHz ISM, while skipping over the vast spectrum in between (see **Figure 7**). This results in a fast and efficient way to focus only on the parts of the spectrum where drones are known to operate. Each band is configured with different resolution bandwidths (RBW) and trace averaging schemes based on the typical bandwidths and features of the drone control signals. For example, drone control signals found in the SRD band (400 MHz) are usually only tens of kHz wide and have unique spectral shapes. For that reason, narrow RBW (i.e., less than 3 kHz) is appropriate in this band. The signals of interest in the 2.4 and 5.8 GHz ISM bands tend to be 1 to 2 MHz wide; therefore, a wider RBW (i.e., 20 kHz) is beneficial. The wider RBW allows for faster processing of

the spectrum and higher probability of intercepting a drone RC transmission.

Isolating the Right Signals

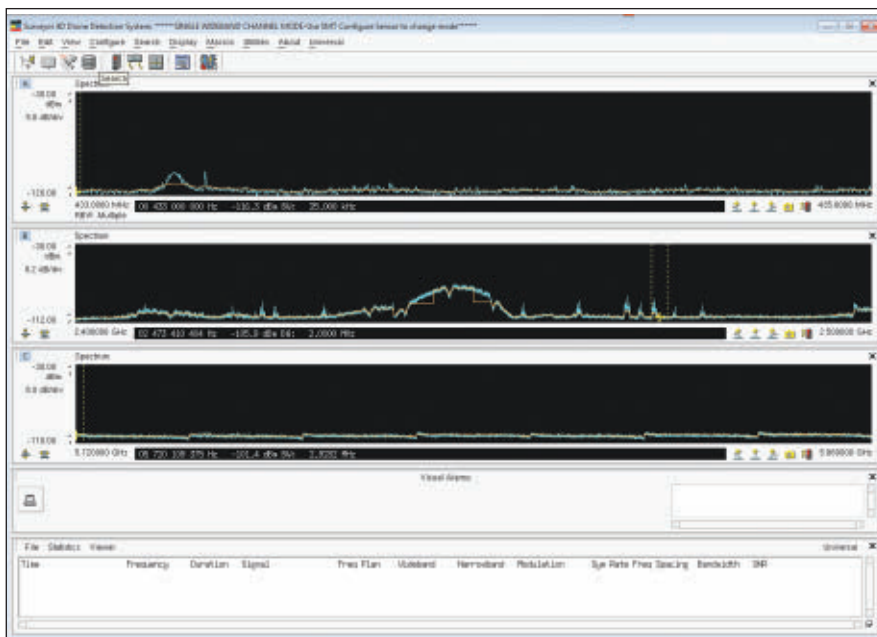
A robust method for automatically detecting energy relative to the "noise" floor that can function across all three bands is needed. A noise riding technique is used that was originally developed as part of a signals development system for the HF Band (2 to 32 MHz) at Keysight. The algorithm has variables related to the margin (amplitude offset), segmentation (frequency granularity) and smoothing (a running average). By properly setting these values, the auto-threshold can "ride" up and down active Wi-Fi channels but still properly respond to and isolate drone control signals from other transmitters legally authorized to operate.

Figure 8 shows how the algorithm works. The vertical green lines show

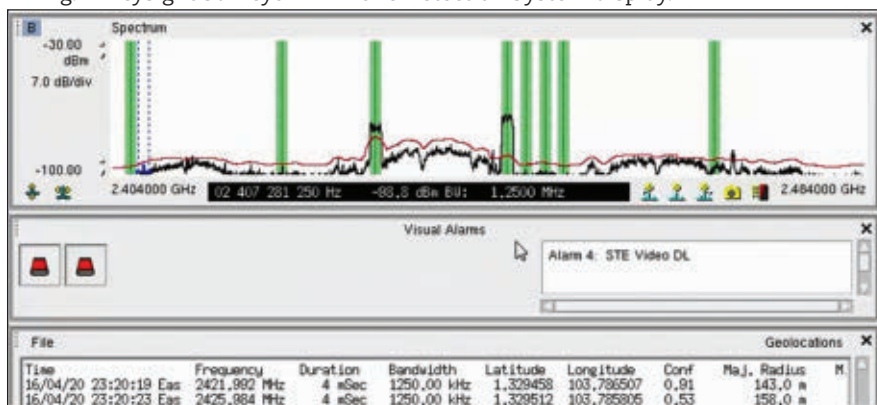
detections of frequencies with the drone RC. The red line represents the noise riding threshold which is "riding" on top of the Wi-Fi signals but detecting the control signals. The next challenge is to discriminate one type of drone control signal from another. The noise riding threshold helps by rejecting ambient Wi-Fi signals, treating them somewhat like a noise floor. However, there are other signals that may resemble the drone RF of interest. But what if more than one RC is operating, how can they be differentiated?

Differentiating Drone Control Types

This challenge can be addressed by spectral shape correlation. This isolation technique uses a spectral correlation line consisting of points horizontally separated by the frequency bin spacing (a value related to the RBW by the FFT filter shape factor). The points are verti-



▲ Fig. 7 Keysight Surveyor 4D Drone Detection System display.



▲ Fig. 8 Operation of the Auto Threshold algorithm in ISM band.



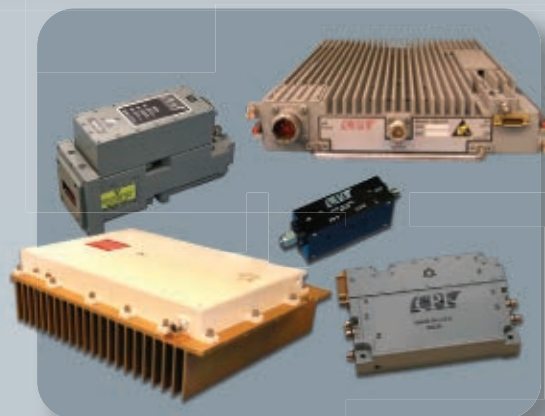
Communications & Power Industries

beverly microwave division

Proven Technology

**New designs, legacy
sustainment and upgrades**

**Contact the experts at CPI BMD
for your radar and EW needs.**



**Integrated Microwave
Assemblies**

**Solid State
Power Amplifiers**

**Receiver
Protectors**

Transmitters

RADAR & EW

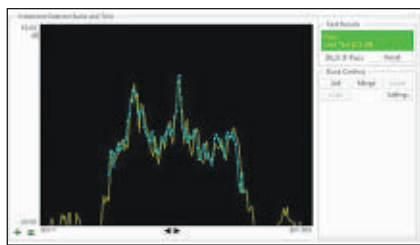


Solid State Power Amplifiers
Integrated Microwave Assemblies
Control Components
Transmitters Amplifiers
Modulators

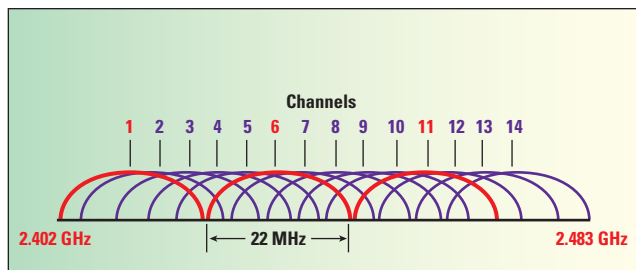
Receiver Protectors
Magnetrons
Crossed Field
Amplifiers



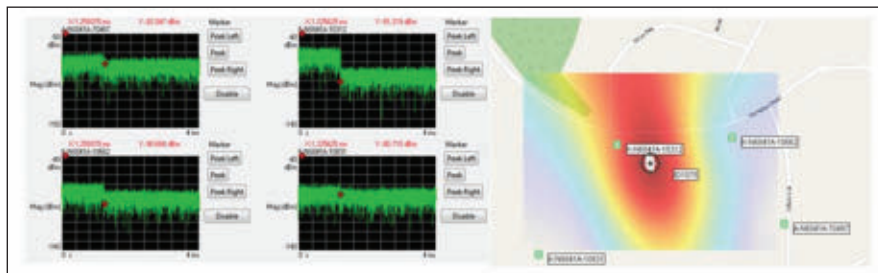
150 Sohier Road, Beverly, MA U.S.A 01915, +1 (978) 922-6000, bmdmarketing@cpii.com, www.cpii.com/bmd



▲ Fig. 9 Spectral Shape correlator for a specific drone signature.



▲ Fig. 10 Overlap of Wi-Fi channels in 2.4 GHz ISM band.



▲ Fig. 11 Drone RC burst capture and TDOA geolocation in the Keysight N6854A Geolocation Server Software.

cally positioned based on the unique amplitude features of the transmission. The number of points in the detector is based on the signal bandwidth, or the bandwidth of the exploitable feature of the signal. Basically, these are matched filters used to evaluate every set of frequency bins in the sweep for a match within a defined tolerance (expressed in percent or dB). Correlation lines for specific signals are built from recordings and validated in several steps prior to being put into use.

Each make of radio controller employs a slightly different scheme to communicate with the drone. It is these differences that can be exploited by a spectral shape correlator. **Figure 9** shows the signature of one type of controller.

A Keysight Signal Surveyor 4D feature called "Universal Signal Detector" or USD is used, which has a spectral shape correlator referred to as a wide-band detector. This feature enables the user to apply signal discriminators designed to recognize various drone controllers with minimal false positive results. The USD "detector" applies three other elements that work together, or independently, to distinguish signals of different types. Once again, this feature was originally developed for use in the HF spectrum where signals often have unique spectral signatures that can be exploited. The other elements used by the USD feature are:

- Frequency plan, which can include a frequency band with or without channelization and individual frequencies,

- Bandwidth filter, with a tolerance expressed in percent,
- Narrowband confirmation of the modulation and symbol rates, not typically required for drone RC discrimination.

Locating the Radio Controller Using Time Difference of Arrival (TDOA)

Locating transmissions in the ISM band can be a challenge for many reasons. Ambient signal energy is literally everywhere due to the overlap of the Wi-Fi channels, Bluetooth activity and an increasing number of IoT signals presenting in this 80 MHz wide band (see **Figure 10**). The signals are short in duration, frequency hopping (over most of the band) and relatively low power. Affordable network-enabled sensors can be distributed around an area and used to both detect and locate these signals. A distributed detection system is beneficial in expanding the coverage area. Since drone control signals will most likely be operated from the ground, at an elevation of about 1.5 meters, the detection range of any monitoring system will be less than for an elevated transmitter. Additionally, since the signals are moderately wide bandwidth (1 to 2 MHz), the power spectral density is less than that of, for example, a PMR radio (12.5 to 25 kHz). Thus, the propagation distance is less.

Given these conditions, for successful geolocation using TDOA, the signals must be isolated both in frequency and in time. For TDOA to work, the right "snippet" of synchronous

IQ data from each sensor must be collected and correlated at a common host computer. The bigger challenge is isolating the correct samples of IQ (i.e., that contains the RC signal) from all sensors. For this to be feasible, each sensor must have precisely time-

stamped IQ memory to get the right pulse. Given that drones can occur in any one of three bands, it is assumed the receiver is sweeping across all bands. This means the IQ from each frequency segment, corresponding to the tuner IF bandwidth, must be properly time-stamped and indexed in the sensor memory. When an RC signal is detected, the system must communicate the refined time to each sensor and request that data specifically from the memory. The host PC can then correlate the IQ data between all sensor pairs and estimate the position. **Figure 11** shows an example of how this measurement looks.

The four sensors have synchronously isolated the RC signal from the 2.4 GHz ISM band and successfully isolated, in time, the 1.2 ms burst. The host computer was able to correlate the IQ time series data to successfully estimate the location of the controller. This measurement was taken during field testing, so the time record was 3x longer than required. This "lookback" method of isolating short duration signals has proven effective for locating drone RCs.

Another challenge presented by the ISM band is co-channel interference, which presents issues for any technique used for emitter location. When using traditional direction finders (i.e., angle of arrival techniques), strong co-channel signals present during signal acquisition can produce angular errors or a result based on the interferer rather than the intended signal. Angular errors can be difficult to overcome whether they are produced by reflections or co-channel interference, both of which dominate the landscape especially considering the ISM band in urban environments. TDOA algorithms usually base the result on the strongest correlation. This is where isolation of the RC signal burst in time is critical. By triggering the geolocation measurement window on the exact RC signature, the likelihood of a strong correlation is very high. Since

From components to subsystem solutions

API delivers value-added integration solutions to meet the most challenging RF, microwave, power, electromagnetic and security requirements.



Superior Stability and Low Input Power for Mobile and Airborne Applications



Greenray Industries' new dual compensated T1250 TCXO is designed for applications that require **superior temperature stability** and **low input power** performance in high vibration, shock-sensitive environments.

T1250 Features:



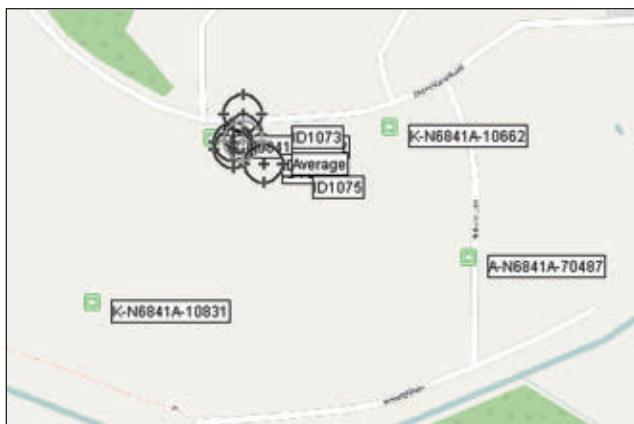
- Temp. Stability to ± 50 ppb over -40 to $+85^{\circ}\text{C}$
- Acceleration sensitivity to $\leq 7 \times 10^{-10}/\text{g}$
- Freq. Range: 10 - 50MHz
- +3.3 to +5.0VDC supply
- 9 x 14mm, SMT package
- Output: CMOS or Clipped Sinewave
- Long term aging to 3ppm over 20 years
- EFC, incl. compensation for EFC trim skew effects
- Ideal for Instrumentation & Mobile Communications

For more information about Greenray's full line of high performance oscillators, call us at **717-766-0223** or visit greenrayindustries.com.

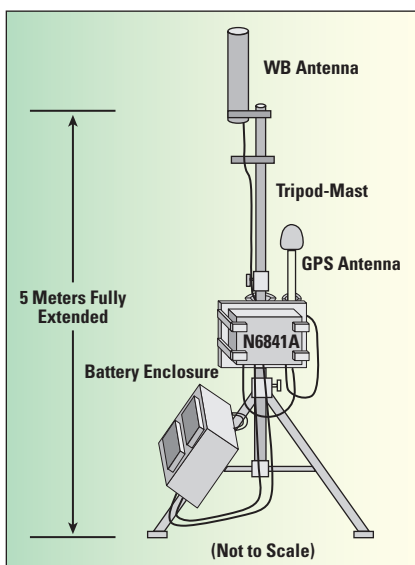


frequency control solutions

AEROSPACE AND DEFENSE ELECTRONICS COVER FEATURE



▲ Fig. 12 Clustering of TDOA results around RC.



▲ Fig. 13 Keysight Surveyor 4D Drone Detection System.

the RC is hopping, several TDOA measurements will be completed in a short time increasing further the chance of a strong clustering of the geolocation results (see **Figure 12**). A direction finding system employing multi-channel correlative techniques could overcome this situation, but at a far higher cost.

Techniques developed to detect, isolate and classify signals in the HF band can be effective against signals in the ISM band. While the HF band has a poorly behaved noise floor that varies based on environmental conditions, the ISM band also has a very active ambient signal floor consisting of a variety of overlapped wideband and frequency agile narrowband activity. This signal activity behaves somewhat like the HF band except at a much higher speed of variation. An automated noise riding threshold combined with spectral shape correlation detection makes for an ef-

fective, low cost way to detect and isolate specific signal energy. Once detected, TDOA methods using sensor memory can effectively isolate the pulsed signal data for cross-correlation to estimate the RF controller location. Such systems can be implemented with low-cost, synchronous sensor networks.

An example system is the Keysight Surveyor 4D Sys-

tem (see **Figure 13**), which is effective at detecting, classifying and locating drone controllers operating within a 1 km range. Detection range can be extended by additional elevation on the system that extends line of sight. The enabling technology is in the Surveyor 4D's high-speed multiband search mode and the Universal Signal Detection (USD) wideband detector. The system can create detectors as new drone systems are introduced. This provides the user with the ability to update the library of drone detectors as new control units and drone products enter the market.

