

# RUGGED & RELIABLE

MADE IN THE USA FOR 50 YEARS!

M\*E\*C\*A\* - MICROWAVE ELECTRONIC COMPONENTS OF AMERICA



- \* Aviation
- **\* Earth Station**
- \* Instrumentation
- & L, S, C, X, and Ku Bands
- \* Microwave Radio
- Mobile Satellite
- \* Radar
- \* Telemetry

#### MOST MODELS AVAILABLE FROM STOCK - 4 WEEKS ARO

#### **POWER DIVIDERS/** COMBINERS



2-way through 16-way in N, SMA, BNC, TNC and 7/16 DIN connector styles from 0.4 to 18.0 GHz.

#### **ATTENUATORS**



Most available in dB increments from 0 - 40dB. Power ratings from 2 to 150 Watts.

#### **RF LOADS**



Power ratings from 1 to 500 watts and frequency ranges up to 18 GHz.

Covering

bands from 0.5

- 2.5 GHz and

#### **DIRECTIONAL & HYBRID** COUPLERS



Average power handling from 50W to 1kW. Standard coupling values of 3, 6, 10, 20, 30 and 40 dB

#### DC BLOCKS



Available in N, BNC, TNC, SMA & 7/16 DIN configurations. Power ratings to 500 watts (2.5 kW peak).

#### **INTEGRATED ASSEMBLIES**



create an integrated assembly with any of our standard RF/Microwave products on 19" panels, shelves

Let MECA

#### **BIAS TEES**



0.7 to 2.7 GHz in 7/16 DIN, SMA, N, BNC & TNC configurations with RF power ratings to 300 watts (3 kW peak).

#### **CIRCULATORS & ISOLATORS**



In both N & **SMA-Female** connectors with average power ratings from 2 to

250 watts. "Popular" frequency bands between 0.7 - 18.0 GHz.





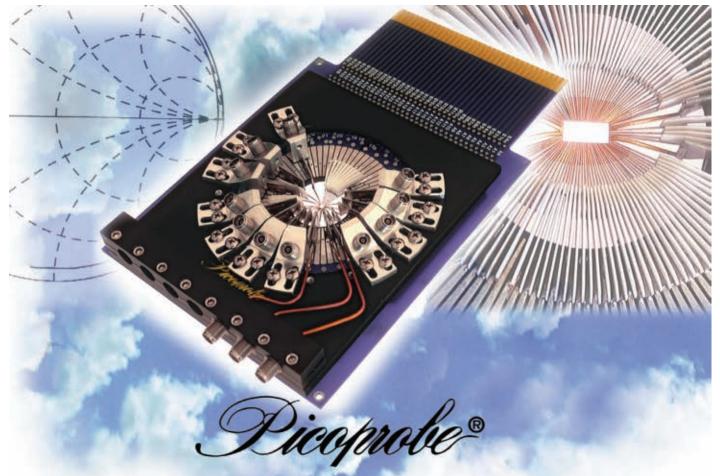
## MECA ELECTRONICS, INC.

459 East Main Street

Denville, NJ 07834

To learn more, please call 866-444-6322 or visit our website at www.e-MECA.com





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





Mini-Circuits

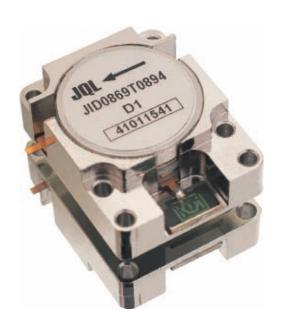
ISO 9001 ISO 14001 AS 9100 CERTIFIED

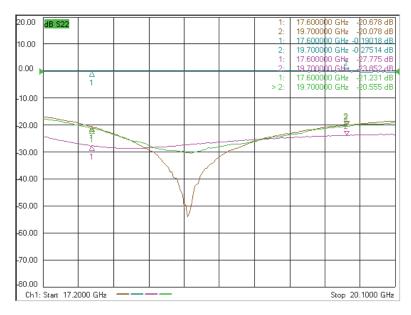
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

The Design Engineers Search Engine finds the model you need, Instantly • For detailed performance specs & shopping online see minicipality.

# **Newly Designed!**

# Drop-in Isolators!





Broad Selection of Frequency and Bandwidth Wide Variety of Packages High Power Handling Available Hight Typical Isolation Above 25dB











Visit http://mwj.hotims.com/28495-59 or use RS# 59 at www.mwjournal.com/info



# INNOVATION

We provide the innovation to help your ideas grow.

Technical expertise and manufacturing savvy have made K&L a pioneer in the filter industry.









#### Technical Expertise

K&L maintains a large staff of design and application engineers with access to an extensive design library and a variety of software tools for approximation, synthesis, realization, analysis, and simulation. Two applied R&D groups focus on developing advanced passive and active solutions for customer requirements.









#### Manufacturing Savvy

Numerous CNC machining stations are networked with CAD/CAM computing stations, allowing efficient transfer of data from one process area to the next. A state-of-the-art plating facility, temperature chambers, vibration and leak testing equipment, laser-welding and laser-labeling devices, dedicated low PIM and millimeter wave test stations, and 150 network analyzers support efficient flow of product throughout the company to meet delivery deadlines.



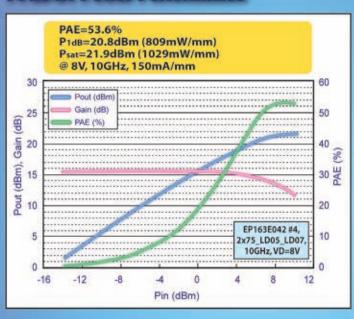
K&L Microwave, Inc. • 2250 Northwood Drive • Salisbury • MD • 21801 • P: 410-749-2424 • F: 443-260-2268 www.klmicrowave.com • www.klfilterwizard.com • sales@klmicrowave.com • sales@kleurope.com

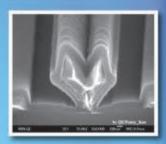


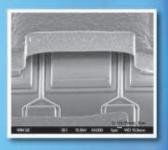
# High Voltage 8V Ku-Band 0.25µm Power pHEMT

- Stepper based 0.25µm gate length
- 8V operation / 70 GHz Ft
- -1 W/mm saturated power density
- BCB encapsulation for repeatable packaged performance

#### PP25-21 Power Performance

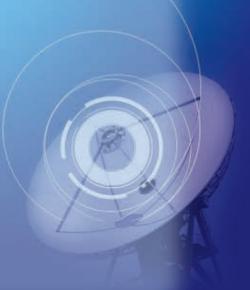






# Comparison Table for 0.1μm, 0.15μm, 0.25μm and 0.5μm pHEMT

	PP10	PP15	PP25-21	PP50-11
Vto (V)	-0.9	-1.2	-1.2	-1.4
Idss (mA/mm)	450	500	345	350
Idmax (mA/mm)	720	650	460	480
GM (mS/mm)	750	495	380	310
VDG (V)	9	10	19.2	20
ft (GHz)	130	85	65~72	32
Fmax (GHz)	175	180	160	85
PldB (mW/mm)	533.25 (3.5V)	670 (5V)	809 (8V)	587 (8V)
Psat (mW/mm)	764.3 (3.5V)	820 (5V)	1029 (8V)	851 (8V)
Gain (dB)	14.35	18.1	15.6	15.5
PAE (%)	53.57	55	53.6	53.5
Frequency	29 GHz	10 GHz	10 GHz	10 GHz



Visit http://mwj.hotims.com/28495-148 or use RS# 148 at www.mwjournal.com/info



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

### The Lactical Advantage The Right Performance At the Right Price



#### Instrument-grade Precision VNA Calibration Kits and Adapters

- Rugged and Durable
- Ideal for High-Volume, Field Service & Repetitive Measurement Applications.
- Priced to Provide You with Significant Cost Savings

#### The TactiCal™ Advantage Gives You:

· Designed to Exceed 500 Matings

Compensated Female Contacts

- · Lower Cost AND Better Performance Specs Than Brand "R" or Brand "P"
- · Maury Quality

#### Performance (Specifications) Need Adapters? TactiCal Coaxial Adapters Are

- Available For: • 1.85mm
- 2 4mm • 7mm • 2.92mm • Type N (Configurations at right)
- 1.85mr

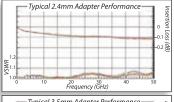
Higher

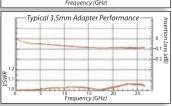
#### TactiCal™ Coax-To-Waveguide Adapters

7mm or Type N. Male or Female, From WR284 to WR62

in Right-Angle Launch Configuration

#### TactiCal™ Adapter Performance





#### Superior Electrical Performance in a Right-Priced Package Doesn't Just Happen.

It results from the disciplined application of the BEST DESIGN practices, PRECISION CONSTRUCTION techniques, SKILLFUL ASSEMBLY work, and STRINGENT QUALITY CONTROL backed up by RIGOROUS TESTING. These elements combine to give you what we call...

The TactiCal<sup>™</sup> Advantage.

Coupling Nuts with Standard Hex Wrench Flats Facilitate Proper Torquing for Best Repeatability

Compensated Beads Maintain an Accurate 50 Ohm Transmission Line For Best VSWR

Orbital Consistency & Concentricity Ensure Proper Alignment & **Best Repeatability** 

are Designed to Maintain Function for >500 Matings Mating Surface Flatness/Finish Minimizes Signal Loss Critical Pin Depth/Position Tolerance Prevents Performance Degradation (Due to "Gap-Fit") or Component Damage (Due to "Interference-Fit") Inner & Outer Conductors Finish & Materials Ensure

The Tactical solutions Family

High Conductivity with Reduced Signal Loss

	OPENS		SHORTS	LOADS	VNA CALIBRATION KITS	IN-SERIE	S ADAPTERS (sold separately)	BETWEEN SERIES ADAPTERS (sold separately)			
.85mm	Female	TC-O-185-F	TC-S-185-F	TC-L-185-F	TC-CK-185 including:  • 2 1.85mm Shorts (1 M /1 F)  • 2 1.85mm Opens (1 M /1 F)	TC-A-185-FF TC-A-185-MM	1.85mm Female to 1.85mm Female 1.85mm Male to 1.85mm Male	TC-A-2435-FF TC-A-2435-FM TC-A-2435-MF	2.4mm Female to 3.5mm Female 2.4mm Female to 3.5mm Male 2.4mm Male to 3.5mm Female		
1.8	Male	TC-O-185-M	TC-S-185-M	TC-L-185-M	1.85mm Loads (1 M /1 F)     1 TC-TW-8 Torque Wrench	TC-A-185-MF	1.85mm Male to 1.85mm Female	TC-A-2435-MM	2.4mm Male to 3.5mm Male		
2.4mm	Female	TC-O-24-F	TC-S-24-F	TC-L-24-F	TC-CK-24 Including:  • 2 2.4mm Shorts (1 M /1 F)  • 2 2.4mm Opens (1 M /1 F)	TC-A-24-FF TC-A-24-MM	2.4mm Female to 2.4mm Female 2.4mm Male to 2.4mm Male	TC-A-2435-FF TC-A-2435-FM TC-A-2435-MF	2.4mm Female to 3.5mm Female 2.4mm Female to 3.5mm Male 2.4mm Male to 3.5mm Female		
2.7	Male	TC-O-24-M	TC-S-24-M	TC-L-24-M	2 2.4mm Loads (1 M /1 F)     1 TC-TW-8 Torque Wrench	TC-A-24-MF	2.4mm Male to 2.4mm Female	TC-A-2435-MM	2.4mm Male to 3.5mm Male		
2.92mm	Female	TC-O-29-F	TC-S-29-F	TC-L-185-F	TC-CK-29 Including:  • 2 2.92mm Shorts (1 M /1 F)  • 2 2.92mm Opens (1 M /1 F)	TC-A-29-FF TC-A-29-MM	2.92mm Female to 2.92mm Female 2.92mm Male to 2.92mm Male	TC-A-2429-FF TC-A-2429-FM	2.4mm Female to 2.92mm Female 2.4mm Female to 2.92mm Male 2.4mm Male to 2.92mm Female 2.4mm Male to 2.92mm Male		
2.9	Male	TC-O-29-M	TC-S-29-M	TC-L-29-M	2 2.92mm Loads (1 M /1 F)     1 TC-TW-8 Torque Wrench	TC-A-29-MF	2.92mm Male to 2.92mm Female	TC-A-2429-MF TC-A-2429-MM			
.5mm	Female	TC-O-35-F	TC-S-35-F	TC-L-35-F	TC-CK-35 Including: • 2 3.5mm Shorts (1 M /1 F) • 2 3.5mm Opens (1 M /1 F)	TC-A-35-FF TC-A-35-MM	3.5mm Female to 3.5mm Female 3.5mm Male to 3.5mm Male	TC-A-357-F TC-A-357-M TC-A-35N-FF	3.5mm Female to 7mm 3.5mm Male to 7mm Female to Type N Female		
3.5	Male	TC-O-35-M	TC-S-35-M	TC-L-35-M	2 3.5mm Loads (1 M /1 F)     1 TC-TW-8 Torque Wrench	TC-A-35-MF	3.5mm Male to 3.5mm Female	TC-A-35N-MM TC-A-35N-FM TC-A-35N-MF	3.5mm Male to Type N Male 3.5mm Female to Type N Male 3.5mm Male to Type N Female		
Z	Female	TC-O-N-F	TC-S-N-F	TC-L-N-F18 (High Band) TC-L-N-F2 (Low Band)	TC-CK-N Including:  • 2 Type N Shorts (1 M & 1 F)	TC-A-N-FF	Type N Female to Type N Female	TC-A-7N-F TC-A-7N-M	Type N Female to 7mm Type N Male to 7mm		
TYPE	Male	TC-O-N-M	TC-S-N-M	TC-L-N-M18 (High Band) TC-L-N-M2 (Low Band)	2 Type N Opens (1 M &1 F) Type N High Band Loads (1 M /1 F) (Low Band Loads sold separately) TC-TW-12 Torque Wrench	TC-A-N-MM TC-A-N-MF	Type N Male to Type N Male Type N Male to Type N Female	TC-A-35N-FF TC-A-35N-MM TC-A-35N-FM TC-A-35N-MF	3.5mm Female to Type N Female 3.5mm Male to Type N Male 3.5mm Female to Type N Male 3.5mm Male to Type N Female		



2900 Inland Empire Blvd., Ontario, California 91764 • USA Tel: 909-987-4715 • Fax: 909-987-1112 • Email: maury@maurymw.com

On The Web At: MAURYMW.COM







OCTOBER 2010 VOL. 53 • NO. 10

#### **COVER FEATURE**

#### **22** On the Right Wavelength: Microwave and RF Technology for Defence

Michael Sieber and Attila Simon, European Defense Agency (EDA)

In-depth overview of current European research and technology activities for radio frequency and microwave applications

#### MVP: MOST VALUABLE PRODUCT

#### 40 SSPA Drives Ka-band Links from 26 to 31 GHz

MITEQ Inc.

Introduction to a solid-state power amplifier providing better than 15 W (+43 dBm) saturated output power from 26 to 31 GHz

#### TECHNICAL FEATURES

#### **64** Effects of Single-tone Spurious Responses on Signals in ESM Receivers

S.J. Caprio

Presentation of the effects of spurious responses in ESM receivers used to geo-locate threat emitters

#### 72 Side Lobe Suppression of Printed Antenna Arrays for Integration with Microwave Circuits

A. Nešić, I. Radnović, Z. Mićić and S. Jovanović, IMTEL Institute

Presentation of a linear printed array with pentagonal dipoles as radiating elements operating on second resonance enabling high side lobe suppression

#### 84 Direct Plated Copper Metallized Substrate and Its Application on Microwave Circuits

Chien-Cheng Wei, Chin-Ta Fan, Ta-Hsiang Chiang, Ming-Kuen Chiu and Shao-Pin Ru, Tong Hsing Electronic Industries Ltd. Introduction to a direct plated copper metallized substrate suitable for radio frequency and microwave package design

#### 96 Analysis and Modeling of the Pads for RF CMOS Based on EM Simulation

J. Cheng, S. Li, B. Han and J. Gao, East China Normal University; X. Yao, Semiconductor Manufacturing International Corp. Presentation of the modeling of the test structure of a radio frequency metal oxide semiconductor field effect transistor up to 40 GHz

#### 110 Miniaturized Semi-lumped UWB Bandpass Filter with Improved Out-of-band Performances

D. Kaddour, J.D. Arnould and P. Ferrari, ESISAR

Proposed topology of a semi-lumped ultra-wideband bandpass filter with improved out-of-band performance based on the combination of low-pass and high-pass filters



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, 179 Periodic Entry Department, 300 N. Zeeb Rd., Ann Arbor, MI 48106 (313) 761-4700. Reprints: For requests of 100 or more reprints, contact Barbara Walsh at (781) 769-9750.

POSTMASTER: Send address corrections to Microwave Journal, PO Box 3256, Northbrook, IL 60065-3256 or e-mail mwj@omeda.com. Subscription information: (847) 291-5216. This journal is issued without charge upon written request to qualified persons working in that part of the electronics industry, including governmental and university installation, that deal with VHF through light frequencies. 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.

©2010 by Horizon House Publications Inc.

Posted under Canadian international publications mail agreement #PM40063731

# COBHAM SENSOR SYSTEMS

#### WHERE THE POWER OF INTEGRATION IS WORKING FOR YOU





Cobham Sensor Systems is comprised of the following groups: Sensor Electronics, Microwave Electronics, and Microwave Components. For added assurance, all our products, from the smallest MMIC components to the largest antenna subsystems, are designed, manufactured, tested and inspected to meet the most stringent customer specifications.

Count on Cobham for all your product needs -- Electronic Warfare, Homeland Security, Radar, Ground & Mobile Communications, Smart Munitions, Search & Surveillance, Force Protection, Missiles, Space, Satellite Communication, SIGINT, and Overhaul & Repair.



















ATLANTIC POSITIONING SYSTEMS www.atlanticpositioners.com 727.299.0150 ATLANTIC MICROWAVE www.atlanticmicrowave.com 978.779.5963
CONTINENTAL MICROWAVE www.contmicro.com 603.775.5200 KEVIIN www.keviin.com 978.557.2400 LANSDALE www.cobhamdes.com 215.996.2000
M/A-COM www.macom.com North America 800.366.2266 Europe +44 0 1908.574200 APLANSDALE www.cobhamdes.com 410.542.1700
REMEC DEFENSE & SPACE www.remeerds.com 858.560.1301 SIVERS LAB AB www.siverslab.se +46 8 477 6811

Visit http://mwj.hotims.com/28495-21 or use RS# 21 at www.mwjournal.com/info



#### APPLICATION NOTE

# 128 A 1.7 to 2.7 GHz Transmission-line GaN HEMT Power Amplifier for Wireless Applications

Andrei Grebennikov, Alcatel-Lucent

Design and measurement of a broadband transmission-line GaN HEMT power amplifier covering the 1.7 to 2.7 operating frequency range

#### SPECIAL REPORT

#### 136 Power Sub-miniature Connectors for Space Applications

HUBER+SUHNER AG

Development of a power sub-miniature space connector optimized for corona, multi-paction and overheating effects

#### PRODUCT FEATURES

#### 142 Integral Planar Resistors Save Circuit Board Space

Rogers Corp.

Introduction to printed-circuit-board laminates with thin-film resistive foils for integral planar resistors

#### 146 T/R Module Solution for X-band Phased-array Radar

United Monolithic Semiconductors SAS

Development of a complete solution for high performance T/R modules based on internal fully qualified and space evaluated processes

#### **152** 1000 W Amplifier for S-band Linear Accelerator Applications

Integra Technologies Inc.

Introduction to an amplifier designed for RF pulsed power for S-band linear accelerator or linac applications

#### **DEPARTMENTS**

17... Mark Your Calendar

18... Coming Events

45... Defense News

49... International Report

53... Commercial Market

56... Around the Circuit

156... Catalog Update

162... New Products

174...The Book End

176...Ad Index

176... Sales Reps

178...MWJ Puzzler

#### STAFF

PUBLISHER: CARL SHEFFRES
EDITOR: DAVID VYE

MANAGING EDITOR: KEITH W. MOORE
TECHNICAL EDITOR: PATRICK HINDLE
ASSOCIATE TECHNICAL EDITOR: DAN MASSÉ

STAFF EDITOR: JENNIFER DIMARCO
EDITORIAL ASSISTANT: BARBARA WALSH
CONSULTING EDITOR: HARLAN HOWE, JR.
CONSULTING EDITOR: FRANK BASHORE

CONSULTING EDITOR: PETER STAECKER
CONSULTING EDITOR: DAN SWANSON
WEB EDITOR: CHRIS STANFA

AUDIENCE DEVELOPMENT MANAGER:

MICHELLE FRAZIER

TRAFFIC MANAGER: EDWARD KIESSLING
MARKETING AND EVENT COORDINATOR:

KRISTEN ANDERSON

DIRECTOR OF PRODUCTION & DISTRIBUTION:

ROBERT BASS

LEAD DESIGNER & PRODUCTION COORDINATOR:

JANICE LEVENSON

GRAPHIC DESIGNER: SACHIKO STIGLITZ

#### **EUROPE**

INTERNATIONAL EDITOR: RICHARD MUMFORD

OFFICE MANAGER: NINA PLESU

#### **CORPORATE STAFF**

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

#### EDITORIAL REVIEW BOARD

Dr. I.J. Bahl Dr. J.C. Lin D.K. Barton Dr. S. Maas F.M. Bashore Dr. R.J. Mailloux Dr. E.F. Belohoubek S. March Dr. G.L. Matthaei Dr. D.N. McQuiddy Dr. C.R. Boyd N R Dietrich Dr. J.M. Osepchuk Dr. Z. Galani Dr. F.E. Gardiol Dr. J. Rautio G. Goldberg Dr. U. Rohde M. Goldfarb Dr. G.F. Ross Dr. P. Goldsmith M. Schindler Dr. M.A.K. Hamid Dr. P. Staecker F. Sullivan J.L. Heaton Dr. G. Heiter D. Swanson N Herscovici Dr. R.I. Trew Dr. W.E. Hord G.D. Vendelin H. Howe, Jr. C. Wheatley Dr. T. Itoh Dr. J. Wiltse Dr. J. Lasker Prof. K. Wu

#### EXECUTIVE EDITORIAL OFFICE:

Dr. L. Lewin

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

#### **EUROPEAN EDITORIAL OFFICE:**

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

www.mwjournal.com

Printed in the USA



# Complete RF/Microwave Solutions

Carlisle's high performance connectors, cables and assemblies encompass a wide selection of sizes, materials and operating frequencies. Contact us for a comprehensive list of product offerings or custom solutions to meet YOUR unique application needs.

- Our SMP and SSMP® products provide superb isolation and performance and are excellent choices for high frequency, small form factor connectors and assemblies.
- Swept Right Angles allow for superior performance in a tighter package and reduce shock or vibration failures that mitered right angles or semi-rigid assemblies incur.
- Phase Adjusters Our family of precision coaxial phase adjusters is ideally suited for Electronically Scanned Arrays (ESAs) and other military and space applications.
- AccuPhase™ low loss phase stable flexible assemblies are optimal for any application where performance and stability at higher frequency ranges is critical.
- HDRFI® assemblies provide designers the ability to gang multiple RF contacts into a small area and reduce stubbing, especially in blind mate applications.

phone 866.282.4708 email rf@CarlisleIT.com



For more information visit www.CarlisleIT.com



# Go to www.mwjournal.com

The latest industry news, product updates, resources and web exclusives from the editors of *Microwave Journal* 

### **Free Webinars**

# MWJ/Besser Associates Webinar Series: MIMO and Other Multiple Antenna Techniques

This webinar presents the technical considerations behind multiple antennas and adaptive beam forming techniques that are transforming today's communication systems such as LTE.

Live Webcast: 10/19/2010, 11:00 am (ET) and on demand

# MWJ/Strategy Analytics Webinar Series: MilSatcom Electronic Market Trends through 2020

This session will examine the impact that future satellite launches and the insertion of increasingly sophisticated capabilities will have on the annual market for electronics.

Live Webcast: 10/26/2010, 11:00 am (ET) and on demand

#### MWJ/Agilent Innovations in EDA Series: A Practical Approach to Verifying RFICs with Fast Mismatch Analysis

This webinar introduces a new Fast Mismatch analysis that delivers the same level of accuracy with the benefit of significantly reducing overall cost, verification time, and increasing compute resource availability.

Live Webcast: 10/28/2010, 1:00 pm (ET) and on demand

#### **Executive Interview**

John Titizian, President and Founder of Integra Technologies Inc., talks about how new requirements in both commercial and defense markets are driving development in high power RF transistors and how Integra's products are meeting these challenges.



## Expert Advice

Randall Rhea, founder of Eagleware Software, was recently the featured speaker at the *Microwave Journal*/Agilent Technologies: Innovations in EDA Webcast Series. Rhea presented discrete oscillator design tools and techniques. Some of his responses to audience questions are featured in this month's expert advice.



#### Join Us

(direct links at www.mwjournal.com)







Microwave Journal Fan Page



@mwjournal @pathindle @KAatMWJ

# **Online Technical Papers**

EMC Pre-compliance Testing: Making Conducted and Radiated Emissions Measurements Application Note

White Paper, Agilent Technologies Inc.

## Application Guide to RF Coaxial Connectors and Cables

Michael J. Hannon and Pat Malloy, AR Worldwide

Analysis and Design of the Rectangular Microstrip Patch Antennas for TM0n0 Operating Mode

Pasquale Dottorato, Consultant

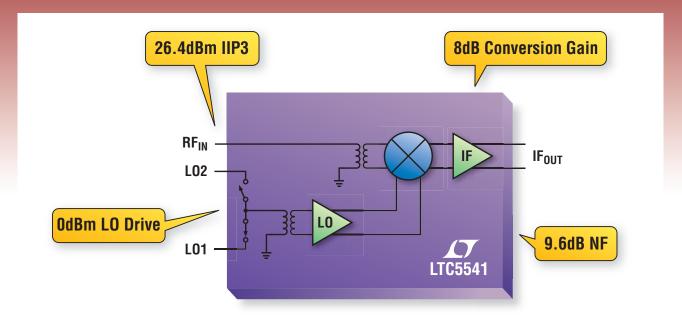
Problem of Physical Non-realizable Equivalent Current Amplitude Distributions in Waveguide Antenna Feeding Slots

Michal Grabowski, Cobham Antenna Systems

# Simulation of Multipath Fading Effects in Mobile Radio Systems

Firas Mohammed Ali Al-Raie, Polytechnic Higher Institute of Yefren, Libya

# Highest Dynamic Range Mixers—Only 660mW



## 3.3V Optimized Passive Mixers with +8dB Gain—No Compromise

The pin-compatible LTC°5540 mixer family delivers outstanding linearity and noise figure, even in the presence of blocking signals. These new 3.3V low power mixers provide the most robust receiver performance for all 4G, 3G and 2.5G cellular and broadband wireless basestation standards, including LTE, WiMAX and other high performance infrastructure radios.

#### **▼** 3.3V Passive Mixer Family

Parameters	LTCEF40	LTOSE 44	LTOFF 40	LTOFF 40	
Parameters	LTC5540	LTC5541	LTC5542	LTC5543	
Operating Frequency	600MHz to 1.3GHz	1.3GHz to 2.3GHz	1.6GHz to 2.7GHz	2.3GHz to 4.0GHz	
Input IP3	26dBm	26.4dBm	26.4dBm	24.5dBm	
Conversion Gain	8dB	8dB	8dB	8dB	
Noise Figure (NF)	9.9dB	9.6dB	9.9dB	10.2dB	
NF @ 5dBm Blocking	16.2dB	16.0dB	17.3dB	17.5dB	
Power Consumption	0.66W	0.63W	0.65W	0.66W	

#### ▼ Info & Free Samples

#### www.linear.com/554X

1-800-4-LINEAR



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





10 to 6840 MHZ from 1195 ea. (qty. 5)

Want a miniature surface mount, shielded plug-in, or rugged coaxial voltage controlled oscillator with the right stuff for your project? Contact Mini-Circuits! From custom designs to standard catalog models *always in stock*, we'll supply extra robust, 100% tested VCO solutions you need at a price you can afford. Choose from narrow to broad to octave band widths. Select linear tuning, low phase noise, and 5V models optimized for PLLs and synthesizers. And pick from an innovative array of miniature SM packages as small as 0.370" square for a variety of designs and applications. You can quickly find the model you need using "The YONI2 Search Engine" at the Mini-Circuits web site. Just enter yourspecifications into YONI2...click...and immediately

start evaluating suggested VCO solutions using the actual measured performance data displayed. But perhaps you need a custom design. Not a problem! Contact us for our lightning fast response, low prices, and quick turnaround. Give the competition real competition... specify Mini-Circuits VCOs!

Mini-Circuits...Your partners for success since 1969



For high reliability, all Mini-Circuits VCOs are tested with the Agilent E5052B Signal Source Analyzer. www.agilent.com/find/ssa

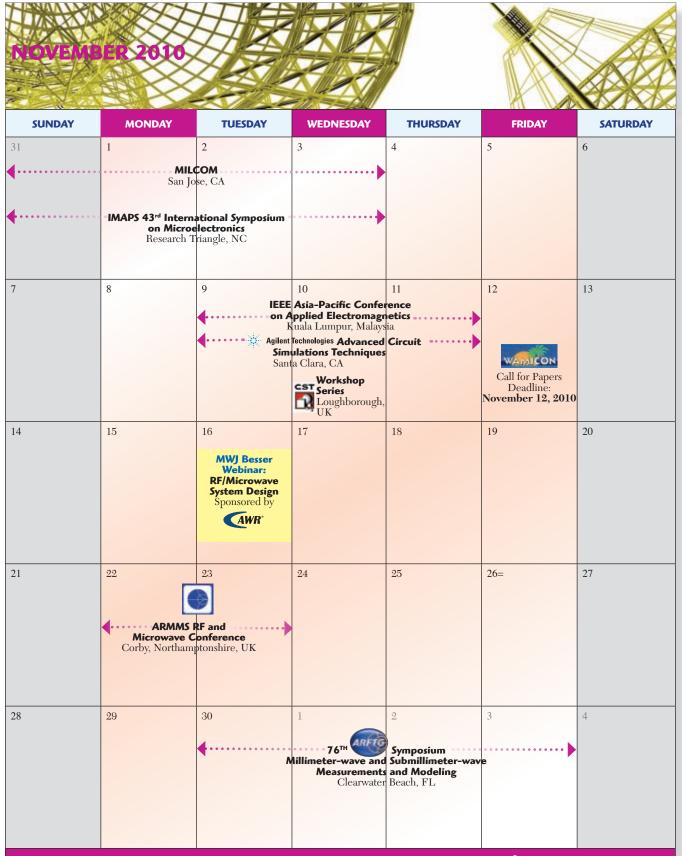




P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

The Design Engineers Search Engine finds the model you need, Instantly • For detailed performance specs & shopping online see minicipality.





Go to: www.mwjournal.com/events



Announcing the M/A-COM Tech m² advantage...

Ask about our range of visionary PtP solutions covering the 6-42 GHz bands.