Keysight offers a modeling and simulation tool for planning RF Sensor installations called SPOT (Sensor Planning and Optimization Tool). With this tool, detection sites can be planned to provide the best possible coverage for critical infrastructure or event locations. With the deployment of four or more sensors, emitter location by Time Difference of Arrival (TDOA) is possible.

Detection of UAV's Based on Their RF Emissions

Aaronia AG
Strickscheid, Germany



A final example is Aaronia's Drone Detector, a product that exploits the RF radiation emitted by the UAV's onboard systems and by the operator's control unit (see **Figure 14**). Aaronia recognized the need for a reliable method to detect tiny airborne intruders. Following a four-year development program, it launched the product. Real-time RF signal detection, combined with what the company terms "pattern triggering," provides rapid warning of any UAV or UAV control unit that is operating within the area being monitored.



Proven Performance



GORE-FLIGHT™ Microwave Assemblies, 6 Series are ruggedized, lightweight and vapor-sealed airframe assemblies that withstand the challenges of aerospace.

With GORE-FLIGHT™ Microwave Assemblies, 6 Series, a fit-and-forget philosophy is now a reality – providing the most cost-effective solution that ensures mission-critical system performance for military and civil aircraft operators.

Find out why at:
www.gore.com/GORE-FLIGHT



precision

lightweight

durability

GORE, GORE-FLIGHT, the purple cable and designs are trademarks of W. L. Gore & Associates.

Follow us on





▲ Fig. 14 Aaronia's Drone Detector System.

Military communications links often exploit techniques such as frequency agility in order to reduce the probability of interception, but the designers of UAVs are selling an inexpensive commercial prod-

ucts. As a result, UAV communications links are low-cost, unsophisticated sub-systems that have few clandestine qualities. Since the Drone Detector has more sophisticated receiver facilities than those of the UAV and its control unit, it has a longer range than the UAV operator.

Two types of 3D direction finding antennas are offered by the Drone Detector—the IsoLOG 3D 80 and IsoLOG 3D 160. These have eight sectors with 16 antennas, and 16 sectors with 32 antennas, respectively. Both cover from 680 MHz to 6 GHz, and extenders are available should LF, MF, HF and VLF (9 kHz to 680 MHz) and 6 to 20 GHz coverage be required.

These antennas are teamed with either an XFR V5 PRO (used for portable installations) or an RF Command Centre (for stationary use). Both cover frequencies from 9 kHz to 20 GHz, so include the frequencies commonly used for UAV control and video links—typically 433, 900, 915 MHz and 1.3, 2.4, 5.8 GHz.

Locating the UAV and its Control Unit

Using these basic components, the user can opt for systems of varying complexity. The simplest consists of a single IsoLOG 3D antenna and a stationary or mobile spectrum analyzer. This is sufficient for surveillance of an area with up to 4 to 5 km radius. If a fully mobile solution is required, the system can be installed on a vehicle and operated from battery power. Its antennas are resistant to the effects of salt water splashes or spray, allowing deployment on a boat.

Once a signal has been detected, its approximate bearing will be shown to an accuracy of 2 to 3 degrees, which depends on which model of antenna is being used. With the standard IsoLOG 3D 80, the bearing accuracy will be at least within the 4 to 6 degrees coverage of a single antenna sector.

When larger areas must be covered, several antennas and spectrum analyzers can be connected to a single centralized PC which manages these simultaneously. The larger the area to be covered, the greater the number of antennas and analyzers that must be deployed. Any threat signal is likely to be received by several antennas, so the results can be triangulated to provide detailed and accurate information on the location of the UAV and/or its operator.

The system has no limitation in detection range; usually the detection range is the same as the usable distance from the operator to the drone (or better), so it always depends on the transmitter power of the drone/operator. Depending on the drone type, it could be several kilometers/miles without a problem (e.g. approximately 5 km for a DJI Phantom 4).

Since the system is designed to recognize the RF signals

BROADBAND L \otimes MODULES

**PHASE COHERENT
AGILE SWITCHING
>240kHrs MTBF**

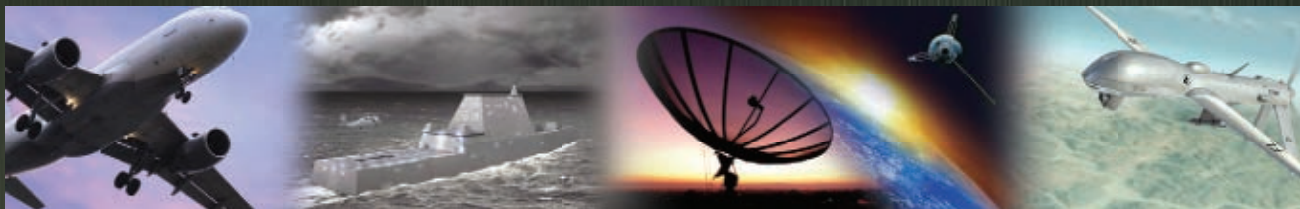


Holzworth's **HSM Series** RF Synthesizer Modules are non-PLL based COTS products that have field proven reliability since 2009. These Hi-REL modules are also available for ATE test systems via the **HS9000 Series** Multi-Channel RF Synthesizers.



SEVEN COTS MODELS AVAILABLE

Model No.	Frequency Range	Step Size	Amplitude Range	Phase Noise (10kHz offset)
HSM1001A	100kHz to 1GHz	1mHz	-100dBm to +13dBm	-134 dBc/Hz (1GHz)
HSM2001A	100kHz to 2GHz			-128 dBc/Hz (2GHz)
HSM3001A	100kHz to 3GHz			-124 dBc/Hz (3GHz)
HSM4001A	100kHz to 4GHz		-100dBm to +10dBm	-122 dBc/Hz (4GHz)
HSM6001A	100kHz to 6.7GHz			-118 dBc/Hz (6GHz)
HSM12001B	10MHz to 12.5GHz			-110 dBc/Hz (12GHz)
HSM18001B	10MHz to >20GHz		-20dBm to +20dBm	-106 dBc/Hz (18GHz)



Reliability matters.

Gain a tactical advantage.

Mission-critical applications have relied on Rogers' microwave materials like RT/duroid® and TMM® Materials for years. The superior electrical & mechanical characteristics of Rogers' high reliability laminates provide the stable, consistent performance over time and temperature that's so critical for aerospace and defense applications.

Rogers' high performance printed circuit board materials have been supporting mission critical applications with a proven record of reliability for over 45 years. Can your mission afford anything else?

Visit www.rogerscorp.com/acs to learn more about Rogers' aerospace and defense microwave material solutions.

RT/duroid® 5880LZ Laminates

- Dielectric constant of 1.96
- Low z-axis coefficient of thermal expansion
- Light weight

2929 Bondply

- Unreinforced, thermoset based thin film adhesive system
- Dielectric constant of 2.9 and low loss tangent (<0.003)
- Predictable control of post bond thickness



Recently added to Rogers' family of High Reliability Products

TC Series™ Laminates

- High Thermal Conductivity (up to 1.4 W/mK) RF & Microwave PCB Materials
- Low CTE, Low Loss Tangent and Stable Dk over Temperature

CLTE-X™ Laminates

Offered in a range of constructions to satisfy requirements for insertion loss, phase stability, inner-layer registration and plated through hole reliability for demanding multilayer designs

CuClad® Series

Unique, crossplied constructions provide electrical and mechanical isotropy and registration, assuring high performance

IsoClad® Series

Available up to 48" x 54" and engineered for conformal antenna applications, where enhanced flexibility enables physical shape and electrical design goals

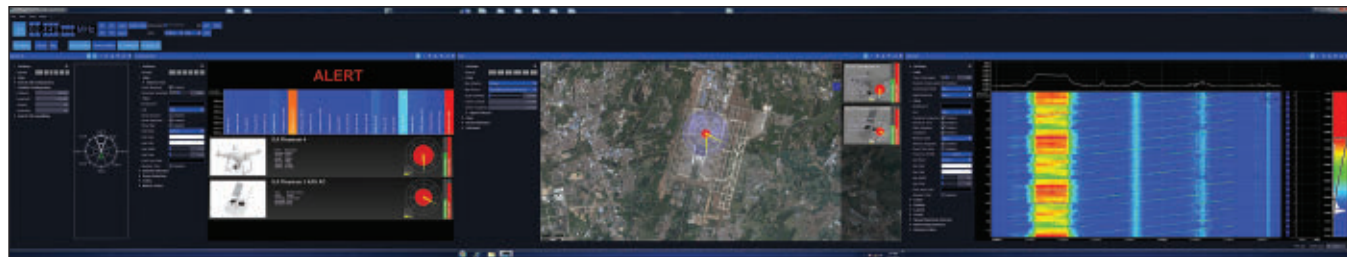
Become a member of our Technology Support Hub

www.rogerscorp.com/techub



ROGERS
CORPORATION

Advanced Connectivity Solutions




▲ Fig. 15 Identification of multiple drones.

NOISE: 26.1
ELEV: 0.75

Reliability isn't an option – it's a requirement.

**dB Control
delivers.**

RADAR



TWT AMPLIFIERS | MICROWAVE POWER MODULES | POWER SUPPLIES



Our high-power solutions for radar, ECM and EW threat simulation systems save lives every day. Easy to maintain, custom configured and modularly designed, our TWTAs, MPMs and power supplies are so reliable that we're sole source on mission-critical ground-based, shipborne and high-altitude military manned and unmanned aircraft platforms with the U.S. Army, Navy, Air Force and major defense contractors worldwide. If your expectations are as high as your power requirements, contact us today.

+1 (510) 656-2325
marketing@dBControl.com
www.dBControl.com

dB Control
a HEICO company
Reliability by Design®



© 2017 dB Control Corp. All rights reserved. Photos provided courtesy U.S. Air Force, U.S. Army and U.S. Navy.

associated with UAVs by observing their frequency and other characteristics, it will not provide false alarms when faced with other types of RF signals. When faced with several UAVs, the system can detect these, even if the drones are the same or different types (see **Figure 15**).

The average time needed for detection of a UAV is between 10 microseconds and 500 milliseconds. It depends on factors such as the complexity of the deployed system and the number of antenna arrays being used. While a clear line of sight between the antennas and the UAV or its operator gives the best results, the system can detect RF signals whose source is obscured by trees, bushes or a crowd of people. The system is passive, emitting no signals of its own that could interfere with the normal operation of nearby assets, such as airports, or give the UAV operator warning of its presence. System performance is unaffected by darkness or poor weather—if meteorological conditions allow UAVs to fly, they can be detected.

The Aaronia system has some unique features like 24/7 recording and playback. Further it can be equipped with multi-receivers allowing real-time measurement of each individual frequency band (e.g. 2.4 and 5.8 GHz, 434 and 868 MHz) without the need to switch between bands.

SUMMARY

While drones will enable many new exciting applications in commercial markets, they also represent a potential threat to public safety. Since they are small and agile, they can access most protected areas and are difficult to detect and prevent them from entering these areas. However, new drone detection and location systems, mostly based on RF technologies, are rapidly evolving to protect the public from these threats. Many RF test and measurement companies are uniquely positioned to leverage their spectrum monitoring capabilities to field systems in this area. ■



\$139⁹⁵
from (qty. 1-9)
 Rugged connectorized package
 0.75 x 0.74 x 0.46"

\$11⁹⁵
from (qty. 20)
 3x3mm MMIC

0.5 to 8 GHz

LOW NOISE AMPLIFIERS

IN/OUT Termination Matched!

Low noise, high dynamic range, high output power, and flat gain from 0.5 to 8 GHz, all in a single amplifier! Mini-Circuits' popular ultra-wideband LNAs are now available in both a 3x3mm QFN for your PCB and a rugged connectorized package to facilitate your cable assemblies. Both models are matched over the 0.5 to 8 GHz range*, making them a snap to use for sensitive, high-dynamic-range receivers, instrumentation, defense systems, LTE, WiFi, S-Band and C-Band radar, SatCom and more! They're available off the shelf for a great value, so visit minicircuits.com and place your order today for delivery as soon as tomorrow!

*See datasheet for suggested application circuit for PMA3-83LN+

†Flatness specified over 0.5 to 7 GHz

FEATURES:

- **Low Noise Figure, 1.3 dB**
- **High Gain, 21 dB**
- **Excellent Gain Flatness, ± 0.7 dB[†]**
- **High IP3, +35 dBm**
- **High POUT, +23.2 dBm**





Solid-State PAs Battle TWTAs for ECM Systems

Rick Montgomery and Patrick Courtney

Qorvo, Greensboro, N.C.



Electronic countermeasures or ECM systems are typically comprised of receivers, processors, displays and jamming transmitters.

Until recently, solid-state amplifiers fell short of the required combination of power, bandwidth and efficiency for the transmitter of an ECM system. Maturing GaN power amplifier MMICs and low loss, broadband combining techniques now make it possible to meet the power, bandwidth and efficiency requirements of ECM systems with solid-state power amplifiers (SSPA). Compared to GaAs and other solid-state semiconductor materials, GaN provides an order-of-magnitude increase in transistor power density, and the higher impedance of the devices eases the design of matching networks.

Historically, traveling wave tubes (TWT) and other vacuum tubes have provided the microwave power for ECM transmitters. Since the 1950s, the broadband, high-power microwave amplification necessary for ECM transmitters was only feasible with vacuum tube technology and, in particular, with traveling wave tube amplifiers (TWTAs). ECM jamming transmitters typically need to generate hundreds of watts of microwave power over several octaves. The efficiency of the amplifiers must be high enough to meet the limited power budget of airborne platforms and the heat generated can be dissipated. TWTAs were the only technology that could meet these critical requirements.

SOLID-STATE VS. TUBE

Solid-state devices have long been preferred to vacuum devices. Vacuum tubes, with their as-

sociated high voltage power supplies—typically in the multi-kV range—have lower reliability than solid-state devices operating with low voltage power supplies (i.e., under 50 V). Manufacturers and users of vacuum tubes face diminishing sources of supply and material shortages.

Solid-state devices generate lower noise and have better linearity than vacuum tubes. For instance, solid-state devices in “standby mode”—where the DC bias voltage is applied with no RF input signal—generate significantly less noise power across the spectrum. Noise figures for a medium power TWT can be around 30 dB, versus about 10 dB for a solid-state GaN MMIC PA. This is a significant difference in an ECM system, as the lower noise may allow the transmitter’s output stage to remain in standby mode when not transmitting. The overall switching time decreases, since the main DC power to the PA does not need to be switched on and off.

Another operational benefit of a solid-state transmitter is the reduced harmonic content in the output signal. A solid-state PA that operates over an octave or greater bandwidth will typically have worst-case harmonic content about 8 dB down from the fundamental at its saturated output power. The harmonic content of a vacuum tube will only be down 2 dB from the fundamental under the same operating conditions. These higher harmonics can impose stricter filtering requirements for the transmitter, driving larger and costlier components for the overall ECM system.

POWERING UP WITH GaN

While GaN devices have significantly increased the power density, power and band-

Our Goal Was To Build The Lightest, Long Range Booster Amplifier.



Mission Accomplished.

The AR-20H Booster Amplifier weighs just 2.6 lbs., but it's no lightweight in terms of performance. It extends the range of your signal so important communications can be reliably transmitted and clearly heard.

This 30 – 512 MHz, 20-watt booster amp works with all modern signal modulation schemes and is certified to meet the toughest vibration standards on the ground, in the air, at sea... everywhere. And it has passed all real world tests under the harshest operating conditions. So, put it to the test and you won't be disappointed.

To learn more, visit us at www.arworld.us/tactical or call 425-485-9000.



modular rf

Other **ar** divisions: rf/microwave instrumentation • sunar rf motion • receiver systems • ar europe

The Battle Tested logo is Reg. U.S. Pat. & TM. Off. # 3,821,099.

www.arworld.us

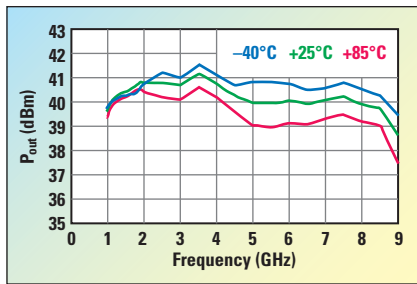
Download the AR RF/Microwave Mobile App:

www.arworld.us/arApp

Copyright © 2017 AR.

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

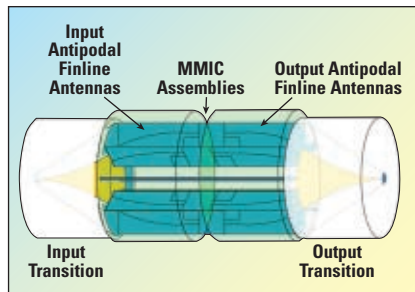




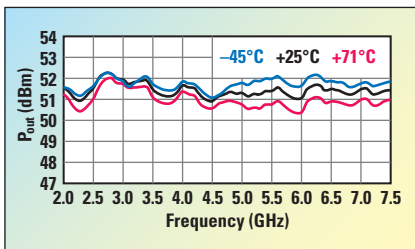
▲ Fig. 1 Output power vs. frequency and temperature of a Qorvo QPA1003P GaN MMIC, with 15 dBm CW input power, 28 V bias and 650 mA current consumption.

width over other heterojunction semiconductor technologies, a single device or MMIC still has insufficient power for most ECM system transmitters. It is not unusual to have a requirement of 100 W or more from 2 to 7.5 GHz. **Figure 1** shows the output of a single Qorvo GaN power MMIC. This packaged MMIC nominally delivers 10 W from 1 to 8 GHz, but the output power decreases at 85°C backside temperature to as low as 8 W. More than 10 of these MMICs must be combined to deliver 100 W across the band and over the temperature range required in an ECM system.

There are many ways to power combine devices to make a SSPA. For an ECM system transmitter, the approach must have low loss and wide bandwidth. Many combining techniques use two-port binary combiners such as Wilkinson or magic tees. Combining two MMICs requires a single two-port combiner, four MMICs requires three combiners and 16-way combining requires 15 combining elements. Magic tees have relatively low loss; however, they typically operate over a maximum of 10 percent bandwidth, and double-ridged magic tees only have about an octave bandwidth, which is short of a 2 to 7.5 GHz ECM requirement. With two-way combining, four stages of combining are needed to achieve the desired power. A typical double-ridge magic tee has 0.3 dB of loss at these frequencies, so the total loss through the combiner would be 1.2 dB. Combining the 30 percent efficient GaN PA MMICs shown in Figure 1 through a 16-way magic tee, the efficiency of the combined output would be about 23 percent and deliver approximately 95 W output at 6 GHz at 85°C. However, the typical double-ridge magic tee network only works over an octave of bandwidth (e.g., from 2 to 4 GHz).



▲ Fig. 2 Spatium amplifier structure.



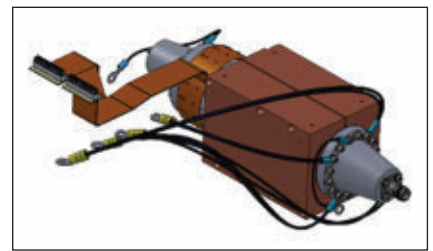
▲ Fig. 3 Measured output power of the Spatium amplifier that combines 16 QPA1003P MMICs.

SPATIAL COMBINING

Spatial combining techniques are potentially lower loss than circuit-based techniques. Spatium® is Qorvo's patented coaxial spatial method of power combining (see **Figure 2**). It uses broadband antipodal finline antennas as the launch to and from the coaxial mode, splitting into multiple microstrip circuits, then combining the power from those circuits after amplification with a power MMIC. It uniquely enables broadband, efficient and compact combining of multiple power MMICs in a single combining step, with free space as the combining medium. A typical Spatium design combines 16 devices in one step, with a combining loss of only 0.5 dB.

Combining 16 of the MMICs from Figure 1 yields an SSPA efficiency of 27 percent, compared to 30 percent for each MMIC. This is a significant difference compared to the 23 percent achieved with magic tee combining. The increased combining efficiency enables higher output power from a given prime power as well as reducing the heat dissipation.

An actual Spatium amplifier was designed that combined 16 radial blades



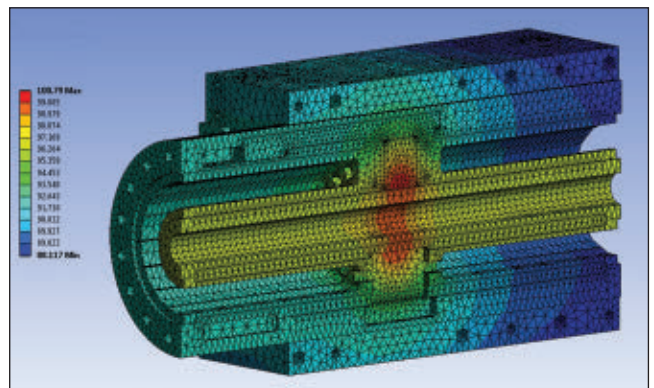
▲ Fig. 4 Spatium amplifier with clamp to conduct heat from the MMIC PAs.

with the Qorvo GaN MMIC PA on each blade. **Figure 3** shows the measured output power versus clamp surface temperature; the baseplate temperature below the MMIC is approximately 12°C hotter than the clamp temperature, so the maximum baseplate temperature is 85°C. This unit achieves greater than 100 W from 2 to 7.5 GHz and an average efficiency of 25 percent.

THERMAL DESIGN

Thermal management is one of the design challenges when using a solid-state amplifier in an ECM transmitter. In a typical application, the outer surface of the clamp around the Spatium SSPA is conduction cooled on one or more sides (see **Figure 4**). For some systems, a liquid coolant may be available, for others a heat sink with fans. The clamp is designed to make contact with all of the blades in the Spatium and provide a conduction path to a cold plate or heat sink. Spatium blades and clamps can be made of different metals, including aluminum and copper. Size, weight and power trade-offs determine the appropriate material set for a given application.

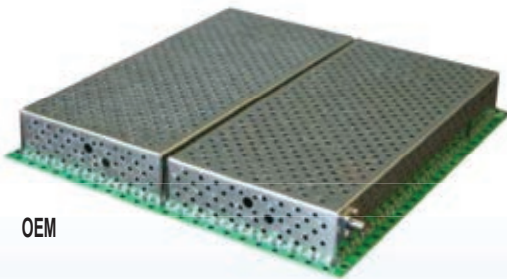
The thermal resistance from the back of the MMICs to the mounting plates can be calculated and used to derive the backside MMIC temperature. From the thermal resistance of



▲ Fig. 5 Thermal simulation of the Spatium SSPA, showing cross section of the construction.



Rackmount



OEM



Bench-Top

Multi Channel Phase Coherent RF/Microwave Signal Generators and Synthesizers. Best in class performance, size, cost, and reliability

- Extremely low phase noise performance
- Frequency range from 10Mhz to 20GHz
- Very fast switching speed to 10us
- Multi-Channel phase coherent system from 2 to 8 Independent outputs
- Very small form factor at 1U 19" rackmount
- Rich library of API's
- OEM options for direct integration



Berkeley Nucleonics Corp., 2955 Kerner Blvd. San Rafael CA 94901

Email RFsales@berkeleynucleonics.com, Call 800-234-7858 or LIVE-Chat @ www.berkeleynucleonics.com

TABLE 1

DEMONSTRATED SPATIUM SSPA PERFORMANCE

Frequency Range (GHz)	Nominal Output Power (W)	Nominal Power-Added Efficiency
2 to 6	300	30%
2 to 8	150	25%
2 to 18	60	15%

the MMIC and package, the junction temperature of the MMIC can be calculated and, from that, the reliability of the SSPA can be estimated. **Figure 5** is a thermal simulation of the SSPA shown in Figure 4, with the

MMICs operating at saturated output power and the worst-case efficiency within the frequency band (i.e., 25 W dissipated per MMIC). The thermal model shows an approximate 12°C rise from the coolest spot of the outside surface of the clamp to the backside of the packaged MMIC and an additional 164°C temperature rise from the back of the package to the junction of the output transistor, assuming 6.56°C/W thermal resistance. The junction temperature of the MMIC is estimated to be 247°C with the surface of the clamp held to 71°C. At 247°C junction temperature, the MTBF of the MMIC is some 1.2 million hours.

The MTBF of the overall Spatium module will be the MTBF of the individual MMICs divided by the number of MMICs: 75,000 hours. The calculation deems a single MMIC failure to be a failure of the entire amplifier assembly—a worst-case assumption since the Spatium amplifier will gracefully degrade with the failure of any individual MMIC (i.e., approximately 0.7 dB reduction in output power per MMIC failure).

For a TWT, MIL-HDBK-217F Notice 2 provides the following formula to calculate the MTBF in a ground fixed environment:

$$MTBF = \frac{10^6}{16.5 \times (1.00001)^P \times (1.1)^F} \quad (1)$$

where P is the rated power in watts, from 1 mW to 40 kW, and F is the operating frequency in GHz, from 100 MHz to 18 GHz. Utilizing this formula, a TWT with an output power of 150 W at a frequency of 7.5 GHz has an MTBF of 29,609 hours. This is 2.5x lower than that of the comparable solid-state Spatium power amplifier module under similar environmental conditions.

SUMMARY

For the first time, GaN MMICs and broadband spatial combining techniques such as Spatium allow ECM system designers to use reliable, solid-state amplifiers instead of TWTAs. The ability to deliver hundreds of watts over broad bandwidths, while staying within the prime power available from the platform and dissipating the heat to ensure reliable operation, opens up new system opportunities for a solid-state ECM transmitter. **Table 1** shows the frequency, power and efficiency achieved with three recent Spatium amplifiers. The size and weight of these SSPAs are less than the boxes previously occupied by their respective TWTAs. ■



Miniature Portable Rugged PC-based Instrument with 4 DDC, 2 DUC, Spectrum Analyzer & Xilinx Kintex-7 FPGA

Arbitrary Waveform Generator/Player • Digital Receiver • Surveillance

Features

- Two 14-bit, 1 GHz ADCs; analog bandwidth 1 GHz (AC Coupled)
- Two 16-bit, 1 GHz DACs; analog bandwidth 1 GHz (AC Coupled)

Digital Down-Converter (DDC)

- Four independent 16-bit DDC channels
- Programmable tuner: 1 – 1000 MHz; resolution 0.2328 Hz

Digital Up-Converter (DUC)

- Two independent 16-bit DUC channels
- Programmable tuner: 1 – 1000 MHz; res. 0.2328 Hz

Real-Time Spectrum Analyzer

- FFT length: 32,768; 50% overlapped
- Real-time bandwidth: 100 MHz



DOWNLOAD DATASHEETS NOW!

805.383.8994 phone
www.innovative-dsp.com





Microwave Absorbers For Cavity Suppression and Free Space Applications

Product Lines

C-RAM® RF/Microwave Absorbers

Featuring flat sheet and pyramidal, high power honeycomb material

C-RAM® Anechoic & Free-Space materials

C-STOCK® Low Loss Dielectric Materials

Turn-key Anechoic & EMC Chamber Design and Installation

Custom Formulations and Custom Fabrication Available

Visit us at EDI CON 2017 – Boston, MA – Booth 226

Cuming Microwave



Cuming Microwave is an ISO 9001:2008 manufacturer of materials that absorb EMI/RFI between 10 MHz – 100 GHz



5 W, Ku-Band GaAs T/R MMIC with Switch Topology

Ye Yuan, Yong Fan, Ziqiang Yang and Haodong Lin

University of Electronic Science and Technology of China

A power amplifier (PA), low noise amplifier (LNA) and two switches are integrated in a single GaAs PHEMT Ku-Band transceiver (T/R) MMIC, which can be used for phased array systems. A novel topology increases the power handling capability of the switch without increasing insertion loss. High saturated power (greater than 5 W) and very low noise figure (less than 3.3 dB) are achieved in the frequency range of 14.5 to 17 GHz. The size of the MMIC is 3 mm × 4 mm.



market growth in active phased array (AESA) radar has created a large need for multi-function T/R chips.¹⁻⁴ T/R chips based on the Si CMOS

process currently enable higher integration levels

than counterparts based on the GaAs PHEMT process. However, RF performance of Si-based chips, such as output power, power-added efficiency (PAE) and noise figure, is poorer than that of GaAs-based chips. Van Vliet and De Boer³ developed a GaAs T/R chip containing a driver amplifier, LNA, phase shifter and attenuator; however, its power and noise figure are not given. A T/R chip with wide bandwidth was presented by Bettidi et al.,⁴ but its output power was only 20 dBm. The limited output power was due mainly to low P1dB performance of the traditional GaAs FET switch.⁵⁻⁸

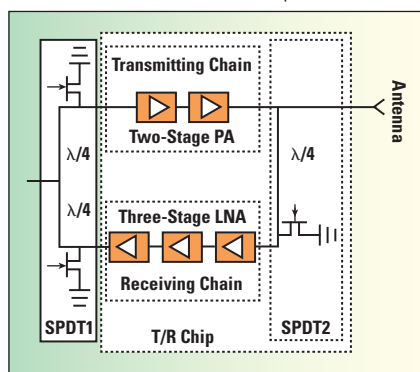
To address these problems, a T/R chip with high output power and low noise figure is presented here. The switch is based on a novel topology, which increases its power handling capability without increasing insertion loss. Measurement results show that saturated power (P_{sat}) and gain of the transmitting branch of the T/R chip are more than 5 W and

15 dB, respectively, while noise figure and gain of the receiving branch are better than 3.3 dB and 18 dB, respectively, in the frequency range from 14.5 to 17 GHz.

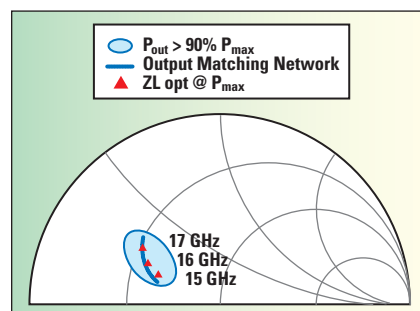
CIRCUIT CONFIGURATION AND DESIGN

The T/R chip architecture contains a PA, LNA and two T/R switches (see **Figure 1**). The PA has two amplifier stages: 16 transistors with 8 × 125 μm gate width and eight transistors with 6 × 125 μm gate width at the output and input stages, respectively. Good input return loss is obtained by tuning the input matching network. Sufficient output power to drive the output stage is realized by proper design of the interstage matching network. Maximum output power is achieved through matching circuit design based on load-pull simulation using the nonlinear model of the active device. **Figure 2** shows the optimum load impedance of the output stage transistor corresponding to maximum saturated power in the range from 15 to 17 GHz, along with the output matching network frequency response; their close correspondence implies that a wide power matching bandwidth can be achieved.

The LNA contains three stages; the gate width of the transistor in each stage is 2 × 25 μm. Bias voltages are selected with the aid of Agilent ADS software to ensure that the active devices operate in their low noise regions; the gate-source voltages (V_{gs}) and drain-source voltages (V_{ds}) are set at -1 V and +3 V, respectively. The input matching network is designed to achieve a low noise figure, while interstage



▲ Fig. 1 T/R chip block diagram.



▲ Fig. 2 Output matching network frequency response.

Innovation That's Scalable.



Mercury offers a portfolio of RF and Microwave components that enable solutions at the block diagram level including:

- Amplifiers
- Detectors
- Ferrites
- Mixers
- Multipliers
- Noise products
- Switches
- VCOs



Visit mrcy.com/rfm and download our short-form catalog.



These components are designed to work together thus delivering lower technology risk. And all are manufactured in our scalable, world-class Advanced Microelectronics Centers.

and output matching networks are designed for high gain.

At the antenna side of the circuit, a novel topology single pole double throw switch (SPDT2 in Figure 1) selects the transmit or receive branch. At the input, an off-chip SPDT switch (SPDT1) with traditional parallel topology selects transmit or receive. SPDT2 is the key device, consisting of a $\lambda/4$ transmission line and FET with a gate width of $4 \times 100 \mu\text{m}$ (see **Figure 3**). When transmitting, the FET is turned on and is equivalent to a small shunt resistor (R_{on}), as shown in Figure 3a. RF power leaks to the FET through the $\lambda/4$ transmission line. If the voltage magnitude of the leaked RF signal is greater than the knee voltage of the FET, the switch is compressed. In this design, the leaked RF power at the FET can be decreased by tuning the characteristic impedance (Z_r) of the $\lambda/4$ transmission line to increase the power handling capability of SPDT2, enabling increased output power from the T/R MMIC. An optimized Z_r of 112Ω is chosen. The shunt capacitor (C_1) is also designed to tune the impedance at point B. When receiving, the FET is turned off and is equivalent to a shunt capacitance

(C_{off}), as shown in Figure 3b. The active devices in the last stage of the PA are equivalent to a parallel resistor and capacitor (R_{ds} and C_{ds}). All of these components are used as part of the input matching circuit of the LNA. A low LNA noise figure is obtained by tuning transmission lines TL_1 and TL_2 .