[the m<sup>2</sup> advantage]



Mimix



## The First Name in **Microwave**

## **Delivering TOTAL SOLUTIONS**

macomtech.com mimixbroadband.com m2advantage.com



#### **CALL FOR PAPERS**

WAMICON 2011

Deadline: November 12, 2010 **IMS 2011** 

Deadline: December 3, 2010 **RFIC 2011** 

Deadline: January 11, 2011

#### **ONLINE**

**EuMW Show Wrap-up** Post date: October 7, 2010 **AMTA Show Wrap-up** 

Post date: October 21, 2010 www.mwjournal.com/events

#### **OCTOBER**





#### **AMTA 2010**

### ANTENNA MEASUREMENT TECHNIQUES

October 10-15, 2010 • Atlanta, GA www.amta2010.com

#### **IEEE INTERNATIONAL SYMPOSIUM ON PHASED ARRAY SYSTEMS & TECHNOLOGY**

October 12-15, 2010 • Waltham, MA www.array2010.org

#### AWR's 2010 Users Group Meeting

October 14, 2010 • Munich, Germany http://web.awrcorp.com/UGM-2010-Germany

#### 4G WORLD

October 18-21, 2010 • Chicago, IL www.4gworld.com

#### MICROWAVE UPDATE (MUD)

October 21-24, 2010 • Cerritos, CA www.microwaveupdate.org

#### MICROWAVE ANTENNA DESIGN, TESTING AND WIRELESS PROPAGATION

October 26-29, 2010 • Ottawa, Canada www.nearfield.com/shortcourses.htm

#### MILCOM 2010

October 31-November 3, 2010 • San Jose, CA www.milcom.org

#### **NOVEMBER**

## ARMMS RF AND MICROWAVE CONFERENCE

November 22-23, 2010 Corby, Northamptonshire, UK

www.armms.org

#### 76TH ARFTG SYMPOSIUM MILLIMETER-WAVE AND SUBMILLIMETER-WAVE MEASUREMENTS AND MODELING

November 30-December 3, 2010 Clearwater Beach, FL www.arftg.org

#### **DECEMBER**

#### **APMC 2010**

#### ASIA PACIFIC MICROWAVE CONFERENCE

December 7–10, 2010 • Yokohama, Japan www.apmc2010.org

## COMING EVENTS

#### **JANUARY**

#### **RWS 2011**

#### RADIO AND WIRELESS SYMPOSIUM

January 16-20, 2011 • Phoenix, AZ http://rawcon.org

#### **MEMS 2011**

#### **IEEE I**NTERNATIONAL CONFERENCE ON MICRO **ELECTROMECHANICAL SYSTEMS**

January 23-27, 2011 • Cancun, Mexico www.ieee-mems2011.org

#### **FEBRUARY**

#### **MWC 2011**

#### MOBILE WORLD CONGRESS

February 14–17, 2011 • Barcelona, Spain www.mobileworldcongress.com

#### **ISSCC 2011**

#### INTERNATIONAL SOLID-STATE CIRCUITS CONFERENCE

February 20-24, 2011 • San Francisco, CA http://issec.org

#### **NATE 2011**

#### **NATIONAL ASSOCIATION OF TOWER ERECTORS**

February 21-24, 2011 • Oklahoma City, OK www.natehome.com

#### **MARCH**



#### **SATELLITE 2011**

March 14-17, 2011 • Washington, DC www.satellite2011.com

#### CTIA with RF/Microwave and M2M Zones

March 22-24, 2011 • Orlando, FL www.ctiawireless.com

#### **ACES 2011**

#### 27<sup>TH</sup> INTERNATIONAL REVIEW OF PROGRESS IN **APPLIED COMPUTATIONAL ELECTROMAGNETICS**

March 27-31, 2011 • Williamsburg, VA http://aces.ee.olemiss.edu/conference/



#### **WAMICON 2011**

#### IEEE WIRELESS AND MICROWAVE TECHNOLOGY CONFERENCE

April 18-19, 2011 • Clearwater, FL www.wamicon.org

#### JUNE







#### **RFIC 2011**

#### **IEEE RADIO FREQUENCY INTEGRATED CIRCUITS S**YMPOSIUM

June 5-7, 2011 • Baltimore, MD www.rfic2011.org

#### **IMS 2011**

#### **IEEE MTT-S I**NTERNATIONAL MICROWAVE **S**YMPOSIUM

June 5-10, 2011 • Baltimore, MD www.ims2011.org

#### **ARFTG 2011**

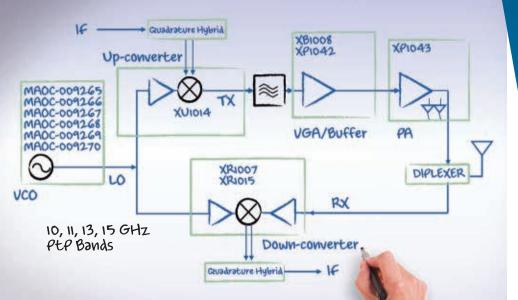
#### **ARFTG MICROWAVE MEASUREMENT SYMPOSIUM**

June 10, 2011 • Baltimore, MD www.arftg.org

# The First Name in Microwave







## [the m<sup>2</sup> advantage]



MAOC-009270

12.2-13.8

	4				100		1	
Part Number	Frequency (GHz)	Gain (dB)	P1dB (dBm)	OIP3 (dBm)	Pout (dBm)	PN at 100 kHz (dBc/Hz)	Current (mA)	Package (mm)
XP1043-QH	12.0-16.0	21.5	30.0	41.0			700	4x4
XP1042-QT	12.0-16.0	21.0	25.0	38.0			500	3x3
XB1008-QT	10.0-21.0	17.0	19.0	32.0			100	3x3
XU1014-QH	8.0-18.0	-10.0	2.0	12.0			80	4x4
XR1007-QD	10.0-18.0	13.5		4.0 (I/P)			150	7x7
XR1015-QH	10.0-16.0	12.0		2.0 (I/P)			170	4x4
MAOC-009265	9.0-10.3				6.0	-110	175	5x5
MAOC-009266	10.2-11.3				9.0	-114	185	5x5
MAOC-009267	11.2-12.6				3.5	-110	165	5x5
MAOC-009268	12.7-14.2				7.0	-105	175	5x5
MAOC-009269	11.4-12.8				3.0	-110	165	5x5

6.5

-105

155

5 x 5

# Delivering TOTAL SOLUTIONS

M/A-COM Tech and Mimix products provide a total solution for many radio provide a total solution for many radio applications, including point-to-point.

#### **M/A-COM Technology Solutions**

engineers developed many of the most innovative products in our industry's history. With the merger of M/A-COM Tech and Mimix—creating the m² advantage—together we're looking to the future and the next generation of technological advancements.

Call on **M/A-COM Tech** for our visionary range of PtP solutions covering the 6-42 GHz bands, and for your most challenging RF, microwave and millimeter-wave requirements.

For more information on M/A-COM Tech products, visit:

macomtech.com mimixbroadband.com m2advantage.com

©2010 M/A-COM Technology Solutions Inc. Visit http://mwj.hotims.com/28495-66 or use RS# 66 at www.mwjournal.com/info

# Third generation. Four times smaller. One powerful option.





Lower-loss, higher isolation, and superior CTE properties make tiny Xinger-III couplers an excellent alternative to ceramics in today's more demanding base station equipment applications.

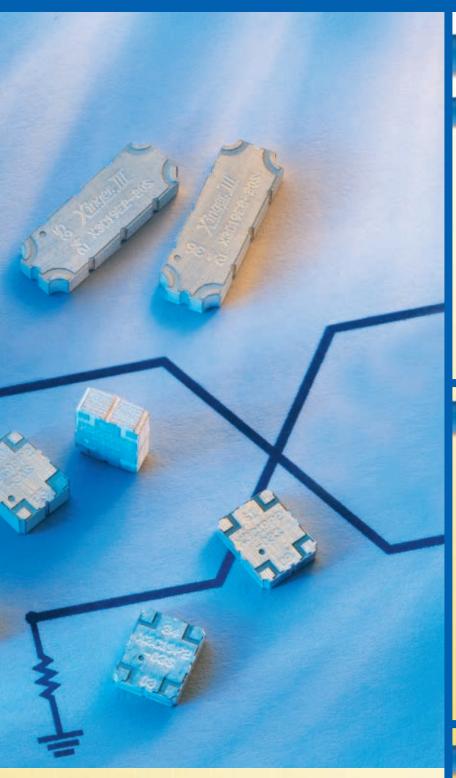
Introducing the Xinger®-III brand family of surface-mount hybrid and directional couplers, our latest, innovation-driven reinvention of the SMT RF coupler – and designed especially for today's higher-power, more compact, and hotter-running equipment.

Matter of fact, inch for inch, watt for watt, the Xinger-III family offers the highest performance of any softboard coupler on the market... even when compared to similarly sized members of our own

category-leading, Xinger-II family.

- > Xinger-III hybrids offer up to 5.35 times the power-handling ability; 52-66% lower insertion loss (down to 0.12dB); 25-28% higher isolation; and 63-71% better amplitude balance.
- > Xinger-III directionals offer 37-64% lower insertion loss (down to 0.05dB); same directivity; and 50% higher power handling at ¼ the size.

Best of all, Xinger-III technology now



makes softboard a viable alternative to ceramics in higher-power applications. And because our CTE characteristics match those of your board, you don't risk solder joint cracking that can result with ceramic implementations. That means you can lose your costly, high-performance PCB and use Xinger-III parts on low cost PCB instead!

Interested in the latest generation of Xinger-brand SMT softboard couplers from the company who invented them in the first place? Email, call, or visit our website today for your free Xinger-III intro kit.

Anaren®
What'll we think of next?

www.anaren.com > 800-411-6596

Visit http://mwj.hotims.com/28495-11 or use RS# 11 at www.mwjournal.com/info

#### Ask Anaren about:

#### All-new, 'lowest cost' resistive line family



Our new resistive components line offers an optimal balance of high performance in commercial bands, higher-power handling, and low cost. Constructed of RoHS-compliant Alumina or AIN ceramic, this family of SMT, chip, flanged, and flangeless terminations and attenuators covers DC to 6.0GHz. Email

resistives@anaren.com to learn more or obtain a sample kit.



# All-new Anaren Integrated Radio (AIR) modules



Say hello to the industry's easiest and most cost-effective RF implementation! AIR modules are developed using Texas Instruments' industry-leading chip technology. Choose from 433MHz, 900MHz, and 2.4GHz models. There's virtually no RF engineering experience required. A tiny footprint saves precious board space. And much more! To learn more and acquire an eval kit, email AIR@anaren.com





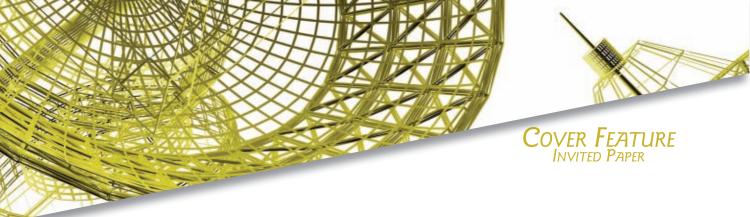
#### Balun for analog-to-digital conversion



Designing an A-to-D converter? Our low-profile, subminiature transformer (part no. BD0205F5050A00) is ideal for the job! Offering an easy-to-use 4.1 x 2.1mm SMT package. Covering 200MHz to 500MHz. And with CMRR performances over 2x that of traditional wire wound components. Email ccg@anaren.com or

visit www.anaren.com to download our latest app notes.





# ON THE RIGHT WAVELENGTH: MICROWAVE AND RF TECHNOLOGY FOR DEFENCE

icrowave (MW) and radio frequency (RF) applications such as advanced radars, missiles, communication, electronic warfare and Electronic Support Measures (ESM) act as battlefield force multipliers and are thus the focus of research and technology (R&T) activities of many ministries of defence throughout the world. With the demand for new MW and RF applications in military operations increasing, stakeholders should be aware of the changing defence environment and the necessity for addressing new capabilities. This article gives an overview of the challenges of defence R&T activities for MW and RF applications, presents the main drivers and current technology trends and, finally, touches upon how Europe addresses them by means of international cooperation under the aegis of the European Defence Agency (EDA). Illustrative EDA projects and programmes set good examples of how the international defence R&T collaboration contributes to the improvement of joint European defence capabilities.

# THE CHANGING DEFENCE ENVIRONMENT

The nature of military threats is changing, from encounters in large scale open terrain to disparate, small scale pin-prick tactics in less explored and/or rough desert, urban or moun-

tainous operational environments. Such threats call for new capabilities in the principal military domains—command, inform, engage, protect, manoeuvre and deploy—operating within an international network centric environment. In order to realise fully networked military operations, 'owning the spectrum' has become one of the prerequisites of successful information warfare, a trend that came along with the digitisation of the battlefield and the optimisation of the functional chain from the sensor to the shooter.

The technological response to these threats requires new MW and RF solutions, in general terms, to become smaller, more mobile, remotely engageable, consume less energy, be more accurate, highly integrated, versatile and robust. These broad common requirements drive R&T investments in MW and RF technologies on both the component and system-levels

While new capability needs will continue to emerge due to the changing nature of military operations, it is expected that as a result of the global economic downturn, most national defence budgets will be severely reduced in

MICHAEL SIEBER AND ATTILA SIMON European Defence Agency (EDA)

# RF & MICROWAVE FILTERS

# RLC has the customized filter solutions you need.

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

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

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

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



#### RLC ELECTRONICS, INC.

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

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

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

2010 and beyond. Severe restrictions in public spending have meant that defence budgets in several countries have been reduced, from a few percent in some to more than 10 percent in others. As a result of budgetary restrictions, industrial defence capacities are shrinking, and the emphasis is moving from innovation to lobbying.

To meet these challenges, R&T efforts and budgets need to be more focussed, invested more efficiently and be more transparent, while military assets have to become cheaper, both in terms of operational and life cycle costs. International co-operation can be an effective tool for eliminating the adverse effects of budgetary restrictions and countering budget shortages.

Technological advances and economic liberalisation over recent years have dramatically increased the electromagnetic spectrum consumption in both the military and civilian domain. While military operations have become more complex and sophisticated in their use and need of spectrum, civilian stakeholders are placing great pressure on regulators to transfer more spectrum from governmental to commercial use. This requires the protection of current frequency bands and the allocation of new freguency bands for new MW and RF applications, alongside the need to explore new technology solutions able to tackle the scarcity of electromagnetic spectrum. *Figure 1* shows the current allocation of frequency bands.

## DRIVERS OF NEW DEFENCE MW AND RF TECHNOLOGIES

Lessons learned from military operations in the last two decades show that forces and assets are usually dislocated in the homeland and intermediate logistical bases, as well as being scattered in the operational area. Typically, multinational units act in complex operational environments, which are diverse and unpredictable in most cases.

Operational environments for RF sensors are getting more and more difficult, offering up challenges that include dense electromagnetic spectrum (increased level of unintentional RF interference and increased pressure for commercial use of the spectrum), efficient Electronic Counter Measures (ECM), inhomogeneous natural environments, urban terrain, operations in brown water and poor weather conditions.

Targets to be detected, identified and tracked by RF sensors have become more difficult than ever:

- Small boats and sea skimming missiles in littoral scenarios
- Vehicles and personnel in the urban environment, people inside buildings and/or ground targets employing camouflage, concealment and deception techniques including concealment under foliage
- Mobile and fleeting targets
- Mines, Improvised Explosive Devices (IED) and mortars
- Low radar cross section and/or low altitude and/or low speed air targets (missiles, cruise missiles, UAS, etc.)
- High velocity and/or high altitude targets (satellites, ballistic missiles, supersonic missiles, reconnaissance aircraft, etc.)

The need for RF sensors with improved detection, identification and tracking capabilities is increasing, especially on board small unmanned platforms and long endurance air vehicles, as well as unattended ground and man-portable sensors. Large sensor networks, integrating thousands of nodes geographically distributed in

large areas, also require significant improvements of RF sensors.

In addition, 'friendly fire' incidents highlight the need for a technological breakthrough in reliable non-cooperative target recognition, especially in adverse weather conditions when the recognition potential of RF sensors is strongly affected by meteorological phenomena. Also significant is the fact that modern military communication networks are expected to have the capability to be structured as smart subnets, regardless of which part of the electromagnetic spectrum their subsystems and devices operate. In addition, these networks must usually work in co-existence (or even interoperate) with civilian or commercial networks without interfering with them. At the same time they are exposed to local electrical and electronic systems, which may not comply with EMC regulations, thus creating electronic hazards.

In the homeland and intermediate bases, sustainable communication networks are required, with hubs and backbones being able to handle high traffic loads. Since stationary links and assets are highly vulnerable to attack, defence communication networks will continue to mainly rely on military satellite communications (Satcom) and radio relay systems. However, there is an immense broadband requirement due to high transmission data rate services and the data intensive applications that have to be provided in the operational area. However, transponder capacities on satellite payloads will remain a bottleneck.

In most areas in which forces have been engaged recently there has been little local communication infrastructure, either because it has never existed or because it was destroyed. Therefore, there is a great demand for highly mobile, flexible, reactive and adaptive networks and miniaturized, low energy consumption devices. Although today's state-of-the-art RF and information technology makes it possible to utilise such equipment, they need to be interoperable with the vital backbone of tactical information supply—Tactical Data Links.

For military systems 'in orbit', UAS RF, radio communication payloads and the like need to be small, light-weight, exhibit low energy consumption, etc., so that they can be accom-

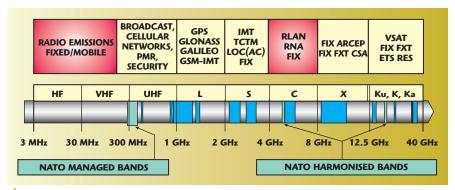


Fig. 1 The current allocation of frequency bands.



# The force is with you

Use the power of CST STUDIO SUITE,

the No 1 technology for electromagnetic simulation.



→ Get equipped with leading edge EM technology. CST's tools enable you to characterize, design and optimize electromagnetic devices all before going into the lab or measurement chamber. This can help save substantial costs especially for new or cutting edge products, and also reduce design risk and improve overall performance and profitability.

Involved in mobile phone development? You can read about how CST technology was used to simulate this handset's antenna performance at www.cst.com/handset. If you're more interested in filters, couplers, planar and multi-layer structures, we've a wide variety of worked application examples live on our website at www.cst.com/apps

The extensive range of tools integrated in CST STUDIO SUITE enables numerous applications to be analyzed without leaving the familiar CST design environment. This complete technology approach enables unprecedented simulation reliability and additional security through cross verification.

→ Grab the latest in simulation technology. Choose the accuracy and speed offered by CST STUDIO SUITE.



TABLE I  ILLUSTRATIVE EXAMPLES OF US AND EDA INITIATIVES WHICH ADDRESS THE SAME OR									
SIMILAR TECHNOLOGIES									
US initiatives	EDA initiatives								
Wide Bandgap Semiconductor Technology Initiative (WBGS-RF) for reliable GaN- based devices employed in RF power	Key organisation for research on integrated circuits in GaN technology (KORRIGAN 1 and 2)								
amplifiers	Manufacturable GaN: SiC substrates and GaN epi wafers supply chain (MANGA)								
Scalable Millimeter-wave Architectures for Reconfigurable Transceivers (SMART)	Scalable multifunction RF systems and implementation (SMRF & SIMPLE)								
Terahertz Electronics program	Terahertz technologies for detection of hidden weapons and IEDs								
Next Generation (XG) program (development of enabling technologies and system concepts to dynamically redistribute	Enabling Technology for Advanced Radio in Europe (ETARE) to study advanced waveform technologies								
allocated spectrum and novel waveforms to improve military communications)	Cognitive Radio for dynamic Spectrum Management (CORASMA)								
	Software defined and Cognitive Radio (SCORED) and study spectrum management for European defence								
	Frequency Allocation for RADArs in the coming YearS (FARADAYS)								
Remote Detection of Activities (RDA) program to create an extremely inexpensive, unattended ground sensor network with long RF communication ranges and specialized algorithms	Study on miniature RF sensors, including scatterable unattended RF sensors								
Wireless Network after Next (WNaN) to develop wireless nodes and adaptive	Wireless rObust Link for urban Force operations (WOLF)								
network technologies enabling the nodes to form autonomously adhoc networks	Wireless Interoperability for Security (WINTSEC)								
WolfPack to enable the military to deny the enemy use of communications and radars	Intelligent Control of Adversary Radio- communications (ICAR), addressing the capability shortfall related to the reliable selective prevention, control, capture and blocking of adversary mobile communications, with reduced collateral effects								
System on Chip (SoC)	System on Chip (SoC)								

modated on board. Radio links and networks also have to be extremely reliable and sustainable, with intelligent network management, not only to guarantee seamless operation (handovers), but also to provide autonomy in case of a temporary command and control blackout.

Communication technology also needs to evolve in the areas of Engage and Protect. It is evident that Information Warfare/Electronic Warfare has become a key instrument for military commanders. Although most attention is given to the sensor domain (SIGINT/ELINT, ESM and ECCM), there is also the vital need to protect communication links and assets, or to engage against such assets (e.g. C-RCIED).

Last but not least, it is worth mentioning a specific type of non-lethal weapon: namely, high power microwave (HPM) weapons, which can disable adversary information systems and power supplies and stop moving vehicles, etc., without collateral damage and human losses.

## R&T TRENDS OF DEFENCE MW AND RF TECHNOLOGIES

As has been mentioned, new capabilities require the introduction of specific R&T programmes and projects to fill the technological gaps that have been identified. Because of the lessons learned from joint military operations and certain limitations of existing MW and RF defence technologies, the typical trends and targeted solutions do not differ significantly among countries and regions where R&T is most advanced (US, Europe, Russia, China and Israel). *Table 1* 

gives illustrative examples of US and EDA initiatives that address the same or similar technology objectives. The US and Europe hold very strong positions with regards to MW and RF technologies and their world-leading roles seem unquestionable.

In Europe, the EDA, together with the experts from its Member States, has played a significant role in establishing the European Defence Research and Technology (EDRT) Strategy, which identifies what defence technologies should be developed ('Ends') and what actions ('Means') need to be taken to achieve those 'Ends'. Governmental experts in the relevant technical groups, called CapTechs, which are under the overall management of the Agency, have established a list of key technologies and skills within the 22 priorities ('Ends').

Focusing on the EDRT Strategy, all CapTechs were instructed by the EDA Steering Board to develop the corresponding Strategic Research Agendas (SRA), which will reflect the shared vision of both governmental and industrial experts on the most urgent technical challenges. The SRAs will not only respond to the actions defined by the EDRT Strategy and encourage the necessary push in technology, but will also take into account the required capabilities. The 'Ends' of the EDRT Strategy and SRAs under development in the CapTechs reflect the viewpoints of a wide range of European technology experts, and consequently can be considered as main technology trends.

For instance, in the area of RF sensors, efforts for the detection, localisation and identification of difficult targets in complex environments are focussed on increased sensitivity, improved clutter rejection and enhanced jamming suppression. These efforts include both the comprehensive development of generic technologies (system concepts and architectures, signal and data processing, platforms and integration, control and operation, and design and production) and main hardware components (transmitters, receivers, antennas, amplifiers, filters, converters, etc.)

Adaptive, self-learning and anticipative technologies for dynamically changing operational situations and various environmental conditions will enable defence forces to operate such

# HFSS-IE



#### HIGH-PERFORMANCE COMPUTING

- 3D Method of Moments -Ideal for radiation and scattering studies
- Industry-standard HFSS user interface
- Automatic and adaptive mesh generation
- Ability to link HFSS and HFSS-IE projects
- HFSS

THE GOLD STANDARD FOR 3D FULL-WAVE ELECTROMAGNETIC FIELD SIMULATION

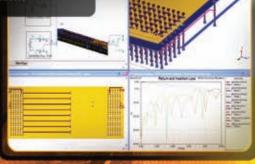
- Distributed Solve for fast, parallel parametric analysis
- HFSS HPC for large scale, 3D EM field simulation
- Multiprocessing for faster simulation throughput

#### MULTIPHYSICS

- Direct links to ANSYS Mechanical
  - Thermal
  - Stress
  - Vibration
- Coupled EM-Mechanical analysis

#### **ECAD INTERFACE**

- Planar (layout based) front-end for HFSS
- Links to popular EDA layout for package and board simulations
- Add HFSS accuracy to circuit and system simulations



HFSS", the gold-standard simulation tool for 3D full-wave electromagnetic field simulation, has raised the bar! New high-performance computing (HPC) and HFSS-IE capabilities allow you to perform parametric studies and solve large-scale simulations fast. The new ECAD interface delivers the accuracy and power of HFSS directly from the layout based Ansoft Designer® interface creating an ideal platform for signal integrity analysis. New links with ANSYS® Mechanical provide a full-featured environment for multiphysics studies. HFSS can help you raise the bar on your RF, microwave and high-speed electronics competitors.



**ANSYS Product Suite** 

ansoft.com

RF sensors as radars without the direct involvement of human operators. To achieve this objective, more investment needs to be directed towards wideband antennas, waveform generators, power amplifiers and wideband high dynamic range receivers, and most importantly, new signal processing techniques.

Developments cannot stop at the component level, however. It is also vital to acquire greater knowledge regarding adaptive sensor management,

the prediction of target behaviour and

intent, software controlled sensors, dynamic frequency management, coexistence and effective interference suppression of RF systems and adaptive beam forming. More intelligent and efficient multisensory and networking technologies are needed in order to provide a more accurate common operational picture, improve reconnaissance, surveillance and target acquisition capabilities, and enhance the survivability of RF sensors.



Teledyne Cougar's new line of medium-power broadband amplifiers are a unique family of performance-based solutions designed for demanding applications. This family covers 20 MHz to 2600 MHZ and uses Gallium Nitride (GaN) technology. Each amplifier is hermetically sealed, and includes multiple RF performance options so engineers can specify standard catalog or custom-tuned performance.

The amplifiers include an internal sequencer, assuring application of the proper gate voltage applied to the FET prior to voltage applied to the drain. Higher gain versions include pre-amps, providing excellent noise figure and IP performance. The small package footprint is designed for high performance applications and operates from -40 to +85°C.

Model	Frequency Range MHz	Gain dB Typ.	Noise Figure dB Typ.	P1dB dBm Typ.	P3dB dBm Typ.	P3dB Watts Typ.	IP3/IP2 Pout dBm Typ.	Driver D.C. Volts Nom.	Driver D.C. mA Max.	D.C. Volt Nom.	Amps Q/@P3dB Typ.
	MEDIUM POWER BROADBAND AMPLIFIERS										
AVP598	20-400	16.5	2.5	38	43.2	20.9	50/64/40	N/A	N/A	28	0.85/1.5
AVP514	20-400	40	3.5*	38	43.2	20.9	50/62/40	12	185	28	1.25/1.95
AVP2515	600-2600	17	4.5	35	41	12.6	48/50/37	N/A	N/A	28	0.85/1.50
AVP2524	600-2600	41	4.5	35	41	12.6	47/48/37	15	185	28	1.25/1.9
AVP2030	650-2200	16	4.5	39	44	25.1	53/65/40	N/A	N/A	28	0.85/2.6
AVP2034	650-2200	40	4.5	39	44	25.1	52/62/40	15	370	28	1.25/3.1
AVP2050	900-2000	14	4	42	48	63.1	55/68/43	N/A	N/A	28	1.6/5.50
			Р	REAM	DRIV	ER AMPL	.IFIERS				
A2CP2595	20-500	24	3*	34	36.2	4.2	45/58/27	12	185	28	0.39/0.47
	500-2500	24	3	32.5	34	2.5	40/56/27	12	185	28	0.39/0.47
A2CP2596	10-500 500-2500	24 24	4.8* 4.3	36.5 34.5	37.5 37.5	5.6 5.6	48/52/23 42/48/23	15 15	335 335	28 28	0.53/0.75 0.53/0.75

All specifications subject to change. \* Freq ≥ 100 MHz

Teledyne Cougar is your one-stop source for reliable GaN amplifiers, integrated assemblies, amplifiers, subsystems, and value-add service needs for space, defense and industry applications.





ISO 9001:2000 · AS9100 MIL-PRF-38534 · Class H & Class K Certified

408-522-3838 • Fax 408-522-3839 www.teledyne-cougar.com email: cougar@teledyne.com

Improvements must include the comprehensive development of bimultistatic, active-passive RF sensors, generic technologies (system concepts and architectures, waveform generation, signal and data processing, platforms and integration, control and operation, design and production) and all the main hardware components (transmitters, receivers, antennas, amplifiers, filters, converters, etc.).

In the RF domain it is worth mentioning technology trends such as:

- Multifunction, scalable, modular, open systems and networks
- Active Electronically Scanned Array (AESA) antenna design and manufacture
- Low cost, mass, volume, power consumption and maintenance technologies
- Technologies for high confidence and all weather non-cooperative target recognition
- Simulation and modelling (highly accurate) for design, specification and performance assessment
- ESM techniques in dense signal environments, in particular emitter identification and high accuracy geolocation
- HPM weapons

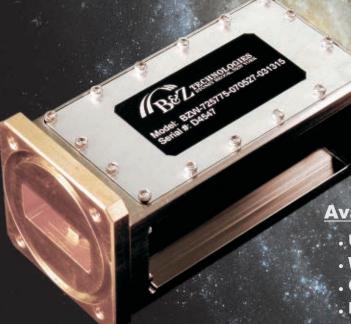
In the communication domain the use of commercial off-the-shelf (COTS) products is beneficial both to saving time and reducing the spending budget. Civilian radio communications and IT services continue to be developed over short innovation cycles. However, due to the constraints prevalent in crisis operations, many COTS technologies and products still require a military add-on to be suitable for defence purposes.

With regards to Satcom technology, satellite payloads will operate in the EHF frequency range in order to achieve broader bandwidth and higher capacity. They will have more sophisticated features such as broadband switching techniques. Their antennas will be electronically controlled (beam forming) and thus adaptive and agile. A smart ground segment with automatic (re-)configuration capabilities will take care of networking functionality, which cannot be accommodated by the satellite payload. To keep military forces connected regardless of the constraints of the electronic environment (poor footprint, jamming, etc.) it is most important to imple-



# SATCOM LNAs

**Lowest Noise Temperatures Available!** 



### **Available Options:**

- . Up To 50 Ghz
- . Weatherproof
- . Custom Gain
- . Phase & Gain Match
- . Higher Output Power
- Input Power Limiter
   Example: X-Band, 2W C.W. Limiter
   adds <0.2 dB Insertion Loss</li>

B&Z Technologies, LLC 25 Health Sciences Drive Stony Brook, New York 11790 USA

Ph: +1 (631) 444-8827 Fax: +1 (631) 444-8825 E-Mail: info@bnztech.com

Some Available Models										
Frequency (GHz)	No K	ise dB	Gain (dB)	Input VSWR	Output P1dB					
0.390 to 0.410	28	0.40	30	1.3:1	+8					
7.25 to 7.75	40	0.56	30	1.3:1	+8					
10.9 to 12.75	60	0.82	30	1.3:1	+8					
12.4 to 18.2	100	1.29	30	2.0:1	+8					
17.7 to 21.2	100	1.29	30	1.5:1	+8					
25.5 to 27.5	149	1.80	30	1.3:1	+8					
26 to 40	225	2.49	25	2.0:1	+8					



Fig. 2 Various examples of software-defined radios.

ment a robust waveform.

As for the new tactical radio technologies, up to now, even digital ra-

dios have had to be developed individually for each category of use and assigned part of the spectrum (e.g. HF, VHF and UHF). In an international engagement scenario a command cell may

require a dozen different radios to be set up and collocated. Softwaredefined radios (SDR) should have a robust software generated waveform and broadband antenna technology, enabling them to integrate the functionality of a series of different single radios. Various examples of SDRs are shown in *Figure 2*.

Web services, service oriented architectures and sophisticated IT security features should be implemented down to the tactical level. To cope with the resources needed in terms of bandwidth, studies are being conducted into high data rates (HDR) for tactical radio and cognitive radio for optimal exploitation of the spectrum, especially with regards to stressful electronic environments (dynamic spectrum management).

The demand for services even under highly mobile and electronically hostile conditions is defining new benchmarks for networking performance with commercially available standards like WiFi being adapted to military requirements. A Tactical Wireless LAN will have extended ranges and a robust waveform. In order to maximise individual network access, Body Area Networks aim to integrate any electronic device carried by the soldier (e.g. sensors, command and control).

The network layer has to be interfaced with service architectures like Service-Oriented Architecture (SOA), for tactical infrastructures such as radio networks and Tactical Data Links, and to a secure, intelligent network management system, which is disruption tolerant, fast (re-)configurable and can manage Quality of Service as dictated by the specific applications. The use of common standards for architectures and interfaces (in the RF, network and application domains) can significantly reduce lifecycle costs.

On the RF and MW components level it is first worth mentioning that AESA architectures use thousands of modules and few receivers. The main objective then is to decrease the number of modules and increase the reliability of AESA architectures. In the long term it is expected that AESA will be wideband, multifunctional and use a large number of receivers. Also, new ESM equipment requires higher sensitivity and probability of intercept of AESA, operating on new frequency bands in dense electromagnetic environments.

We've condensed all the power, performance and function of our rack-mounted amplifier systems into a highly compact package

Comtech, the industry's leader for solid state, broadband, high power amplifier systems, offers a new line of compact integrated systems for frequencies up to 6 GHz and beyond. These systems combine RF and microwave components, such as LNAs, High Power Switches, Limiters, Directional Couplers, and Detectors, into a highly compact package. These units can be configured to your

Model BME25869-35 2500-6000MHz 35 Watt Power Amplifier System

package. These units can be configured to your exact needs and are ideally suited for many defense applications. 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

# MULTIPLY UP TO 20 GHz



# Frequency Multipliers from \$595

For your leading-edge synthesizers, local oscillators, and Satellite up/down converters, Mini-Circuits offers a large selection of broadband doublers, triplers, quadruplers, and x12 frequency multipliers.

Now generate output frequencies from 100 kHz to 20 GHz with excellent suppression of fundamental frequency and undesired harmonics, as well as spurious. All featuring low conversion loss and designed into a wide array of, off-the-shelf, rugged coaxial, and surface mount packages to meet your requirements.

Visit our website to choose and view comprehensive performance curves, data sheets, pcb layouts, and environmental specifications. And you can even order direct from our web store and have a unit in your hands as early as tomorrow! Mini-Circuits... Your partners for success since 1969



P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

The Design Engineers Search Engine finds the model you need, Instantly • For detailed performance specs & shopping online see minicipality.