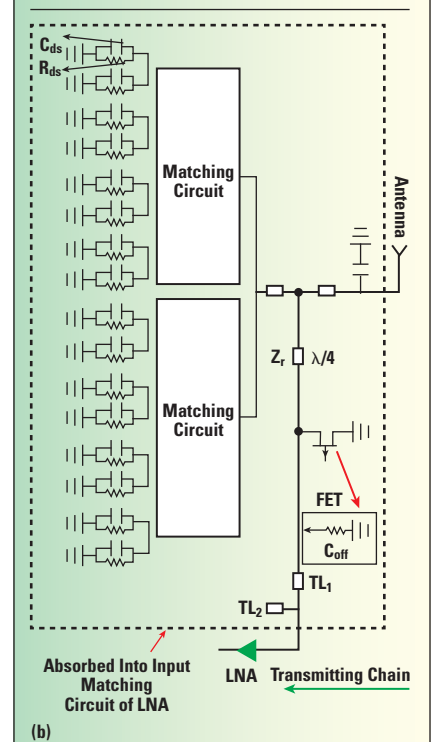
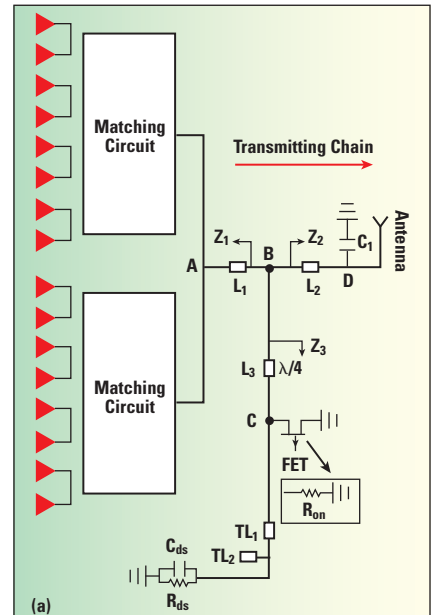
This design decreases the insertion loss of the output matching network due to the shorter transmission line. By optimizing the impedance at point B, the power handling capability of the switch can be improved without widening the gate width of the FET. This is explained as follows: Assume that the characteristic impedances of stubs L_1 and L_2 are both Z_t . The characteristic impedance of the $\lambda/4$ transmission line (L_3) at the receiving branch is Z_r , and the on resistance of the switching FET is R_{on} . In the transmitting branch, the impedance Z_1 at point B is given by:

$$Z_1 = Z_t \frac{Z_A + jZ_t \tan \beta L_1}{Z_t + jZ_A \tan \beta L_1} \quad (1)$$

In the receiving branch, the impedance Z_3 is given by:

$$Z_3 = \frac{Z_r^2}{R_{\text{on}}} \quad (2)$$

Because R_{on} is very small, Z_3 is a very high impedance compared to Z_1 . In the design, therefore, it is just necessary to ensure that impedances Z_1 and Z_2 are conjugately matched:



▲ Fig. 3 Equivalent circuit of the SPDT switch, LNA input stage and PA output stage when transmitting (a) and receiving (b).

Need Space and Mil-Qualified Parts?

Search No Further. Weinschel Associates (WA) delivers solutions for your toughest requirements - on-time and in compliance. Look to WA to launch your next program with Space and MIL-Qualified RF and Microwave Components.

Space and Mil-Qualified Components

- Attenuators
- Terminations
- Dividers
- DC Blocks
- Tuners
- High Performance Designs
- Power Handling to Design Specifications
- Frequency Range: DC to 40 GHz



Visit our new website with interactive catalog and online RFQ!

www.WeinschelAssociates.com

19212 Orbit Drive
Gaithersburg, MD 20879
Voice: 301.963.4630
Fax: 301.963.8640
RF@WeinschelAssociates.com





Planar Monolithics Industries, Inc.

Ultra Broadband & mmW State-Of-The-Art Digital / Programmable Attenuators

PMI offers the highest quality digitally controlled programmable attenuators for industrial and military applications. Choice of attenuation ranges with resolution as low as 0.04 dB and operating frequency ranges up to 40 GHz available.

Model: DTA-100M40G-30-CD-1 & DTA-14G40G-32-CD-2

<http://www.pmi-rf.com/Products/attenuators/DTA-100M40G-30-CD-1.htm>

<http://www.pmi-rf.com/Products/attenuators/DTA-14G40G-32-CD-2.htm>



Package Size: 2.0" x 1.8" x 0.5"
DC Voltage: +15 VDC @ 38 mA
Connectors: 2.92mm (F) &
15 Pin Micro-D-Female
Switching Speed:
Measured 0.25 μ s



Package Size: 2.0" x 1.8" x 0.5"
DC Voltage: +15 VDC @ 38 mA
Connectors: 2.92mm (F) &
15 Pin Micro-D-Female
Switching Speed:
Measured 0.266 μ s

Specifications	DTA-100M40G-30-CD-1	DTA-14G40G-32-CD-2
Frequency	0.1 to 40.0 GHz	14.0 to 40.0 GHz
Attenuation Range	30 dB	32 dB
Insertion Loss	5.0 dB Typ. (to 20 GHz) - Measured 4.9 dB 8.0 dB Typ. (to 40 GHz) - Measured 7.1 dB	9.0 dB Typ. - Measured 8.62 dB
VSWR	2.5:1 Max. - Measured 2.49:1	2.0:1 Typ. - Measured 1.75:1
Attenuation Flatness	± 1.5 dB Typ. Measured: @ 10 dB: ± 0.95 dB @ 20 dB: ± 1.47 dB @ 30 dB: ± 2.13 dB	± 1.5 dB Typ. Measured: @ 8 dB: ± 0.61 dB @ 16 dB: ± 1.01 dB @ 32 dB: ± 1.77 dB
Attenuation Accuracy	± 2.5 dB Typ. Measured: 0 to 10 dB: ± 0.59 dB 10 to 20 dB: ± 0.09 dB 20 to 30 dB: ± 0.20 dB	± 2.0 dB Typ. Measured: 0 to 8 dB: ± 0.28 dB 8 to 16 dB: ± 0.05 dB 16 to 32 dB: ± 0.15 dB
Operating Temperature	-50 $^{\circ}$ C to +85 $^{\circ}$ C	-40 $^{\circ}$ C to +85 $^{\circ}$ C

Model: DTA-18G40G-30-CD-1 & DTA-18G40G-50-CD-1

<http://www.pmi-rf.com/Products/attenuators/DTA-18G40G-30-CD-1.htm>

<http://www.pmi-rf.com/Products/attenuators/DTA-18G40G-50-CD-1.htm>



Package Size: 2.0" x 1.8" x 0.5"
DC Voltage: +15 VDC @ 38 mA
Connectors: 2.92mm (F) &
15 Pin Micro-D-Female
Switching Speed:
Measured 0.30 μ s



Package Size: 2.0" x 1.8" x 0.5"
DC Voltage: +15 VDC @ 38 mA
Connectors: 2.92mm (F) &
15 Pin Micro-D-Female
Switching Speed:
Measured 0.12 μ s

Specifications	DTA-18G40G-30-CD-1	DTA-18G40G-50-CD-1
Frequency	18.0 to 40.0 GHz	18.0 to 40.0 GHz
Attenuation Range	30 dB	50 dB
Insertion Loss	6.0 dB Typ. - Measured 6.1 dB	8.5 dB Typ. - Measured 10.4 dB
VSWR	2.5:1 Max. - Measured 2.11:1	2.5:1 Typ. - Measured 2.27:1
Attenuation Flatness	± 1.5 dB Typ Measured: @ 10 dB: ± 0.98 dB @ 20 dB: ± 1.27 dB @ 30 dB: ± 1.93 dB	± 1.5 dB Typ Measured: @ 16 dB: ± 2.10 dB @ 32 dB: ± 2.10 dB @ 50 dB: ± 3.88 dB
Attenuation Accuracy	± 2.0 dB Typ. Measured: 0 to 10 dB: ± 0.39 dB 10 to 20 dB: ± 0.54 dB 20 to 30 dB: ± 0.76 dB	± 2.0 dB Typ. Measured: 0 to 16 dB: ± 0.14 dB 16 to 32 dB: ± 0.18 dB 32 to 50 dB: ± 0.48 dB
Operating Temperature	-40 $^{\circ}$ C to +85 $^{\circ}$ C	-40 $^{\circ}$ C to +85 $^{\circ}$ C

Amplifiers – Solid State

Attenuators – Variable/
Programmable

Couplers (Quadrature,
180 $^{\circ}$ & Directional)

Detectors – RF/Microwave

DLVAs, ERDLVAs
& SDLVAs

DTOs, VCOs, PLO, DROs,
& Frequency Synthesizers

Filters & Switched
Filter Banks

Form, Fit, Functional
Products & Services

Frequency Discriminators
& IFMs

Integrated MIC/MMIC
Assemblies (IMAs)

IQ Vector Modulators

Limiters – RF/Microwave

Log Amplifiers

Millimeter Wave
Components
(Up to 50 GHz)

Miscellaneous Products

Multifunction Integrated
Assemblies (MIAs)

Phase Shifters & Bi-Phase
Modulators

Power Dividers/Combiners
(Passive & Active)

Pulse Modulators (SPST)

Rack & Chassis Mount
Products

Receiver Front Ends
& Transceivers

SDLVAs, ERDLVAs
& DLVAs

Single Side Band
Modulators

SMT & QFN Products

Switch Matrices

Switched Filter Banks

Switches – Solid State

Systems – Fly Eye Radars

Threshold Detectors

USB Products



IEEE MTT-S International Microwave Symposium
Hawaii Convention Center Honolulu, Hawaii
June 4-9, 2017
Booth #701
ims2017.org



52nd International Paris Air Show
Le Bourget Parc des Expositions,
a few kilometers North of Paris
June 19 - 25, 2017
Hall 3/A38 (Maryland Pavilion)
www.siae.fr/en

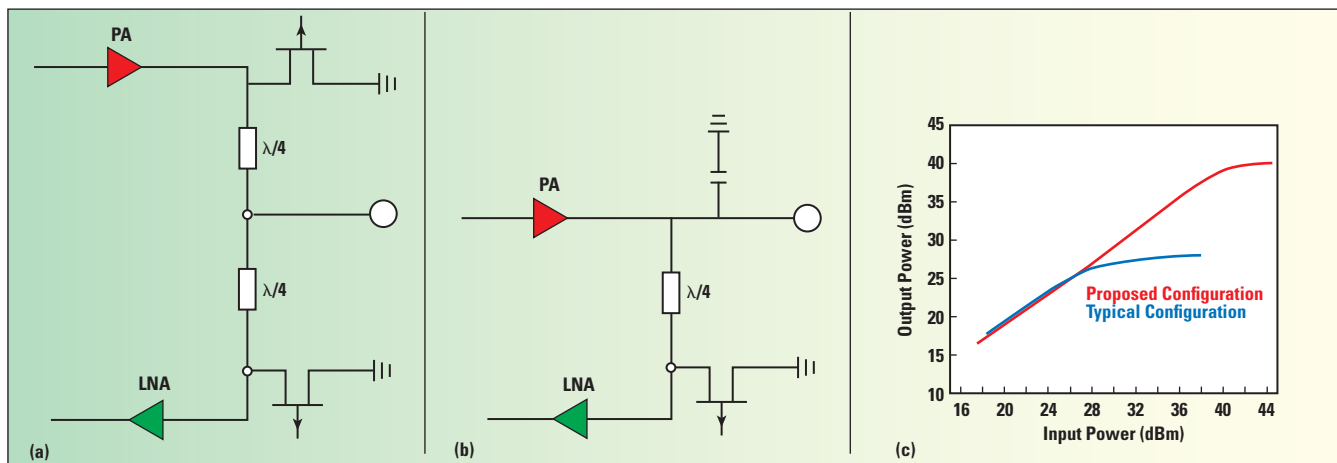
West Coast Operation:

4921 Robert J. Mathews Pkwy, Suite 1
El Dorado Hills, CA 95762 USA
Tel: 916-542-1401, Fax: 916-265-2597

East Coast Operation:

7311-F Grove Road
Frederick, MD 21704 USA
Tel: 301-662-5019, Fax: 301-662-1731

sales@pmi-rf.com • www.pmi-rf.com
ISO9001-2008 REGISTERED



▲ Fig. 4 Typical SPDT switch configuration (a), new SPDT switch configuration (b), simulated output power of the two configurations (c).

$$Z_1 = Z_2^* \quad (3)$$

The voltage magnitude at point D of the RF signal in the transmitting branch is given by Equation 4:

$$V_D = \sqrt{100 \times P_A} \times \frac{|Z_3|}{|Z_2| + |Z_3|} \quad (4)$$

where P_A is the output power at point A. The voltage magnitude of the leaked RF signal at the switching FET in the receiving branch is given by Equation 5.

$$V_C = \sqrt{100 \times P_A} \times \frac{|Z_2|}{|Z_2| + |Z_3|} = \quad (5)$$

$$\begin{aligned} & \sqrt{100 \times P_A} \times \frac{R_{on}|Z_1|}{R_{on}|Z_1| + |Z_r^2|} \\ &= \sqrt{100 \times P_A} \times \\ & \frac{R_{on} \left| Z_t \frac{Z_A + jZ_t \tan \beta L_1}{Z_t + jZ_A \tan \beta L_1} \right|}{R_{on} \left| Z_t \frac{Z_A + jZ_t \tan \beta L_1}{Z_t + jZ_A \tan \beta L_1} \right| + |Z_r^2|} \end{aligned}$$

To keep the switch operating in the linear region, $V_C \leq V_{knee}$, where V_{knee} is the knee voltage of the switching FET. Equation 5 shows that for a given P_A , V_C is affected mainly by three parameters (R_{on} , Z_1 and Z_r). R_{on} is determined

by the gate width of the switching FET, Z_1 is determined by the output matching network design and Z_r is determined by the width of transmission line L_3 in the receiving branch.

Equation 5 also shows that V_C is proportional to P_A , R_{on} and Z_1 and is inversely proportional to Z_r . For a given P_A , the switch can be operated without being compressed by carefully choosing Z_1 and Z_r . The shunt capacitor C_1 is optimized to decrease the modulus of Z_1 . The gate width of the FET is chosen to be $2 \times 100 \mu m$. The knee voltage of the 0.15 μm PHEMT process is about 0.9V, which means that if the RF leakage voltage at the drain port of the FET is less than 0.9 V, the switch will exhibit good linearity.

To test the validity of this method, the power handling capability of this

MILLIMETER WAVE AMPLIFIERS POWERING THE FUTURE

L3 Electron Devices now offers a full range of TWTs, MPMs, TWTAs and other vacuum electronic devices for defense, space and commercial applications. With design-to-production capability, our industry-leading portfolio of miniature, lightweight, high-efficiency microwave and millimeter wave sources and amplifiers provides solutions for your satellite, airborne, naval or ground-based requirements.

To learn more about how L3 can help you power the future, please go to L3T.com/EDD.



Electron Devices

[f in L3T.com](https://www.l3.com)



Performance matters!

Today's security and military missions require a ECM-asset that is capable of providing person protection in international scenarios that range from operations against symmetric and asymmetric opponents. Therefore, it is crucial to control the opponent's communication in a wide frequency range and to protect convoys against the hazardous Remote Controlled Improvised Explosive Devices (RC-IEDs) in a flexible and efficient way.

HUBER+SUHNER's excellence in connectivity solutions provides a complete offering that meets both current and future performance requirements. Our vast experience in cable assemblies, connectors and antenna designs are key solutions that are suitable for toughest environments.