With regards to materials and technologies, Gallium Nitride (GaN) High Electron Mobility Transistors (HEMT) are the next generation of RF power transistor technology that offers the combination of higher power, higher efficiency and wider bandwidth than GaAs and silicon (Si)based technologies. However, many long-term issues still have to be considered: high thermal conductivity materials and related packaging and

assembly technology for adequate management of very high power solid-state components.

GaN-based receiver chain capabilities in S-band for radar applications and devices on free-standing or large GaN substrates will have to be developed as well as new composite substrates such as GaN on poly silicon carbide (SiC), where the surface material constitutes the best base for low cost epitaxies. The goal is to get

reproducible structures with fewer defects and to demonstrate high quality devices with the high yield associated with high reliability.

Future wireless applications will require high performance and ultra low power consuming electronics. For that very reason materials and device architectures other than conventional silicon CMOS must also be investigated. As more and wider frequency bands are used in the future, the dimensions of all RF and MW modules will have to be very small, requiring the development of new 3D packaging and miniaturization technologies.

## EUROPEAN R&T COLLABORATION

One of the four main functions of EDA is to promote the defence R&T by the establishment of international collaborative programmes and projects. The cumulative budget of the EDA R&T programmes and projects, in respect of the current portfolio, is between €50 and €130 M a year; approximately 40 to 50 percent of that amount is invested in RF and MW technologies.

The number of ongoing projects in the three most concerned CapTechs (Components IAP1, RF Sensor Systems IAP2, and Communication and Information Systems IAP4) is also considerable, with usually 20 to 25 projects running in parallel. Obviously, this article cannot give a complete overview of all EDA RF and MW programmes and projects, but the following illustrative examples may give readers some idea of how the EDA is addressing current technological needs.

Since the mid-nineties, defence has been interested in GaN technology because of its high power density, robustness and linearity, in particular for such microwave applications as radars, EW equipment and multifunction systems. For that very reason the EDA launched two projects in recent years. The KORRIGAN project, which has been completed, developed a stand-alone European supply chain and capability for GaN technology, providing all major European defence industries with reliable state-of-the-art GaN foundry services for micro-electronic components and devices. The integration of KORRI-GAN MMICs is shown in *Figure 3*.

As a result of KORRIGAN the sec-



# Putting components together shouldn't be a puzzle

EROFLEX CONTROL COMPONENTS Visit http://mwj.hotims.com/28495-3 or use S# 3 at www.mwjournal.com/info

To make it even easier for you, we've just put together two proven companies that fit like the pieces of a puzzle. **Advanced Control Components** and Aeroflex / KDI-Integrated **Products** have now merged to become Aeroflex / Control Components. ACC supplies high-performance solid-state RF and microwave components and sub-systems to the military, aerospace, commercial, and instrumentation markets. Our industry-leading team of design engineers has extensive experience and an impressive track record in passive and active component design and subsystem integration up to 40 GHz. Using the latest and most advanced CAD software, we can solve the toughest design puzzles with compre-

- Attentuators
- Detectors
- Limiters
- Switches and switch matrices

hensive solutions, including:

- Phase shifters
- Frequency converters
- Integrated assemblies
  Let us put the pieces of the puzzle together for you!

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

A passion for performance.

ond project, MANGA, was launched to further develop GaN technology. The main objective of the three and a half year programme is to build an independent European supply chain for the cost-effective processing of 100 mm SiC substrates and GaN HEMT epitaxial wafers. MANGA will mitigate the risk of export restrictions from the US on SiC substrates/GaN HEMT epitaxial wafers, demonstrate the European industrial capability for the supply of competitive and state-

of-the-art SiC substrates and GaN HEMT epitaxial wafers, and develop a capability to supply SiC substrates and GaN epitaxial wafers to meet European defence needs.

MANGA will strengthen the European industrialisation and supply chain of the GaN HEMT transistors/ MMIC technology, and support the development of next generation high performance radar, communication and electronic warfare components and system technologies.

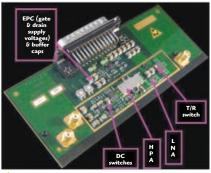


Fig. 3 The integration of KORRIGAN MMICs.

Also concerned with materials technology is the Technology for HIgh speed Mixed Signal circuits (THIMS) project, which is at a stage where the contributing member states are close to finalizing the Technical Arrangement. THIMS will demonstrate the accessibility of the European defence industry to state-of-the-art SiGe technology in a secure, cost-effective way, and ensure that all design tools for mixed-signal designs are in place. The project will assess the limits of the currently available technologies, and quantify the benefits of implementing the next generation of technology in order to encourage availability within Europe.

Software-defined radio has been on the EDA's agenda since 2006, with the focus on the standardization and certification of SDR products. The results of the studies on 'Software defined and Cognitive Radio as well as spectrum management for European Defence' (SCORED) and on 'Wireless Interoperability for Security' (WINTSEC) are forming the background for the future development of SDR technology for military and civilian security users and providing the basis for interoperability.

The SCORED project was carried out by a consortium of 20 European companies and research organisations. Its objective was to provide a vision of current SDR issues from a military perspective, analyse the added value of the technology and provide an industrial view on its possible evolution at a European level. Followon programmes will implement SDR technology reference systems and demonstrators.

As part of the Joint Investment Programme on Force Protection (JIP-FP), the Wireless rObust Link for urban Force operations (WOLF) proj-

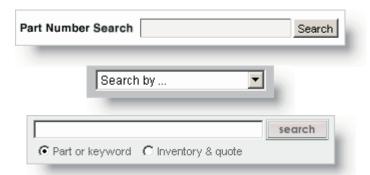


Engineering, without compromise.

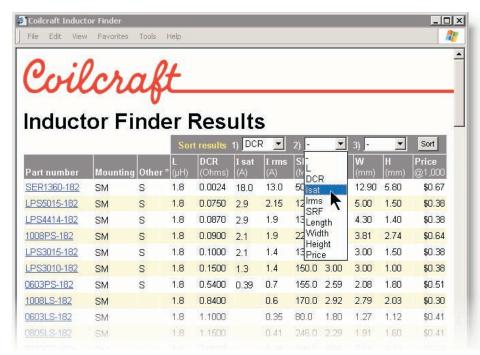
435 Moreland Road, Hauppauge, NY 11788 Tel: 631.231.1700 • Fax: 631.231.1711

e-mail: nardaeast@L-3com.com

www.nardamicrowave.com/east



# Their sites have search engines. Ours has a <u>find</u> engine.



On most inductor web sites, their search engine results in more aggravation than answers.

But Coilcraft's web site is different.

In seconds, our Inductor Finder will show you all the parts that meet your electrical and size requirements. You can sort the results by your most important parameters. Compare pricing. Even analyze the core and winding losses of up to four different power inductors!

You'll find lots of other design tools to help you choose the perfect part. And then request free samples with just a few clicks.

So quit searching for magnetics and start finding them at www.coilcraft.com!





ect will provide innovative solutions in order to increase "Wireless & robust communication" and "Information processing & situation awareness" capabilities, with a view to the survivability of such systems in operation.

Another JIP-FP initiative is the Intelligent Control of Adversary Radio-communications (ICAR) project, another JIP-FP offspring, which relates to the reliable selective prevention, control, capture and blocking of adversary mobile communications

in multi-path environments such as urban or mountain areas. It aims to define an affordable, complete and integrated response for intercepting, localizing monitoring, and selectively blocking the threats at the radio interface that current and new mobile radio-communication technologies face.

Demonstrating European cooperation, experts from Italy, Belgium, Finland and France involved with Enabling Technology for Advanced Radio in Europe (ETARE), are studying

advanced waveform technologies (ad hoc networkability, high throughput) that could be used for future operational waveform definition, at national or multinational level in Europe. These technologies will enable the development of future operational High Data Rate Networking (HDRN) waveforms.

The High Data Rate Technology for HF Communications (HDR-HF) project was contracted in 2009 and is jointly funded by Germany, Belgium and France. The project will develop and validate the concept of a Very High Data Rate (VHDR) communication in the HF band, providing a cheaper alternative to Satellite Communications solutions for long-range data communication.

Cognitive Radio has the potential to provide more flexible use of spectrum, enabling systems to adapt to their context while maintaining performance (e.g. robustness, availability, QoS). The Cognitive Radio for dynamic Spectrum Management (CORASMA) project, involving France, Italy, Poland, Portugal, Sweden, Belgium and Germany, aims to study the application of Cognitive Radio for military applications and assess its benefits.

Launched last year, the Signal Processing for Radar and EW Systems (SPREWS) project will identify and develop new solutions to increase the effectiveness of radar target detection, positioning, imaging, classification and identification in severe clutter, EW and propagation environments.

This year the Technology Enablers for Light & Low cost Urban RF Systems (TELLUS) project to investigate light, affordable and energy efficient radar and ESM systems has been launched.

The Scalable Multifunction RF (SMRF) programme and SMRF Implementation (SIMPLE) project will look into the development of technical architectures for multifunction, scalable, modular, open systems and networks.

Finally, the International Technology Partnership (ITP) on Studies for Integrated Multifunction Compact Lightweight Airborne Radars and Systems (SIMCLAIRS) was launched in 2009. At €25 M it is one of the highest value RF projects in the history of the EDA, aimed at developing a new generation of UAS and missile payloads based on synthetic aperture radar, while fulfilling the extreme mass, volume power consumption require-

# **Excellence in Frequency Control**



PLL/Synthesizers 1GHz to 5GHz in bands CPLL58, CPLL66



SAW Oscillators 300MHz to 1090MHz Ultra-Low Noise





#### Massachusetts Bay Technologies, Inc. (MBT)

specializes in the design, manufacture and distribution of RF/Microwave semiconductor diodes. MBT is committed to the continuance of innovations in service to its customers, improvement of design, product performance and quality control.

MBT's product frequencies range from 100Hz up to and including millimeter wave; our quality devices are used in various industry applications such as university and laboratory research, consumer products, telecommunications, aerospace and military.

MBT's consistent objective is to provide a superior product with unsurpassed customer service to our clients. Our engineers are available to discuss your specific design and application requirements that are both cost and time effective. We look forward to providing you component expertise and a quality product.

# MBT's product line includes but is not limited to the following RF/Microwave devices:

Abrupt Tuning Varactors Diodes
Hyperabrupt Tuning Varactors Diodes
Step Recovery/Multiplier Diodes
PIN/Beam Lead PIN/Limiter Diodes
Point Contact Diodes
Schottky Diodes
MIS Chip Capacitors
Custom Designed Components

Are you looking for a discontinued Alpha Industries, Frequency Sources, Hewlett Packard, M/A-Com, Microwave Associates, MEDL, Motorola, NEC, Philips, Parametric Industries, Siemens, Thomson CSF, Toshiba or Varian part? MBT will cross reference and manufacture your discrete, obsolete or custom RF/Microwave application.



# MASSA CHUSETTS BAY TECHN OLOGIES

RF/MICROWAVE SEMICONDUCTORS



Motivated By Performance, Focused on Reliability ®

Massachusetts Bay Technologies, Inc. 378 Page Street, Stoughton, MA 02072 • Tele: 781-344-8809 • Fax: 781-341-8177

• Website: www.massbaytech.com • Email: sales@massbaytech.com

© 2010 Massachusetts Bay Technologies, Inc. All trademarks of Massachusetts Bay Technologies

ments posed by such platforms as UAS and missiles.

#### CONCLUSION

The military/defence sector is constantly evolving. Over recent years the very nature of the threats being faced, the arenas they are being fought in, etc., have changed considerably. Also, the economic downturn has forced budgetary constraints on governments and made it necessary for individual companies, universities and research establish-

ments to seriously consider the cost and payback of ongoing or planned projects.

Budgets may be tight, but homeland security and defence issues still have to be addressed and the RF and microwave industry/community has a significant role to play in developing efficient and cost-effective technology to combat threats, secure borders and safeguard citizens.

Technological development is ongoing across the military/defence spectrum at both the component and system level. There is significant activity in the field or RF sensors, the development of modern military communications networks, both in orbit and on the ground, the evolution and implementation of semiconductor materials and packaging, just to name a few.

More general common objectives are miniaturisation, greater efficiency, reduced power consumption, and the reduction of development and lifecycle costs. It is widely recognised that collaboration, on every level, is becoming increasingly important to provide the necessary structure, support and incentive for projects to be successful and achieve their goals.

This article has used the EDA as an example of the importance of establishing international collaborative programmes and projects and demonstrated the scope, level of international cooperation, and scale of technology being addressed by current projects. They are just examples of the extent of current activity, not only in Europe but across the globe, and reflect that, despite changing threats and financial constraints, RF and microwave R&T development is on the right wavelength.



After studying Engineering in Electrical Sciences at the Armed Forces University, Munich, Germany, Michael Sieber gained a Tactical and Technical Leadership Training qualification from the German Army Schools. His employment has included: Combat Data Systems

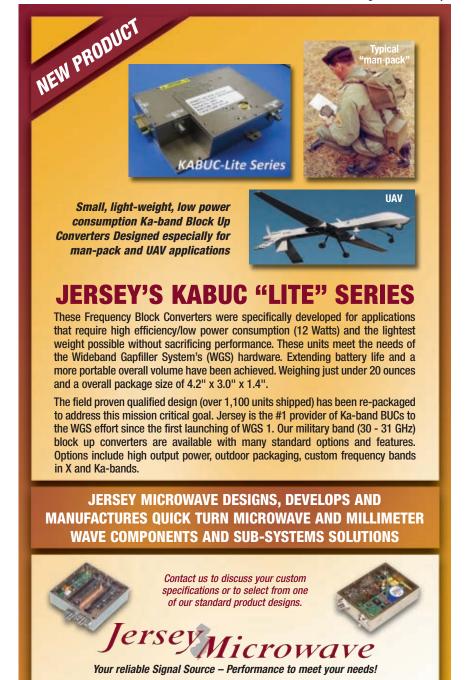
Engineer, Directorate for

Maritime Combat Systems, Department of Defence, Ottawa, Canada, Deputy Director, International Armaments Affairs, Ministry of Defence, Bonn, Germany, and Chief, Information Acquisition Division, Technical Centre for Information Technology and Electronics, Greding, Germany. Sieber took up his current post as Assistant Director Research & Technology, European Defence Agency, Brussels/R&T Directorate, in 2010.



Attila Simon studied at Zalka Máté Military Technology College, Budapest, Hungary, and gained qualifications in Air Surveillance Radar Technology and Air Force and Air Defence Operations at Zrínyi Miklós National Defence University, Budapest. He gained his MBA degree in

2004. Starting as a Lieutenant and reaching the military rank of Colonel in 2007, Simon began his career as Platoon Commander of Air Defence C2 System/2nd Air Defence Radar Battalion, Air Force Base, Taszár, and held various military posts before becoming taking up his current role as Technical Project Officer for Radiofrequency Sensor Systems & Signal Processing, European Defence Agency, Brussels/R&T Directorate, in 2007.



230 Route 206, Suite 407 • Flanders, NJ 07836 • Phone: 908.684.2390 (ext 23)

Fax: 908.684.2391 • email: sales@jerseymicrowave.com • www.jerseymicrowave.com



# Breaking Barriers!

Microwave Amplifiers and Assemblies -







# SSPA Drives Ka-band Links from 26 to 31 GHz

is vital to a number of different terrestrial and satellite communication links, especially where the available bandwidth is needed for high data rates. For example, the spectrum is used in Ka-band satellite systems as the Tracking and Data Relay Satellite System (TDRSS). Closer to earth, the frequency band is home to terrestrial 28 GHz point-to-point and point-to-multipoint (PMP) systems, and in landand sea-based terminals for common data link (CDL) and tactical common data link (TCDL) wireless and communications control links between manned and unmanned aircraft and landand sea-based terminals.

To power transmitters for links in the 26 to 31 GHz frequency range, the engineers at MITEO have developed the model AMF-5B-26003100-100-42P solid-state power amplifier (SSPA) as an alternative to the traveling-wave-tube amplifiers (TWTA) commonly used for transmitters

at these frequencies. Based on GaAs pseudomorphic high electron mobility transistor (PHEMT) device technology, the AMF-5B-26003100-100-42P provides better than 15 W (+43 dBm) saturated output power from 26 to 31 GHz with high gain and low distortion, in a package that is a fraction of the size and weight of a TWTA.

The AMF-5B-26003100-100-42P SSPA is suitable for terrestrial and satellite communication links using complex modulation formats, either backed off from its saturated output level or operated under linear conditions. As measurements of saturated and linear output power show (see *Figure 1*), the amplifier is actually usable from 25.5 to 31.5 GHz. The plot of linear output power is the total output power based on a two-tone input and maintaining intermodulation distortion (IMD) of -25 dBc or better.

The compact SSPA provides generous gain of at least 40 dB, with peak-to-peak gain flatness that remains within a  $\pm 3$  dB window, as shown in *Figure 2*. Over any 40 MHz segment of the total frequency range, the maximum gain slope is  $\pm 0.5$  dB. The model AMF-5B-26003100-100-42P provides a 20 dB analog gain adjustment range for adapting to different input signal levels. With a gain control setting of 0 dB (0 dB attenuation), the SSPA's noise figure is 10 dB.

This solid-state power amplifier exhibits maximum input VSWR of 1.3:1 and maximum output VSWR of 1.5:1, indicating that it should deliver its rated output power level with minimal reflections in systems with characteristic impedance of 50 ohms. It minimizes IMD levels to better than -20 dBc for most of the operating frequency range even under saturated output power conditions, and to -25 dBc or better under linear operating conditions, making it suitable for single- and

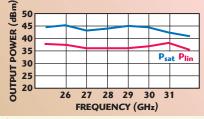


Fig. 1 Measured data of saturated and linear output power for the AMF-5B-26003100-100-42P SSPA show usable output power across an additional 1 GHz of bandwidth.

MITEQ INC. Hauppauge, NY

# **Everything you need to get from 3G to LTE.**



Getting to market fast with LTE products requires up-to-date test tools and reliable insights. Count on the Agilent LTE Design and Test Portfolio for the broadest set of LTE design and test tools, plus a robust knowledge library of LTE app notes, CDs, expert help and more. In short, everything you need to interpret, clarify and test to the evolving LTE standard. With greater insight, and greater confidence. That's Agilent.

Gain greater LTE insight and confidence www.agilent.com/find/LTEInsight

u.s. 1-800-829-4444 canada: 1-877-894-4414

© 2010 Agilent Technologies, Inc.



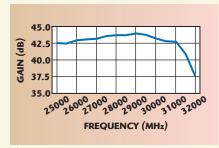


Fig. 2 Broadband gain of the AMF-5B-26003100-100-42P SSPA remains within a  $\pm 3$  dB window, with a gain slope of  $\pm 0.5$  dB for any 40 MHz band segment.

multiple-carrier applications. It also features tightly controlled group delay, with delay that is flat within ±40 ps across any 2 GHz band and within ±0.2 ns across the full 26 to 31 GHz band. as shown in Figure 3. Harmonics are a maximum of -40 dBc at both 1 and 3 dB output power levels, while spurious content is a maximum of -60 dBc when operating at 1 dB compression or under linear conditions.

AMF-5B-26003100-The model 100-42P typically consumes 150 W of power. It is designed to operate over

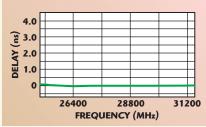


Fig. 3 Group delay of the model AMF-5B-26003100-100-42P SSPA is flat within ±40 ps across any 2 GHz band and within ±0.2 ns across the full 26 to 31 GHz band.

a wide range of standard supply voltages, from +12 to +28 VDC, with options for supplies of +36 to +48 VDC. The SSPA can handle ambient temperatures from -40° to +60°C and baseplate temperatures from -40° to +85°C. It has a non-operating or storage temperature range of -50° to +70°C. It is built to operate at altitudes (atmospheric pressure) to 10,000 ft and 100 percent non-condensing relative humidity. This rugged power amplifier can withstand altitudes to 40,000 ft under non-operating conditions.

The amplifier is EMI and environ-

mentally shielded, with integral voltage regulation and over temperature protection, as well as cooling, monitoring and control systems. For example, an alarm signal alerts an operator to over current or over temperature conditions. In addition, a high VSWR detector will determine when reflected power, such as caused by a bad load, exceeds a safe threshold level and shuts down the amplifier to prevent damage.

The SSPA is supplied in a rugged aluminum housing measuring 5" × 7" × 1.75"  $(127 \times 177.8 \times 44.45 \text{ mm})$  and typically weighing 2.5 lbs. (1.2 kg). The RF input and output ports use female K connectors, with an option for a WR-28 rectangular waveguide at the output port for Satcom systems equipped with waveguide flanges. The amplifier also includes a 20 dB coupled output sample port with a female K connector for power measurements.

MITEQ Inc., Hauppauge, NY (631) 436-7400, www.miteq.com.

RS No. 303



# When They're Counting on You, You Can Count on Us.











### **Products**

- Coaxial Switches
- Pin Diode Switches
- Switch Matrices
- Couplers
- W/G Ferrite Products

# **Applications**

- Avionics
- **Defense**
- Industrial
- Medical
- Telecommunications

# **Ducommun Technologies**

- RF/Microwave Products since 1969
- Heritage includes: Dynatech, DB Products & WiseWave
- Customer Focused
- Engineered Solutions

Request a Free copy of our NEW Coaxial Switch Catalog at www.ducommun.com/mwj or phone: 310-513-7214.



UP TO 100 Watt

ANDLIFIERS



Heavy duty, ruggedness and reliable operation to meet your demanding communication applications describe Mini-Circuits collection of 3, 5, 10, 16, 20, 30, 32, 50 and 100 Watt high power amplifiers! Covering 5 MHz up to 18.0 GHz, these broadband solutions are available with or without integrated heat sink/fan to fit your system requirements. Each amplifier operates with low current consumption and is designed to work off a single DC supply, including the fan! Plus, each model can withstand open or short output load without damage under full CW output power. They also offer built-in protection against over-voltage, thermal overloads, and an internal regulated power supply to handle fluctuations from the supply source and still deliver high performance. Need a robust power amplifier solution? Then come to Mini-Circuits where quality & reliability is built into every unit.

# IN STOCK! FAST DELIVERY!

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

ŗ				1dB	3dB	(dB)	(dBm)	(V)	(A)	Qty. 1-9	suffix
	Model	fL-fu	Тур.	Тур.	Typ.	Тур.	Typ.	Nom.	Max		
	With Heat Sink	(/Fan									
	LZY-1+ LZY-2+ ZHL-5W-1 ZHL-5W-2G+ ZHL-16W-2G+ ZHL-16W-43+ ZHL-20W-13	20-512 500-1000 5-500 800-2000 800-2000 1800-4000 20-1000	43 46 44 45 43 45 50	+45.7 +45.0 +39.5 +37.0 +40.0 +41.0	+47.0 +45.8 +40.5 +38.0 +41.0 +42.0 +43.0	8.6 8.0 4.0 8.0 7.0 6.0 3.5	+54 +54 +49 +44 +50 +47 +50	26 28 25 24 24 28 24	7.3 8.0 3.3 2.0 5.0 4.3 2.8	1995 1995 995 995 1295 1595 1395	1895 1895 970 945 1220 1545 1320
	ZHL-30W-252+ ZHL-50W-52 ZHL-100W-52	700-2500 50-500 50-500	50 50 50	+44.0 +46.0 +47.0	+46.0 +48.0 +48.5	5.5 6.0 6.5	+52 +55 +57	28 24 24	6.3 9.3 10.5	2995 1395 1995	2920 1320 1920
	NEW ZVE-3W-183+ ZVE-3W-83+ ZVE-3W-GAN- ZHL-30W-262+	6000-18000 2000-8000 + 20-500 2300-2550	35 36 42 50	+34.0 +33.0 +49.0 +43.0	+35.0 +35.0 +50.0 +45.0	5.5 5.8 7.0 7.0	+44 +42 +60 +50	15 15 30 28	2.2 1.5 9.5 4.3	1295 1295 1295 2395 1995	1220 1220 2320 1920

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

For models without heat sink, add **X suffix** to model No. Example: (LZY-1+ LZY-1X+)



# Mini-Circuits ISO 9001 ISO 14001 AS 9100 CERTIFIED

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

The Design Engineers Search Engine finds the model you need, Instantly • For detailed performance specs & shopping online see minicipcuits.com

Price

Price

Χ

# 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)

and AS9100E CERTIFIED

Unconditional	ily Stable (	100% test	ea)			- 14
OCTAVE BA	ND LOW N	OISE AMP	LIFIERS			
Model No.	Freq (GHz)	Gain (dB) MI	N Noise Figure (dB)	Power -out @ P1-dB		VSWR
CA01-2110 CA12-2110	0.5-1.0 1.0-2.0	28 30	1.0 MAX, 0.7 TYP 1.0 MAX, 0.7 TYP	+10 MIN +10 MIN	+20 dBm +20 dBm	2.0:1 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 CA1218-4111	8.0-12.0 12.0-18.0	27 25	1.6 MAX, 1.4 TYP 1.9 MAX, 1.7 TYP	+10 MIN +10 MIN	+20 dBm +20 dBm	2.0:1 2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1
		NOISE AN	ID MEDIUM POV			2.0:1
CA01-2111 CA01-2113	0.4 - 0.5 0.8 - 1.0	28	0.6 MAX, 0.4 TYP 0.6 MAX, 0.4 TYP	+10 MIN +10 MIN	+20 dBm +20 dBm	2.0.1
CA12-3117	1.2 - 1.6 2.2 - 2.4	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111 CA23-3116	2.2 - 2.4 2.7 - 2.9	30 29	0.6 MAX, 0.45 TYP 0.7 MAX, 0.5 TYP	+10 MIN +10 MIN	+20 dBm +20 dBm	2.0:1 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 CA910-3110	7.25 - 7.75 9.0 - 10.6	32 25	1.2 MAX, 1.0 TYP 1.4 MAX, 1.2 TYP	+10 MIN +10 MIN	+20 dBm +20 dBm	2.0:1 2.0:1
CA1315-3110	13.75 - 15.4		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 CA56-5114	3.1 - 3.5 5.9 - 6.4	40 30	4.5 MAX, 3.5 TYP 5.0 MAX, 4.0 TYP	+35 MIN +30 MIN	+43 dBm +40 dBm	2.0:1 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 28	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110 CA1415-7110	12.2 - 13.25 14.0 - 15.0	30	6.0 MAX, 5.5 TYP 5.0 MAX, 4.0 TYP	+33 MIN +30 MIN	+42 dBm +40 dBm	2.0:1 2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1
Model No.	Freq (GHz)	Gain (dB) MI	CTAVE BAND AN N Noise Figure (dB)	APLIFIERS 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 CA0108-4112	0.1-8.0 0.1-8.0	26 32	2.2 Max, 1.8 TYP 3.0 MAX, 1.8 TYP	+10 MIN +22 MIN	+20 dBm +32 dBm	2.0:1 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 CA618-4112	2.0-6.0 6.0-18.0	22 25	5.0 MAX, 3.5 TYP 5.0 MAX, 3.5 TYP	+30 MIN +23 MIN	+40 dBm +33 dBm	2.0:1 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 CA218-4110	2.0-18.0 2.0-18.0	30 30	3.5 MAX, 2.8 TYP 5.0 MAX, 3.5 TYP	+10 MIN +20 MIN	+20 dBm +30 dBm	2.0:1 2.0:1
CA218-4110	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+30 dBm	2.0.1
LIMITING A	<b>MPLIFIERS</b>					
Model No. CLA24-4001	Freq (GHz) 2.0 - 4.0	-28 to +10 (	Range Output Power I	Kange Psat Pov I dRm +	ver Flatness dB -/- 1.5 MAX	VSWR 2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 d	dBm +14 to +1	8 dBm +	-/- 1.5 MAX -/- 1.5 MAX	2.0:1
CLA712-5001 CLA618-1201	7.0 - 12.4 6.0 - 18.0	-21 to +10 (		9 dBm +	-/- 1.5 MAX -/- 1.5 MAX	2.0:1 2.0:1
			ATTENUATION	7 UDIII +	-/- 1.3 MAA	2.0.1
Model No.	Freq (GHz)	Gain (dB) MIN		rer-out@P1-dB Gain		
CA001-2511A CA05-3110A	0.025-0.150 0.5-5.5	21 23	2.5 MAX, 1.5 TYP	+12 MIN +18 MIN	30 dB MIN 20 dB MIN	2.0:1 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 CA1315-4110A	6.0-12.0 13.75-15.4	24 25		+12 MIN +16 MIN	15 dB MIN 20 dB MIN	1.9:1 1.8:1
CA1518-4110A	15.0-18.0	30		+18 MIN	20 dB MIN	1.85:1
LOW FREQUE Model No.				Power-out @ pl .le	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	Gain (dB) MIN 18	4.0 MAX, 2.2 TYP	Yower-out@P1-dB +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 CA001-3113	0.04-0.15 0.01-1.0	23 28	4.0 MAX, 2.2 TYP 4.0 MAX, 2.8 TYP	+23 MIN +17 MIN	+33 dBm +27 dBm	2.0:1 2.0:1
CA002-3114	0.01-1.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+27 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
			ls to meet your "exact" requi			ring

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

Visit http://mwj.hotims.com/28495-20 or use RS# 20 at www.mwjournal.com/info



# Defense News

Dan Massé, Associate Technical Editor

# Upgraded Aegis Weapon Systems Proven Operational on Two US Navy Cruisers

he US Navy, supported by Lockheed Martin, successfully completed Combat System Ship Qualification Trials for upgraded Aegis Combat Systems installed aboard two Navy ships. The Navy determined that the Aegis Combat Systems aboard the cruisers USS Mobile Bay and USS Philippine Sea are fully operational. As part of the cruiser modernization program, the computer suites on these ships were upgraded with enhanced technical data collection capability and radar data display systems, as well as a new digital fire control interface between the antisubmarine warfare control system and the vertical launch system.

During the trials, the ships' Aegis Combat Systems were evaluated for combat-readiness through comprehensive surface, subsurface and anti-air warfare exercises. These included manned raids and electronic attack scenarios, as well as thorough testing of the systems' tactical data link and air defense capabilities. "Lockheed Martin continues its legacy of working with the Navy to evolve the Aegis system," said Jeff Bantle, Lockheed Martin's Vice President of Surface-Sea Based Missile Defense Systems. "We take great pride in our partnership as the Aegis Platform System Engineering Agent and look forward to using our experience to increase program affordability."

The Aegis Weapon System includes the SPY-1 radar, the Navy's most advanced radar system. When paired with the MK 41 Vertical Launching System, it is capable of deliv-

The Aegis Weapon System includes the SPY-1 radar, the Navy's most advanced radar system. ering missiles for every mission and threat environment in naval warfare. The Aegis Weapon System is deployed on 93 ships around the globe. Aegis is the weapon system of choice for Australia, Japan, Norway, the Republic of Korea and Spain. Aegis-equipped

ships have more than 1,200 years of at-sea operational experience and have launched more than 3,800 missiles in tests and actual operations. The USS Mobile Bay and the USS Philippine Sea are both Ticonderoga-class guided-missile cruisers.

# **US Air Force Awards Harris \$18 M Contract** for AMRAAM Missile Telemetry Modules

arris Corp., an international communications and information technology company, has been awarded a 2-1/2 year, \$18 M contract to produce telemetry modules supporting the US Air Force Advanced Medium-Range Air-to-Air Missile (AMRAAM). This follow-on con-

tract brings the overall value of the program for Harris to \$154 M since 1991.

The AIM-120 AMRAAM takes maximum advantage of the highly accurate target detection capabilities offered by the advanced radar systems of modern-day warplanes. During test and training firings at Tyndall Air Force Base, FL, the Harris Warhead Replacement Tactical Telemetry Module provided weapon system evaluators with critical flight and performance information about the AMRAAM. The module also has command destruct capability for the missile from the time it is launched from F-15, F-16 and F/A-22 aircraft until final impact.

"The proven performance, reliability and availability of our telemetry modules are key contributors to the longstanding success of the Air Force's Weapon System Evaluation program," said Pat Seamon, Vice President, Avionics and Electronics Programs, Harris Government Communications Systems.

# Raytheon's SLAMRAAM Completes First FMTV Launcher Test Firing

aytheon Co.'s Surface Launched Advanced Medium Range Air-to-Air Missile (SLAMRAAM) system successfully participated in a ballistic test vehicle (BTV) firing at Eglin Air Force Base, FL. The test included the firing of multiple AMRAAM missiles from the new Family of Medium Tactical Vehicle (FMTV) platform. The FMTV was chosen as the new platform for the SLAMRAAM system to increase survivability. The new platform provides additional armored capability and is more ruggedized to support the SLAMRAAM mission.

"We continue to partner with the US Army to develop a SLAMRAAM system that is affordable, adaptable and

responsive to today's evolving threats," said Karen Kalil-Brown, Vice President, National & Theater Security Programs for Raytheon Integrated Defense Systems. "The firing of an AMRAAM missile from the new FMTV platform culminates the successful efforts of our

The primary objective of the BTV firing was to characterize missile dynamic launch effects on the new platform.

government-industry team to transition this critical air and missile defense capability to a more survivable platform for our warfighters."

The primary objective of the BTV firing was to characterize missile dynamic launch effects on the new platform. Raytheon Missile Systems, developer and producer of the AMRAAM missile, successfully collected initial launch condition data, which will reduce risk on future potential FMTV missile integration efforts, such as the AIM-9X. Ad-

Go to www.mwjournal.com for more defense news items

ditional BTV missile firings are planned later this month to support Army safety assessments required for manning by soldiers.

SLAMRAAM is a tailorable, state-of-the-art air defense system that can defeat current and emerging cruise missile threats and a wide range of air breathing threats. This affordable adaptation of the AMRAAM to meet emerging needs provides the warfighter with a system of highly mobile battlefield elements networked and geographically distributed to provide integrated fire control capability against airborne threats.

# **Lockheed Martin Completes Second Live Tracking Exercise for Ballistic Missile Defense**

ockheed Martin successfully identified and tracked four live targets during a test of its Multi-Mission Signal Processor (MMSP) being fielded as part of the Aegis next-generation Ballistic Missile Defense (BMD) capability. The MMSP is part of the Navy's Advanced Capability Build 12 system, intended to help combine nextgeneration Aegis BMD and anti-air warfare (AAW) capabilities in an open combat system architecture.

"This is our second demonstration of the MMSP capability, and both have successfully shown its abilities to detect and track targets," said Allan Croly, Director, Naval Radar Programs, for Lockheed Martin's Mission Systems and Sen-

"MMSP allows our customers to track threats that would have gone undetected with lesser capabilities."

sors business unit. "MMSP allows our customers to track threats that would have gone undetected with lesser capabilities."

The first demonstration conducted earlier this year showcased the radar's AAW capability while this test focused on the radar's BMD capability. Both were conducted using an augmented Aegis system at the Navy's land-based test facility, the Vice Admiral James H. Doyle Combat Systems Engineering Development Site in New Jersey. Additional testing will occur through 2011.

As part of the Aegis Modernization Program, MMSP is scheduled for installation on guided missile destroyers currently equipped with the Aegis Weapon System, starting in 2012. The Aegis BMD element of the nation's ballistic missile defense system provides the capability to use hit-to-kill technology to intercept and destroy short- and mediumrange ballistic missiles.



If your RADAR, EW, or SIGINT system requires the cleanest signals, ITT Microwave Systems has the solutions. We deliver premium RF and digital subsystems by integrating our proprietary technologies within densely populated custom and standard packages. Our expertise is in frequencies through 20 GHz and includes FPGA-based Direct Digital Synthesis (DDS) LO synthesizers and waveform generators, as well as software controlled, wideband RF/digital tuners and upconverters.

**ITT Microwave Systems** 978-441-0200

Engineered for life

Visit our website for more information. ittmicrowave.com



# A FULL SPECTRUM OF SOLUTIONS





Salisbury, Maryland 21802 · USA · 800.780.2169 · 410.860.5100 Brackenholme Y08 6EL, UK · Tel/Fax +44 (0) 1757 633 755

www.lorch.com



# Reactel, Incorporated

Reacting First to All Your Filter Needs.



# **GPS FILTERS**

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

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

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



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





REACTEL,





COMMERCIAL

Download a copy of our new full line catalog today!

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









# International Report

Richard Mumford, International Editor

# TTA and ETSI Renew Memorandum of **Understanding**

he Telecommunications Technology Association (TTA) of South Korea and the European Telecommunications Standards Institute (ETSI) have renewed their Memorandum of Understanding (MoU). This renewal confirms the willingness of two major standards development organizations to continue to share their work and expertise in order to contribute to the development of globally-applicable standards for Information and Communications Technologies (ICT). The original MoU was established in 1992 and was last renewed in 2005.

TTA and ETSI have many common areas where the work of the two organizations intersects at the point where specifications and standards development come together.

"... this collaboration a high level of alignment will lead to many benefits for the development of ICT standards with worldwide impact."

The agreement ensures between the two organizations and their respective regions. In the foreseen life span of the new MoU, TTA and ETSI and their respective secretariats will work together to further stimulate collaboration on identified technical areas

with a global impact. These include Intelligent Transport Systems, the fast growing sector of Machine-to-Machine (M2M) communications, and Digital Multimedia Broadcasting.

"While reviewing the text of the MoU, TTA recognized that ETSI and TTA are covering more areas where there is scope for cooperation, including mobile communication aspects such as IMT-Advanced and 3GPP, and next generation networks such as M2M, Intelligent Transport Systems, Cloud Computing and TETRA. I believe these areas are essential for both organizations and certainly ones where we can be the international standardization leaders," said Keun Hyeob Lee, TTA President.

ETSI's Director-General, Walter Weigel, remarked, "ETSI is committed to ensuring global collaboration with all the important standardization organizations of the world. TTA is unquestionably one of our long-standing partners with whom we have collaborated very effectively in the past, especially in the big success story of 3GPP. I am therefore delighted by the renewal of the MoU with TTA and I am confident that this collaboration will lead to many benefits for the development of ICT standards with worldwide impact."

# **Astrium and Avanti Launch Military and Government Ka-band Test-bed**

strium Services is launching its military and government advanced Ka-band test-bed in cooperation with Avanti Communications, who will be providing the satellite bandwidth. Astrium Services has entered into a pioneering agreement with Avanti Communications to use transponder capacity for Ka-band tests on the soon to be launched Hylas 1 satellite.

The technology test-bed comprises a dedicated secure laboratory facility equipped with RF, modem and encryption and routing equipment, which will enable government and military customers to work in close collaboration with

Astrium Services' engineers in testing and refining future military Ka-band system requirements. System tests on the satellite will cover military use of Ka-

"Military Ka-band capability will play a very strong role in future Con Ops..."

band, including tactical and comms on the move (CoTM) terminals in field locations. It will be based in Stevenage, UK, and use proven in-house system and terminal capabilities supplied by Astrium Secure Satcom Systems.

Astrium Services CEO Eric Beranger said: "As the world's first provider of military grade secure satellite communications to government customers we are continually looking at how to improve our services and solutions. Our goal with the technology test-bed and the capacity lease on Hylas 1 is to test and validate potential future service opportunities to give our existing and future customers an edge over the competition.

"Military Ka-band capability will play a very strong role in future Con Ops, particularly for very high data rate services to and from disadvantaged terminals in theatre. One area we are looking at is multiple Unmanned Aerial Systems (UAS) streaming real time surveillance data to support military or governmental operations across areas of military or political interest. Current satellite systems simply do not have the available bandwidth to support such operations."

# **GSA Reports Growing Momentum for LTE**

he Global mobile Suppliers Association (GSA) has published an update to its Evolution to LTE report, which confirms that 101 firm LTE network deployments are in progress or planned in 41 countries. The

GSA Evolution to LTE Report covers both LTE FDD and LTE TDD modes and divulges that the number of network commitments is 71 percent higher than GSA reported in a similar survey six months earlier.

... 101 firm LTE network deployments are in progress or planned in 41 countries.

This figure includes three LTE systems that have launched commercial service in Sweden, Norway and Uzbekistan, and the GSA anticipates up to 22 LTE networks will be in commercial service by the end of 2010. Another

# International Report

31 operators are engaged in various LTE pilot trials and technology tests, which means that 132 operators are now investing in LTE in 56 countries. Significantly, the recently concluded BWA spectrum auction in India has paved the way for early and large scale introduction of TDD LTE into the world's fastest developing market.

Governments around the world are preparing the way to ensure the availability of spectrum to support delivery of next generation mobile broadband services for the mass market, by allocating or preparing for the release of new spectrum such as 2.6 GHz, and in the digital dividend (700 MHz, 800 MHz) bands, or re-farming existing spectrum, e.g. 900 MHz, 1800 MHz, etc., or facilitating a combination of new and re-farmed bands. The report notes that several trial licenses have been granted in many countries to allow operators to familiarize with the technology, capabilities and performance aspects.

# Turkey's Göktürk Satellite System Enters Design and Construction Phase

elespazio and Thales Alenia Space announced the official start of the Göktürk observation satellite system for the Turkish Ministry of Defence. The original contract was signed by Telespazio and the Turkish Defence Ministry in 2009, and the programme now officially enters the design and

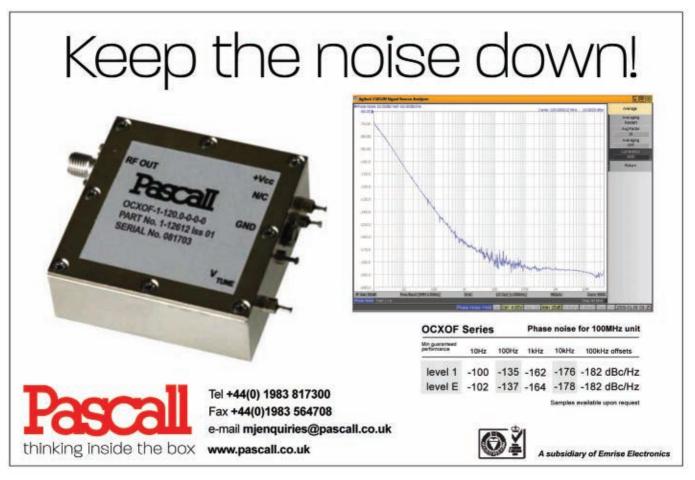
construction phase, with the satellite launch planned for 2013. Telespazio, a Finmeccanica/Thales company, is the prime

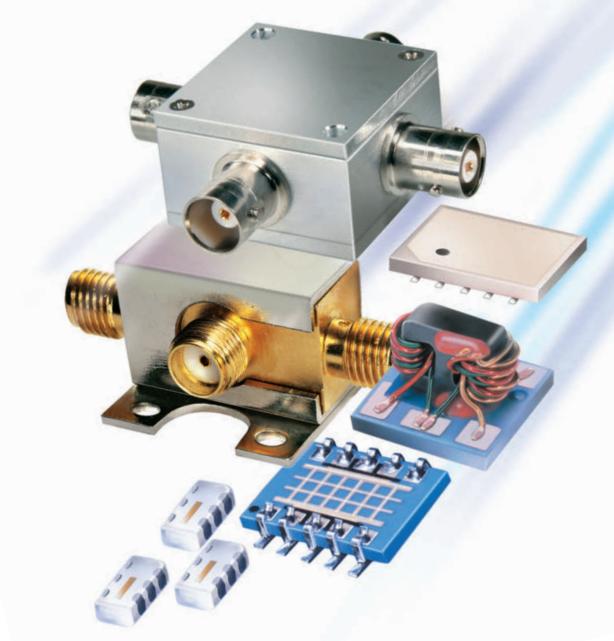
contractor for the system, which comprises an Earth observation satellite equipped with a high-resolution optical sensor, a satellite integration and test centre to be built in Turkey, and the complete ground segment, in charge of mission control, in-orbit operation, data acquisition

Thales Alenia Space will build the satellite and develop an integration and test centre in Turkey.

and processing. Local industrial partners include Tai A.S., Aselsan A.S., Tubitak Uekae, Roketsan A.S. and TR Tecnoloji. Telespazio will also create a joint venture with a local partner to develop and market application services.

Thales Alenia Space will build the satellite and develop an integration and test centre in Turkey. Telespazio, in addition to the ground segment, is responsible for services during the satellite launch, early orbit and test phase. Turkish industry will be involved in the system design and development, as well as supplying some Göktürk system components. In particular, local partners will assist in the construction of the data acquisition station, the satellite integration centre, mission planning systems and remote sensing data processors.





Directional/Bi-Directional

# LTCC COUPLER FAMILY



Mini-Circuits LTCC coupler family offers versatile, low cost solutions for your **5** kHz to **6** GHz needs with rugged connectorized models from .74"x.50" to surface mount couplers from .12"x.06", the smallest in the world! Choose from our 50 & 75  $\Omega$  directional and bi-directional couplers with coupling ranging from 6-22 dB and with capability to pass DC. Mini-Circuits offers the world's most highly evolved LTCC

technology delivering both minimal insertion loss and high directivity with models handling up to 65 W. All of our couplers are ESD compliant and available as RoHS compliant. For full product details and specifications for all our couplers, go to Mini-Circuits web site and select the best couplers for your commercial, industrial and military requirements.

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



P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

The Design Engineers Search Engine finds the model you need, Instantly • For detailed performance specs & shopping online see minicipality.



# 90° SPLITTERS

5 MHz to 7.2 GHz from \$395

At Mini-Circuits, we understand that two-way 90° power splitters (hybrids) are critical building blocks in a wide array of RF design solutions. That's why we offer them in extra-tight phase and amplitude balance to ensure your expected high-performance design results. Plus, our robust, rugged units deliver repeatable performance and are available in over 91 different models, in the widest range of frequencies in the industry (from 5 MHz to 7.2 GHz), and in package sizes as small as 0.08" x 0.05".

For full performance details and product availability, visit our web site www.minicircuits.com. You can order online and have units in-hand as soon as next-day.

Mini-Circuits... Your partners for success since 1969



C RoHS compliant





# COMMERCIAL MARKET

Dan Massé, Associate Technical Editor

# **Strong Growth Continues for GaAs Industry**

he GaAs market staged a strong recovery toward the end of a tumultuous 2009 as a result of positive trends in wireless markets. The Strategy Analytics GaAs and Compound Semiconductor Technologies (GaAs) service report, "GaAs Industry Forecast 2009-2014," calculates that despite a recession, GaAs industry revenues managed to escape a drop in 2009, with a strong performance in the second half of the year translating to year-on-year revenues remaining flat at \$3.7 B.

GaAs technology will maintain its position as the enabling technology for next generation cellular handsets.

"... GaAs device demand will continue to see continued growth through 2014." The smartphone category of the handset market, in particular, provided a vital lifeline in 2009, boasting stronger than average annual growth in terminal volumes. With an increasing average number of GaAs

power amplifiers per terminal as well as increasing switch complexity in this sector, GaAs device demand from next generation handsets will grow faster than overall industry revenue growth.

"Our analysis incorporates individual wireless, consumer, infrastructure and defense market forecasts—taking into account technology trends," noted Asif Anwar at Strategy Analytics. "There is no question that the improving capabilities of silicon and silicon germanium technologies, as well as emerging technologies such as gallium nitride, will provide increasing competition for GaAs technologies."

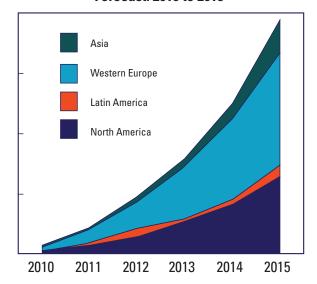
"Despite this competition, GaAs device demand will continue to see continued growth through 2014. The market will grow at a compound annual growth rate of 5 percent to be worth over \$4.7 B," concluded Anwar.

# Digital Radio Installed Base Will Approach 200 Million by 2015

igital radio has just begun to see consumer adoption in the US and Western Europe. By the end of 2010, about four million digital radios using iBiquity's proprietary HD Radio technology will have shipped in the US. In Europe (led by Britain) governments have chosen the DAB standard and consumers have purchased nearly 13.5 million radio receivers. By 2015, the worldwide installed base of digital radio receivers, excluding handsets, is expected to reach nearly 200 million units. Smartphones are expected to include digital radio receivers starting in mid-2011, driven by carriers' desire to offer users premium audio content while limiting the use of scarce radio spectrum.

Listeners will have access to niche programming targeted to narrower demographic segments and will respond to a more interactive user experience enabled by program

## Digital Radio Shipments by Region World Markets, Forecast: 2010 to 2015



Source: ABI Research

guides and other enhancements. Broadcasters, in turn, will have a larger reach and the ability to provide better targeted and more interactive ads.

To learn more about the digital radio market, please visit ABI Research's "Digital Radio" study, which covers digital radio receivers and subscriptions within the home and on the go (portable media players and automotive), and digital radio receiver shipments into cellphones.

# \$1 B Microwave Tube Market Holding Off GaN Threat

hile microwave and millimeter-wave high-power vacuum electron devices (VED) remain "below the radar" of many industry observers, the total available market (TAM) for this segment is over \$1 B. The size of this market continues to surprise everyone and its longev-

ity and firm resistance to RF power semiconductor encroachment is just as surprising. Essentially, this is now a stable industry after several rounds of consolidation

The size of this market continues to surprise everyone...

in recent years. There is potential for some further consolidation, but there are no signs of that happening yet.

One new RF semiconductor technology—gallium nitride (GaN)—may change the landscape, but has not yet done so to any meaningful degree. While it is not yet monopolizing the microwave RF power industry, GaN is advancing steadily and is a technology that should be closely watched.

To learn more about the microwave tube (valve) market



Go to www.mwjournal.com for more commercial market news items

# Commercial Market

and how it may affect business models now and in the future, please visit ABI Research's new study "Microwave and Millimeter-Wave High-power Vacuum Electron Devices: Successfully Holding Off the Gallium Nitride Threat," which examines the microwave and millimeter-wave high power vacuum electron device market and assesses how gallium nitride (GaN) devices could affect that business. It will be of interest to organizations involved in defense electronic, energy and scientific research, and spacecraft electronics, as well as VED manufacturers, RF power semiconductor users and manufacturers, and government.

# TiaLinx Announces Launch of Wearable, Hands-free Sense-Through-The-Wall Imager

iaLinx Inc., a developer of miniaturized mm-wave radars with integrated radio and antenna arrays, recently announced the launch of the Eagle 45-W, a hands-free precision Sense-Through-The-Wall Imager.

The lightweight, ultra-wideband (UWB), multi-Gigahertz RF imager requires only limited use of hands and is operated through a miniaturized display. Through the software controlled interface, which is integrated into the wearable imager, the hands are free for performing mission critical tasks. The user is not distracted by searching for the control functions. The display unit can be mounted on a pair of glasses or goggles for ease-of-use.

The lightweight arm mounted scanner unit transmits wideband pulses (nano-sec) that are directional and can penetrate concrete walls greater than 16" of thickness. In the receiver, a pulse detector circuit is employed to capture the reflections from potential targets. Ampli-

tude and delay information are then extracted and processed in an integrated signal processor. Advanced signal and image processing algorithms are employed to detect moving targets or the breathing pattern of a person.

"Reduced weight, increased battery life, enhanced user-friendly in-

The... unit transmits wideband pulses that... can penetrate concrete walls greater than 16" of thickness.

terface, and providing improved visual perception were the key factors in the design of the Eagle45-W," said Fred Mohamadi, Founder and CEO of TiaLinx. "The disruptive Sense-Through-The-Wall imaging technology from TiaLinx assists the user by enhanced situational awareness and minimizes the Sense-To-Reaction time significantly. The combination of the two functions is essential for successful fielding in the near future. Further modifications are ongoing to put the user out of harm's way completely by extending the range through remote sensing."



# SPECIAL HERMETIC PRODUCTS, INC.

Hi-Rel By Design

# SHP seals are identifiable in many ways: • The uniformity of the solder joint when installed • The uniformity and fire polish of the glass • The absence of voids and cracks in the glass • The quality and consistency of plating • The success of the companies who use them Call us today for your FREE SAMPLES!

39 Souhegan Street – P.O. Box 269, Wilton, New Hampshire 03086 TEL (603)654-2002 FAX (603)654-2533 email: sales@shp-seals.com - website: <a href="www.shp-seals.com">www.shp-seals.com</a>

# Stop doing interconnect layout and extraction by hand.

Say good-bye to the snail's pace of manual interconnect, layout and extraction techniques. With AWR's ACE and iNets technology - for automated interconnect and circuit extraction — you cut out the monotony of hand constructing interconnect, fracturing layout and brute-force EM. Fewer mouse clicks and innovative AWR technology mean shorter process times, right-the-first-time designs, and less stress for you. Don't you deserve that? Grab your own test copy at www.awrcorp.com/MWO.



# **INDUSTRY NEWS**

# AROUND THE CIRCUIT

Jennifer DiMarco, Staff Editor



Roger W. Sudbury, a longtime MIT Lincoln Laboratory staff member and dedicated IEEE volunteer, passed away on August 22, 2010. Joining Lincoln Labs in 1969 as a technical staff member researching solid-state devices for modern radars, he went on to become the Laboratory's executive officer, serving within the Director's Office. He was a dedicated volunteer for

the MTT-Society and IEEE for 30 years, and his wisdom, honesty and energy were widely respected by all who worked with him. Sudbury was nationally recognized as a visionary leader in the development of gallium-arsenide monolithic circuits for applications in electronically scanned radars. The work that he led at the Laboratory encouraged and influenced efforts at a number of major electronic firms, leading to the United States' world leadership in military solid-state radars for missile and air defense. Sudbury was valedictorian of his high school class in 1956 and was one of the initial National Merit Scholars. In 1960, he graduated from the Georgia Institute of Technology with a degree in electrical engineering with highest honors and did his graduate work at MIT. Through his 41-year career at Lincoln Laboratory, he served as a knowledgeable adviser and mentor, receiving the MIT Lincoln Laboratory Career Achievement Award "in recognition of his lifetime commitment and technical contributions for the Massachusetts Institute of Technology and MIT Lincoln Laboratory and for his exceptional service to the nation." He was active in a leadership role in the IEEE, most recently serving on the IEEE Board of Directors as Director of Division IV: Electromagnetism and Radiation, and chaired its Employee Benefits and Compensation Committee, and was to be the 2011 Chair of the IEEE Strategic Planning Committee. He was President of the IEEE Microwave Theory and Techniques Society in 2000, and in 2010 was the recipient of the Society's Distinguished Service Award "for outstanding and dedicated service to the Society." He was elevated to the member grade of IEEE Fellow in 2004 for "contributions to leadership in gallium-arsenide integrated circuits.'

Infineon Technologies AG and Intel Corp. have entered into a definitive agreement to transfer Infineon's Wireless Solutions (WLS) business to Intel in a cash transaction valued at approximately \$1.4 B. WLS, a provider of cellular platforms to top tier global phone makers, will operate as a standalone business serving its existing customers. WLS will also contribute to Intel's strategy to make connected computing ubiquitous from smartphones to laptops to embedded computing.

As part of the recent merger that added **Mimix Broadband Inc.** and its subsidiaries to the **M/A-COM Tech** family of companies, **Mimix Asia** has changed its operating name to **M/A-COM Tech Asia**. M/A-COM Tech Asia is focused on the design and manufacture of innovative products aimed at addressing the microwave and millimeterwave applications requirements of its customers across the globe. Located in Hsinchu Science-Based Industrial Park,

the M/A-COM Tech Asia facility is ISO 9001-registered and includes a Class 10,000 clean room for die picking and visual inspection and 8,000 square feet of production floor space. M/A-COM Tech Asia also has an ISO 9001-registered design center in Belfast, Northern Ireland, for product development and qualification with comprehensive assembly and test facilities for designing industry-leading devices.

**RF Monolithics Inc.** (RFM) announced that **Murata Electronics North America Inc.** has purchased 533,000 shares of RFM Common Stock at \$1.31/share, representing a small premium over RFM's recent 30-day volume weighted average price, in a private transaction. The purchase represents less than five percent of RFM's outstanding stock. Additionally, RFM and Murata Manufacturing Co. Ltd., Murata Electronics North America's parent, have entered into a collaboration agreement.

MtronPTI announced it is collaborating with Jackson Labs Technologies Inc. for development and marketing of Global Positioning Satellite – Disciplined Oscillators (GPSDO) modules. The partnership takes advantage of Jackson Labs Technologies Inc.'s extensive technology portfolio and combines this with MtronPTI's oscillator product and manufacturing expertise to provide state-of-the-art timing and frequency solutions to customers.

**WiSpry Inc.** announced that the company has signed an agreement with **NTT DOCOMO Inc.** to jointly develop tunable filters for mobile phone applications based on WiSpry's RF-MEMS technology. Under the terms of the agreement, both companies will work together and draw on each other's expertise to design and develop new and enhanced tunable filters. WiSpry will supply tunable RF-MEMS technology, and DOCOMO will provide system and application technology. This project is expected to provide tunable filters for use in mobile phone platforms.

**Analog Devices Inc.** (ADI) introduced a high performance development platform for wireless infrastructure equipment designers who need to quickly evaluate systems using digital pre-distortion (DPD) techniques in multi-carrier cellular base stations. ADI's mixed-signal digital pre-distortion development (MS-DPD) platform seamlessly integrates a complete high performance RF and mixed-signal transmit chain from ADI with any field-programmable gate array (FPGA) development kit with a high-speed mezzanine card (HSMC) connector from programmable-logic vendor **Altera Corp.** 

**WIN Semiconductors Corp.**, a pure-play Gallium Arsenide (GaAs) foundry, and **Presto Engineering**, a semiconductor product engineering company, announced a strategic collaboration to deliver characterization and testing services for companies developing products utilizing GaAs

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



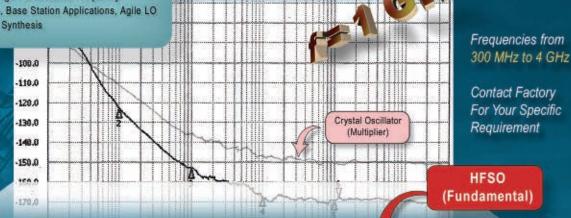
roducing
Our new line of Low Phase Noise Introducing Free Running & Phase Locked Signal Sources

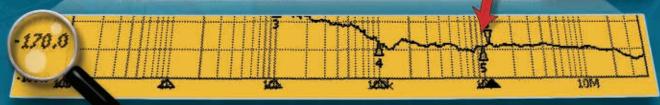
# **Features**

- Cost Effective
- Eliminates Noisy Multipliers
- Patent Pending Technology

# **Applications**

Test & Measurement Equipment, High Frequency Network Clocking, Scanning & Radar Systems, High Performance Frequency Converters, Base Station Applications, Agile LO Frequency Synthesis





Available In Surface Mount

HFSO - Free Running VCO Series (0.5" x 0.5" x 0.18") FCTS - Phase Locked Series (0.9" x 0.9" x 0.22")

& Connectorized Package



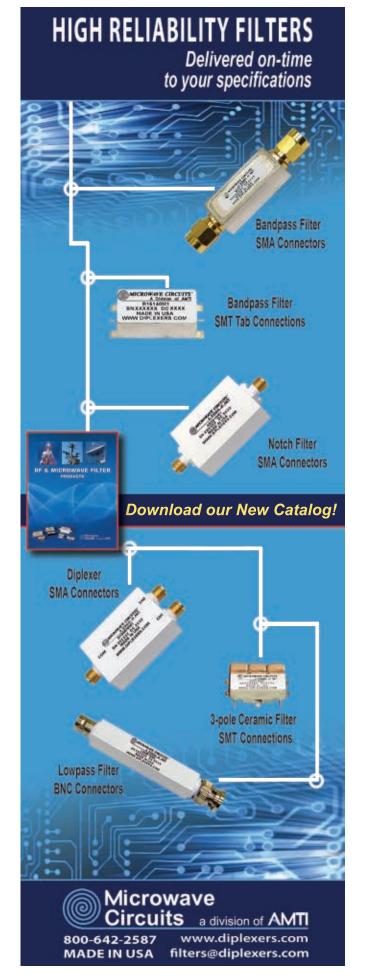


When There's, SYNERGY
There's INNOVATION



For additional information, contact Synergy's sales and application team. 201 McLean Boulevard, Paterson, NJ 07504 | Phone: (973) 881-8800 Fax: (973) 881-8361 | E-mail: sales@synergymwave.com

Visit Our Website At WWW.SYNERGYMWAVE.COM



technology from WIN. The agreement covers wafer-level and packaged part development activities, including design characterization and production testing. Customers of WIN Semiconductors can now gain access to these highly specialized GaAs testing services from the Presto Engineering Hubs in Silicon Valley and in Grenoble, France.

Linwave Electronic Manufacturing Services, a division of Linwave Technology, announced the opening of a new UK-based high technology microwave manufacturing centre. The facility will support key activities of diode manufacturing, MMIC packaging and high frequency/precision manufacturing solutions. The facility, which is a technology partnership between e2v and Linwave Technology, has been enabled by the transfer of equipment, processes and 15 highly skilled personnel into the new facility. Focused around a 2000 sq ft class 10,000 clean room, the facility offers a background dust count of below 10,000 parts per milion localised to class 100 under laminar flow for critical operations.

**Skyworks Solutions Inc.**, an innovator of high reliability analog and mixed signal semiconductors enabling a broad range of end markets, announced that **Samsung** is leveraging several of its solutions for its newest femtocell offering, including Verizon's Wireless Network Extender. Samsung's latest offering, the new code division multiple access (CDMA) plug-and-play personal base station, or femtocell, for homes or small offices, provides customers with enhanced cellular coverage, helping to eliminate "dead spots". It also reduces the need for a landline given its ability to manage up to three calls simultaneously with a fourth channel reserved for emergency 911 calls.

**Tektronix Inc.**, a manufacturer of oscilloscopes, announced that its next-generation, scalable performance oscilloscope platform will make broad use of **IBM** 8HP silicon germanium (SiGe) technology. Tektronix demonstrates its commitment to help engineers around the world speed debug and test tomorrow's designs. The 130 nanometer (nm) SiGe bipolar complementary metal oxide semiconductor (BiCMOS) foundry technology offers 2× performance over the previous generation, and targets delivery of oscilloscopes with real-time bandwidth beyond 30 GHz.

**AT4 wireless Inc.** (Taiwan) announced new testing services to cover Release 8 (LTE) and Release 7 (HSPA+) under ISO 17025 accreditation. AT4 wireless started operations in Taiwan last October 2009, and during 2010 this testing laboratory obtained ISO 17025 accreditation and became GCF and PTCRB accredited laboratory for GSM, GPRS, EDGE, W-CDMA and HSPA conformance testing, including Protocol and RF. With this new accreditation, the scope of services is one of the most complete in Asia.

**Cobham SATCOM**, a manufacturer of Inmarsat satellite communications equipment, announced that its HGA-7001 High Gain Antenna system has been certified on the Airbus Long Range family of aircraft. This complements an ever growing range of airframes on which the system is deployed, including Boeing B737, B747, B767, B777 and B787 and Airbus A320, A350 and A400M, and confirms

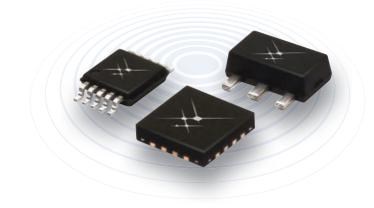


# **Discrete and Integrated RF Solutions**

# **Broad Product Portfolio:**

- Amplifiers Cellular, WLAN, Infrastructure, LNA, General Purpose
- Front-End Modules Cellular, WLAN / WiMAX, ZigBee® and ISM
- **Switches** SP2T to SP10T Switches and Antenna Switch Modules for Cellular, WCDMA, LTE, Embedded WiFi, WiMAX
- Mixers Demodulators/Modulators, Single Channel, Diversity, Up/Down Converters
- Synthesizers High Performance Integer-N, Fractional-N
- Attenuators Fixed, Digital, Voltage Variable
- **Technical Ceramics** Magnetic Materials, Dielectric Resonators, RF Components, Advanced Materials
- **Diodes** Limiter, PIN, Schottky, Varactor

**Skyworks Solutions** is an innovator of high reliability analog and mixed signal semiconductors enabling a broad range of end markets. The Company's solutions are increasingly at the heart of smart phone, broadband access, network infrastructure and smart grid applications.





# **New Designer Kits**

Select products and sample/designer kits available for purchase online.

www.skyworksinc.com



# **Visit us at MILCOM Booth 1619**















# Rosenberger





# Customized **Footprints**

The performance of surface mount RF connectors is dependent on a variety of parameters, e.g. substrate thickness, board-stack up

At Rosenberger, we not only provide you with the surface mount connectors, we provide - as a free service - a footprint that is optimized for your application.

RF surface mount connectors from Rosenberger - along with optimized footprints - are available in various standard interfaces - SMP, Mini-SMP, MCX, SMA, QMA and for various test & measurement connectors.

# **Exploring new directions**

Ask us for more information:

Rosenberger of North America, LLC · Greenfield Corporate Center P.O.Box 10113 · USA – Lancaster, PA 17605-0113 Phone: 717-290-8000 · Fax: 717-399-9885 · info@rosenbergerna.com

Rosenberger Hochfrequenztechnik GmbH & Co. KG P.O.Box 1260 · D-84526 Tittmoning Phone: +49-8684-18-0 · Fax: +49-8684-18-499 · info@rosenberger.de

Visit http://mwj.hotims.com/28495-121

#### the general appeal and acceptance that this product enjoys in the aeronautical market.

**Agilent Technologies Inc.** announced it is the recipient of Frost & Sullivan's 2010 Global Award for Product Line Strategy in the Microwave Test Equipment Market. The award is conferred on the company that has developed a comprehensive product line that addresses the breadth of the market it serves. The award recognizes the extent to which the product line meets customer demands and adds value for customers.