> defense.hubersuhner.com

HUBER+SUHNER AG 9100 Herisau/Switzerland
HUBER+SUHNER INC. Charlotte NC 28273/USA

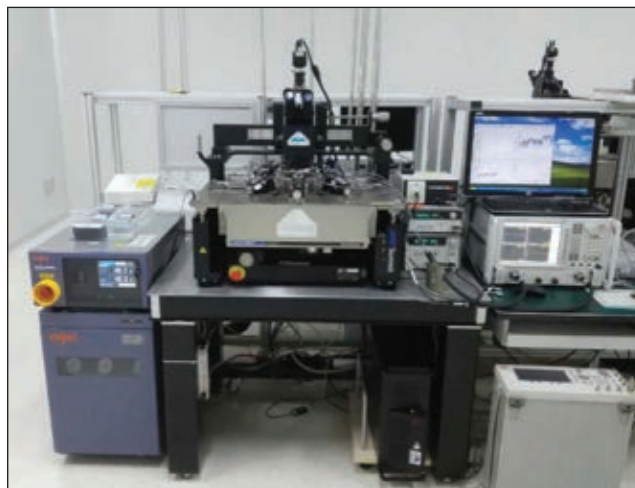


switch design is simulated in Keysight ADS and compared to a typical SPDT switch. In this topology, the switch and output matching network of the PA are designed together. Unlike a typi-

cal design (see **Figure 4a**), there is no $\lambda/4$ transmission line and shunt FET placed at the output of the transmitting branch (see **Figure 4b**). **Figure 4c** shows that the 1 dB compression point of the new switch is 39 dBm compared to 25.5 dBm for the typical parallel configuration, demonstrating a significant improvement. The gate widths of the FETs in the two designs are the same.



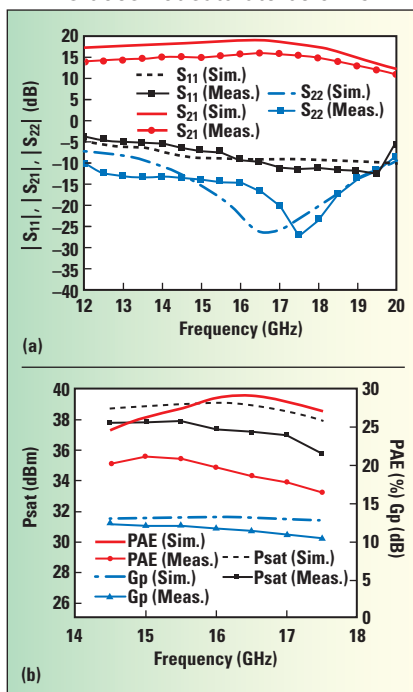
▲ Fig. 5 GaAs T/R chip.



▲ Fig. 6 Measurement setup.

MEASURED RESULTS

The Ku-Band GaAs T/R MMIC is fabricated using a 0.25 μm GaAs PHEMT process and measures 3 mm \times 4 mm (see **Figure 5**). The performance of the design is measured on wafer with a Cascade M150 probe station and a Cascade ACP40-A Ku-Band GSG probe under pulsed conditions, with 0.2 ms pulse width and 10 percent duty cycle (see **Figure 6**). A vector network analyzer is used to measure the small-signal response and a signal generator and microwave power meter are used for the large-signal measurements. **Figure 7** shows the simulated and measured small-signal and large-signal responses of the transmit path. Measured small-signal gain, large-signal gain, Psat and PAE are better than 15 dB, 10 dB, 37 dBm and 17 percent, respectively. The measured small-signal gain and noise figure of the receiving branch are greater than 18 dB and less than 3.3 dB, respectively (see **Figure 8**). **Figure 9** confirms that the T/R MMIC does not saturate below 5 W.



▲ Fig. 7 Small-signal (a) and large-signal (b) performance of the transmit path.

QRb SYNC

10 MHz or 100 MHz GPS/GNSS-DISCIPLINED
LOW PHASE NOISE OCMO+Rb CLOCK

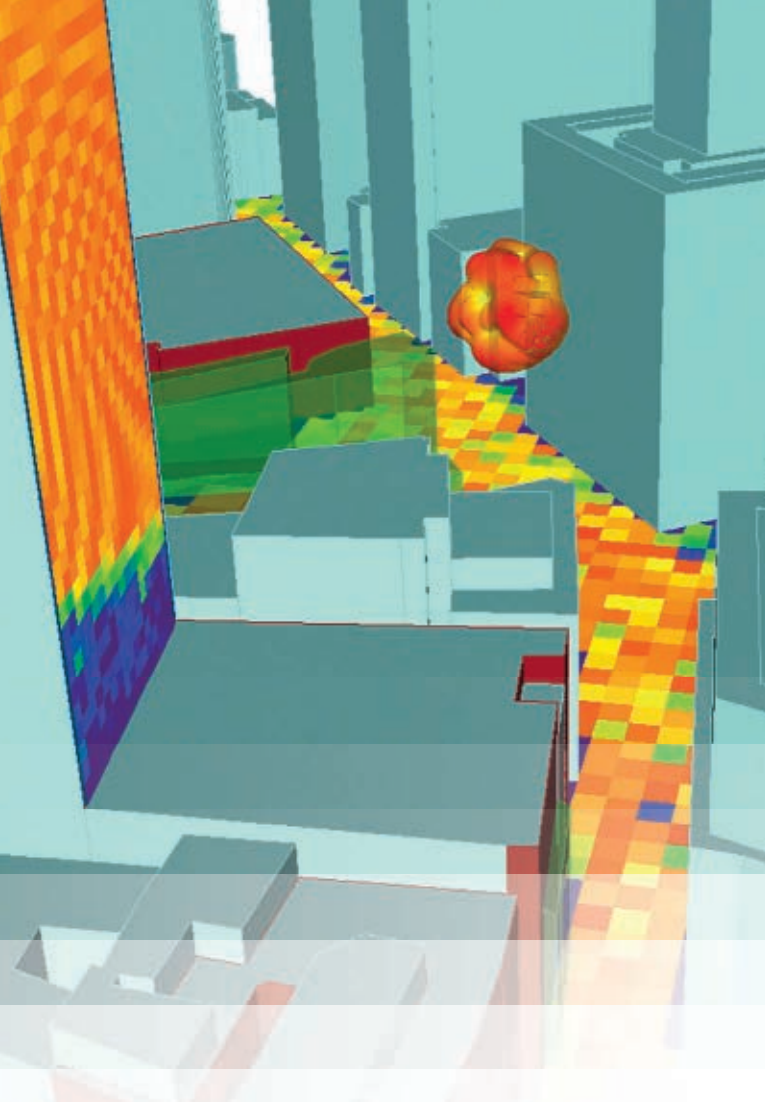


- ULN Oscillators and Disciplined Rb Combined
- Exceptional Phase Noise to -180 dBc/Hz Noise Floor
- Excellent Stability $\leq 5\text{E-11/month}$; $\leq 1\text{E-10}$, -30 to +60°C
- Low G-Sensitivity to 1E-10/g
- Internal Vibration Isolation Options to 5E-12/g @ 2k Offset
- Auto-Adaptive Smarttiming+ SAASM/Non-SAASM GPS/GNSS Disciplining Technology @ 1 ns Resolution
- 6 x 5.7 x 1.1", Typical; 6 x 5.7 x 1.4" with Internal Isolation

"Quietly the Best"

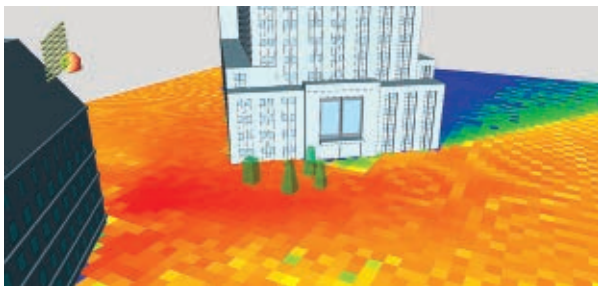


Wenzel Associates, Inc.
2215 Kramer Lane, Austin, Texas 78758
512-835-2038 • sales@wenzel.com
www.wenzel.com



Wireless InSite® for 5G MIMO Simulations

Remcom's unique ray tracing capability simulates the detailed multipath of large MIMO arrays while overcoming the limitations of traditional ray tracing methods.



Analyze massive MIMO coverage using highly detailed building models, including windows, frames, and foliage.

- Simulate MIMO antennas for applications up to 100 GHz
- Full 3D scenario modeling with control over path interactions
- Includes diffuse scattering effects
- Efficiently simulate massive MIMO arrays
- Utilizes GPU and MPI to minimize runtime
- Outputs include: received power, H-matrix, complex impulse response and more
- Easily post-process outputs for beamforming

Learn more at | www.remcom.com/5g-mimo >>>

REMC  M®



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

CONCLUSION

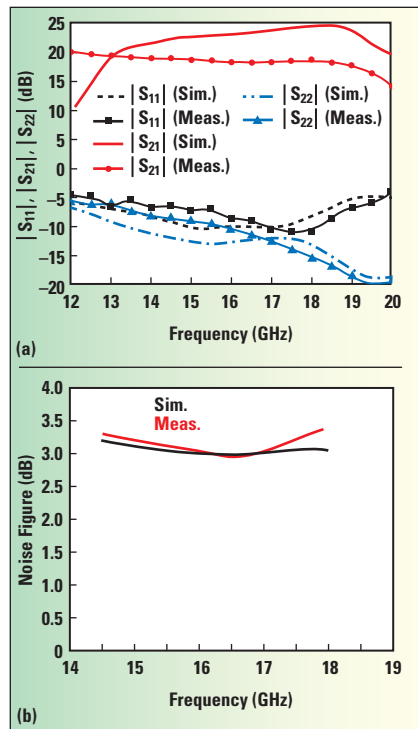
A Ku-Band T/R MMIC, proposed for use in AESA systems, employs a novel SPDT switch with improved power handling and low insertion loss to realize higher transmitter power and lower receiver noise figure.

ACKNOWLEDGMENT

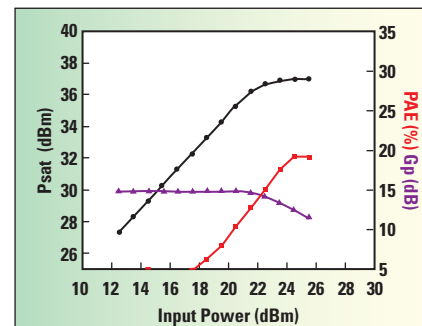
T/R chip measurement was supported by RML Technology Company Ltd. ■

References

1. H. Wang, K. Y. Lin, Z. M. Tsai, L. H. Lu, H. C. Lu, C. H. Wang, T. H. Tsai, T. W. Huang and Y. C. Lin, "MMICs in the Millimeter-Wave Regime," *IEEE Microwave Magazine*, Vol. 10, No. 1, January 2009, pp. 99–117.
2. S. Sim, L. Jeon and J. G. Kim, "A Compact X-Band Bi-Directional Phased-Array TR Chipset in 0.13 CMOS Technology," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 61, No. 1, January 2013, pp. 562–569.
3. F. E. Van Vliet and A. De Boer, "Fully-Integrated



▲ Fig. 8 Small-signal (a) and noise figure (b) of the receive path.



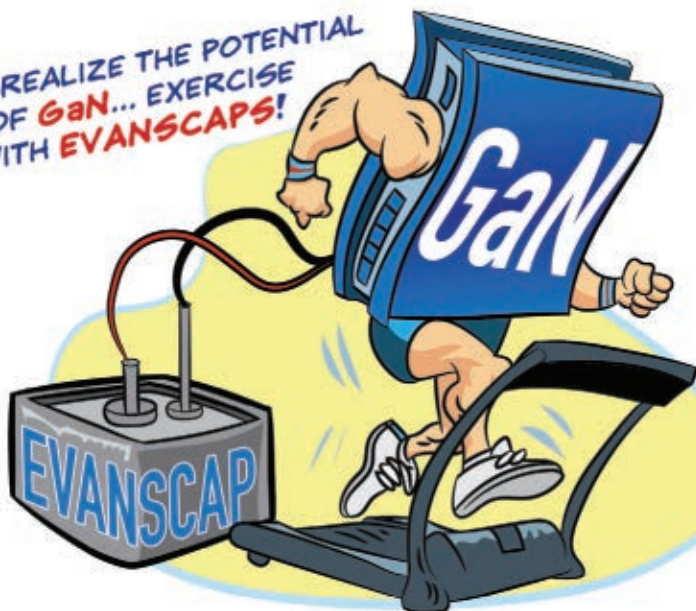
▲ Fig. 9 Large-signal performance of the T/R chip.

Core Chip for X-Band Phased Array T/R Modules," *IEEE International Microwave Symposium*, June 2004, pp. 1753–1756.

4. A. Bettidi, F. Carosi, D. Corsaro, L. Marescialli, A. Nanni and P. Romanini, "MMIC Chipset for Wideband Multifunction T/R Module," *IEEE International Microwave Symposium*, June 2011.
5. H. Mizutani and Y. Takayama, "DC-110 GHz MMIC Traveling-Wave Switch," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 48, No. 5, August 2000, pp. 840–845.
6. R. Sanusi, M. A. Ismail, K. Norhapizin, A. Rahim, A. Marzuki and M. R. Yahya, "15 GHz SPDT Switch Design Using 0.15 μ m GaAs Technology for Microwave Applications," *International Conference on Electronic Design*, December 2008.
7. "TGS2306 Data Sheet," *TriQuint*, www.triquint.com/search?s=TGS2306.
8. R. Sanusi, M. A. Ismail, K. Norhapizin, A. Marzuki and M. R. Yahya, "30 GHz SPDT Switch Design using 0.15 μ m GaAs Technology for Microwave Applications," *International Conference on Semiconductor Electronics*, Johor Bahru, November 2008, pp. 130–133.

EVANSCAPS

REALIZE THE POTENTIAL
OF GaN... EXERCISE
WITH EVANSCAPS!



Advanced Capacitors for Demanding Applications

High Power • 10V to 125V • Low ESR • >100 Amp Discharge • Hermetic
Unlimited Cycle Life • Unlimited Shelf Life • Low Weight / Volume
High Shock and Vibe • >5 Million Hour MTBF • -55°C to 125°C Operation



TDD4080123
80V • 12,000 μ F • 0.015 Ω • <25 cc

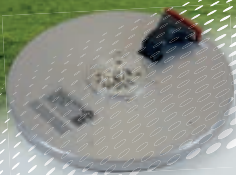


EVANS
CAPACITOR
Company

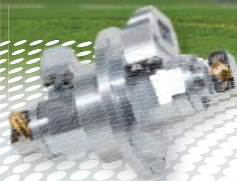


401-435-3555 • info@evanscap.com • www.evanscap.com

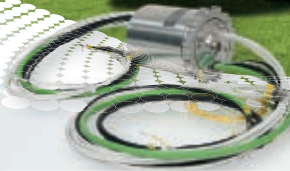
Superior Hybrid Rotary Joints and Slip Rings



Slim Sized
Rotary Joint



Dual Channel
WG Coax



Fiber Optic Rotary Joint
and Slip Ring



Hybrid Rotary Joint

- Defence Applications – Air, Sea, Land
- Civil Applications – Automotive, Satellite Tracking
- Rotating Camera Applications
- Space Applications
- Air Traffic Control Radars
- Contactless Power, Contactless Data Signals
- Fiber Optic – Single & Multi Channel (up to 52 channels)
- Media Joints and Slip Rings

HIGH FREQUENCY PERFORMANCE WORLDWIDE

SPINNER designs and builds cutting-edge radio frequency systems, setting performance and longevity standards for others to follow. Many of today's mainstream products are rooted in SPINNER inventions. Headquartered in Munich, Germany, the global front-runner in RF components remains the first choice in simple-yet-smart RF solutions.

SPINNER GmbH | Germany | info@spinner-group.com | www.spinner-group.com



Optimizing ASIC Designs for SWaP

GLOBALFOUNDRIES



Today's aerospace and defense (A&D) systems rely on semiconductors that address mission-critical availability, performance, processing and security requirements, while balancing demands for continuous size, weight and power (SWaP) reduction in each new generation of hardware. The GLOBALFOUNDRIES® (GF) FX-14™ ASIC design system merges advanced semiconductor technology with a unique combination of ASIC development methodology, tools, services and GF yield ownership to help A&D companies meet these demands and quickly bring ASICs from concept to production.

FX-14 is designed for next-generation communications and data center hardware, including digital baseband processing solutions for A&D command and control, radar and global positioning system applications. To meet the requirements of these applications, where both SWaP and frequency are crucial, FX-14 utilizes GF's commercial 14 nm low power FinFET CMOS process technology, 14LPP.

SWaP-OPTIMIZED IP AND FEATURES

The FX-14 design system includes a library of silicon-proven IP:

- Multiple threshold voltage (Vt) FET options for managing power and performance
- Standard cell combinatorial gates, flip-flops and latches

- Phase-locked loops
- 64-bit and 32-bit ARM® processors
- A memory compiler that provides multiple embedded memory options (register arrays, register files, ROM, SRAMs and TCAM)
- An array of high speed SerDes (HSS) cores, including an advanced 56G offering.