### PERSONNEL



Flann Microwave announced the appointment of James Watts as Chief Executive Officer (CEO), with effect from 1st September 2010. Ian Crane is now stepping into the position of Chief Technical Officer (CTO). This interchange of roles provides a sound basis for the future growth of Flann and continues the

tradition of technical leadership. In the five years that Watts has been with Flann, he has led the Design and Development group and has presented lectures and papers on millimeter and terahertz technology and applications. He has previous experience working for Plessey Radar, DERA and QinetiQ on antenna systems and millimeter-wave radar.

International Manufacturing Services Inc. (IMS), a manufacturer and supplier of high quality thick film resistors, terminations, attenuators, couplers, thermal management devices, planar dividers and planar filters to the electronics industry, announced the appointment of John J.B. Silvia Jr. as President. Silvia has served IMS for more than 27 years and has been a member of IMS's Board of Directors since 1990. He has served as Vice President of Manufacturing from 1990 to 1998, and Vice President of Operations up to the present. In his role as President, Silvia will work closely with all departments to ensure the continued success of IMS.

# **REP APPOINTMENTS**

**Channel Microwave**, a supplier of ferrite and waveguide components, announced the appointment of Spartech-**South** as its company's representative. Spartech-South will cover Florida and the Dixie land states. Spartech-South brings 40 years of sales experience and expertise to the RF and microwave industry.

MITEQ Inc. announced the appointment of Lionheart **Northwest Inc.** as the company's exclusive sales representative in Washington State, Oregon, Idaho and British Columbia. Lionheart Northwest Inc. will represent MITEQ's Component division of products, which includes amplifiers, mixers, frequency multipliers, passive power components, switches, attenuators, limiters, phase shifters, IF signal processing components, oscillators, synthesizers, integrated





Microlab

multifunction assemblies and fiber optic products. Lionheart Northwest Inc. can be contacted at sales@lionheartnw.com.

**AtlanTecRF**, a UK-based manufacturer of microwave and RF components and equipment, has announced the appointment of **Giza Technologies** as the company's exclusive representative for France. The broad AtlanTecRF range will complement Giza Technologies' existing product lines and the operation will be overseen by the French distributor's Managing Director, Fabrice Hery, who offers a wealth of knowledge and experience of microwave and RF.

**Star Microwave Inc.**, a provider of technology solutions for the growing requirements for catalog and specialized designs of high-power drop-in and connectorized isolators and circulators, for the US and international markets, has announced the expansion of regional sales representatives with the appointment of **Matrix Sales Inc.**, Chelmsford, MA, phone: (978) 459-4000, web site www.matrixsalesinc.com.

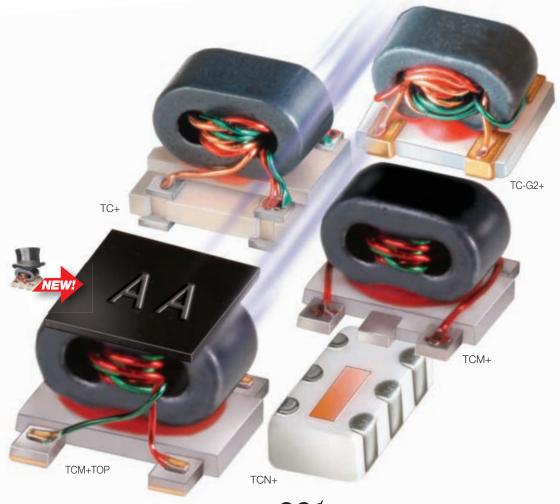
**Paciwave Inc.**, a supplier of microwave solid-state switches, attenuators, DLVAs and custom integrated microwave assemblies, announced the expansion of its network of regional sales representatives with the following new representative appointments: DURA Sales of Southern California (909-612-1044), located in Diamond Bar, CA, will be representing the company in the SoCal territory; **Microcom Sales** of Midland Park, NJ (201-669-7599), will be representing the company in Upstate New York; Potomac Technical Sales of Salisbury, MD (410-860-1985), will be representing the company in the mid-Atlantic states including southern New Jersey, eastern and central Pennsylvania, Delaware, Maryland, Virginia, West Virginia and the Washington, DC area; Hi-Peak Technical Sales of Hudson, NH (508-878-8711), will be representing the company in Maine, Vermont, New Hampshire, Rhode Island, Massachusetts and northern Connecticut; GIGACOMP GmbH (+49-89-32208783) and sister company **GIGACOMP AG** (+41-31-868-4455) will be representing the company in Germany, Switzerland, Austria, Czech Republic, Holland, Belgium and Luxemburg; **Syratron Marketing Pvt. Ltd.** (+91-80-2559-1031) will be representing the company in India.

**Lorch Microwave** announced the appointment of **GLOBES Elektronik** as the company's exclusive sales representative in Germany, Austria and Switzerland. GLOBES will represent Lorch's complete range of RF and microwave products, which include discrete, cavity, ceramic and tubular filters, digitally- and manually-controlled tunable filters, RF components and multi-function assemblies.

**Spanawave Corp.**, a supplier of RF, IF, and microwave components, assemblies, transceivers and test fixtures covering from DC to 26 GHz, announced new regional sales representative appointments: **Val Jackson & Associates Inc.** of Port Angeles, WA (360) 452-7308 will be representing the company in northern California, northwestern Nevada, Oregon and Washington; **Grant Technical Sales LLC** of Phoenix, AZ (602) 625-3196 will be representing the company in Arizona, New Mexico and Texas (El Paso County only).



# TINY RF & MICROWAVE TRANSFORMERS



0.15-6200 MHz as low as 99 each (qty. 1000)

### Every transformer you need, right off the shelf!

Need an RF or microwave frequency transformer with a small footprint? Mini-Circuits has what you need, already in stock. Our TC-series transformers cover a wide variety of frequency ranges, with rugged construction, outstanding VSWR performance and several packages to fit your size, reliability and environmental requirements—and we can ship within a week of your order. Don't see what you need? Our engineers can customize a model to your needs at no extra charge.









Your choice of package styles includes:

**TC-G2+** Ceramic with gold-plated terminals for military and high-reliability requirements.

**TCN+ and NCS+** Low Temperature Co-fired Ceramic (LTCC) miniature packaging for superior thermal stability and reliability.

**TC+ and TCM+** All-welded construction and a plastic base for commercial applications.

**TC-TOP** Features a "top-hat" package with square top surface and model markings that can improve your manufacturing throughput.

Detailed technical specifications and pricing info are available at minicircuits.com.

THE TRANSFORMER YOU NEED IS JUST A CLICK AWAY!

Mini-Circuits... Your partners for success since 1969



P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

The Design Engineers Search Engine finds the model you need, Instantly • For detailed performance specs & shopping online see minicipality.



# EFFECTS OF SINGLE-TONE SPURIOUS RESPONSES ON SIGNALS IN ESM RECEIVERS

This article presents the effects of spurious responses in ESM receivers used to geo-locate threat emitters. These spurs contaminate the measured values of phase and frequency of detected signals in the receivers, beyond the effect of receiver noise, causing errors in geo-location of emitters. In some cases the spurious responses change in frequency as the detected signals change in frequency; the spur frequency sometimes will cross the true detected signal frequency generating a crossing spur.

lectronic Support Measures (ESM) receivers geolocate threat emitters by measurement of angle of arrival (AOA), time difference of arrival (TDOA) or frequency difference of arrival (FDOA). Errors in the measurement of phase and frequency may be contaminated, due to spurious responses that yield irresolvable errors.

#### **PHASE CONTAMINATION**

Radar signals in a receiver generate single-tone spurious response due to frequency conversion in mixers. Consider a unit amplitude signal and a single-tone generated spurious response as given below:

$$s(t) = \cos(2\pi f t) - r\cos\left[2\pi (f - \Delta f)t + \theta\right] \tag{1}$$

where f is the IF frequency of the signal, r is the ratio of spur level with respect to the true signal level that is less than unity,  $\Delta f$  is the spur frequency off-set from the signal frequency and  $\theta$  is an arbitrary phase angle. Using trigonometric identities, Equation 1 may be reduced as shown below:

$$s(t) = \sqrt{1 - 2r cos \left[2\pi\Delta f + \theta\right] + r^2} \cos(2\pi f t - \gamma(t)) \tag{2}$$

where

$$\gamma(t) = \arctan \frac{r\sin(2\pi\Delta f t + \theta)}{1 - \cos(2\pi\Delta f t + \theta)} \tag{3}$$

Equation 3 can be expanded as an infinite sine series for the case where  $r^2$  is less than 1.1

$$\gamma(t) = \sum_{k=1}^{\infty} \frac{r^k \sin(2\pi k \Delta f t + k \theta)}{k} \tag{4}$$

Note that the spur signal contaminates the signal by appearing to cause amplitude modulation and frequency modulation on the signal.

For k=1 and  $(2\pi\Delta f + \theta) = \pi/2$ , Equation 4 becomes:

$$\gamma(t)_{\text{Max}} = r - \frac{r^3}{3} + \frac{r^5}{5} - \frac{r^7}{7} + \frac{r^9}{9} - \dots$$
 (5)

For k=1 and  $(2\pi\Delta f + \theta) = 3\pi/2$ , Equation 5 becomes:

$$\gamma(t)_{\text{Min}} = -r + \frac{r^3}{3} - \frac{r^5}{5} + \frac{r^7}{7} - \frac{r^9}{9} + \dots$$
 (6)

The peak to peak angle variation in degrees is:

$$\gamma(t)_{Pk-Pk} = 114.5^0 \left[ r - \frac{r^3}{3} + \frac{r^5}{5} - \frac{r^7}{7} + \frac{r^9}{9} - \dots \right] \eqno(7)$$

For the case where r is less than or equal to 0.1, Equation 7 reduces to:

$$\gamma(t)_{Pk-Pk} = 114.5^{0} r \tag{8}$$

**Figure 1** shows the peak phase error due to spurs of various levels. Spur levels greater than -29 dB may cause phase errors of  $4^{\circ}$  or greater.

S.J. Caprio *Laurel*, *MD* 





# **RO4360™ + RO4460™ A** Complete Laminate & Prepreg System Formulated To 6.15 Dk.

For laminates and prepregs that add up to low-cost solutions for multilayer amplifiers and other high-frequency designs, count on Rogers RO4360™ and RO4460™ materials. Built on the legacy of Rogers RO4000® series platform, with a dielectric constant of 6.15 and low loss, these thermoset resin materials help designers shrink the size of amplifiers, antennas, and other circuits as much as 30%.

Costing less than PTFE, the combination of RO4360 + RO4460 is environmentally friendly, supporting lead-free, RoHS-compliant manufacturing. This high-performance material system delivers electrical performance similar to that of PTFE, but is compatible with low-cost FR-4 circuit-board processing. For circuit size reduction with low loss, impressive thermal conductivity, and dielectric constant of 6.15, only one material solution adds up: RO4360 + RO4460.



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



Advanced Circuit Materials Division

The world runs better with Rogers.®

Features & Benefits of RO4360 Laminate + RO4460 Prepreg

#### HIGH PERFORMANCE

- Dielectric constant of 6.15
- High thermal conductivity
- Low loss
- Low Z-axis CTE

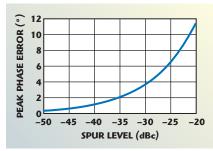


#### LOW COST

- Priced below PTFE
- Supports automated assembly
- Yields multilayer circuits as much as 30% smaller than lower Dk options

### **EASE OF FABRICATION**

- Ideal for compact multilayer circuits
- Compatible with FR-4 circuit-board processing
- Formulated for lead-free,
   RoHS-compliant manufacturing



▲ Fig. 1 Peak phase error due to spurious response.

#### **FREQUENCY CONTAMINATION**

The instantaneous frequency is the time derivative of the instantaneous phase.

$$f(t) =$$

$$\frac{d\gamma(t)}{2\pi dt} = \Delta f \sum_{k=1}^{\infty} r^k \cos(2\pi k \Delta f t + k\theta) \quad (9$$

For k=1 and  $(2\pi\Delta ft+\theta)=2\pi N$ , where N is an integer, Equation 1 becomes:

$$f(t)_{Max} = \Delta f[r + r^2 + r^3 + r^4 + \dots + r^k + \dots]$$
 (10)

$$f(t)_{\text{Max}} = \frac{\Delta fr}{1 - r} \tag{11}$$

For k=1 and  $(2\pi\Delta ft+\theta)=\pi N$ , where N is an integer, Equation 9 becomes:

$$\begin{split} f(t)_{Min} &= \\ &-\Delta f[r-r^2+r^3-r^4+\cdots-r^k+\cdots] (12) \end{split}$$

$$f(t)_{\text{Min}} = \frac{-\Delta fr}{1+r} \tag{13}$$

The peak to peak frequecy deviation is given below:

$$f(t)_{Max} = \frac{2\Delta fr}{1 - r^2} \tag{14}$$

#### **SPURIOUS RESPONSES**

The two parameters that determine the degree of frequency contamination are the frequency difference between the true IF signal and the spur frequency. The order of the spurious response is defined by the notation MRF × NLO, where M and N represent the harmonic of the RF and LO signals, respectively. The frequency difference is considered for the case where the LO signal is greater than

**TABLE I** 

#### TRUE IF FREQUENCIES AND DIFFERENCE BETWEEN TRUE IF AND SPUR FREQUENCIES

LO=4750 MHz; RF Spur Order M=2; LO Spur Order N=1								
RF (MHz)	True IF (MHz)	Spur Freq. (MHz)	Spur Level (dBc)	∆IF Freq. (MHz)				
2490	1810	1130	-95	680				
2950	1800	1150	-85	650				
2960	1790	1170	-75	620				
2970	1780	1190	-65	590				
2980	1770	1210	-52	560				
2990	1760	1230	-49	530				
3000	1750	1250	-49	500				
3010	1740	1270	-49	470				
3020	1730	1290	-49	440				
3030	1720	1310	-49	410				
3040	1710	1330	-49	380				
3050	1700	1350	-49	350				
3060	1690	1370	-49	320				
3070	1680	1390	-49	290				
3080	1670	1410	-49	260				
3090	1660	1430	-49	230				
3100	1650	1450	-49	200				
3110	1640	1470	-49	170				
3120	1630	1490	-49	140				
3130	1620	1510	-49	110				
3140	1610	1530	-49	80				
3150	1600	1550	-49	50				
3160	1590	1570	-49	20				
3170	1580	1590	-49	-10				
3180	1570	1610	-49	-40				
3190	1560	1630	-49	-70				
3200	1550	1650	-49	-100				
3210	1540	1670	-49	-130				
3220	1530	1690	-49	-160				
3230	1520	1710	-49	-190				
3240	1510	1730	-49	-220				
3250	1500	1750	-49	-250				
3260	1490	1770	-49	-280				
3270	1480	1790	-52	-310				
3280	1470	1810	-60	-340				
3290	1460	1830	-67	-370				
3300	1450	1850	-75	-400				
3310	1440	1870	-80	-430				
3320	1430	1890	-85	-460				
3330	1420	1910	-90	-490				
3340	1410	1930	-95	-520				
3350	1400	1950	-99	-550				

the RF signal.

$$\Delta f = (LO - RF) - (MRF - NLO) =$$

$$(N+1)LO - (M+1)RF \qquad (15)$$

For the case where M equals two and N equals one:

$$\Delta f = 2LO - 3RF = 2(LO - RF) - RF$$
 (16)

**Table 1** lists the true IF frequencies, the difference between the true IF and the spurs frequencies for the case of a  $2RF \times 1LO$  spur frequency conversion. **Figure 2** shows the fre-

quency contamination for the 2RF × 1LO spurs for various spur amplitudes. The predicted spur analysis is shown in *Appendix A*. This shows that the frequency error due to a -20 dBc spur may vary from approximately 5 to -11 MHz.

#### **CROSSING SPURS**

Spurious responses of a received signal may create spurious signals that cross the true IF signal. These are called "crossing spurs" and may cause phase measurement errors, depending on the spur level. The following equations allow a determination if a

# **Innovative Design Solutions for Performance-Driven Applications**



Aeroflex / Weinschel has been pioneering developments in microwave and RF technologies for more than 58 years. Today part of Aeroflex, we are continuing to set new standards in component and subsystem innovation with a wide variety of new products to fit the most demanding customer applications.

Our mission is to provide superior design capabilities, products of consistently high quality, and a high level of service to help our customers compete in today's demanding global markets.

From broadband to base stations, defense subsystems to satellites, whatever your application, you can count on Aeroflex / Weinschel for innovative, high performance product solutions.

Call 800-638-2048 weinschel-sales@aeroflex.com www.aeroflex.com/weinschelMJ

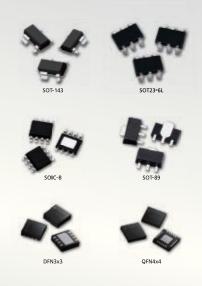
A passion for performance.

- & 0-110 dB / 10 dB steps (Model 153-110).
- // Low insertion loss & excellent repeatability
- Long-Life of 5 million operations
- // 2.92mm connectors

# E-pHEMT MMIC

P1dB 19dBm~33dBm

- ·Transient and ESD protected
- · Low current consumption
- · Extremely low distortion



#### Perfect for:

- · Digital TV Multi-Tuner
- · Optical Node, RFoG
- · TV Set-top box, Cable modem
- · CATV Booster, Trunk Amplifier
- · LTE, WIMAX, WCDMA

Freq. Range	5~100MHz		
	45~1000MHz		
	45~2600MHz		
	400~4000MHz		
Gain	12~25dB		
NF	0.8~3dB		
IP3	30~48dBm		
P1dB	19dBm~33dBm		
Voltage	3V~12V		



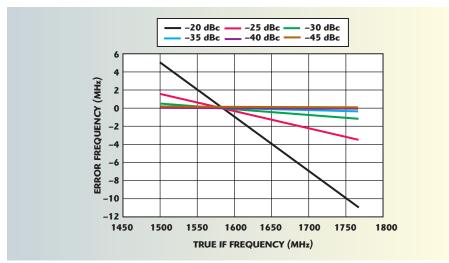


Fig. 2 Frequency contamination due to 2RFxLO spurs.

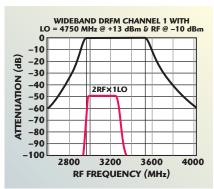


Fig. 3 Spurious response due to input RF

spur of an RF signal will generate a crossing spur for a selected LO signal frequency. At some point in an RF band, the crossing spur frequency will equal the true IF signal frequency.

Case I: The LO signal frequency is above the RF signal frequency and the IF is the difference frequency.

The true IF signal is:

$$IF_{T} = LO - RF \tag{17}$$

The MRF × NLO spur frequency, for positive frequencies, is:

$$IF_{s} = MRF - NLO \tag{18}$$

The difference frequency between the spur signal and the true IF signal is:

$$\Delta IF = MRF - NLO - LO + RF = (M+1)RF - (N+1)LO = 0$$
 (19)

For a given LO signal, the RF signal at which the spur frequency equals the true frequency:

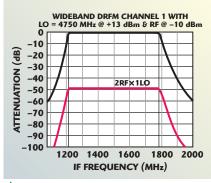


Fig. 4 Spurious response appearing in the IF output.

$$RF = \left(\frac{N+1}{M+1}\right) LO, M \neq N$$
 (20)

It can be shown that the same result is obtained for the case where the RF signal frequency is above the LO signal frequency and the IF is the difference frequency. Appendix A lists the predicted spurious responses for a special purpose receiver. *Figures* 3 and 4 show the predicted spurious response due to input RF signals and the spurs that appear in the IF output. The maximum predicted IF level spur is -49 dBc and causes a phase error of 0.06°. The frequency due to the -49 dBc for the data in Table 1 varies from 3.73 to -1.99 MHz.

#### **CONCLUSION**

Spurious responses generated in ESM receivers greater than -25 dBc may cause significant frequency and phase measurement errors, affecting the geo-location accuracy of threat emitters.

# The Force Behind The HIRF!



AR's High Intensity Radiated Fields (HIRF) Equipment.
Designed To Meet Tomorrow's Needs.



You know the dangers that electronic fields can cause. Whether from radar, other devices, natural causes or generated by enemy forces, high fields can cause equipment to fail, bombs to explode or aircraft to fall from the sky.

The only way to be sure is to test. And the best way to test is with AR amplifiers and power-matched antennas.

Whether you're generating high-intensity field strengths for HIRF testing, or recreating RF/microwave environments for

intelligence/counterintelligence/jamming measures, and infrastructure

susceptibility or immunity to HIRF (such as power and, communications, transport, security/emergency) AR has the amps, antennas, field probes, field monitors, power meters, directional couplers and other testing accessories to fit any of your needs. Our amps are designed so that power can be added as needed. So the AR amplifiers you get today will serve you well into the future.

AR's limitless support network is second to none, and everything we sell is backed by the most comprehensive warranty in the industry.

To learn more, visit www.ar-worldwide.com or call us at 215-723-8181.

ISO 9001:2008 Certified



### rf/microwave instrumentation

Other  $\operatorname{ar}$  divisions: modular rf  $\bullet$  receiver systems  $\bullet$  ar europe

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

In Europe, call ar United Kingdom 441-908-282766 • ar France 33-1-47-91-75-30 • emv GmbH 89-614-1710 • ar Benelux 31-172-423-000

# GaN Pallet Type Power Amplifiers

" based on internally matched GaN-on-SiC device and Doherty technology"

# Excellent for LTE RRH and Telecom applications

- · 40% Efficiency (When interlocked with DPD)
- · 40-50dB Gain
- · 8W, 10W, 16W, 25W
- · 80-200MHz Bandwidth
- · 800MHz, 2100MHz, 2300MHz, 2600MHz
- · Small size
- · Very low cost
- · Custom-design available





#### **APPENDIX A**

#### PREDICTED SPUR ANALYSIS FOR 2RF×1LO SPURS

Wideband DRFM Channel 1

The RF band is 2965 to 3535 MHz; the IF band is 1215 to 1785 MHz.

Preselector Ripple Bandwidth = 570 MHz; Preselector Center Frequency = 3250 MHz Number of RF Filter Poles = 6; Band Pass ripple = 0.1000 dB Start, Stop RF frequencies = 2595 to 4038 MHz

IF Ripple Bandwidth = 570 MHz; IF Center Frequency = 1500 MHz Number of IF Filter Poles = 9; Band Pass ripple = 0.1000 dB Start, Stop IF frequencies = 1084 to 2000 MHz

Maximum spur  $M \times N$  calculated =  $4 \times 4$ 

Conversion Loss of Mixer in dB for higher orders of LO referred to  $1 \times 1 = 20 \text{ dB}$ 

Mixer Type - Double Balanced; Mixer Intercept Point = 19 dBm

Mixer  $1 \times 1$  conversion loss = 8 dB

Mixer conversion loss above 1×1 due to balance techniques of mixer type = 20 dB

Maximum Preselector input signal level = -10 dBm

Required spurious level below 1×1 response = 100 dB

Mixer & Preselector LO to RF leakage level = 100 dB

Mixer Response - Fif=M×Frf-N×Flo

LO is above signal; LO frequency range is 4750 to 4750 MHz

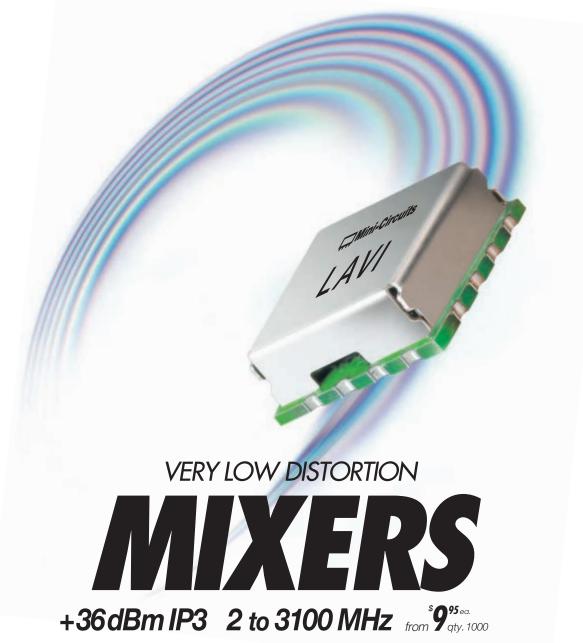
Spur Freq (MHz)	Signal Freq (MHz)	Atten Level (dBm)	Sig Har MRF	LO Har NLO	Mixer Level (dBc)	True IF Freq (MHz)
1132.6	2941.3	95.0	2.0	1.0	49.0	1808.7
1161.5	2955.8	80.1	2.0	1.0	49.0	1794.3
1190.4	2970.2	62.8	2.0	1.0	49.0	1779.8
1219.2	2984.6	49.0	2.0	1.0	49.0	1765.4
1248.1	2999.0	49.0	2.0	1.0	49.0	1751.0
1276.9	3013.5	49.1	2.0	1.0	49.0	1736.5
1305.8	3027.9	48.9	2.0	1.0	49.0	1722.1
1334.7	3042.3	49.0	2.0	1.0	49.0	1707.7
1363.5	3056.8	48.9	2.0	1.0	49.0	1693.2
1392.4	3071.2	49.0	2.0	1.0	49.0	1678.8
1421.2	3085.6	49.1	2.0	1.0	49.0	1664.4
1450.1	3100.1	49.0	2.0	1.0	49.0	1649.9
1479.0	3114.5	49.0	2.0	1.0	49.0	1635.5
1507.8	3128.9	49.0	2.0	1.0	49.0	1621.1
1536.7	3143.3	49.0	2.0	1.0	49.0	1606.7
1565.5	3157.8	48.9	2.0	1.0	49.0	1592.2
1594.4	3172.2	48.9	2.0	1.0	49.0	1577.8
1623.3	3186.6	49.0	2.0	1.0	49.0	1563.4
1652.1	3201.1	49.0	2.0	1.0	49.0	1548.9
1681.0	3215.5	49.0	2.0	1.0	49.0	1534.5
1709.8	3229.9	49.1	2.0	1.0	49.0	1520.1
1738.7	3244.3	49.0	2.0	1.0	49.0	1505.7
1767.6	3258.8	49.1	2.0	1.0	49.0	1491.2
1796.4	3273.2	51.1	2.0	1.0	49.0	1476.8
1825.3	3287.6	64.3	2.0	1.0	49.0	1462.4
1854.1	3302.1	75.3	2.0	1.0	49.0	1447.9
1883.0	3316.5	84.0	2.0	1.0	49.0	1433.5
1911.9	3330.9	91.4	2.0	1.0	49.0	1419.1

#### Reference

 L.B.W. Jolley, Summation of Series, Dover Publications Inc., New York, NY, p. 100, Equation 536; p. 102, Equation 540.

Samuel J. Caprio is a consultant with over 30 years experience in ESM receiver systems design and six years experience in the design of transmitter systems. He was the receiver system engineer for the EA-6B ADVACP system, the ESM receiver system for the A-12 Navy Stealth aircraft, the AIEWS shipboard system and the ICAP-III ESM receiver system while employed at Litton. He designed the receiver and transmitter systems for two DRFM-based decoy systems for NRL while employed by CACI.

70



Mini-Circuits shielded LAVI frequency mixers deliver the breakthrough combination of very high IP3 and IP2, ultra-wideband operation, and outstanding electrical performance. By combining our advanced ceramic, core & wire, and semi-conductor technologies, we've created these evolutionary patented broadband mixers that are specially designed to help improve overall dynamic range.

With a wide selection of models, you'll find a LAVI mixer optimized for your down converter and up converter requirements. Visit the Mini-Circuits website at <a href="https://www.minicircuits.com">www.minicircuits.com</a> for comprehensive performance data, circuit layouts, and environmental specifications. Price & availability for on-line ordering is provided for your convenience.

### Check these LAVI Mixer outstanding features!

- Very wide band, 2 to 3100 MHz
- Ultra high IP2 (+60 dBm) and IP3 (+36 dBm)
- -73 dBc harmonic rejection 2LO-2RF, 2RF-LO
- Super high isolation, up to 52 dB
- High1dB compression, up to +23 dBm
- Extremely low conversion loss, from 6.3 dB
   RoHS compliant U.S. Patent Number 6,807,407

Mini-Circuits... Your partners for success since 1969



P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

The Design Engineers Search Engine finds the model you need, Instantly • For detailed performance specs & shopping online see minicipality.com



# SIDE LOBE SUPPRESSION OF PRINTED ANTENNA ARRAYS FOR INTEGRATION WITH MICROWAVE CIRCUITS

Various factors that limit high side lobe suppression (SLS) in printed antenna arrays (PAA) have been analyzed in this article. A new type of linear printed antenna array, with pentagonal dipoles as radiating elements operating at a second resonance enabling high SLSs, is presented. When operated at the second resonant frequency, the variation of the real and imaginary parts of their impedances with frequency is much slower than in the case with conventional printed patches, which contributes to obtaining high SLSs. The in-phase feed network for the PAA is realized with symmetrical (balanced) microstrip lines with impedance transformers, enabling tapered feeding of the radiating elements. A second order Dolph-Chebyshev distribution has been used. The SLS obtained in the E-plane of the realized antenna array is better than 34 dB in the range of approximately 26 GHz. In order to achieve a higher gain, that is a narrower beamwidth in the H-plane, the PAA is placed in a corner reflector. The antenna is especially suitable for integration with other passive or active microwave circuits; it is low cost and easy to fabricate.

icrowave printed antenna arrays (PAA) have various advantages over conventional antenna systems, due to their low cost, great reproducibility and the possibility of integration with other microwave circuits. Because of this, they are often used in telecommunication systems, such as indoor and outdoor wireless LANs, point-to-point and point-to-multipoint, and also in radar microwave and millimeter-wave systems. One of the main antenna characteristics is SLS in radiation patterns, which is defined for telecommu-

nication systems (usually for microwave links) by international standards and recommendations. Also, in conventional radar systems, the SLS requirements are much more severe since responses from side lobes are practically false targets. Depending on the antenna class, the desired SLS in telecommunication systems is

A. NEŠIĆ, I. RADNOVIĆ, Z. MIĆIĆ AND S. JOVANOVIĆ IMTEL Institute, Belgrade, Serbia



# WE MAKE HARDWARE THAT SAVES LIVES.



#### **PRODUCTS**

High Power RF Amplifiers High Power RF Subsystems High Power RF Systems

#### **SPECIFICATIONS**

DC - 40+ GHz Power levels to 10,000+ watts MIC and Hybrid Construction AS9100 Certification

#### **PLATFORMS**

Abrahms Main Battle Tank Stryker Combat Vehicle Humvee Bradley Fighting Vehicle Black Hawk Helicopter Joint Strike Fighter AV8B Harrier F15 Eagle F16 Fighting Falcon F18 Super Hornet F35 Joint Strike Fighter

#### SYSTEMS & ENVIRONMENTS

Electronic Warfare RADAR Communication Systems Pulsed or CW Airborne Land, Sea and Space









approximately 20 to 40 dB; in radar systems the required suppression is even higher. Such SLSs are hardly achievable with conventional microstrip antenna arrays (with patches). In conventional microstrip PAAs presented in the literature, side lobe levels are at best suppressed by 25 dB (related to the main lobe). A relatively small number of publications dealing with this issue are available.<sup>2-4</sup>

The main characteristics of conventional PAAs with patches, which prevent obtaining high SLSs, are the following: great influence of the patches dimensions tolerances on the real and imaginary part of their impedances; mutual coupling between radiating elements; limitations in the feasibility of feed network realization; and surface wave effects as well as parasitic radiation from the feed network. This article introduces solutions that overcome or considerably diminish practically all these limiting factors. The proposed antenna structure is suitable for integration with other passive or active microwave circuits on a common dielectric substrate.

# RELEVANT LIMITING FACTORS IN THE REALIZATION OF PAAS WITH HIGH SLS

The great influence of patches dimensional tolerances on the possibility of realizing antenna arrays with high SLS is the consequence of their rapid impedance variation with dimensional changes that may occur during fabrication or with temperature change. A similar conclusion relates also to a feed network—phase and amplitude deviations appear due to tolerances of feeding lines dimensions (lengths and widths) as well as of impedance transformers, which enable tapered distribution—resulting in high SLS.

## PENTAGONAL DIPOLE FED BY A SYMMETRICAL MICROSTRIP LINE

Besides conventional printed antenna arrays with patches fed by a conventional nonsymmetrical microstrip line, there are printed antenna arrays with printed dipoles usually of pentagonal shape (one half of them on one side and another half on the opposite side of the substrate). These dipoles operate at their second resonance and are fed by a symmetrical (balanced) microstrip line, <sup>5-7</sup> as shown in *Figure 1*.