The inherent advantages of the 14LPP process technology and FinFET architecture enable significant SWaP benefits (see **Figure 1**). In addition, the FX-14 library features SWaP-centric elements that enable extensive design flexibility in optimizing solutions for the A&D industry. The embedded memory compiler takes advantage of multiple memory bit cell designs to meet design operational (row address/bit word, single/multiport), density (die area/size) and frequency requirements. An exceptionally small memory cell can be used to optimize memory density for applications requiring minimal die area, while a performance-tuned memory cell can help maximize memory performance (frequency) for performance-driven applications.

The variety of I/Os available with FX-14 provides additional SWaP benefits, useful for reducing ASIC I/O count, die size and power. I/O choices include:

- Three-state bidirectional CMOS I/Os
- Low voltage differential signaling (LVDS) I/Os
- Multiple HSS cores for both short and long reach communication

PROVEN RELIABILITY. TRUSTED PERFORMANCE.

Thick & Thin Film Resistor Products

- Faithful scheduled deliveries under 2 weeks
- Values from 0.1 Ohm to 100G Ohm
- Abs. tolerance to $\pm 0.005\%$, matching to $\pm 0.0025\%$
- TCR's to $\pm 2\text{ppm}/^\circ\text{C}$, tracking to $\pm 1\text{ppm}/^\circ\text{C}$
- Operating frequencies to 40GHz
- High performance at cryogenic temperatures
- Case sizes to 0101
- Space level QPL's, F.R.-"S", per MIL-PRF-55342
- Zero failures with over 200 million life test hours
- ISO 9001:2000 certified
- Full line of RoHS compliant products
- 24-hour quote turnaround

Electronic Package Products

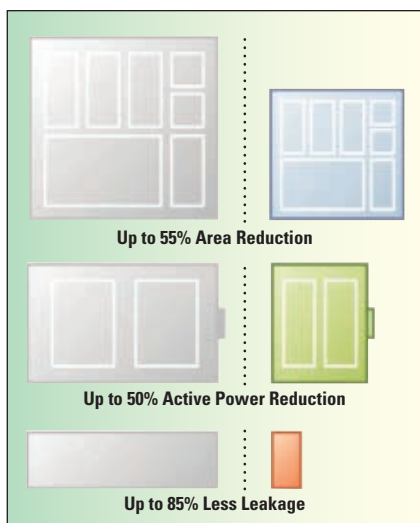
- Hi Reliability Hermetic Packages:
 - Lightweight glass sidewall flatpacks, SO-8, and SO-14 packages
 - Surface mount and plug-in packages
 - Metal flatpacks, leadless chip carriers (LCC), ceramic quad flatpacks (CQFP)
- Hermeticity per MIL-STD-883, Method 1014, Condition A4 (less than 10^{-10} atm cc/sec)
- Plating per MIL-DTL-45204 and QQ-N-290 for standard packages (unless otherwise specified)
- Custom design available
- RoHS and DFARS compliant

When it comes to today's military, aerospace, and medical applications, the reliability and performance requirements of electronic components have never been so demanding. By delivering superior-quality products for over forty five years, it's easy to see why Mini-Systems is a supplier of choice among design engineers.

48 YEARS OF EXCELLENCE

- LPDDR4 PHY
- A high bandwidth memory (HBM) Gen2 PHY, compliant with the JEDEC HBM2 standard and supporting data rates up to 2000 Mbps per data pin.

Features such as selective voltage binning and off-die switched voltage islands provide further opportunities for SWaP reduction. Voltage binning allows the ASIC supply voltage to be chosen according to the process speed, which is measured during ASIC manufacturing test and recorded within the die. Voltage islands can be used to power down circuits and IP when not in use.

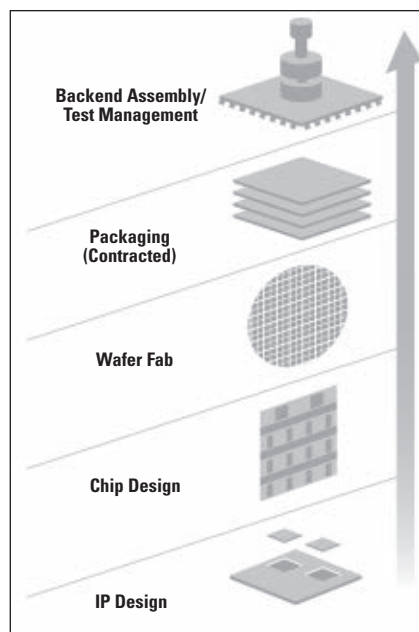


▲ Fig. 1 FX-14 SWaP benefits compared to GF Cu-32 ASIC process. Results will vary with design.

END-TO-END SOLUTION

GF pairs FX-14 silicon IP with a vertically integrated and validated ASIC development methodology, optimized through decades of development experience and a strong record of first-time-right designs for a full service ASIC solution (see **Figure 2**). This combination helps optimize customer development schedules and minimize expense risks.

The GF ASIC development



▲ Fig. 2 GF offers a vertically integrated, full service ASIC solution.

utilizes industry-standard design tools and a three-phase netlist signoff process (release-to-floorplanning, release-to-preliminary and release-to-layout) with highly structured entrance and exit milestones. GF is responsible for manufacturing test insertion, ASIC physical design and first-level ASIC package design. GF is also responsible for physical design checking (design rule checking and layout versus schematic), mask build, test generation, wafer manufacturing, ASIC wafer test, package manufacturing, die-package bond and assembly (module) and ASIC module test. Additional service options are available, including architecture services and detailed design services.

The GF FX-14 ASIC design system encompasses both FX-14 IP and development methodology, resulting in GF owning manufacturing yield. This further minimizes customer development risk. Customers purchase yielded FX-14 modules from GF: modules containing both die and packages that pass GF ASIC manufacturing tests.

GF's FX-14 die/package estimation tool estimates both ASIC die content and dimensions, including package (module) dimensions, based on customer and GF inputs. The tool affords valuable insights for A&D customers that need to meet specific application SWaP requirements. Additionally, GF development tools for ASIC voltage planning/selection and early ASIC power analysis enable early power estimation and trade-off analysis to help minimize power consumption in power-sensitive applications.

As part of GF's extensive commercial semiconductor portfolio, FX-14 builds on 30 years of ASIC expertise, more than a decade of A&D insights gained as a Trusted Foundry supplier and more than 2000 designs released to mask build. The high performance processing, density and power-efficient features of the FX-14 underlying 14LPP technology, combined with an extensive silicon IP portfolio, holistic ASIC methodology services and vertically integrated supply chain, are designed to enable GF FX-14 A&D customers to quickly develop differentiated solutions addressing next-generation challenges.

GLOBALFOUNDRIES
globalfoundries.com

AUTOMATED RF TEST SYSTEMS

from

JFW INDUSTRIES

Attenuator Assemblies
Transceiver Testing
RF Switch Assemblies
RF Matrix Switches
Handover Test Systems

JFW Industries
317-887-1340 877-887-4539
www.jfwindustries.com
sales@jfwindustries.com



AEROSPACE

Aerospace Products

Whether aviation or spaceflight applications – Rosenberger is a qualified and trusted supplier of connectors and cable assemblies to the aerospace industry. Our aerospace products are designed and manufactured in accordance with ESCC, MIL-PRF 39012, or DIN EN 9100.

www.rosenberger.com/aerospace

Product range

- Cable assemblies
- Board-to-Board connections
- Board-to-Cable connections
- SMD types
- PCB connectors

Rosenberger



Noise Injection Loop Test Translator for Satcom Systems

AtlantechRF
Braintree, UK



Equipment failure costs money and nowhere is this truer than in the world of satellite communications. Satellites themselves, of course, become just about the most expensive junk of all time when they fail, but ground stations of every kind can also inflict unwanted bills on owners, users and customers alike when performance of any constituent part falls below par or stops altogether.

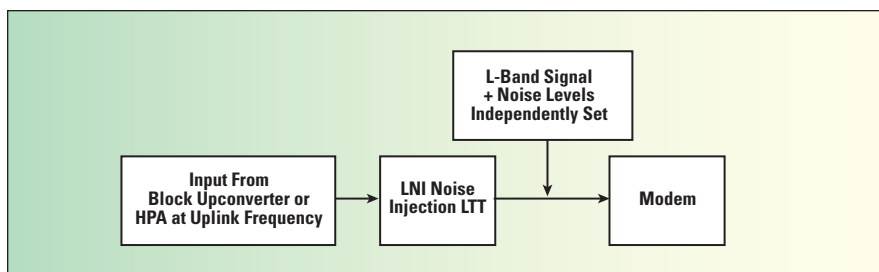
Testing of satcom equipment and assurance of reliability is therefore a serious issue. It starts at the component level, runs through equipment manufacture and continues into system operation. Redundancy can, in some cases, cater for the catastrophic failure, but this is expensive in itself. Taking steps to avoid breakdowns and to maintain full performance is a better option. With this in mind, AtlantechRF has introduced the LNI noise injection loop test translator (LTT) system, said to be the first combined system of loop test and noise injection.

In the RF/microwave environment, there is a wealth of general purpose and immensely ver-

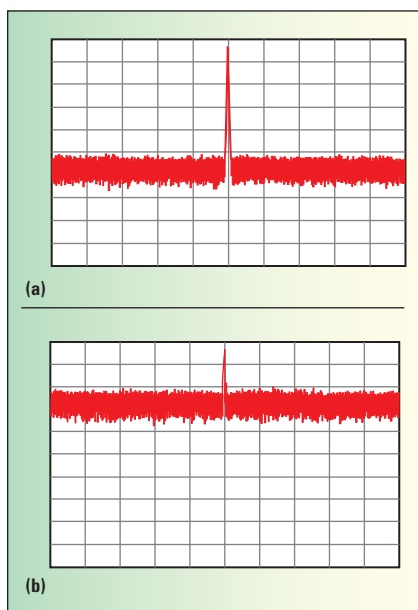
satile laboratory and field test equipment available, but it comes with a pretty hefty price tag if your test regime is narrow and very focused. The RF focus in satellite communications ground stations concerns the performance of the transmitter and of the receiver. A non-performing receiver can certainly ruin the user's day, but a bad transmitter has the ability to extend the upset to many other satellite users, as well as the satellite owner.

LTT OPERATION

A long-standing item of specialized test equipment in this industry has been the LTT. It has the ability to facilitate off-satellite RF testing of ground systems (including vehicle, aircraft and shipborne) by looping back a portion of the transmit carrier to the receiver. Both arms of the system are then set up for optimum performance, such that when the switch to "live" is made, everything functions as it should. Partial tests are also possible with different loop back conversions, and these include transmit (Tx) to L-Band for transmitter alone testing and L-Band



▲ Fig. 1 Test setup for off-satellite RF testing with noise injection.



▲ Fig. 2 Spectrum analyzer plots showing a 1200 MHz signal at 0 dBm with the noise level attenuated 30 dB (a) and 0 dB (b).

to receive (Rx) for checking out just the receiver.

Another parameter that is essential in the satisfactory operation of the satcom system is receiver sensitivity. How well does the receiver distinguish the wanted signal from the all-too-abundant noise? One approach in common use in all types of RF receivers is to inject white RF noise into the receive chain somewhere downstream of the antenna and, by varying its intensity, determine the point at which the signal is no longer detectable. One of those

downstream points is often at the entry to the modem at L-Band.

TEST REQUIREMENTS

Certainly it is important for the manufacturers of satellite communications systems to carry out both loop back frequency tests and receiver sensitivity tests. Loop back frequency because how else can one test a transmitter/receiver combination in a factory without a satellite? Sensitivity because this is key in supporting the claims made for the product to potential customers and users.

Of course, testing takes time and money and therefore designing test equipment to minimize this expense along with down time should be high on the priority list for the test equipment manufacturer.

LNI SERIES

These issues are all addressed by AtlanTecRF's LNI series of Ku-Band, Ka-Band and Q-Band noise injection LTT systems. The series is designed to provide the satellite communications engineer with a complete and versatile setup for off-satellite loop back testing of the transmit (Tx) signal to L-Band, combined with the ability to inject white symmetrical Gaussian noise for simultaneous receiver and modem testing.

Figure 1 shows the test setup using the LNI unit. The unit accepts an input at the Ku- (12.75 to 14.50 GHz), Ka- (27.5 to 31.5 GHz) or Q-Band (43.5 to 45.5 GHz) uplink frequency from a suitable point in the uplink chain—the block up-converter output or as a

coupled signal from the high power amplifier output, for example. The test translator converts this to an L-Band signal suitable for the modem input. Noise is coupled into the signal path at L-Band; both the signal and noise levels can be independently adjusted. This enables the modem's performance under varying signal-to-noise ratios to be assessed, simulating the effects of varying system noise on link performance.

The loop test function is controllable in terms of input attenuation over a 60 dB range in 0.5 dB steps and local oscillator (LO) frequency in 25 MHz steps, while the white noise level, at the common L-Band of 800 to 2600 MHz, is variable by up to 60 dB in 0.25 dB steps with an additional mute facility. A full list of input, output and LO frequency ranges for the complete range of noise injection LTT systems is given in **Table 1**.

The LTT has a typical 0 dB conversion loss at zero input attenuation, while the base noise level generated is nominally -84 dBm/Hz and is injected via a variable attenuator and 20 dB directional coupler into the LTT's L-Band output. The noise level can be muted completely for LTT-only operation and is also switchable to an external output for noise-only operation. **Figure 2** shows two spectrum plots with the same signal level and varying noise power. Filtering is included to prevent noise appearing at the Tx input port or mixing with the synthesized LO output.

Control of both LTT and noise injection is affected by either front panel controls or remotely via Ethernet with an easy-to-use graphical interface. Frequency stability of the LO is derived from either the internal oven controlled crystal oscillator (OCXO) or from a system 10 MHz reference.

In addition to the 2U x 19 in configuration, the LNI noise injection LTT systems are available in portable bench mount instruments for transportation to multiple test sites and laboratory locations.

The new system has the capability to cut testing time by combining the normal loop back signal test with noise injection at modem level, all in one compact 2U rack unit. It can greatly enhance the capability for satellite communications engineers for factory system testing or at a satcom ground terminal.



AtlanTecRF
Braintree, UK
www.atlantecrf.com

TABLE 1

NOISE INJECTION LTT OPTIONS

Noise Injection LTT Systems	Input Frequency Range (GHz)	Output Frequency Range (GHz)	LO Frequency (GHz)
LNI-1180-1305-Ku	12.75 to 14.5	0.8 to 2.6	11.8 to 13.05
LNI-2500-2700-Ka	27.5 to 31.5	0.8 to 2.6	25.0 to 27.0
LNI-4250-4400-Q	43.5 to 45.5	0.8 to 2.6	42.5 to 44.0

Selecting the Best Fan-Out for Military Radio Testing

JFW Industries Inc.
Indianapolis, Ind.



uring the past 10 years, the use of military radios has increased dramatically—so has the need to test those radios. This stems from the advent of such military-based communication applications as the land mobile radio and tactical networks, as well as the introduction of both software defined radios and cognitive/multi-user multiple-input-multiple-output (MIMO) wireless radios. Typically, these military radios are tested together in a closed mesh network, with programmable attenuators used to vary the attenuation and simulate different distances between the radios. While this test platform (i.e., military radio testbed) enables test engineers to conduct rigorous, transparent and replicable testing, it has limitations: the size of the mesh network or the number of radios that can be tested together.

For test engineers wanting to build their own testbed with individual components, JFW provides the necessary programmable attenuators and the power divider/combiners to be cabled together. JFW also provides RF test systems

with the components already packaged together with a computer interface for an all-in-one solution. These test systems are available in three different configurations, depending on how many military radios test engineers want to test together. The result is a comprehensive approach to quickly and successfully test modern military radios.

TESTBED OPTIONS

JFW offers three different test setups for testing military radios: hub, full and limited fan-out (see **Figure 1**).

Hub Fan-Out

Most test engineers building military radio testbeds use a hub design to create a mesh network in which each radio is able to communicate with the entire network at one power level (see **Figure 1a**). The other ports must adjust their own attenuation to the mesh to receive the input radio at the desired power. The hub fan-out design utilizes a resistive divider/combiner with

Join the High-Frequency, High-Speed Revolution!

EDICON is coming! EDICON is coming!

EDICON 2017

Electronic Design **Innovation** Conference & Exhibition

September 11-13, 2017

HYNES CONVENTION CENTER • BOSTON, MA

Where RF, microwave, EMC/EMI, signal integrity, and power integrity engineers meet for networking, product demonstrations, training and learning.