By using the proposed radiating elements, a phase change of approximately 12.5° for a frequency variation of 30 percent was obtained, which is approximately 30 times greater than in the case with patch antennas.<sup>2</sup> The magnitude variation in the same frequency range is only 2 dB. Also, due to the fact that the feed network is symmetrical and consists of symmetrical (balanced) microstrip lines, the parasitic radiation from it, as well as the surface wave effect, are practically eliminated. The majority of the factors that make difficult the realization of printed antenna arrays with high SLS has been eliminated by using the proposed radiating elements.

#### **TAPERED DISTRIBUTION**

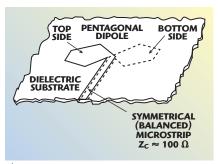
In order to decrease the side lobe levels, various tapered distributions are used in antenna arrays: cosine, cosine-squared, Gaussian, Taylor, Dolph-Chebyshev, etc. These distributions are chosen depending on the required side lobe attenuation, possible pedestal in distribution ( $I_{max}/I_{min}$  ratio), desired position of the radiating elements, desired position, that is distribution of side lobes, distance between radiating elements, number of radiating elements and expected tolerances in fabrication.

An axial array of eight printed pentagonal dipoles, operating at their second resonance and with mutual distance of  $0.85\lambda_0$ , are investigated and shown in **Figure 2**. The dipoles are fed by a feed network enabling Dolph-Chebyshev distribution of the second order with pedestal ( $I_{max}/I_{min}$ ) of 17 dB.<sup>8</sup> Under these conditions, the distribution coefficients shown in **Table 1** have been obtained, which enable the highest side lobe level of

-40.72 dB in the ideal case.

# ERROR INFLUENCE ON DEGRADATION OF SLS

Due to tolerances in the photolithographic process, as well as to dimensional changes caused by temperature variation, deviations from



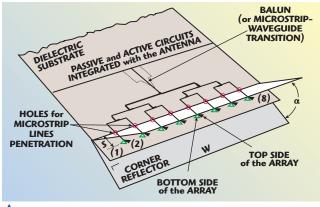
▲ Fig. 1 Pentagonal dipole as a basic element of the antenna array printed on a dielectric substrate.

projected values of position, amplitude and phase of radiating elements in the array occur. The influence of these tolerances has been investigated in the case of a printed antenna array with eight axially placed broadband pentagonal dipoles operating at their second resonance. Expected tolerances in standard photolithographic process have been assumed with moderate precision, in order to estimate the SLS degradation, due to amplitude and phase deviations as well as radiating elements positioning deviations from optimized values.

Realizable values of relative tolerances have been assumed at the operating frequency of 26 GHz:

- deviations in distances between radiating elements in the array: 1 or 2 percent of  $\lambda_0$  (corresponding to approximately 115 or 230  $\mu$ m)
- phase deviations: 2° or 4° (corresponding to approximately 40 or 80 µm tolerances in the length of the feeding line)
- amplitude deviations along tapered feeding lines: 1 or 2 dB (occurring as a consequence of tolerances in transformer lines widths and lengths)

Using a previously published method,<sup>8</sup> the SLS has been calculated for



▲ Fig. 2 Sketch of the axial pentagonal dipole array in the corner reflector.













#### Simulate multiple telemetry contacts for your flight test at IF or RF real-time - without ever leaving the pad.

- Saves time and money
- Full and realistic prelaunch/contact system checkout
- Flight and ground system assurance
- Performance and functional verification
- Compliance and regression testing

The RT Logic Telemetrix® 400 Telemetry Signal Simulator (T400TSS)

is a modular software-defined telemetry simulator, command formatter, and signal generator.



719-598-2801

RT LOGIC

sales@rtlogic.com

www.rtlogic.com









TABLE I								
CALCULATED DOLPH-CHEBYSHEV DISTRIBUTION COEFFICIENTS ENABLING THE HIGHEST SIDE LOBE LEVEL OF -40.72 dB								
Dipole No.	1	2	3	4	5	6	7	8
I*	0.146	0.418	0.759	1.0	1.0	0.759	0.418	0.146
I* (dB)	-16.713	-7.576	-2.395	0	0	-2.395	-7.576	-16.713
*I - excitation in	tensity							

	TABLE II									
	SIDE LOBE SUPPRESSION OF THE HIGHEST LOBE									
	Radiating elements positioning error	Amplitude error	Phase error	Side lobe suppression of the highest lobe (dB)						
a	0	0	0	40.72						
ь	$0.01\lambda_{0}$	1 dB	2°	35.04						
c	$0.02\lambda_{0}$	2 dB	4°	32.15						
/	a) ideal case b) real case with minor errors									

the Dolph-Chebyshev distribution of the second order with pedestal ( $I_{max}\!\!\!/ I_{min}$ ) of 17 dB for the array with eight axially placed dipoles (the distance between dipoles was  $0.85\lambda_0$ ). The results are presented in Table 2. The errors were randomly distributed in the simulation process (Monte-Carlo method).

c) real case when all existing errors are of greater value

Figure 3 shows the simulated E-plane radiation patterns for the cases given in Table 2. The blue trace is the ideal case, while the red and green traces are for the two real cases (with minor and greater amplitude, phase and radiating elements positioning deviations, respectively). The results of tolerance simulation (performed at 26 GHz) of particular factors that degrade SLS of the proposed PAA show that the expected SLS is 35.04 dB (in the case of minor errors) and 32.15 dB (in the case of greater errors in the standard photolithographic process).

# CONCEPT AND DESIGN OF THE LINEAR PAA WITH A CORNER REFLECTOR

The proposed antenna array consists of three parts: (1) an axial array of eight printed pentagonal dipoles; (2) a feeding network and a balun printed on the same dielectric substrate as the pentagonal dipoles; (3) and a corner reflector consisting of two metal plates with the aperture angle  $\alpha = 45^{\circ}$ . The distance between the dipoles (at the center frequency) is chosen in such a way as to obtain a relatively high array gain with sufficient SLS in the tapered

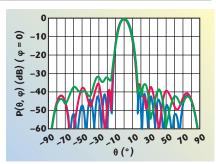


Fig. 3 Simulated E-plane radiation patterns.

array. In the present case, the distance between the axial dipoles is  $0.85\lambda_0$ . Also, with such a distance between axial dipoles, the mutual coupling is very low, which makes the design and optimization of the antenna array relatively easy.

The dipoles and the feed network are fabricated on the same dielectric substrate with  $\varepsilon_r = 2.1$ , thickness h = 0.254 mm and dissipation factor tan  $\delta$ =  $4 \cdot 10^{-4}$ . The dimensions of a single radiating element (printed pentagonal dipole) placed in a corner reflector are optimized as to obtain an impedance  $\vec{Z} \approx 100 \,\Omega$ . The corner reflector plate's length is  $L = 4\lambda_0$ , while the dipole distance from the apex (S) is  $0.7\lambda_0$ . The optimized impedance obtained at 26 GHz is  $(98.6 - j6.5) \Omega$ . The simulated real and imaginary parts of the single dipole's impedance versus frequency are shown in *Figure 4*.

The simulated VSWR is less than 2 in the frequency range from 24 to 33 GHz. Then the array, consisting of four identical axially placed pentago-

# ACTIVE BIAS CONTROLLER

New DC Power Management Product Line for Class-A Amplifiers!



Analog, Digital & Mixed-Signal ICs, Modules, Subsystems & Instrumentation



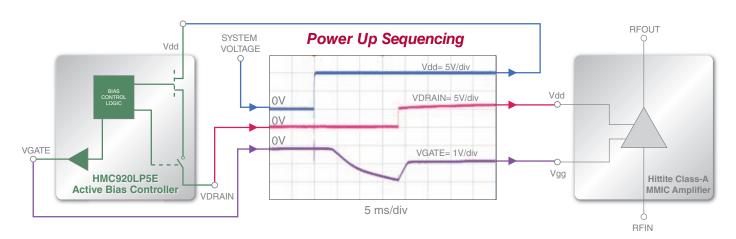


HMC920LP5E 32 Lead 5 x 5 mm SMT Package Active Bias Controller Covers +3.0 to +15V DC Supply Range!

- ♦ Integrated Negative Voltage Generator
- **♦** Automated Power-up Sequencing
- ♦ Active & Adjustable Output Voltages & Currents:

  Drain Voltage: +3.0 to +15 Vdc

  Gate Voltage: -2.5 to +2.5 Vdc
- ♦ Stable Bias Current Over
  Temperature, Process Variation & Aging



Ideal for Power Management & Control in All RF, Microwave, Millimeterwave & Fiber Optic Applications

#### AMPLIFIERS THAT BENEFIT FROM HMC920LP5E ACTIVE BIAS CONTROLLER

Low Noise Amplifiers	Driver Amplifiers	Linear & Power Amplifiers	Wideband Driver Amplifiers	Wideband Power Amplifiers	Optical Modulator Driver Amplifiers
HMC490LP5E	HMC633LC4	HMC442LM1	HMC460LC5	HMC464LP5E	HMC870LC5
HMC504LC4B	HMC634LC4	HMC442LC3B	HMC462LP5E	HMC619LP5E	HMC871LC5
HMC594LC3B	HMC635LC4	HMC498LC4	HMC463LP5E	HMC637LP5E	
HMC609LC4		HMC499LC4	HMC465LP5E	HMC659LC5	
HMC753LP4E		HMC608LC4	HMC633LC4	HMC797LP5E	
HMC752LC4			HMC634LC4		
HMC772LC4					
HMC902LP3E					

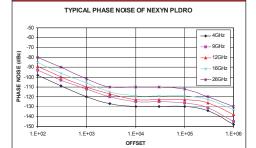


#### **Dare to Compare!**

## QUIET!

N<sup>on</sup>in<sup>g</sup> and PRECISE Pe<sup>live</sup> OCXO, PLXO Phase Locked & FR DROs

New Products! Details on website



# Typical Phase Noise at 14 GHz 100 Hz - 88 dBc/Hz 1 KHz -109 dBc/Hz 10 KHz -119 dBc/Hz 100 KHz -120 dBc/Hz

-135 dBc/Hz

- Reliable and Rugged Design
- Extremely Low Microphonics
- 5-500 MHz External Reference
- Frequency: 3 to 30 GHz
- Power output: +15 dBm
- Spurious: < -80 dBc

1 MHz

- -55 to +85 C (temp range)
- Int. Ref. Stability to +/- 0.05 ppm
- Now offering PLO .3 to 3 GHz
- Low Noise crystal reference
- Dual Loop Output Frequency to nearest KHz w/ Ext. 10 MHz Ref



# \_\\<del>ex</del>yn

## We have moved!

Nexyn Corporation

1287 Forgewood Ave. Sunnyvale, CA 94089

Tel: (408) 962-0895 Fax: (408) 743-5354

Visit our website at www.nexyn.com

Excellent Technical Support Guaranteed Performance and Competitive Pricing

nal dipoles with dimensions obtained in the optimization of a single dipole, was modeled. The distance between dipoles was  $0.85\lambda_0$ . Due to mutual impedances, deviated impedances values:  $Z1 = Z4 = (84.4 - j24.3) \Omega$  and  $Z2 = Z3 = (70.3 - j26.5)^{\circ}\Omega$ . Since the values obtained differed slightly from the ideal ones, as well as the optimization process with a greater number of dipoles (together with a reflector) would require great computational capacity, in the next step, an array consisting of eight dipoles with the same dimensions as in the case with four dipoles was analyzed; impedances: Z1 =  $Z8 = (82.6 - j18.0) \Omega, Z2 = Z7 = (70.7)$  $- j18.0) \Omega$ , Z3 = Z6 = (70.6 - j19.8)  $\Omega$ ,  $Z4 = Z5 = (71 - i16.6) \Omega$  were obtained. The software package WIPL-D<sup>9</sup> has been used in these analyses.

# FEED NETWORK AND ITS COMPONENT PARTS WITH IMPEDANCE TRANSFORMERS

In order to attain the desired distribution (see Table 1), the feed network was designed using a symmetrical (balanced) microstrip technique with  $\lambda/4$  transformers, assuming 100  $\Omega$  impedances at its ends. The corresponding layout is shown in *Figure* 5. Characteristics and dimensions of the  $\lambda/4$  transformers with symmetrical microstrip lines have been calculated using TEM analysis.

The feed network was loaded with the impedances obtained in the previous step of the analysis (Z1,..., Z8). Since certain deviations from the ideal required network were observed, corrections of phase deviations were accomplished by changing the lengths of particular branches in the feed network using the program package IE3D<sup>10</sup> in order to achieve an inphase network.

# REALIZATION OF PRINTED TAPERED ANTENNA ARRAY WITH A CORNER REFLECTOR

The corner reflector is designed using results from an A.C. Wilson published article, <sup>11</sup> which contains very detailed experimental results obtained by variation of length (L), width (W), aperture angle between corner reflector plates ( $\alpha$ ) and distance of radiating element from apex (S). A suitable radiation pattern with relatively high SLS in the H-plane is obtained with L = W =  $4\lambda_0$ ,  $\alpha$  =  $45^\circ$  and S =  $0.7\lambda_0$ .

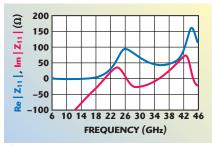


Fig. 4 Simulated real and imaginary parts of the dipole's impedance vs. frequency ( $\alpha = 45^{\circ}$ ).

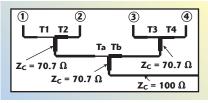


Fig. 5 Layout of one half of the tapered feed network of the 26 GHz array.

The axial array with feed network and balun<sup>12</sup> is placed between two metallic plates forming a corner reflector with  $\alpha = 45^{\circ}$ . The beamwidth in the H-plane (azimuth) depends mainly on the angle between the metallic plates and the length of the reflector plates (L), while the SLS in the E-plane depends only on the PAA. The feeding lines for the dipoles penetrate the junction of the two reflector plates. At the junction there are holes through which symmetrical microstrip lines of the feeding network pass. The influence of the metallic plate on the microstrip lines is minimized by selecting a sufficient diameter (2 mm) for the holes.

#### **RESULTS AND COMMENTS**

The simulated and measured results are shown in *Figures 6* to 8. The discrepancy between simulated and measured SLS is due to tolerances in photolithography and mounting process because relatively small inaccuracies can significantly influence the precise distribution, which corresponds to simulations given in Table 2. The measured highest SLS in the E-plane is 34.7 dB (see *Table 3*) showing excellent agreement with the result of tolerances influence simulation (35.4 dB; see Table 3).

The return loss measured at the SMA connector is shown in Figure 8. The measured gain of the antenna is approximately 1 dB lower than the simulated one because the feed net-

# BROADBAND TIME DELAY

New Broadband Time Delay for Serial Data Transmissions Up to 32 Gbps!



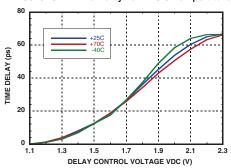
Analog, Digital & Mixed-Signal ICs, Modules, Subsystems & Instrumentation



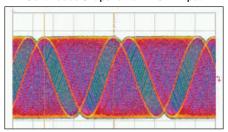


#### 24 Lead 4 x 4 mm SMT Package

HMC910LC4B Time Delay vs. VDC & Temperature

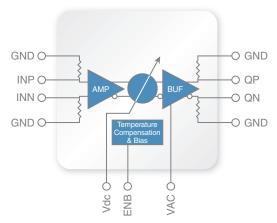


HMC910LC4B Output Eye Diagram Continuous Snapshot for 24 GHz Input



#### HMC910LC4B Broadband Analog Time Delay, DC to 24 GHz

- ♦ Continuous Adjustable Delay Range: 0 to 70 ps
- ♦ Single-Ended or Differential Operation
- ♦ Adjustable Differential Output Voltage Swing: 150 - 600 mVp-p @ 24 GHz
- ♦ Delay Control Modulation Bandwidth: 600 MHz
- **♦** Integrated Temperature Compensation



Time Scale: 10 ps/div Amplitude Scale: 80 mV/div

Test Conditions: VCC = 3.3V, VAC = 2.6V,

VDC = varied from 1.6V to 1.9V (25% of the whole delay range) Input Data: Single ended 300 mVp-p 24 GHz clock signal

Measurement Result: Time Delay = 34 ps

#### **BROADBAND TIME DELAY - New Product Line!**

Data / Clock Rate (Gbps/GHz)	Function	Rise / Fall (ps)	Deterministic Jitter (ps)	Differential Output Voltage Swing (Vp-p)	DC Power Consumption (mW)	Vcc Power Supply (Vdc)	Part Number
32 / 24	Analog Time Delay	14 / 14	6	0.1 - 0.8	1450	+3.3	HMC910LC4B
28 / 28	Digital Time Delay	20 / 18	< 2	0.5 - 1.35	610	-3.3	HMC856LC5

Ideal for Synchronization of Clock & Data, Transponder Designs, Serial Data Transmission Up to 32 Gbps, Broadband Test & Measurement and RF ATE Applications!



Order On-Line at: www.hittite.com

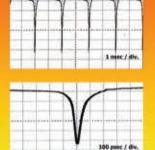
Receive the latest product releases - click on "My Subscription"

### Impulse Generators 100 - 2000 MHz

#### Application:

- > Clock Reference
- > Sampling Circuit
- > Sharp Biasing or Triggering Source
- > Optical Modulator Driving





MODEL	INPUT (DRIVING) PREQ. (MHz)	TYPICAL IMPULSE OUTPUT VOLTAGE (V)	TYPICAL IMPULSE PULSE WIDTH (P SEC)
GBM100A	100	-12	100
GIM200A	200	-18	90
GIM250A	250	-18	80
GIM500A	500	-15	60
GM1000A	1000	-10	50
GIM1500A	1500	-8	45
GIM2000A	2000	.7	35

#### Your Source for the Most Complete Line of Comb & Impulse Generators

Other Herotek Products: Detectors . Limiters . Amplifiers Switches . Comb Generators Multipliers . Subassemblies

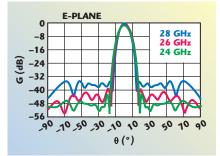


The Microwave Products Source

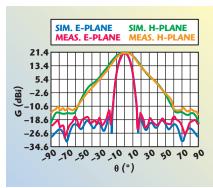
Herotek, Inc. 155 Baytech Drive San Jose, CA 95134



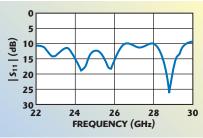
Tel: (408) 941-8399
Fax: (408) 941-8388
Email: Info @ herotek.com
Website: www.herotek.com



▲ Fig. 6 Normalized simulated E-plane pattern at 24, 26 and 28 GHz.



▲ Fig. 7 Simulated and measured radiation patterns in the E- and H-planes at 26 GHz.



▲ Fig. 8 Measured return loss of the antenna array.

work, balun and transition from microstrip to SMA connector were not taken into account. A photograph of the fabricated PAA with tapered distribution and a 45° corner reflector operating in the 26 GHz range is shown in *Figure 9*, compared to a US quarter. The most significant achievement is the high SLS in the E-plane, since it depends only on the PAA.



▲ Fig. 9 Photograph of the fabricated antenna array with corner reflector.

#### CONCLUSION

Conventional antenna arrays, with patches used as radiating elements, have relatively low suppression of side lobes, and thus do not satisfy the standards and recommendations for most telecommunication and radar systems. The several limiting factors in the realization of printed antenna arrays with relatively high SLS are investigated and simulated: phase deviations, amplitude deviations, radiating elements positioning deviations, mutual coupling between elements and parasitic radiation from the feed network.

The characteristics of the linear antenna array, consisting of axially placed pentagonal dipoles operating on the second resonance and fed by a symmetrical (balanced) microstrip line, are analyzed. The analysis has shown that tolerance sensitivity of the investigated array (real and imaginary part of dipoles' impedances variation, which is one of the main limiting factors in the realization of printed arrays with high SLS) is about 30 times less in comparison with conventional antenna arrays

## TABLE III SIMULATED AND MEASURED RESULTS FOR THE EIGHT DIPOLE PAA AT 28 GHz

	G (dBi)	HSLS <sup>E</sup> (dB)	HSLSH (dB)	F/B (dB)	HPBW <sup>E</sup> (°)	HPBW <sup>H</sup> (°)
Simul.	21.4	38.4	35	32	10.5	23.8
Meas.	20.8	34.7	32.6	35.4	10.7	23.8

G: Gain

 $HSLS^{E}$ ,  $HSLS^{H}$  = highest side lobe suppression (E-plane, H-plane)

F/B=front to back ratio

 $HPBW^E$ ,  $HPBW^H$ = 3 dB beamwidth (E-plane, H-plane)

# TUNABLE FILTER MMICS

Low Pass and Band Pass Filters in 5x5 mm SMT Packages!



Analog, Digital & Mixed-Signal ICs, Modules, Subsystems & Instrumentation



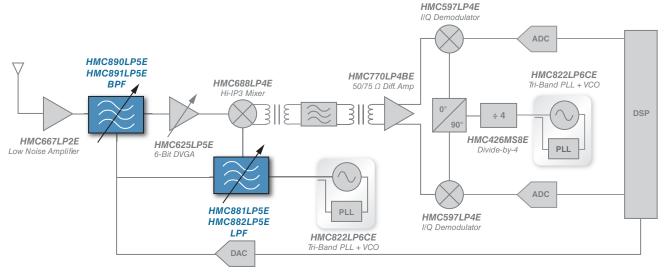


**Low Pass** 

**Band Pass** 

## Low & Band Pass Filters Cover DC to 8.0 GHz!

- ♦ Fast Tuning Response: 150 ns
- ♦ Excellent Wideband Rejection: 30 dB
- ♦ Single Analog Tuning Voltage: 0 to 14V
- ♦ Single Chip, Solid State Replacement for Mechanically Tuned & Switched Bank Filters



#### **BAND PASS**

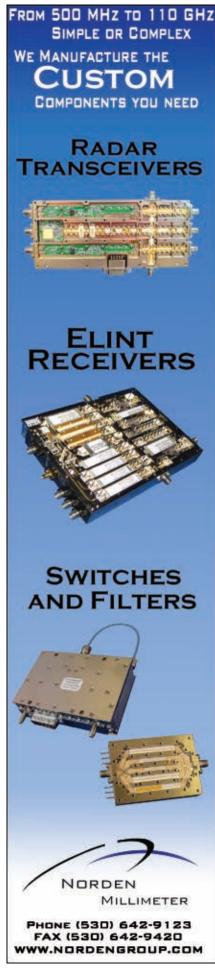
R	Freq. ange (GHz)	Return Loss (dB)	3 dB Bandwidth (%)	Low Side Rejection Frequency (Rej. >20 dB)	High Side Rejection Frequency (Rej. >20 dB)	Tuning Response (ns)	Part Number
	1 - 2	10	11	0.8 x Fcenter	1.2 x Fcenter	200	HMC890LP5E
	2 - 3.9	10	9	0.9 x Fcenter	1.15 x Fcenter	200	HMC891LP5E
EW!	4 - 7.7	15	9	0.9 x Fcenter	1.13 x Fcenter	200	HMC892LP5E

#### **LOW PASS**

Freq. Range (GHz)	Return Loss (dB)	Cutoff Frequency Range (GHz)	Stopband Frequency (Rej. >20 dB)	Tuning Response (ns)	Part Number
DC - 4.0	10	2.2 - 4.0	1.25 x Fcutoff	150	HMC881LP5E
DC - 7.6	10	4.5 - 7.6	1.23 x Fcutoff	150	HMC882LP5E

Ideal for Frequency Selection in Multi-Band Synthesizer Systems, Wideband Radar, and Test & Measurement Equipment





with patches. An antenna structure, with printed pentagonal dipoles forming the array, is proposed. The dipoles operate at their second resonance and are fed by symmetrical (balanced) microstrip lines. An array, consisting of eight axially placed dipoles, is fed through the feed network with impedance transformers, enabling Dolph-Chebyshev distribution of the second order with pedestal  $I_{max}\!/I_{min}$  = 17 dB. The corner reflector, in which the linear antenna array is placed, achieves a relatively high SLS and narrow beamwidth even in the H-plane. The effects of particular parameters, with assumed tolerances on which SLS depends, have been analyzed.

The measured beamwidth in the E-plane at 26 GHz is 10.7°. The experimentally obtained E-plane SLS at 26 GHz, which depends only on the antenna array, is better than 34 dB and is, to the authors' knowledge, the best result published to date. The measured  $|S_{11}|^{\dagger}$  is better than 10 dB (VSWR<2) in the range from 22 to nearly 30 GHz. The array is realized using a standard photolithographic process, with a moderate precision of ±10 µm. The simulated and measured results are in very good accordance. The antenna structure shown is suitable for integration with other passive and active microwave circuits on a common dielectric substrate and can also be used in higher millimeterwave ranges up to 110 GHz.

#### **ACKNOWLEDGMENT**

The authors would like to thank Milka Marjanovic and Momeilo Tasic for their contribution to the fabrication of the antenna model. This work has been supported by the Serbian Ministry of Science and Technological Development.

#### References

- IEEE Standard for Local and Metropolitan Area Networks (System Profiles for 10-66 GHz), IEEE, 3 Park Avenue, New York, NY, 15 January 2003
- D.M. Pozar and B. Kaufman, "Design Considerations for Low Sidelobe Microstrip Arrays,' IEEE Transactions on Antennas and Propagation, Vol. 38, No. 8, August 1990, pp. 1176-1185. J. Hirokawa and M. Ando, "Sidelobe Suppres-
- sion in 76 GHz Post-wall Waveguide-fed Parallel Plate Slot Arrays," IEEE Transactions on Antenna and Propagation, Vol. 48, No. 11, November 2000, pp. 1727-1732.
- Yuichi Kimura, et al., "76 GHz Alternating-phase Fed Single-layer Slotted Waveguide Arrays with Suppressed Sidelobes in the E-plane," 2003 IEEE AP-S International Symposium Digest, Vol.

- 3, pp. 1042-1045. A. Nešić, D. Nešić, V. Brankovic, K. Sasaki and K. Kawasaki, "Antenna Solution for Future Communication Devices in mm-Wave Range," *Microwave Review*, Yugoslav IEEE MTT-S Chapter, Vol. 7, No. 3, December 2001, pp. 9-17.
- A. Nešić, V. Brankovic and I. Radnović, "New Generation of Millimeter-wave Communication Systems," Microwave Review, Yugoslav IEEE MTT-S Chapter, Vol. 6, No. 1, December 1999, pp. 13-18.
- A. Nešić, Z. Mićić, S. Jovanović, I. Radnović and D. Nešić, "Millimeter-wave Printed Antenna Arrays for Covering Various Sector Widths," IEEE Antennas and Propagation Magazine, Vol. 49, No. 1, February 2007, pp. 113-118. M. Mikavica and A. Nešić, *CAD for Linear and*
- Planar Antenna Array of Various Radiating Elements, Artech House Inc., Norwood, MA, 1992.
- B. Kolundzija, J. Ognjanovic and T.K. Sarkar, WIPL-D Pro v5.1.
- 10. Zeland Software Inc., IE3D User's Manual.
- A.C. Wilson and H.V. Cottony, "Radiation Pattern of Finite-size Corner-reflector Antennas, IRE Transaction on Antennas Propagation, Vol. 8, No. 2, March 1960, pp. 144-157
- A. Nešić and S. Dragas, "Frequency Scanning Printed Array Antenna," 1995 IEEE AP-S Inter-
- national Symposium Digest, pp. 950-953.

  A. Nešić, I. Radnović and M. Šunjevarić, "Transmitter Front-end for Millimeter-wave Link Operating at 60 GHz Range," 17th Telecommunications Forum TELFOR 2009, November 2009, Belgrade, Serbia.
- A. Nešić,, I. Radnović and M. Šunjevarić, "Receiver Front-end for Millimeter-wave Link Operating at 60 GHz Range," 17th Telecommunications Forum TELFOR 2009, November 2009, Belgrade, Serbia.

Aleksandar Nešić received his MSc and DSc degrees and the title of full professor in electrical engineering from the University of Belgrade, Yugoslavia, in 1982, 1984 and 1995, respectively. He became scientific advisor at the Institute of Applied Physics-Belgrade in 1985. He is currently Research Director of the Institute for Microwave Techniques and Electronics, Belgrade.

Ivana Radnović received her BS degree in electrical engineering from the School of Electrical Engineering, Belgrade University, in 1987. Since 1987, she has been with the IMTEL Institute, Belgrade, Serbia, as a Research and Design Engineer. She is currently working toward her PhD degree. Her current research interests include the analysis and design of microwave and millimeter-wave printed antenna structures.

Zoran Mićić received his Diploma Engineer degree in electrical engineering from the School of Electrical Engineering, Belgrade University, in 2001. He is currently working toward his PhD degree. Since 2001 he has been with the IMTEL Institute, Belgrade, Serbia, as a Senior Project Engineer. His research interests include microwave parabolic and microstrip antennas.

Sinisa Jovanović received his Diploma Engineer degree in electrical engineering from the School of Electrical Engineering, Belgrade University in 1987. He is currently working toward his PhD degree. From 1987 to 1998 and from 2003 to present he has been with the IMTEL Institute, . Belgrade, Serbia, as a Senior Project Engineer for the microwave section of radio-relay links. From 1998 to 2002 he was with Philips Broadband Networks and C-Cor.net, Manlius, NY, as a design and system engineer for CATV amplifier development. His current research interests include microwave amplifiers, subharmonic mixers as well as printed filters and antennas.



#### ultra small

# 2,3 AND 4 WAY SPLITTERS

0.5-7200 MHz



In today's tough economic situation there is no choice: Reducing cost while improving value is a must. Mini-Circuits has the solution... pay less and get more for your purchases with our industry leading ultra small power splitters.

#### Choose from over a hundred models...

These rugged LTCC and semi conductor power splitters are available with narrowband and broadband coverage through 7200 MHz. Small in size and cost, but big on performance, they can handle as much as 1.5 W input power, with high isolation and low insertion loss. Yet they won't take up valuable circuit board space, with 2 and 3 way power splitters measuring from  $0.126 \times 0.063 \times 0.035$  in. and 4 way splitters as small as  $0.210 \times 0.063 \times 0.077$  in. The small size also contributes to minimal amplitude and phase unbalance with outstanding unit-to-unit repeatability. All Mini-Circuits 2, 3, and 4 way surface-mount power splitters fit easily within your design, and your budget!

Visit our website to choose and view comprehensive performance curves, data sheets, pcb layouts, and environmental specifications. And you can even order direct from our web store and have a unit in your hands as early as tomorrow!

Mini-Circuits...Your partners for success since 1969





P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661



# DIRECT PLATED COPPER METALLIZED SUBSTRATE AND ITS APPLICATION ON MICROWAVE CIRCUITS

A direct plated copper (DPC) metallized substrate technique is introduced and characterized in this article. The proposed DPC metallized substrate provides the main advantages of excellent thermal management and high-frequency characteristics, due to the use of ceramic substrates and metallized copper conductors. Therefore, in order to characterize the electrical properties of a DPC substrate for high-frequency applications, a simple experimental method was adopted to carry out the correlated values of dielectric constant and dielectric loss at Ku-band. In addition, a 10 GHz parallel-coupled line bandpass filter (BPF) was designed and fabricated by using the DPC substrate for verification. This BPF has a measured insertion loss of 0.5 dB and a return loss greater than 10 dB in the pass band, which indicates that the proposed DPC metallized substrate is very suitable for RF module packages and microwave components.

■he direct plated copper (DPC) process on metallized ceramic substrate was originally created to replace the direct bonded copper (DBC) process because of its better electrical, thermal and mechanical performance. 1 Compared to DBC, DPC provides a very strong bond strength between the Al2O3/ AlN substrate and the copper metal, due to the use of a thin film bonding layer.<sup>2</sup> DPC also has a good ability in thickness control for the copper layer, from very thin to very thick. For fine pitch design, a minimum conductor line width/ spacing of 3 mils can be easily obtained, and via holes are filled with copper for good electrical and thermal characteristics. By using the proposed DPC substrate, superior performance can be obtained compared to other technologies in terms of its features and applications, which includes high circuit density, outstand-

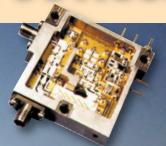
ing high-frequency characteristics, excellent thermal management and heat-transfer performance, outstanding solderability, and wire-bonding assembly characteristics. These DPC substrates can therefore be widely used for high frequency components that require high power and high heat.<sup>3</sup>

In this article, the DPC fabrication is briefly described with a process flow chart, to introduce several key attributes of this process. A simple electrical characterization for DPC substrate is then utilized to extract the high-frequency di-

CHIEN-CHENG WEI, CHIN-TA FAN, TA-HSIANG CHIANG, MING-KUEN CHIU AND SHAO-PIN RU Tong Hsing Electronic Industries Ltd. Taipei Hsien, Taiwan

# An Uncompromising Approach to Ultimate Mission Success

High Efficiency ❖ Light Weight ❖ Small Size





Employing multipurpose payloads including EO/IR, EW, SAR and others, UAVs can now transmit complex information directly to troops in the field while simultaneously sending the information half-way around the world for analysis.