Featuring:

- Exhibition of Industry-Leading Vendors
- High-Speed Demonstration Zone
- Speed Training in Frequency Matters Theater
- In-Depth Short Courses
- Hands-On Workshops
- Peer-Reviewed Technical Sessions
- Panels on Latest Technologies
- Keynotes and Plenary Session
- Outstanding Paper Awards
- Luxury Coach Busing from Boston Area
- Family Fun Program

Organized by

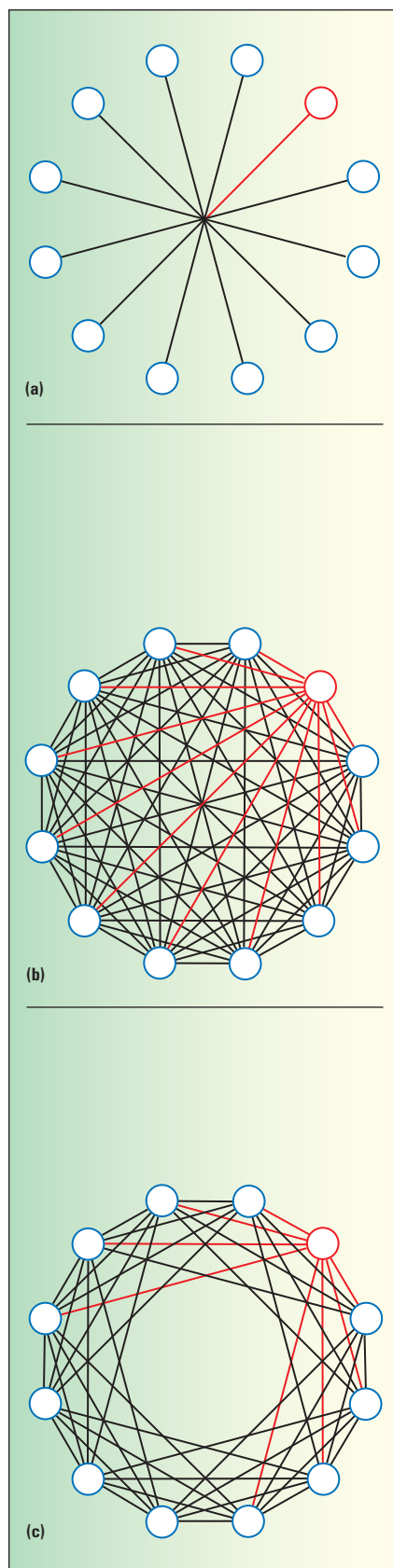
Official Publications



@ediconusa

#ediconusa

REGISTER NOW
www.EDICONUSA.com



▲ Fig. 1 12-port fan-out configurations: hub (a) full (b) and LC8 (c).

TABLE 1 JFW CURRENT CAPABILITIES				
	Hub Fan-Out		Full Fan-Out	Limited Fan-Out
# Radios/Ports	3 to 12 Radios	13 to 18 Radios	3 to 32 Radios	4 to 64 Radios
Frequency Range	DC to 6000 MHz	DC to 3000 MHz	30 to 3000 MHz or 500 to 6000 MHz	30 to 3000 MHz or 500 to 6000 MHz
# Attenuators	# Ports	# Ports	$N \times (N-1)/2$ $N = \# \text{ of Ports}$	$N \times L/2$ $N = \# \text{ of Ports}$ $L = \# \text{ Adjacent Ports each Port can see}$

a star matrix configuration to combine all ports through a central hub. The star configuration limits the number of paths in the matrix to equal the number of ports. Each port has a single programmable attenuator that can be remotely controlled to simulate static or dynamic environments. The hub fan-out design can be used for radio-to-radio communication testing up to 18 radios. Because of the lower number of programmable attenuators—no more than

18—it is much lower in cost than the other two options.

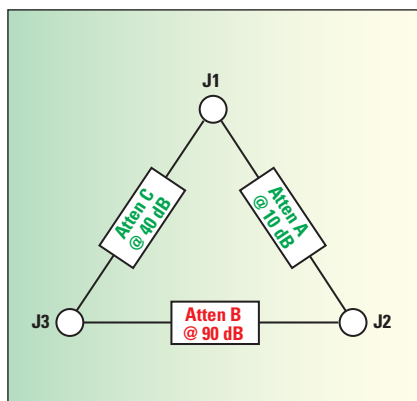
Full Fan-Out

For testing between 19 and 32 radios up to 3 GHz, the simple hub fan-out design is not viable. Instead, a test system based on a full fan-out design is recommended (see Figure 1b). The full fan-out design is constructed as a fully meshed matrix with a path between every pair of ports, each path having its own individually controlled programmable attenuator. The attenuators enable the test engineer to set a different setting for each path through the matrix. The attenuation values can be faded over time to simulate signal fading between radios. Each port can be connected to a device (e.g., a radio or handset) that can transmit/receive signals. Most JFW test systems utilizing this design cover either 30 to 3000 MHz or 500 to 6000 MHz.

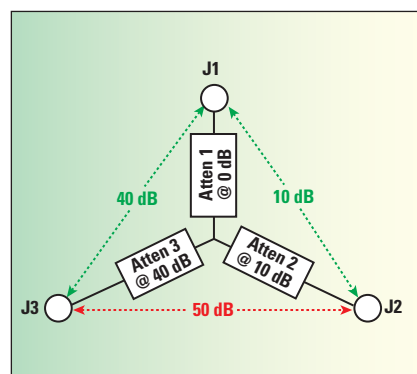
Compared to the hub fan-out design, the full fan-out design uses a reactive, rather than a resistive, combiner/divider. This allows the full fan-out design to test more radios—up to 32 radios or ports—simultaneously. The design also offers the maximum signal fading flexibility. Because it allows every path to be set to a unique attenuation, the full fan-out is ideal for testing radio-to-radio communication. However, this is the most expensive of the three configurations, as the number of attenuators scales quadratically with the total number of radios.

Limited Fan-Out

To test more than 32 radios up to 3 GHz, the limited fan-out design is the best option. With this configuration, each port connects to only “L” number of its neighboring ports, where the number of neighboring ports depends on the application (see Figure 1c). The limited fan-out design is particularly



▲ Fig. 2 With the full fan-out configuration, a unique attenuator on each path maximizes flexibility for radio-to-radio testing.



▲ Fig. 3 The hub fan-out cannot match the full fan-out's 40, 10 and 90 dB attenuator settings.

Exhibition Space is Filling Up Fast. Book Your Booth Today!



2017

**Electronic Design Innovation
Conference & Exhibition**

Where high frequency meets high speed.

September 11-13

**Hynes Convention Center
Boston, MA**

Join the Growing List of Exhibitors:

AEM
AmpliTech, Inc.
Analog Devices
Anritsu
ANSYS
Applied Thin-Film Products
AR RF/Microwave Instrumentation
B & Z Technologies
Barry Industries, Inc.
Berkeley Nucleonics
Cadence Design Systems
Cernex & Cernex Wave
Copper Mountain Technologies
CST-Computer Simulation Technology AG
dBm Corp, INC
EMSCAN
GEIB Refining Corp
Gowanda Electronics
Holzworth Instrumentation
Innovative Integration
Integra Technologies
International Manufacturing Services, Inc.
IW Microwave Product Division
Laser Services Inc

Liberty Test Equipment
Lighthouse Technical Sales
MACOM Technology Solutions Inc
Maury Microwave
MCV Microwave
Mician Inc
Microwave Communications Laboratories,
MCLI
Microwave Development Laboratories
Millitech
Mitsubishi Electric US
MOSIS
National Instruments
Ophir RF Inc
Orban Microwave
PA&E
Passive Plus Inc.
Piconics Inc.
Planar Monolithics Industries, Inc
PPG Aerospace-Cuming Microwave
Princeton Technology Corp
Reactel Inc.
Relcomm Technologies
RF-Lambda

Rogers Corp.
Rohde & Schwarz
SemiGen Inc.
SignalCore Inc
Smith's Microwave Subsystems
Sonnet Software
Southwest Microwave, Inc.
TDK- LAMBDA Americas HP Division
TechPlus Microwave, Inc.
TECOM Industries
Teledyne Labtech
Teledyne LeCroy
Teledyne Microwave Solutions
Teledyne Relays
Times Microwave Systems
TRAK Microwave
Transline Technology Inc.
TTE Filters
T-Tech Inc.
UltraSource, Inc
Weinschel Associates
Wenzel Assoc.
WestBond

Contact your MWJ Sales Representative

EDICONUSA.com

Host Sponsor



AHEAD OF WHAT'S POSSIBLE™

Diamond Sponsor



Gold Sponsors



Organized By



MISSION CRITICAL HIGH POWER



MIL-SPEC Compliant Solutions

SWITCHES

- ◆ 10MHz to 18GHz
- ◆ 1 watt to >10kW
- ◆ SPST to T/R to SPnT
- ◆ Built in fast driver
- ◆ Speeds to 50ns

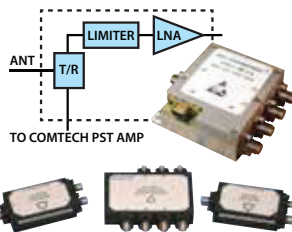


RF LIMITERS

- ◆ SMT, Coax or W/G
- ◆ Active and passive limiting
- ◆ High CW and peak power
- ◆ Low flat leakage
- ◆ Optional: BITE, indicator out

MULTI-FUNCTION MODULES

- ◆ LNA limiters
- ◆ Switch limiters
- ◆ Switch matrix
- ◆ T/R module (T/R-Limiter/LNA)



The Power of Positive Partnering



www.comtechpst.com/hill ISO 9001:2000

978.887.5754 • sales@hilleng.com

AEROSPACE AND DEFENSE ELECTRONICS

PRODUCT FEATURE

useful for reducing the size and cost of testing a large number of ports. By reducing the number of internal paths through the matrix, the size and cost of the test system is reduced. The reduced number of internal paths allows a greater number of ports to be offered, meaning that more radios can be tested simultaneously.

Where a full fan-out design with 48 ports requires 1,128 programmable attenuators, a limited fan-out LC16 design for 48 ports requires only 384 programmable attenuators. For this case, the difference in cost and size between the full fan-out and limited fan-out designs is roughly 66 percent. JFW currently offers limited fan-out models with up to 40 ports, although designs with up to 64 radios or ports are possible.

IDENTIFYING THE LIMITATIONS

The hub fan-out design is limited by utilizing a resistive divider/combiner, which effectively limits the number of radios that can be tested together. In JFW's case, two different types of hub fan-out transceiver test systems are offered. The largest resistive divider/combiner with a star configuration is an 18-port model that covers DC to 3 GHz, limiting the number of radios that can be tested together to 18. The largest JFW resistive divider/combiner with a star configuration is a 12-port model that covers DC to 6 GHz, limiting the number of radios that can be tested together to 12. The hub fan-out design is also limited by not being able to set every possible path to a desired attenuation. To illustrate, **Figure 2** shows a full fan-out with port-to-port attenuation settings of 40, 10 and 90 dB. **Figure 3** shows the hub fan-out, which cannot replicate the 40, 10 and 90 dB path settings.

In the case of the full fan-out design, the limitation is the size of the test system, which is limited to 32 radios or ports. With this design, a connection is required from any port to any other port. For 32 ports, a total of 496 internal paths are required, with each path containing a programmable attenuator. The 32-port full fan-out model offered by JFW occupies an entire 19 inch rack.

For the limited fan-out design, the limitation stems from the design. "Limited" in the phrase "limited fan-out" means not every port is connected to all other ports. In Figure 1c, each port is only connected to its eight neighboring ports. For a transmission on port 1 to reach port 9, it would have to be repeated by one of the radios that can see both ports 1 and 9—in this case, the radio connected to port 6.

Table 1 summarizes the limitations and abilities of each of the three designs and JFW's current capabilities. The relative cost and size can be estimated by the number of attenuators used in each type.

Testing as many military radios together as possible is a key goal for radio testing. There are three test setups that can be employed, each with its limitations. For testing up to 18 radios, the hub fan-out is the best option. When testing up to 32 or 64 radios, a full fan-out or limited fan-out design, respectively, should be used. For maximum flexibility, some applications may require every unique path to have its own attenuation, requiring the full fan-out configuration.

JFW Industries Inc.

Indianapolis, Ind.

www.jfwindustries.com



The 2017 Defence, Security and Space Forum At European Microwave Week



Wednesday, 11 October – Nürnberg Convention Center – Room St. Petersburg

A focused Forum addressing the application of RF and microwave technology to The Internet of Space.

Vast areas of the globe are without sufficient Internet connectivity. Commercial and societal progress as well as safety and security are linked to access to the information superhighway, while military missions require reliable and secure data communication pathways. This one-day Forum highlights **The Internet of Space – Technologies and Applications**, a new class of satellite communication services being developed to address these needs.

Programme:

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

10:50 – 12:30 **The Internet of Space – Technologies and Applications**

Two keynote speakers from the industry will present their view on key applications and the related technologies needed for the realisation of the **Internet of Space**. The presentations will cover commercial as well as military applications.

- The World's Largest Satellite Constellation 'OneWeb' – Redefining Satellite Communications

Wolfgang Duerr, Airbus DS Inc.

- The Connections are Key: The Implications of the Internet of Things on Military Technology – *Joe Mariani, Deloitte*

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

This session adds a further dimension to the topics by offering a market analytics perspective, illustrating the status, development and potential of the market for the **Internet of Space**.

14:20 – 16:00 **Microwave Journal Industry Panel Session**

This session offers an industrial perspective on the key issues to be addressed in the defence, security and space sector. In accordance with this year's Defence, Security and Space theme the panel will investigate the opportunities for applications of the **Internet of Space** as well as address the technological challenges.

16:10 - 17:50 **Defence, Security & Space Executive Forum**

High level speakers from leading Defence and Space companies present their views and experiences on the upcoming technologies and applications in the civil and military domains. They will be complemented by speakers from a government agency, consulting company and a start-up, who will offer their views on research needs, trends and New Space opportunities and challenges. Speakers at the Forum will include:

- *Erich Auer, TeSat SpaceCom*
- *Wolfgang Duerr, Airbus DS Inc.*
- *Matthias Spott, eightyLEO*
- *Joe Mariani, Deloitte*
- *Siegfried Voigt, DLR*

17:50 - 18:30 **Cocktail Reception**

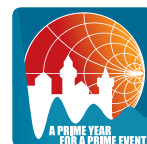
The opportunity to network and discuss the issues raised throughout the Forum in an informal setting.

Registration and Programme Updates

Registration fees are €20 for those who registered for a conference and €60 for those not registered for a conference

As information is formalized, the Conference Special Events section of the EuMW website will be updated on a regular basis.

**Register online at
www.eumweek.com**



Sponsors:





MANET/MIMO Sector Antennas Support High Data Rates



Southwest Antennas has engineered a full line of directional sector antennas designed for tactical mobile ad hoc networks (MANET) and multiple-input-multiple-output (MIMO) mesh radio systems. These antennas support high bandwidth networking for handheld radios, ground and airborne vehicles and security sensor systems. They can easily be deployed as part of a temporary communications network or installed as long-term infrastructure, and they are adaptable as situational needs change.

Standard multi-port antennas are available with two, three or four RF connector ports for use with many radio

systems across a wide range of operating bands and scenarios. The sectorial radiation pattern and high gain provide directional communications, focusing network coverage in specific areas. The antennas also offer polarization diversity—slant left, slant right and vertical options—to help maximize RF link strength and data throughput. These polarization schemes benefit operating environments with powerful co-located transmitters and other sources of RF interference. Optional RF filters can be integrated into the antennas to reject unwanted transmissions, improving the performance of the attached radios.

These MANET/MIMO sector antennas are available now in many frequency

range and RF connector options for a wide variety of government and military applications. Future tactical MANET radio waveforms that will become standard with next-generation military radio systems will offer operators a greater range of frequency bands. Southwest Antennas' sector antennas are forward-compatible with these future waveform updates, covering L-, S- and C-Band options that will be available domestically and internationally.



Southwest Antennas
San Diego, Calif.

www.southwestantennas.com



High Performance GaAs and GaN From a DoD Trusted Supplier



At its 70,000-square-foot Microelectronics Center (MEC) in Nashua, N.H., BAE Systems develops and produces GaAs- and GaN-based compound semiconductor materials, devices, circuits, modules and subsystems at frequencies from below 1 to 200 GHz. The MEC supplies compound semiconductor ICs and modules to a variety of internal and external customers and has been a Department of Defense Category 1A Trusted Supplier since 2008. In addition to advanced device research and development, the company fabricates devices in production quantities for DoD programs, inserting its technology into fielded products. For example, BAE Systems delivered nearly 1 million GaAs MMICs to support F-22 production.