CTT, Inc. continues its expansion of GaAs- and GaNbased solid-state amplifier products and subassemblies designed to accommodate these ever evolving requirements.

CTT's UAV experience includes participation in data and video communication links on programs including Shadow, Hunter, Predator/Reaper, Pioneer, Global Hawk and others.

Building on this experience, CTT is well positioned to offer engineering and production technology solutions — including high-rel manufacturing — in support of your complete UAV system requirements.

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

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

#### Uplink and Downlink Amplifiers

- C, X, Ku, and Ka-Band
- Power Amplifiers Up to 100 Watts
- Low-Noise Amplifiers 1—18 GHz

#### ❖ Power and Driver Amplifiers for SAR

- X thru Ka-Band
- Up to 100 Watts

#### Up Converters and Transceivers

- C thru Ka-Band
- Compact, Space-Saving Designs

#### Surface Terminal Amplifiers

- C thru Ku-Band
- Up to 100 Watts

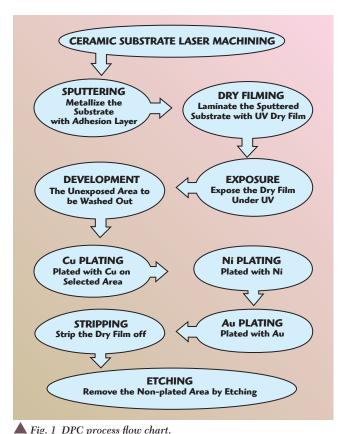
#### CDL and TCDL Subassemblies

- IF and RF
- Digitally Controlled

Visit http://mwj.hotims.com/28495-31 or use RS# 31 at www.mwjournal.com/info



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



electric constant and dissipation factor. Finally, a 10 GHz, parallel-coupled line bandpass filter is designed to validate the extracted dielectric parameters and the excellent high-frequency performance of a DPC metallized substrate.

#### DIRECT PLATED COPPER PROCESS

The entire DPC process basically comprises the steps displayed in *Figure 1*, which include defining holes in the ceramic substrate, sputtering a copper film onto the ceramic substrate, forming a dry film onto the copper film, forming a circuit diagram

with exposure and development, plating copper leads, removing the dry film and etching the seed metal copper.<sup>3</sup> The detailed processes have been described by S.P. Ru,<sup>4</sup> with more theoretical explanations and drawings.

With the flow chart shown, the DPC process is started by defining holes on the bare ceramic substrate with a laser. These holes can be used as via holes to communicate between both sides of the ceramic substrate if it is necessary for some specific designed layout. Then a copper film, used as a seed metal layer, is sputtered on the opposite sides of the ceramic substrate so that it is covered with a copper layer. From the artwork describing the circuit diagram, a photomask is made using conventional photomask technology. The photomask is flatly positioned and adheres to the dry film on the ceramic substrate, which is sent into an exposing chamber.

After creating a vacuum in the exposing chamber, ultraviolet rays irradiate the dry film through the photomask, which is polymerized by the ultraviolet radiation. The dry film, which is not irradiated by the ultraviolet rays, does not react and keeps its chemical composition. The development process etches the polymerized part of the dry film by chemical cleaning or physical cleaning. In this way, some parts of the copper film are exposed from the dry film; those parts of the copper film will form the required circuit diagram as per the artwork of the circuit, in order to produce the required copper areas of a circuit on the ceramic substrate. Thus, the circuit layout can be printed on the dry film.

Copper is then deposited to fill the exposed parts of the dry film on the ceramic substrate, with suitable conductor thickness and width, by a plating technology to form the copper circuit. By the above processes, the metallized circuit area has slender, flat and smooth characteristics, and the heat dissipation is good. Then nickel and gold are deposited on the upper surface of the copper. The nickel film prevents the atoms of the copper leads diffusing into the gold film. The gold film avoids the oxidization of the conductor surface and improves the adhesion for the gold bonding wires. An optical resistance is formed on the upper surface of the copper. The remaining dry film on the ceramic

#### Two new Web sites from Anatech Electronics...

Selecting and buying RF and microwave filters just became a snap!



#### <u>Anatechelectronics.com</u>

For custom filters

Specifying custom filters has never been easier with our simple new intuitive interface that guides you along the way. Technical documents and an interactive design wizard are there to help you too.

# AMCrf.com Buy thousands of our standard products online

It's as easy as one, two, three, thanks to our new step-by-step process that leads you to the right product every time – and lets you buy it directly from the site!



ANATECH ELECTRONICS INC

Phone: (973) 772-4242 Fax: (973) 772-4646

E-mail: sales@anatechelectronics.com

# RFMD<sup>®</sup>.

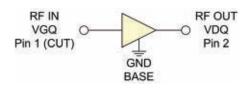
## 120 Watt GaN Wideband Power Amplifier



The RF3934, the newest of RFMD's series of unmatched power transistors, is a 48 volt, 120-watt high power discrete amplifier designed for commercial wireless infrastructure, military, industrial/scientific/medical, and general purpose broadband amplifier applications. Using an advanced high power density Gallium Nitride (GaN) semiconductor process, this high-performance amplifier achieves high efficiency and flat gain over a broad frequency range in a single amplifier design. The RF3934 is an unmatched GaN transistor packaged in a hermetic, flanged ceramic package. This package provides excellent thermal stability through the use of advanced heat sink and power dissipation technologies. Ease of integration is accomplished through the incorporation of simple, optimized matching networks external to the package that provide wideband gain and power performance in a single amplifier.

#### **RF393X SERIES SPECIFICATIONS**

Freq (GHz)	P3 dB at 900 MHz (W)	SS Gain at 0.9 GHz (dB)	Drain Eff at 0.9 GHz (%)	P3 dB at 2.1 GHz (W)	SS Gain at 2.1 GHz (dB)	Drain Eff at 2.1 GHz (%)	V <sub>D</sub> (V)	Package	Export Class	Part Number
DC-3	50	20	70	45	15	65	48	360B	EAR99	RF3931
DC-3	78	21	73	75	14	65	48	360B	EAR99	RF3932
DC-3	116	21	70	100	14	60	48	360B	EAR99	RF3933
DC-3	145	21	75	140	13	60	48	360B	3A001b.3.a	RF3934



#### **RF3934 FEATURES**

- Broadband operation: DC-3 GHz
- Advanced GaN HEMT technology
- Advanced heat-sink technology
- Small signal gain=21 dB at 900 MHz
- · 48 V operation typical performance at 900 MHz
  - o Output power 145 W P3 dB
  - Drain efficiency 75% P3 dB
  - -40° to 85° C operating temperature
- Applications include commercial and wireless infrastructure; cellular and WiMAX infrastructure; civilian and military radar; general purpose broadband amplifiers; public mobile radios; industrial, scientific, and medical.

Order RFMD products online at www.rfmd.com/rfmdExpress.

For sales or technical support, contact your authorized local sales representative (see <a href="www.rfmd.com/globalsales">www.rfmd.com/globalsales</a>). Register to receive RFMD's latest product releases with our Email Component Alerts at <a href="www.rfmd.com/emailalert">www.rfmd.com/emailalert</a>. 7628 Thorndike Rd., Greensboro, NC 27409-9421 USA • Phone 336.664.1233

7628 Inornalke Ra., Greensboro, NC 27409-9421 USA • Phone 336.664.123





rfmd.com

substrate is then removed. After stripping the dry film, the copper circuit is protected by the nickel and gold films. The detaching copper film process etches the copper film not protected by the optical resist.

Due to the processes described and the materials used, several key attributes of the DPC process can be summarized as below:

- Superior thermal performance
- Low electrical resistance conductor lines

- Stable up to temperature > 340°C
- Accurate feature location, compatible with automated, large format assembly
- Fine line resolution allowing high density of devices and circuitry
- Proven reliability
- Mechanically rugged ceramic construction
- Low cost, high performance ceramic solution

The applications of DPC metallized substrate can be selected on

high-brightness LED (HBLED), substrates for solar concentrator cells, power semiconductor packaging and automotive motor control. In addition, DPC substrates with excellent electrical performance can be considered for RF/microwave components, which require very low loss.

## ELECTRICAL PROPERTIES EXTRACTION

In order to utilize DPC substrates for RF/microwave applications, the dielectric properties must be extracted. Dielectric characterization is a very important issue for electronic packaging designs since electrical behavior is greatly influenced by the dielectric constant and dielectric loss at high frequencies.

There are numerous reported methods in the published literature.<sup>5-8</sup> Many of these methods have one or several limitations, such as expensive and complicated instrumentation, difficult-to-fabricate fixtures, measured dielectric properties only valid for one particular frequency, poor repeatability, and inability to obtain both dielectric constant and dielectric loss. However, in this article, a simple approach is used to obtain the accurate dielectric factors for further substrate design and simulation.

Holzman used a computer model of the resonator to extract the dielectric data. Once the circuit is modeled accurately with a computer-aided design (CAD) simulator, the substrate's dielectric properties can be determined by comparing the predictions from the simulator with the measured characteristics. This empirical/analytical approach has been demonstrated by a number of researchers in the microwave field.

Therefore, to extract high-frequency dielectric data for DPC substrate, two modified microstrip parallel-coupled resonators with distinct zeros over a broad bandwidth were fabricated. Figure 2 shows the photos of parallel-coupled microstrip resonators (PCMR). The PCMR1 shown affects transmission zeros with more depth at lower frequencies; PCMR4 generates transmission zeros with deeper depth at higher frequencies. The two resonators have the same coupled-line structure with a line distance of 570 mils and a spacing of 12 mils, but opposite output connections. From the measurements of the



www.gtmicrowave.com

e-mail: sales@gtmicrowave.com

# SATCOM AMPLIFIERS



# For Either Fixed Or Transportable Satellite Base Station Operation.

LNAs In The Following Bands: L, S, C, X, Ku, And Ka-Bands 1:1, 1:2 And Dual 1:1 Redundant Units Are Also Available

#### FEATURES

- Noise Temperature as Low as 28K
- Internal Regulation and Reverse Voltage Protection
- Waveguide Input and SMA Female Output
- Fully Weatherproof
- Operating Temperature of -40 to +60 °C
- Compliant to MIL-STD-810E for Salt/Fog
- Can be Optimized for Custom Solutions for Specific Applications

#### **OPTIONS**

- Fault Alarm Circuitry
- DC Bias applied through the RF Output
- 110/220 VAC Internal Power Supplies
- Higher Output Powers
- Improved Gain Variation over Temperature
- N-Type Female Output Connector
- Input Limiter



For additional information or technical support, please contact our Sales Department at (631) 439-9220 or e-mail components@miteq.com



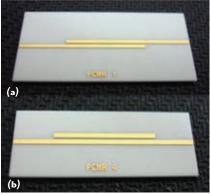
100 Davids Drive, Hauppauge, NY 11788 USA 631-436-7400 FAX: 631-436-7430 • www.miteg.com

two PCMRs, these zeros are sufficient to interpolate correct dielectric values with good accuracy under a broadband frequency response. However, the first transmission zero for PCMR1 and PCMR4 are at 5.2 and 4.2 GHz, respectively, and repeating approximately at every resonant frequency over the band. To make a preliminary simulation of the resonators, a dielectric constant of 9.5 and a dielectric loss of 0.004 were assumed for DPC substrate in ADS Momentum simulation.

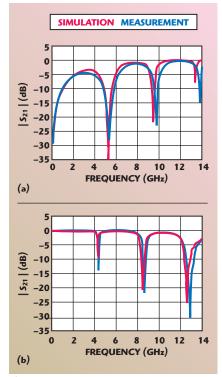
The testing setup consisted of an Agilent E8364A network analyzer, an Anritsu Universal Test Fixture with two K-connector coaxial input ports, and a ground-plane backed DPC metallized substrate with the microstrip resonators. In addition, a TRL calibration is adopted by using DPC fabricated calibration kits to calibrate at the same reference plane of the PCMRs. The comparisons between simulated and measured insertion losses for PCMR1 and PCMR4 are shown in *Figure 3*.

**HIGH-RELIABILITY** FREQUENCY SYNTHESIZERS RUGGEDIZED, HERMETICALLY-SEALED DESIGNS UP TO 18 GHZ **Features:** PLICATIONS USTOM DESIGNS Hermetically-sealed per MIL-STD-883 Fast switching available (<250 µSec) Hybridized, surface-mount designs to 12 GHz Hi-Rel crystal oscillators to 500 MHz • Extended temperature range: -40°C to +85°C High vibration tolerance: 14 G's RMS operating, 20 G's RMS functional Miniature, compact designs Exceptionally low phase noise EM Researc Quality • Consistency • Performance (775) 345-2411 • sales@emresearch.com www.emresearch.com

From the measurements, it is obvious that the assumed dielectric values are in error, with the error increasing at higher frequencies. To extract the correct dielectric constant and dielectric loss, these values are adjusted in ADS Momentum to match the frequency response until the predicted zero matches the measured zero. Figure 4 shows the fitted results for two PCMRs up to 14 GHz, after adjusting the dielectric parameters. In this case, the rise in these two parameters of DPC substrate is from 9.5 to 9.75 for the dielectric constant and 0.0004 to 0.002 for the dielectric loss, respec-



▲ Fig. 2 DPC microstrip parallel-coupled resonators with distinct output connections: (a) PCMR1 and (b) PCMR4.



▲ Fig. 3 Measured and simulated results for the microstrip parallel-coupled resonators: (a) PCMR1 and (b) PCMR4.

# RF & MICROWAVE SOLUTIONS

- Radar Communications
- Electronics Warfare
- IED Jammers

- Missile Guidance
- Land Mobile Radio
- Satellite Communications



In addition to providing a solid supply chain from industry-leading manufacturers, our customers rely on us for COTS-screened components, MIL-STD process screening and Multi-Year Production Management.

Learn more at www.rell.com/defense



Your Global Source for RF, Microwave & Power Conversion Components

Visit http://mwj.hotims.com/28495-115 or use RS# 115 at www.mwjournal.com/info

To contact your local Richardson Electronics sales engineer, go to www.rell.com and select "Local Sales Support" under Contact Us in the main menu. tively. These values are more accurate than the assumed data at higher frequencies and can be widely used for substrate design and simulation.

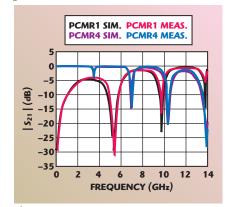
#### MICROWAVE CIRCUIT DESIGN

To validate the accuracy of extracted dielectric data, a microwave filter fabricated on a DPC substrate was demonstrated. This BPF, using a parallel-coupled line structure, has a center frequency of 10 GHz, a bandwidth of 15 percent, 0.1 dB equal-ripple response

and third-order topology, and is shown in *Figure 5*. The BPF was designed and optimized with ADS Momentum using the extracted dielectric constant and dielectric loss. The TRL calibration kits were also fabricated on DPC substrates to cover the frequency range from 4 to 14 GHz.

With these test standards, the Anritsu test fixture's coax-to-microstrip transitions and the microstrip lines up to the input and output ports of the filter can be de-embedded. The measured

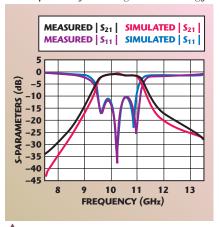
insertion loss and return loss are shown in *Figure 6*. Based on these experimental results, a good prediction of the filter response is achieved by using the extracted dielectric values in the EM simulator. The measured insertion loss of the BPF is only 0.5 dB at 10 GHz. It clearly demonstrated that the DPC process, fabricated with a ceramic sub-



▲ Fig. 4 Measured and simulated results for the microstrip parallel-coupled resonator.



▲ Fig. 5 Photograph of the 10 GHz parallel-coupled line filter using DPC technology.



▲ Fig. 6 Measured and simulated characteristics of the 10 GHz DPC parallel-coupled line filter.



# The Leader in Switching Solutions

The global provider of ultraminiature, hermetically sealed and solid state switching products for over 40 years.

Our products meet a wide range of applications in the defense, aerospace, industrial, commercial, RF,

Test & Measurement and Space markets.



# MICROWAVE COAXIAL SWITCHES

- SPDT, Transfer, Multi-Throw
   Switches and Switch Matrices
- 5 million cycles characteristic life
- DC to 33 GHz
- Custom products
- 3-State attenuated switch

#### **ELECTROMECHANICAL RELAYS**

- Signal integrity up to 12 Gbps
- SMT solutions
- DC-8 GHz

# William Gebis





#### **MILITARY & COTS SOLID-STATE RELAYS**

- Robust design, wide temperature range
- · AC, DC and Bidirectional
- Short circuit protection





# INDUSTRIAL/COMMERCIAL SOLID-STATE RELAYS

- Single, Dual and 3-Phase products
- · Soft start motor controllers
- High current, high voltage







Hall B3, Booth 275 electronica 2010 November 9-12

800-596-3855 • www.teledynerelays.com 800-351-7368 • www.teledynecoax.com







strate and copper conductor, provides excellent low-loss performance at high frequencies and offers the excellent ability to be used in RF packaging and microwave devices.

#### CONCLUSION

This article presents a DPC metallized substrate including the process flow, electrical properties extraction and a microwave circuit design. Owing to the use of the ceramic substrate and metallized copper conductor, the DPC substrate achieves good high-frequency electrical characteristics. Meanwhile, a simple extraction method to obtain the dielectric constant and dielectric loss for the DPC substrate was proposed, and a 10 GHz parallel-coupled line BPF with 0.5 dB insertion loss was built for further verification. This article clearly demonstrates that the DPC metallized substrate is quite suitable for RF and microwave package design, with its excellent low-loss performance.



#### References

- M. Entezarian and R.A.L. Drew, "Direct Bonding of Copper to Aluminum Nitride," *Materials Science* and Engineering, A-212, July 1996, pp. 206-212.
   J. Schulz-Harder, "Advantages and New Develop-
- J. Schulz-Harder, "Advantages and New Development of Direct Boded Copper Substrates," Microelectronics Reliability, Vol. 43, No. 3, 2003, pp. 359-365.
- "DPC-Direct Plated Copper Thin Film Technology," Tong Hsing, www.ready-sourcing.com/sourcing-news/electronic/dpc.html.
- S.P. Ru, "Method for Removing Voids in a Ceramic Substrate," US Patent, US 6,800,211 B2, October 2004
- M.K. Das, S.M. Voda and D.M. Pozar, "Two Methods for the Measurement of Substrate Dielectric Constant," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 35, No. 7, July 1987, pp. 636-642.
- S.H. Chang, H. Kuan, H.W. Wu, R.Y. Yang and M.H. Weng, "Determination of Microwave Dielectric Constant by Two Microstrip Line Method Combined with EM Simulation," Microwave and Optical Technology Letters, Vol. 48, No. 11, November 2006, pp. 2199-2121.
- H. Yue, K.L. Virga and J.L. Prince, "Dielectric Constant and Loss Tangent Measurement Using a Stripline Fixture," *IEEE Transactions on Compo*nents, Packaging and Manufacturing Technology, Part B, Vol. 21, No. 4, November 1998, pp. 441-446.
- P.A. Bernard and J.M. Gautray, "Measurement of Dielectric Constant Using a Microstrip Ring Resonator," *IEEE Transactions on Microwave Theory* and Techniques, Vol. 39, No. 3, March 1991, pp. 592-595.
- E.L. Holzman, "Wideband Measurement of the Dielectric Constant of an FR4 Substrate Using a Parallel-coupled Microstrip Resonator," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 54, No. 7, July 2006, pp. 3127-3130.

Chien-Cheng Wei received his MS and PhD degrees in electronic engineering from Chang Gung University, Taoyuan, Taiwan, ROC, in 2004 and 2008, respectively, During his graduate study, he was involved with RFIC design, ultra-wideband/millimeter-wave IC design, and RF CMOS device modeling. In September 2008, he joined the R&D department, Tong Hsing Electronic Industries, where he is involved with RF packaging, RF module assembling, high-frequency characterization for packaging materials and substrates.

Chin-Ta Fan received his MS degree in electronic engineering from Chung Yuan Christian University, Chung-Li, Taiwan, ROC, in 2003. His research interests include the characterization of metal oxide materials and applications for EGFET sensors. He joined the R&D department of Tong Hsing Electronic Industries in 2003, and is involved with SiP assembling, direct plated copper (DPC) metallized substrate development and gold-to-gold interconnect (GGI) process evaluation.

**Ta-Hsiang Chiang**, R&D Manager of Tong Hsing Electronic Industries, has served in the company for more than 25 years. He is the R&D leader in charge of RF packaging, MEMS packaging, hybrid circuit assembling, DPC substrate fabrication and any other new process development.

Ming-Kuen Chiu, Vice President of Tong Hsing Electronic Industries, has worked at Tong Hsing for more than 30 years. Since joining the company in 1976 as an engineer, he has taken over all works in engineering, equipment, sales, marketing and new process developments.

Shao-Pin Ru, Vice President of Tong Hsing Electronic Industries, has served in the company for more than 30 years. He started in 1976 as an engineer and has had assignments in engineering, operations, sales, marketing and new business development. He received his MBA degree from National Chiao Tung University in 1980 and graduated with a BS in electrical engineering from National Taiwan University in 1974.



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





# Analysis and Modeling OF THE PADS FOR RF CMOS BASED ON **EM SIMULATION**

The modeling of the test structure of an RF MOSFET, up to 40 GHz, is presented. The size of the pads and the width of the interconnection lines of the test structures are analyzed and optimized based on accurate electromagnetic (EM) simulation in order to reduce the impact of the parasitics of the pad and interconnection lines. A 0.13 µm RF CMOS technology with eight levels of metallic layer is used to implement the test structures, which are designed according to the optimization results. Good agreement between the measured and simulated results has been demonstrated.

n the past ten years, an interest in more accurate characterization of RF MOSFETs has emerged. The rapid advancement of low-cost CMOS silicon process has made possible the application of CMOS technology at radio and microwave frequencies. When conducting S-parameter measurements of microwave devices directly on a wafer, the low silicon substrate resistivity and the characterization of the metal lines are of primary concern. 1 Moreover, a characteristic of the low-cost silicon processes is that device performance per unit area is usually low. The test structure must be very large in order to fit the large devices.<sup>2</sup> Consequently, the parasitics of the test structure are significant. To reduce the impact of the parasitics of the test structure, several new techniques have recently been adopted, including compensated de-embedding<sup>3-5</sup> and a shield-based test structure.<sup>2</sup>

In this article, a microwave model of the test structure is proposed and its equivalent circuit

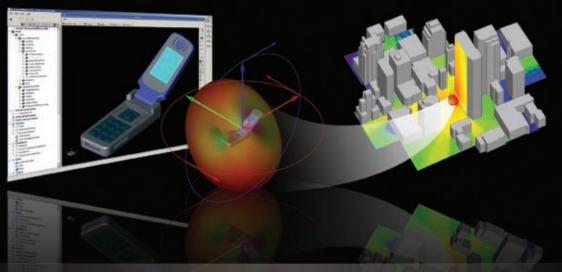
parameters are determined. In order to reduce the impact of the parasitics on the DUT characteristics, the size of the pads and the width of the interconnection lines of the test structures are analyzed and optimized, based on accurate electromagnetic (EM) simulation. A 0.13 μm RF CMOS process, with eight levels of metallic layer, is used to fabricate the test structures, which are designed according to the optimization result.

#### **TEST STRUCTURE**

Because the MOSFET is too small to be contacted directly, measuring its RF behav-

J. Cheng, S. Li, B. Han and J. Gao East China Normal University Shanghai, PR China

Semiconductor Manufacturing International Corp., Shanghai, PR China



Cell phone antenna simulation in XFdtd > and subsequent propagation analysis in Wireless InSite

# XFdtd<sup>®</sup> and Wireless InSite<sup>®</sup>: Remcom's Multiphysics Toolset

Remcom's products are designed to work together to provide complete and accurate results when modeling propagation with real world devices in real world scenarios.

**XFdtd**: Innovative 3D electromagnetic simulation software

Wireless InSite: Ray-based, site-specific radio propagation analysis tool

Visit Remcom to learn more: www.remcom.com

- Sophisticated, highly-refined EM simulation tools
- Superior customer support and customized solutions
- Affordable plans for any budget or level of need



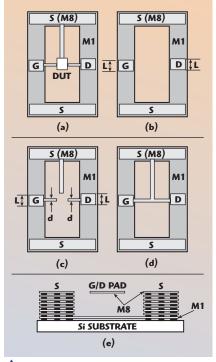
- **+1.888.7.REMCOM** (US/CAN)
- +1.814.861.1299

www.remcom.com

Visit http://mwj.hotims.com/28495-107 or use RS# 107 at www.mwjournal.com/info

Visit Remcom at MILCOM, booth #1510

ior with coplanar probes requires a test structure that consists of probe pads and interconnecting lines and the device under test (DUT). The probe pads connect the meaprobe surement and silicon wafer; the interconnecting lines connect the pads and the DUT. The MOS model parameters are extracted from S-parameter measurements on the structure.4 The parasitic components, which originate mainly from the probe pads and the me-S-parameter



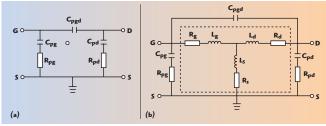
pads and the metallic interconnecting lines, influence the DUT; (b) pad test structure; (c) open test structure; (d) short test structure; and (e) cross-section of the test structure.

measurements of the DUT. Here, the size of the pads and the width of the lines are analyzed in order to minimize the influence of the parasitics.

A 0.13  $\mu$ m RF CMOS technology with eight levels of metal interconnects is used to fabricate the test structure. The layout of the MOS test structure and the de-embedding structures are shown in **Figure 1**. The layout of the pads and the interconnecting lines is identical for the test structure and the de-embedding structures. The length of the test structure is 235  $\mu$ m and the width is 230  $\mu$ m. Starting on the left hand side, there are input pads in GSG arrangement with 100  $\mu$ m pitch and output pads with the same configuration as input pads.

## **EXTRACTION METHODOLOGY FOR THE PARASITIC PARAMETERS**

The equivalent circuits of the open structure and of the short structure are shown in  $\it Figure~2.7~C_{pg}$  and  $C_{pd}$  represent the pad capacitance of the gate and drain between the signal pad and the ground pad, respectively.  $C_{pgd}$  represents the coupling capacitance between the gate and drain pad.  $R_{pg}$  and  $R_{pd}$  represent the substrate loss resistance of the gate pad and the drain pad, respectively.  $L_g,\,L_s$  and



▲ Fig. 2 Equivalent circuits: (a) open structure and (b) short structure.

 $L_{\rm d}$  represent the inductance of the gate, source and drain interconnecting line, respectively.  $R_{\rm g},\,R_{\rm s}$  and  $R_{\rm d}$  represent the resistance of the gate, source and drain interconnecting line, respectively. L is the length of the signal pads and d is the width of the metallic interconnecting lines.  $^8$  All the parameters can be determined by using several steps as follows:

(1) Parameter Extraction of the open test structure:

$$\mathbf{Y}^{\text{open}} = \begin{bmatrix} \mathbf{Y}_{11}^{\text{open}} & \mathbf{Y}_{12}^{\text{open}} \\ \mathbf{Y}_{21}^{\text{open}} & \mathbf{Y}_{22}^{\text{open}} \end{bmatrix} = \begin{bmatrix} \mathbf{Y}_{pg} + \mathbf{Y}_{pgd} & -\mathbf{Y}_{pgd} \\ -\mathbf{Y}_{pgd} & \mathbf{Y}_{pd} + \mathbf{Y}_{pgd} \end{bmatrix}$$
(1)

where  $Y^{open}$  is the matix obtained from conversion of the measured S-parameters of the open test structure. Provided that  $(\omega R_{pg}C_{pg})^2+1\approx 1$ , then

$$Y_{pg} = Y_{11}^{open} + Y_{12}^{open} = \frac{1}{R_{pg} + \frac{1}{j\omega C_{pg}}} = \frac{1}{R_{pg} + \frac{1}{j\omega C_{pg}}}$$

$$\frac{R_{pg}(\omega C_{pg})^2 + j\omega C_{pg}}{(\omega R_{pg}C_{pg})^2 + 1} \approx R_{pg}(\omega C_{pg})^2 + j\omega C_{pg}$$
 (2)

$$Y_{pd} = Y_{22}^{open} + Y_{21}^{open} = \frac{1}{R_{pd} + \frac{1}{j\omega C_{pd}}} = \frac{1}{R_{pd} + \frac{1}{j\omega C_{pd}}}$$

$$\frac{R_{pd}(\omega C_{pd})^2 + j\omega C_{pd}}{(\omega R_{pd}C_{pd})^2 + 1} \approx R_{pd}(\omega C_{pd})^2 + j\omega C_{pd}$$
(3)

$$Y_{pgd} = -Y_{12}^{open} = j\omega C_{pgd} \tag{4}$$

From Equations 2 and 4, one can get

$$C_{pg} = \frac{Im(Y_{pg})}{\omega} = \frac{Im(Y_{11}^{open} + Y_{12}^{open})}{\omega}$$
 (5)

$$C_{pd} = \frac{\operatorname{Im}(Y_{pd})}{\omega} = \frac{\operatorname{Im}(Y_{22}^{open} + Y_{21}^{open})}{\omega} \tag{6}$$

$$R_{pg} = Re(\frac{1}{Y_{pg}}) = Re(R_{pg} + j\omega C_{pg}) = Re(\frac{1}{Y_{11}^{open} + Y_{12}^{open}})$$
(7)

$$R_{pd} = \text{Re}(\frac{1}{Y_{pd}}) = \text{Re}(R_{pd} + j\omega C_{pd}) = \text{Re}(\frac{1}{Y_{99}^{\text{open}} + Y_{91}^{\text{open}}}) \ (8)$$

$$C_{pgd} = \frac{Im(Y_{pgd})}{\omega} = \frac{-Im(Y_{12}^{open})}{\omega}$$
(9)

(2) Parameter Extraction of the short test structure:

$$Y^{\text{short1}} = Y^{\text{short}} - Y^{\text{open}}$$
(10)

S292 2.92mm Connectors



Straight plug, direct solder for .086 semi rigid cable



Straight plug, solder/solder for .047 semi rigid cable



4 hole flange panel receptacle, female, .375" square



2 hole flange panel receptacle, female, .550"



4 hole flange panel receptacle, female, .500" square



4 hole flange panel receptacle, female, .500" x .390" rectangle



4 hole flange panel receptacle, male, .500" square



2 hole flange panel receptacle, male, .625"

Other configurations available.

Frequency Range:

#### **Performance**

DC to 40 GHz

 VSWR:
 DC-12 GHz: <1.04 DC-40 GHz: <1.18</th>

 System Impedance:
 50 ohms

 DWV:
 300 Vrms @ 60 Hz (sea level)

 Temperature Range:
 -65°C to +85°C

#### **Materials**

Socket Contact:	BeCu
Body:	SS-303
Insulator:	Delrin

#### **Plating**

Bodies:	Passivated		
Center Contacts:	Au/Ni		

#### Mechanical

Interface:	MIL-STD-348
Contact Retention:	6 lbs axial
Durability:	500 Cycles





#### K-Band for the masses

If you're part of the high frequency movement that's been held back by overpriced or underperforming connectors, let San-tron set you free. S292 connectors offer exceptional VSWR performance through 40 GHz with prices near standard SMAs. Our internal redesign includes an engineered dielectric match to a hermetic 50 ohm Thunderline-Z® feedthru. The result is precise mating and ultra-pure signal transmission.

Looking for a replacement for K-band specific connectors or other SMA, WSMA, 2.92mm or 3.50mm interconnects? Make the move with S292.