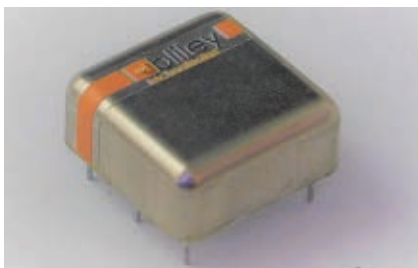
The MEC's advanced 100 kV e-beam lithography capability defines critical features as small as 20 nm, enabling highly repeatable definition of larger gate features. The facility uses MBE technology to precisely grow high quality PHEMT and MHEMT active device layers on GaAs substrates. GaN-on-SiC wafers grown by MOCVD are obtained from carefully-qualified suppliers. The MEC's 6-inch wafer processing line has been running production GaAs MESFET and PHEMT processes since 2004, and the company installed a facility for high rate manufacturing of high power GaN modules in 2015.

In 2016, the company consolidated microwave hardware development and production into the MEC, from material growth and wafer processing to IC and module design, test and manufacturing.

This greatly enhanced the ability to design for manufacturability and affordability.

The foundry's current 4-inch GaN-on-SiC production processes leverage the enhanced uniformity and automation of its 6-inch equipment. Six-inch GaN wafer processes have recently been demonstrated with high yield, equivalent performance and excellent reliability, with an MTTF of more than 10⁷ hours at 200°C channel temperature. Release to production is planned for August 2017. Producing GaN MMICs on 6-inch wafers addresses one of the last remaining challenges to making this new technology affordable.

BAE Systems
Microelectronics Center
Nashua, N.H.
www.baesystems.com



100 MHz OCXO Reference for LEO Satellites



o support the increasing number of commercial low earth orbit (LEO) satellite constellations, Bliley Technologies developed the Iris master reference oscillator. The 100 MHz oven controlled crystal oscillator (OCXO) was designed to be radiation tolerant for both the total ionizing dosage (TID) and linear energy transfer (LET) levels encountered by LEO satellites. The Iris series is tolerant to at least 40 kRAD TID and 40 MeV LET. The OCXOs' low power dissipation and small size, compared to traditional space OCXOs, supports the constraints of LEO payloads. Biased with a nominal 5 V supply, the OCXO dissipates 1.5 W steady-state

(3 W maximum at start-up). Its size is 1 in x 1 in x 0.46 in.

Designing the Iris for LEO satellites did not sacrifice oscillator performance. The phase noise of the 100 MHz oscillator at 10 kHz offset is -168 dBc/Hz or better. Temperature stability over the operating temperature range of -10°C to $+60^{\circ}\text{C}$ is under ± 25 ppb. Aging per day at 30 days is typically ± 5 ppb and projected to be ± 500 ppb after three years. Allan deviation (ADEV) is typically 1.69×10^{-11} with averaging (τ) of 1 s and 8.09×10^{-11} with $\tau = 10$ s. Acceleration sensitivity is typically 0.3 ppb/G.

The Iris master reference can be paired with Bliley's phase-locked loop to create an oscillator subsystem with high performance, low cost and attrac-

tive size, weight and power consumption for LEO constellations.

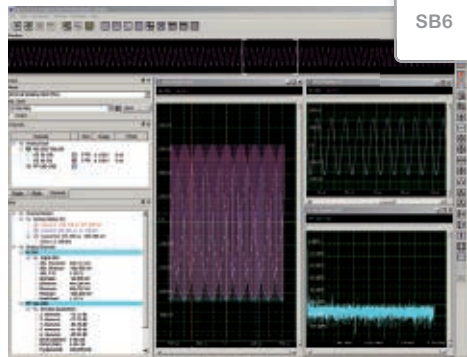
Bliley Technologies, founded in 1930, has a longstanding reputation as a stable source of high quality frequency control products, as well as a solid heritage serving the space market. The company has a long list of quality certifications, required to supply products to the space market, and many Bliley crystal products and oscillators are flying on various military, scientific and commercial missions, accumulating decades of in-space performance.

Bliley Technologies
Erie, Pa.
www.bliley.com

Spectrum's new 16 bit Arbitrary Waveform Generator gives you complete control over signals

- 1, 2 or 4 channels
- PXIe x4 Gen2 Interface
- Streaming up to 1.4 GByte/s
- 1.25 GS/s with 400 MHz bandwidth
- up to ± 2.5 V into 50 Ω
- 4 GByte memory

Feature rich – Outstanding performance – Easy to configure



SB6

SBench 6 – powerful, flexible and easy-to-use professional instrumentation software

Outstanding Support...

- Drivers for Windows and Linux, both 32 bit and 64 bit, included
- SDK's for LabVIEW®, MATLAB®, LabWindows/CVI®, C++, Delphi, .NET, Python, JAVA, ...
- Integrated marker outputs
- Sequence mode
- 2 years warranty
- Individually manufactured in Germany



SPECTRUM

SYSTEMENTWICKLUNG MICROELECTRONIC GMBH

Phone +49 (0)4102-69 56-0 | info@spec.de | www.spectrum-instrumentation.com

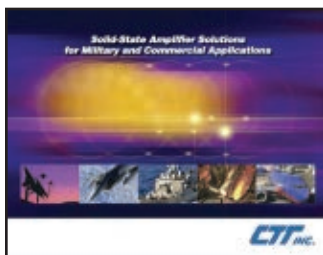


Precision-Engineered MIL-Grade Products

API Technologies designs and manufactures high performance subsystems, assemblies and components for demanding RF, microwave, millimeter wave, electro-

magnetic, power and security applications. API products are used by global defense, industrial and commercial customers in the areas of aerospace, wireless communications, electronic warfare, C4ISR, missile defense, harsh environments, satellites and space. With diverse program experience and preferred supplier status with some of the industry's top prime contractors, the company's precision-engineered MIL-grade products are ideal for applications where uncompromised reliability and uninterrupted performance is required.

API Technologies
www.apitech.com



Solid-State Amplifier Solutions

CTT announced a new 48-page product catalog: Solid-State Amplifier Solutions for Military and Commercial Applications. The new catalog features over 830 amplifier products, of which over 365 are all new. Product offering includes new GaN power amplifier technology for narrowband, wideband and ultra-wideband applications. Many new GaAs-based power and low-noise amplifier designs are also listed, including new Ka-Band, low-noise amplifiers. The catalog also includes application information and case outline drawings. Visit CTT's website for a free download.

CTT Inc.
www.cttinc.com



Military/Homeland Security Defense Supplier

K&L Microwave designs and manufactures a full line of RF and microwave filters, duplexers and subassemblies, including ceramic, lumped element, cavity, waveguide and tunable filters. K&L

supplies many of today's most significant military and homeland security defense electronics programs. Applications include space flight, radar, communications, guidance systems and mobile radio base stations, as well as air traffic communication and control. Visit the company's website to research capabilities, access data sheets, submit quote requests and download catalog to help with your requirements.

K&L Microwave
www.klmicrowave.com



BNC Model 855

The BNC Model 855 is a phase coherent multi-output ultra-fast switching and low phase noise signal generator with frequency ranges from 10 MHz to 6.2, 12.5 or 20 GHz, with excellent phase noise and spurious and harmonic

rejection. A high stability OCXO reference provides excellent frequency accuracy and stability. The Model 855 provides two to eight independent outputs in a 1U or 3U enclosure. Various controls interfaces: USB, LAN or GPIB, and a rich library of API's are provided.

Berkeley Nucleonics
www.berkeleynucleonics.com



Direct GPS-over-Fiber

HUBER+SUHNER's Direct GPSoF solution perfectly addresses the power supply challenges within a GPS system by making use of the company's newly developed Power-over-Fiber technology. This new technology not only enables system improvements by eliminating all copper within the link, but also reduces the amount of hardware within the system by integrating the GPS-over-Fiber transmitter into the antenna's radome. The key benefits are Power-over-Fiber

enabled GPSoF transmitter, truly copperless link (no EMI, RFI and EMP) and less hardware as transmitter integrated into antenna radome.

HUBER+SUHNER
www.aerospacedefense.hubersuhner.com/products



Test Solutions Product Guide

Rapid growth in the number and variety of wireless applications and connected devices in the market has driven the need for more innovative and highly customized test solutions. Customers are looking for equipment to multiplex application-specific test systems across multiple DUTs, which requires signal routing, distribution and conditioning functions in a variety of configurations. This 2017 Test Solutions Product Guide showcases some of the company's

newest, most advanced and most popular test systems developed to date.

Mini-Circuits
www.minicircuits.com

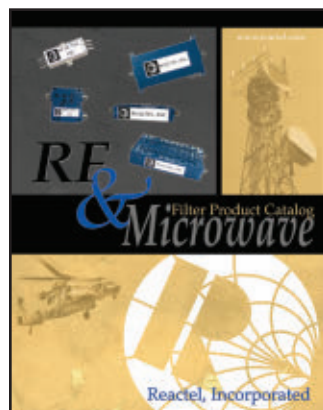


Planar Monolithics Industries Inc.
www.pmi-rf.com/products/SDLVA/SDLVA-2020-70-818.htm

CW-Immune SDLVA

VENDORVIEW

PMI model no. SDLVA-2020 series of DC-coupled, successive detection log video amplifiers (SDLVA) are available in extended 70/75 dB dynamic range over the range of 1 to 18 GHz bandwidth, with true DC coupling. Units employ planar diode detectors and integrated video circuitry for high speed performance and outstanding reliability. The DLVA's are of superior construction using state-of-the-art MIC/MMIC technology. The size is 3 in x 3.5 in x 0.5 in.



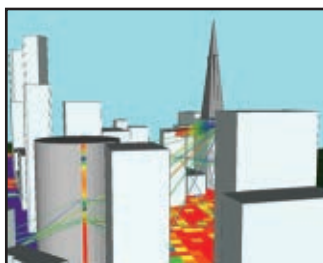
request a copy, visit the company's website or e-mail reactel@reactel.com.

Reactel Inc.
www.reactel.com

Filters, Multiplexers and Multi-Function Assemblies

VENDORVIEW

When being first to react makes all the difference in the world, choose Reactel for your mission-critical filter requirements. You can count on Reactel to satisfy the most demanding requirements for units used in extremely harsh environments. The full line catalog features RF and microwave filters, multiplexers and multi-function assemblies for the military, industrial and commercial industries. To



shadowing, indoor Wi-Fi, wireless backhaul, LTE and WiMAX throughput analysis and ad hoc networks and D2D communication. Visit the company's website to learn more.

Remcom
www.remcom.com/wireless-insite

Predictive Simulation for Wireless Networks

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. Applications include 5G MIMO simulation, macrocell and small cell coverage, urban multipath and



brands like ADI, MACOM, Microsemi, NXP, Peregrine and WanTcom serve diverse A&D applications, including radar, avionics, EW and communications. Among the latest additions to Richardson RFPD's A&D line are Guerilla RF, NewEdge Signal Solutions and Tagore Technology products and the Metelics diodes now offered by MACOM.

Richardson RFPD
www.richardsonrfpd.com

Aerospace & Defense Selector Guide

Richardson RFPD is an AS9120-certified, global component distributor specializing in advanced connectivity solutions. With A&D as its largest market, the company's GaN technology portfolio and wide range of MMICs, RF transistors, PAs and diodes from leading



Rohde & Schwarz GmbH & Co. KG
www.rohde-schwarz.com

Test & Measurement Catalog 2017

VENDORVIEW

Almost 300 pages full of information about the Rohde & Schwarz test and measurement instruments, systems and software. It includes a short description and photos of each product, the most important specifications and the ordering information. You can download this catalog as a PDF from the Rohde & Schwarz website or order from Customer Support (Order number: PD 5213.7590.42 V 07.01).



SPINNER GmbH
www.spinner-group.com

Rotating Solutions for Camera Applications

VENDORVIEW

SPINNER's miniature slip ring/fiber optic rotary joint (FORJ) combinations with diameters as small as 22 mm are the perfect choice for rotating camera applications. They enable interference-free video data transmission in 4K and 8K quality, also with fast-moving images. Among other things, SPINNER has developed and implemented a globally unique solution: the SPINNER type 1.14L. It is a robust, easy-to-use rotary joint for single-mode and multi-mode fibers.

ADVERTISER	PAGE No.	ADVERTISER	PAGE No.
Aaronia AG.....	10	K&L Microwave, Inc.....	COV 2
Analog Devices	COV 4	KRYTAR, Inc.	14
Anokiwave.....	13	L-3 Electron Devices.....	36
API Technologies	19	Mercury Systems, Inc.....	33
AR Modular RF.....	27	Mini-Circuits	25
Berkeley Nucleonics Corp.....	29	Mini-Systems, Inc.	43
Coilcraft CPS.....	7	Phonon Corporation.....	COV 3
Comtech PST Corp.....	12	Planar Monolithics Industries, Inc.....	35
Comtech PST Corp. (Hill Engineering Division).....	52	Qorvo.....	3
CPI Beverly Microwave Division.....	17	Reactel, Incorporated	11
CTT Inc.....	5	Remcom.....	39
Cuming Microwave Corporation	31	Richardson RFPD	15
dB Control Corporation	24	Rogers Corporation.....	23
EDI CON USA 2017	49, 51	Rohde & Schwarz GmbH	9
EuMW Defence, Security and Space Forum 2017	53	Rosenberger	45
Evans Capacitor Co.....	40	Spectrum Systemwicklung Microelectronic GmbH	55
Greenray Industries, Inc.	20	Spinner GmbH.....	41
Holzworth Instrumentation.....	22	W.L. Gore & Associates, Inc.	21
Huber + Suhner AG.....	37	Weinschel Associates	34
Innovative Integration	30	Wenzel Associates, Inc.	38
JFW Industries, Inc.....	44		

Sales Representatives

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) 619-1942
 FAX: (781) 769-5037
 cboyd@mwjournal.com

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

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

China

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

Shanghai
 Linda Li
 ACT International
 Tel: 86-21-62511200
 lindal@actintl.com.hk

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



Frequency Matters.

Hong Kong, Taiwan, Singapore
 Mark Mak
 ACT International
 Tel: 852-28386298
 markm@actintl.com.hk

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

SAW Oscillators

Technology for demanding defense & space applications

Phonon's stable SAW oscillators include VCSOs, OCSOs & PLL-VCSOs

- **Frequency range:**
0.3 – 2.5GHz
- **Temperature stability:**
 ± 10 ppm from -40 to +85°C
- **Low phase noise:**
-170 dBc/Hz noise floor
- **Excellent vibration immunity:**
0.5 ppb/g vibration sensitivity
- **Aging:** < 20ppm over 20 years
- **Spurious:** -80dBc
- **Low power consumption:**
0.5W maximum oven power
- **Small package size:**
1x1x0.2 in. hermetic kovar flatpack
- **Quality:** MIL-PRF-38534 Processing



Phonon designs, fabricates, assembles, trims, seals, and tests all of its quartz SAW resonators in its USA facility. Special attention is paid to mission-critical performance parameters, including Q, flicker noise, loss, power handling, and aging. Phonon also designs, assembles, trims, seals, ages, and 100% tests all of its oscillators in that same USA facility.

Phonon provides complete, comprehensive test reports on every product we deliver. Such attention to detail ensures the high performance and reliability demanded by high-end defense and space customers.

For the most critical missions, when failure is not an option, — Phonon's SAW oscillators. For SAW technology without compromise, visit www.phonon.com/osc to learn more.



AHEAD OF WHAT'S POSSIBLE™

WE DELIVER THE INDUSTRY'S
LARGEST PORTFOLIO
OF SEMICONDUCTORS,
SUBSYSTEMS, AND
HARDWARE- & SOFTWARE-
BASED SECURITY.

Analog Devices provides solutions from antenna to bits to enable today's mission-critical platforms. We offer the industry's deepest portfolio of high-performance electronic signal-chain solutions, decades of system-level knowledge and expertise, custom modules and subsystems, and the capability to secure silicon all the way to data output.

RETHINK THE SIGNAL CHAIN. BREAK THROUGH THE BARRIERS.



#ADIAhead

THE INDUSTRY'S MOST ROBUST
PORTFOLIO NOW OFFERS EVEN MORE
analog.com/ADEF