Always Thinking

ISO 9001:2008 REGISTERED www.santron.com

978-356-1585

ROHS COMPLIANT

where Yshort is the matrix obtained from conversion of the measured S-parameters of the open test structure and Y<sup>short1</sup> is the Y-parameter of the dashed box part of the equivalent circuit.

$$Z^{\text{short1}} =$$

$$\begin{bmatrix} R_g + j\omega L_g + R_s + j\omega L_s & R_s + j\omega L_s \\ R_s + j\omega L_s & R_d + j\omega L_d + R_s + j\omega L_s \end{bmatrix}$$
(11)

where  $Z^{\text{short1}}$  is the Z-parameter matrix obtained from the conversion of Y<sup>short1</sup>. Then one can get the expressions of  $R_s$ ,  $R_g$ ,  $R_d$ ,  $L_s$ ,  $L_g$  and  $L_d$  as follows:

$$\mathbf{R}_{\mathrm{g}} = \mathrm{Re}(\mathbf{Z}_{11}^{\mathrm{short1}} - \mathbf{Z}_{12}^{\mathrm{short1}}) \tag{12}$$

$$R_{d} = \operatorname{Re}(Z_{22}^{\text{short1}} - Z_{21}^{\text{short1}}) \tag{13}$$

$$R_s = \text{Re}(Z_{12}^{\text{short}1}) \tag{14}$$

$$L_g = \frac{\operatorname{Im}(Z_{11}^{short1} - Z_{12}^{short1})}{\omega} \tag{15}$$

$$L_d = \frac{\operatorname{Im}(Z_{22}^{short1} - Z_{21}^{short1})}{\omega} \tag{16}$$

$$L_{\rm d} = \frac{1}{\omega}$$

$$L_{\rm s} = \frac{Im(Z_{12}^{\rm short1})}{\omega}$$

$$(16)$$

#### **EM ANALYSIS**

At RF and microwave frequencies, the geometrical size of the test structure is close to the wavelength of the electromagnetic waves. The influence of electromagnetic interaction and radiation on the characteristics of the DUT increases. Electromagnetic interaction and radiation can be included in the equivalent circuit model of the test structure by an analysis technique based on EM simulation. The conventional approach, which adopts the lumped elements modeling technique, is unable to predict the characteristic of the different size structures. The relationship between the size of the test structure and the extrinsic elements of the equivalent circuit model can be analyzed and predicted by an EM simulation analysis technique before the test structure is fabricated, so that the parasitics can be alleviated as much as possible.6

Here, the commercial software HFSS is used to characterize the test structures and their S-matrix parameters are obtained. The test structure is characterized through its scattering matrix  $S_{\text{EM}}$ , which is computed by means of EM simulation on the basis of device geometry and material parameters. Thus, EM propagation and coupling effects are considered for the test structure. Once the scattering matrix  $\boldsymbol{S}_{EM}$  of the test structure has been obtained, the Y parameters can be deduced from the  $S_{EM}$ . The value of all the components of the test structure can then be extracted.



# **IMT**



## **Microwave Transmit and Receive Solutions**

Military | Defense | Law Enforcement Homeland Security | Airborne | UGV/UAV Surveillance | Reconnaissance | Covert Tactical | Strategic | Portable | Mobile



> Diversity Receivers
PSRX6D, SRx
and MobilCMDR





> Digital Transmission Systems VSTx, STx and CPTx



> Amplifiers, Block Downconverters, LNAs and Repeaters ALPA, HDRLNA and X-Tender

Visit us at MILCOM, Booth 1338

Microwave Digital Radios/Systems = SD/HD Video = COFDM = Diversity Reception

Contact IMT sales at 908.852.3700 or sales@imt-solutions.com

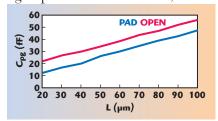


#### **IMT**

101 Bilby Road, Hackettstown, NJ 07840 USA t. +1 908.852.3700 ■+1 800.968.2666 ■ imt-solutions.com

#### THE PAD CAPACITANCE

It is theoretically obvious that the pad capacitance is dependent on the size of the signal pads. Figure 3 shows the relationship between the size of the signal pads and the capacitance  $C_{pg}$ . It is clearly seen that  $C_{pg}$  is directly proportional to L, the length of the signal pads, which are extracted from  $S_{EM}$ , the EM simulation result of the test structure. The characteristic of  $C_{pd}$  is identical with that of  $C_{pg}$ . The reason that the capacitance value of the open structure is bigger than that of the pad structure is that there is a coupling capacitance between the metallic interconnecting lines and the Si substrate in the open structure. In order to reduce parasitic capacitance, the size of the signal pads must be decreased, where-

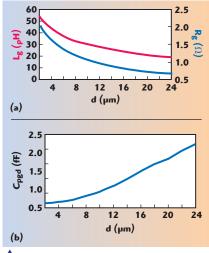


 $\triangle$  Fig. 3  $C_{pg}$  vs. the length of the pads.

as the size of the pads should be bigger than that of the probe pinpoint.

#### THE PARASITIC RESISTANCE AND INDUCTANCE OF THE INTERCONNECTING LINES

Figure 4 shows the relationship between the parasitic inductance and resistance of the interconnecting lines versus d, the width of the lines, which are extracted from the EM simulation



 $\triangle$  Fig. 4 (a)  $L_g$ ,  $R_g$  vs. d and (b)  $C_{pgd}$  vs. d.

result<sup>9</sup> and the coupling capacitance between the two signal pads. It is clearly seen that the parasitic resistance and inductance is inversely proportional to the width of the lines, whereas the coupling capacitance between two signal pads is directly proportional to d.

#### THE COUPLING CAPACITANCE **BETWEEN THE INPUT AND OUTPUT**

The coupling capacitance C<sub>pgd</sub> relates to the location and width of the interconnecting lines of the input and output signal pads. Figure 5 shows

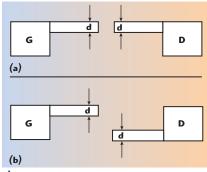


Fig. 5 Layout of the input and output interconnecting lines of the pads: (a) bilateral symmetry and (b) central symmetry.



## When They're **Counting on You,** You Can **Count on Us.**











#### **Products**

- Amplifiers
- Mixers
- Oscillators
- Passive Waveguide Components Level Sensing Radars
- Integrated Assemblies

#### **Applications**

- **Law Enforcement Radar**
- **Surveillance Radars**
- Missile Guidance

#### **Ducommun Technologies**

- Design & manufacture of Millimeter Wave Products
- Heritage includes WiseWave, acquired in 2006
- Lean Manufacturing Implemented
- AS9100 Registered
- Communications Systems
   Customer Focused Engineered Solutions



Email mwj@ducommun.com to request a FREE copy of our Sensor Brochure.





Connect with Teledyne Storm.



#### Harness the Results...

... of more than 30 years of microwave cable design and manufacturing expertise. That's what goes into every Teledyne Storm Products multi-channel harness assembly.

Add to that an unwavering focus on customer service, and you have harness solutions that consistently exceed customer expectations.

Teledyne Storm's multi-channel harnesses are found in a wide range of systems, from active electronically scanned arrays to digital radios, mixed signal applications to test labs and diagnostic units.



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



Microwave Business Unit Woodridge, Illinois 60517 Tel 630.754.3300 Toll Free 888.347.8676 Download our
Multi-Channel Microwave Solutions
brochure at
www.teledynestorm.com/mj1010

the bilateral and the central symmetry of the gate and drain interconnecting lines. *Figure 6* shows the value of  $C_{pgd}$  extracted from EM simulation results. The conclusion can be drawn that the layout with central symmetry is better than the lateral symmetry, because the value of  $C_{pgd}$  is smaller.

## PARAMETER EXTRACTION AND DISCUSSION

After the above analysis, some important conclusions can be drawn re-

garding the relationship between the size of the test structure and the value of the parasitic elements:

1) The length L of the signal pads should be shortened in order to reduce the value of  $C_{pg}$  and  $C_{pd}$ . Because the size of the pads should be larger than that of the probe point, L was set  $C_{pd}$  equal to 35  $\mu m$ .

2) In order to reduce the effect of the parasitics of the interconnecting lines between the input and output pads, the width of the gate, drain and source lines were set to 10, 16 and 30 µm, respectively.

3) In order to reduce the coupling capacitance  $C_{pgd}$ , the layout with a central symmetry of the gate and drain interconnecting lines was chosen.

The test structures have been fabricated and measured in accordance with the dimensions determined above. The parameters of the test structures have been extracted based on Equations 5 to 9 and 13 to 17.<sup>10</sup> *Figure 7* shows the frequency char-

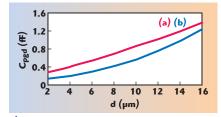
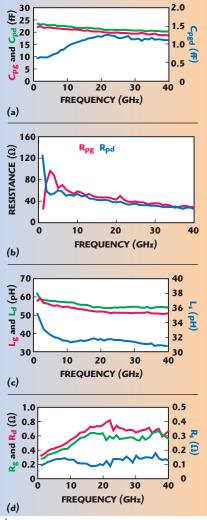


Fig. 6 Coupling capacitance between input and output pads: (a) lateral symmetry and (b) central symmetry.



▲ Fig. 7 Frequency characteristics of: (a) C<sub>pg</sub>, C<sub>pd</sub>, C<sub>pgd</sub>; (b) R<sub>pg</sub> and R<sub>pd</sub>; (c) L<sub>g</sub>, L<sub>d</sub> and L<sub>s</sub>; and (d) R<sub>g</sub>, R<sub>s</sub> and R<sub>d</sub>.

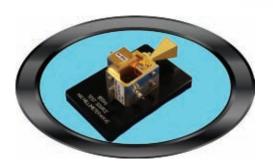


#### Military and Commercial Applications up to 120 GHz

#### No One Does it Better!

#### Why HXI?

- · Broad product range.
- 25+ years average experience within engineering staff.
- Fast prototyping using single function modules from our catalog.
- Optimum subsystem and system configurations using state-of-the-art integration techniques.
- · Small company speed and agility.





Products up to 120 GHz include integrated systems, sub-systems, front-ends, imaging products, low noise and power amps, gunn oscillators, frequency multipliers, isolators, up-converters and detectors, radio links, transceivers...

#### THE NEW THINKING IN WIRELESS TECHNOLOGY

Visit us at hall II stand F63 at the IBC 2010 show in Amsterdam, Netherlands.

Visit us at booth #1359 at the HD World 2010 show in New York, NY.

Visit us at booth #127 at the Milcom 2010 show in San Jose, CA. Visit us at booth #831 at the 4G 2010 show in Chicago, IL.

WE ARE ALWAYS LOOKING FOR TALENTED INDIVIDUALS PLEASE CHECK OUT OUR CAREERS SECTION ONLINE AT WWW.REC-USA.COM





Contact us for more information at 978-772-7774 sales@hxi.com

www.rec-usa.com/Ad/3.html

Visit http://mwj.hotims.com/28495-108 or use RS# 108 at www.mwjournal.com/info

acteristics of all the parameters. All the parameters are optimized with Agilent ADS. Table 1 shows the extracted and optimized values of the parameters of the test structure.

Figure 8 compares the simulated and measured reflection and transmission coefficients, up to 40 GHz for the short test structure. From these figures, it is observed that relatively good agreement between measured and simulated data can be achieved. However, it is noted that the differences between simulated and measured values of  $S_{12}$  and  $S_{21}$  at the higher frequency range are larger than those at the lower frequency range due to the increasing parasitic effects such as EM coupling and unintended radiation.

The possible cause of the differences between the values of the structure parameters extracted from EM simulations and those from measurements are discussed as follows. First, in the EM simulation, it is assumed that a

layer of dielectric is between the pads and the ground metallic layer. In reality, the structures are fabricated with multilayer of different dielectrics.

#### **TABLE I OPTIMIZED PARAMETER VALUES** Optimized Elements **Extracted** Unit 20.3 19.9 fF $C_{pg}$ fF $C_{pd}$ 21.5 21.1 1.18 1.16 fF $C_{pgd}$ $R_{pg}$ 36.0 34.1 Ω 32.1 30.9 Ω $R_{\rm pd}$ 53.9 рН $L_{\sigma}$ 54.8рН 31.4 31.7 $L_{s}$ $L_d$ 51.9 51.2 рН 0.59 0.52 $R_{\sigma}$ Ω 0.14 0.12 Ω $R_{c}$ 0.69 0.62 Ω $R_d$

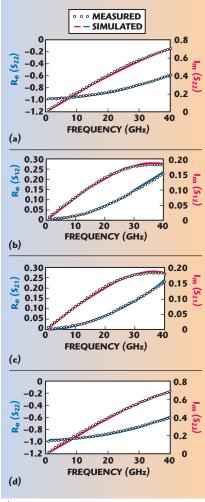


Fig. 8 Measured and simulated Sparameters of the short test structure: (a) S<sub>22</sub>, (b)  $S_{12}$ , (c)  $S_{21}$  and (d)  $S_{22}$ .



**EW/ELINT** SYNTHESIZER

- L-Band Multi-Output Reference Generator
- Phase Locked Multi-Frequency
- Ultra-Low Phase Noise Low g-Sensitivity 125 MHz Reference
- Enhanced Counter Measure: Military Airborne Operating Environment

#### RADAR UPCONVERTER



- Multi-Frequency, Low Phase Noise Synthesized Up-Converter with X-Band BIT Detector
- <50 nSec Switching Speed Between IF Output & Multiplied X-Band Output
- Low Profile Hermetically Sealed Package
- Military Airborne Operating Environment

#### SYNCHRONIZED STANDARD



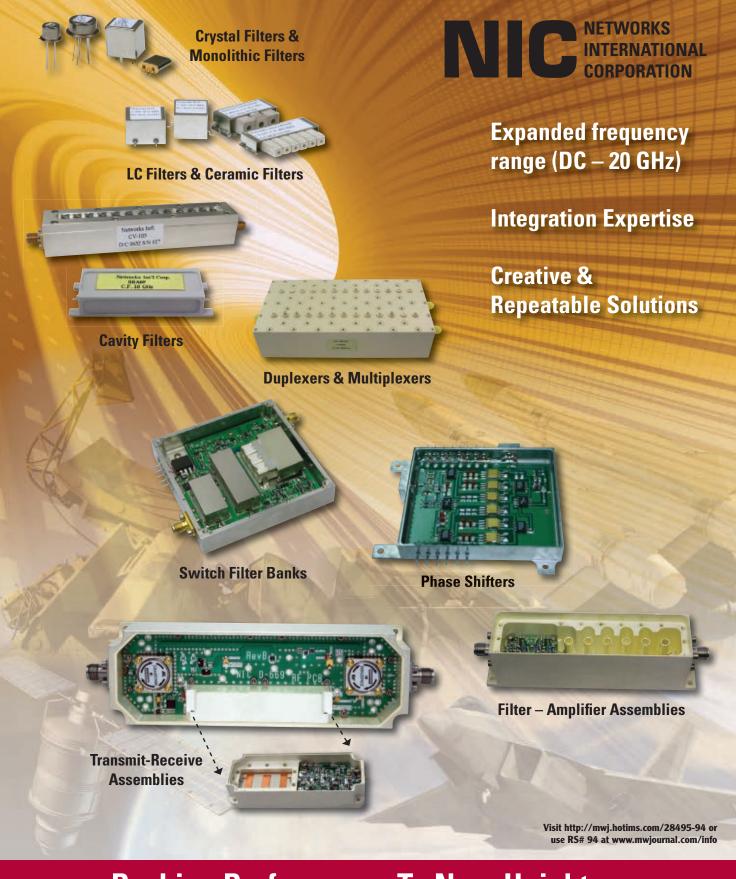
- **Direction Finding** (TOA/AOA) or SatCom Precise Reference OTM
- Low Phase Noise Low g-Sensitivity 10 MHz Reference
- Synchronized From Internal C/A Code GPS or External SAASM GPS 1 PPS
- MIL Ground Mobile and Airborne Operating Environments

www.trak.com

813-901-7200

smiths

bringing technology to life



# **Pushing Performance To New Heights**



913.685.3400

15237 Broadmoor Overland Park, KS

e-mail: sales@nickc.com

20+ Years of Excellence

www.nickc.com

Second, the metallic holes between metallic layers are combined into one hole to simplify the analysis and speed up the computation.

#### **CONCLUSION**

A microwave model of an RF MOS-FET test structure is proposed and the test structures are analyzed and optimized based on accurate EM simulation. A  $0.13~\mu m$  RF CMOS technology with eight levels of metallic layer

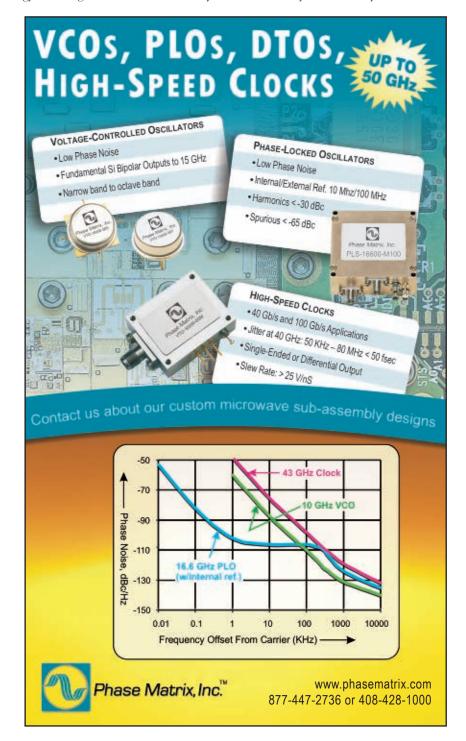
is used to fabricate the test structures. The equivalent circuit parameters of the test structures are then extracted and optimized based on Agilent ADS. Good agreement between the measured and ADS simulated results is obtained up to 40 GHz.

#### **ACKNOWLEDGMENTS**

This work is supported in part by the Open Research Program of the state Key Laboratory of Millimeter Waves, Southeast University, no. K201002. The authors would like to thank Shanghai SMIC for supplying the test structures and Ms. Xiaofang Yao for measuring the test structures.

#### References

- J.L. Carbonéro, G. Morin and B. Cabon, "Comparison between Beryllium-copper and Tungsten High Frequency Air Coplanar Probes," *IEEE Transactions* on Microwave Theory and Techniques, Vol. 43, No. 12, December 1995, pp. 2786-2793.
- T.E. Kolding, "Shield-based Microwave On-wafer Measurements," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 49, No. 6, June 2001, pp. 1039-1044.
- 3. T.E. Kolding, "A Four-step Method for De-embedding Gigahertz On-wafer CMOS Measurements," *IEEE Transactions on Electron Devices*, Vol. 47, No. 4, April 2000, pp. 734-740.
- E.P. Vandamme, D.M.M.P. Schreurs and G. van Dinther, "Improved Threestep De-embedding Method to Accurately Account for the Influence of Pad Parasitics in Silicon On-wafer RF Test Structures," *IEEE Transactions on Elec*tron Devices, Vol. 48, No. 4, April 2001, pp. 737-742.
- J. Gao, RF and Microwave Modeling and Measurement Techniques for Field Effect Transistors, SciTech Publishing, Raleigh, NC, 2010.
- V. Subramanian, Z. Zhang, D. Gruner, F. Korndoerfer and G. Boeck, "Analysis and Characterization of Microstrip Structures up to 90 GHz in SiGe BiC-MOS," 2007 European Microwave Conference Digest, pp. 512-515.
- M. Koolen, J. Geelen and M. Versleijen, "An Improved De-embedding Technique for On-wafer High-frequency Characterization," Proceeding of the BCTM, 1991, pp. 188-191.
- 8. J. Gao and A. Werthof, "Direct Parameter Extraction Method for Deep Submicrometer Metal Oxide Semiconductor Field Effect Transistor Small-signal Equivalent Circuit," *IET Microwaves*, *Antennas & Propagation*, Vol. 3, No. 4, 2009, pp. 564-571.
- B.L. Ooi, Z. Zhong and Y. Wang, "A Distributed Millimeter-wave Small-signal HBT Model Based on Electromagnetic Simulation," *IEEE Transactions on Vehicular Technology*, Vol. 57, No. 5, September 2008, pp. 2667-2674.
- 10. Q. Wang, C. Yuan and Y. Huang, et al., "An Approach for Determining MOS-FET Small-signal Circuit Model Parameters," *Microwave Journal*, Vol. 51, No. 10, October 2008, pp. 116-128.

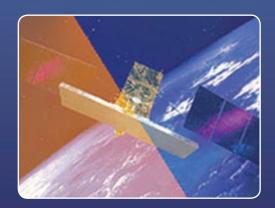


#### **UMS UNIQUE SPACE SOLUTION**

#### A complete selection of catalogue Class S products

For many years, UMS has served the needs of the international space community by offering an extensive selection of space evaluated processes:

- Low Noise PHEMT (PH25, PH15)
- Power MESFET (HP07)
- Power PHEMT (PPH25X, PPH15, ...)
- Power HBT (HB20S, HB20P)
- Analog & Digital HBT (HB20M)
- Schottky Diode (BES)



UMS is now pleased to extend this offer with the introduction of Hi-Rel MMIC products for space use. The new Class S space product selection is certified and qualified as Flight Model according to ESA specifications and MIL-PRF-38534.



Contact us:

UMS SAS France, 91401 Orsay - FRANCE Ph: +33 1 69 33 02 26 e-mail: mktsales@ums-gaas.com UMS USA Inc., Lowell, MA 01851 - USA Ph: +1 978 905 3162 e-mail: philippe.labasse@us.ums-gaas.com UMS (Asia - Pacific), Shanghai 200040 - PR China Ph: +86 21 6103 1703 e-mail: xavier.taltasse@ums-gaas.com

Worldwide Distributor: Richardson Electronics - www.rell.com





# MINIATURIZED SEMI-LUMPED UWB BANDPASS FILTER WITH IMPROVED OUT-OF-BAND PERFORMANCES

In this article, a miniaturized ultra-wideband (UWB) bandpass filter with improved out-of-band performance is presented, based on the combination of low-pass and high-pass filters. The UWB filter is realized in a semi-lumped technology, using microstrip transmission lines and surface-mounted capacitors. The filter design rules have been carried out and filters having a 3 dB fractional bandwidth of 142 percent, centered at 0.77 GHz, have been realized. The measured and simulated characteristics show a good agreement, with attractive return loss (better than 18 dB) and insertion loss (<0.3 dB). In addition, a technique using capacitively loaded stubs was used to extend the stopband to eight times the center frequency.

ince the Federal Communications Commission's (FCC) release of the frequency band from 3.1 to 10.6 GHz for commercial purposes, the UWB radio system has been receiving great attention from both academy and industry. As an essential component, UWB bandpass filters, with good performance, compact size and easily-implemented structures, are in high demand. So far, several prototypes of UWB filters have been reported.

Ishida and Araki have reported a microstrip ring filter with dual stopbands, below 3.1 GHz and above 10.6 GHz, which was the first UWB filter.<sup>2</sup> However, this filter has many problematic issues, such as unexpected passbands below 3.1 GHz, narrow stopbands, large size and complex configuration.

Due to their geometric simplicity, parallel coupled microstrip lines were commonly used to design bandpass filters. Generally, this procedure is used for bandwidths less than approximately 20 percent.<sup>3</sup> To overcome this limitation, a three-coupled-line microstrip structure was proposed<sup>4</sup> to design a bandpass filter with a fractional bandwidth of 50 percent. However, the greater the fractional bandwidth, the smaller the gap size is required to enhance the coupling. For UWB filter design, the necessary gap size is still too narrow to be fabricated.

D. KADDOUR, J.D. ARNOULD AND P. FERRARI ESISAR, Valence, France



Available for shipment within 24 hours from receipt of your order.

## On-Demand minibend® CABLE ASSEMBLIES

minibend® SMA plug to SMA plug cable assemblies (3" to 16") are now available for shipment within 24 hours from receipt of your order. Astrolab's expedited shipping is available for all orders up to 100 cable assemblies. Varying lengths can be ordered in any combination to achieve the best quantity discount.

Astrolab's patented minibend® cable assemblies provide an excellent commercial-off-the-shelf (COTS) solution for your cable assembly needs. The perfect low profile design solution for making point-to-point interconnections between RF modules. minibend® cable assemblies are readily integrated into virtually any commercial, military, or space application.

minibend® cable assemblies are engineered to meet or exceed applicable industry and military standards. They're triple shielded, bend-to-the-end and easily outperform competitive semi-rigid or semi-flex cable. All minibend® assemblies are 100% tested and are superior replacements for custom pre-formed semi-rigid cables.

If your company uses RF cables, you need to talk to us. We'll work with you to supply a minibend® solution that will deliver proven superior performance. Contact our customer service department to experience the minibend® difference.



Email: sales@astrolab.com www.astrolab.com Furthermore, ground plane aperture compensation techniques were successfully used for significant increasing of coupling coefficient between parallel coupled lines, thus leading to wider bandwidths.<sup>5,6</sup>

Stepped-impedance resonators (SIR) have demonstrated their advantageous efficiency for UWB bandpass filters. A UWB bandpass filter with five transmission poles has been proposed, using a multiple-mode resonator (MMR). By properly allocating the first three resonance peaks quasi-equally within the UWB band, a short-circuited coplanar waveguide (CPW) MMR bandpass filter was realized.

A two-stage UWB bandpass filter, using a capacitive-ended interdigital coupled-line topology, was adopted to achieve improved out-of-band performance.<sup>9</sup> Note that some of these filters<sup>7,9</sup> lack design method and synthesis procedure. Later, a modified stub-loaded multiple-mode resonator was proposed, <sup>10-13</sup> aiming to allocate the first resonant frequencies within the 3.1 to 10.6 GHz band while sup-

pressing spurious harmonics at the upper-stopband. A quasi-Chebyshev bandpass filter with nine transmission poles was synthesized using three triple-mode SIRs (two-layer broadside-coupled structure). <sup>14</sup> Ground plane aperture techniques, increasing coupling between pairs MMR resonators, were also widely investigated to improve the out-band rejection in UWB filters. <sup>14,15</sup>

Stub bandpass filters with several configurations could also be used to meet UWB mask requirements. 16-19 Connecting lines between short-circuited stubs were meandered in order to reduce the filter size. 16,17 These UWB filters have sharp rejection, but their spurious response would degrade the out-of-band response and an increase in the number of sections may lead to large insertion loss, as well as poor group delay. In addition, stepped impedance open stubs were implemented on this kind of structure to realize transmission zeros and get sharper attenuations. 18,19 Tight coupling in a microstrip to CPW or slotline transition has also been inves-

tigated.<sup>20-24</sup> The use of microstrip-to-CPW transition has received great attention providing a wide bandpass operation with a good trade-off in terms of insertion loss and group delay flatness.<sup>20</sup> A UWB filter with a multiplemode resonator was proposed using the microstrip-to-CPW transitions as inverter circuits.<sup>21</sup> Composite transition lines exhibiting cross-coupling and slow-wave behavior were later proposed,<sup>22</sup> leading to more compact devices. Recently, back-to-back microstrip-slotline cross-junction transition was rearranged to make up a novel class of UWB bandpass filter with lenient tolerance in fabrication.<sup>23,24</sup>

Basically, a wide bandwidth filter may be implemented by a direct cascade of the low-pass and high-pass filters. Wideband coplanar-waveguide bandpass filters based on the cascade of CPW low- and high-pass periodic structures were constructed.<sup>25</sup> To save circuit area, a high-pass filter, realized by shunt quarter-wave short-circuited stubs, was embedded with a steppedimpedance low-pass filter.<sup>26</sup> As a result of the use of a low degree highpass filter, the filter lacked selectivity or sharpness at the lower frequency. Note that a suspended stripline technology combining low loss with reduced size was also used to fabricate this composite filter.<sup>27</sup> Analytical techniques to synthesize an isolated cascade of high- and low-pass sections based on an iterative algorithm for both Butterworth and Chebychev cases were also reported.<sup>27</sup> In a previous work,<sup>28</sup> several UWB filters were realized in a semi-lumped approach, using both surface-mounted (SMT) capacitors and microstrip transmission lines. Thanks to the slow-wave behavior introduced by capacitively loaded transmission lines, a high degree of miniaturization was demonstrated.<sup>29</sup> In this article, a technique of spurious suppression is studied.

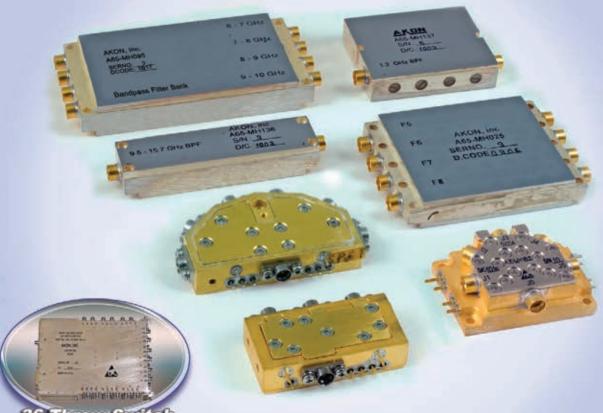


#### **PRINCIPLE**

#### Configuration and Synthesis Technique

Figure 1 shows the equivalent electrical circuit of the proposed semi-lumped UWB bandpass filter. Following the same principle as Hsu, et al.,<sup>26</sup> low-pass and high-pass filters are combined. The high-pass filter is realized by shunt quarter-wave short-

## FILTERS AND SWITCHES FOR SYSTEM GRITICAL APPLICATIONS



36 Throw Switch

#### FILTERS MULTIPLEXERS

umped Element Filters 10 MHz to 25 GHz Bandwidth 1% to 200% High Selectivity Group Delay Equalized Small Size High Reliability

Combline & Interdigital Filters 100 MHz to 40 GHz Bandwidth of 1% to 66% Low Loss Small Size and Weight High Power Handling

2 GHz - 40 GHz Frequency Range Bandpass, Lowpass & Notch Configuration Lowest Loss

witched Filterbanks

10 MHz to 26 GHz
Standard switch filters or custom designs
2 to 16 Channels
Typical switching speed 50 nSec
Use GaAs MMIC or discrete diodes
Integrated with suspended substrate lumped
element, combline, printed microstrip
filter technology.

- Solid State Switching Technologies
- SMA and GPO Connectors Options
- SPST to SP8T, to Custom Multi-throw
- 50 Nanoseconds Switching Time (typical)
- Reflective or Absorptive
- Isolation Greater than 60 dB
- Custom Switch Configurations & Assemblie

#### Contact Us For More Information:

2135 Ringwood Avenue San Jose, CA 95131-1725 (408) 432-8039 Main (408) 432-1089 Fax sales@akoninc.com



www.akoninc.com





TWT Amplifiers · Probes · Antennas **HF Communication Test Systems** Network Analyzers · Synthesizers Signal Generators · and more



#### ATEC HAS IT NOW.

- · Solutions to fit your budget and schedule
- · Rental, lease, and purchase options
- · Various in-house calibration options
- · Invaluable expertise and technical support
- · Same-day shipping on most items







#### a division of Advanced Test Equipment Corporation

Rentals Made Easy

Follow Us! in







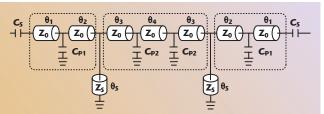


Fig. 1 Equivalent circuit of the proposed semi-lumped UWB filter.

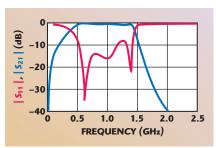


Fig. 2 Simulated response of the UWB bandpass filter.

circuited stubs. The stepped impedance low-pass filter that was used is replaced in this work by a low-pass filter based on capacitively loaded transmission lines as published previously.<sup>29</sup> Compared to the distributed filter,<sup>26</sup> a size reduction reaching 85 percent was demonstrated, thanks to the use of the semi-lumped technology.<sup>28</sup> In addition, two series capacitors are added at the near- and far-ends of the filter in order to give a sharper rejection around the lower stopband.

In order to investigate the synthesis procedure, a UWB filter centered at 0.77 GHz with a 142 percent relative 3 dB bandwidth is considered. In this article, the center frequency fc of the bandpass filter is given by:

$$f_{\rm c} = \sqrt{f_{\rm L} f_{\rm H}} \tag{1}$$

where  $f_{\rm L}$  and  $f_{\rm H}$  are the low and high 3 dB cut-off frequencies, respectively.

The proposed synthesis procedure concerns the establishment of a rough initial estimation of the filter's parameters, by setting both low and high cutoff frequencies. To simplify the study, an initial design with ideal transmission lines and capacitors is adopted. In addition, identical series transmission lines' electrical lengths are first considered, that is  $\theta = \theta_1 = \theta_2 = \theta_3 = \theta_4$ . The main advantage of this filter topology is the independent control of both low and high cut-off frequencies. The upper and lower cut-off frequencies are respectively controlled by the low-pass and highpass sections.

The low-pass sections are realized by capacitively loaded transmission lines following the same principle of the lowpass filters published previously.<sup>29</sup> In this

previous work, the low-pass section was studied and the design equations relating the characteristic impedance  $Z_0$ , the loading capacitance  $C_{\mathfrak{p}}$  and the transmission line electrical length  $\theta$  to the cut-off frequency  $f_{\rm H}$  were derived. For a characteristic impedance equal to 120  $\Omega$  and assuming a 1.5 GHz high cut-off frequency, the equations established lead to  $C_p \text{=}~3.1~pF$  and  $\theta = 29^\circ$ at 1.5 GHz.

While the high cut-off frequency  $f_{
m H}$  is adjusted by the low-pass section, the low cut-off frequency  $f_{\rm L}$  is directly controlled by the short-circuited stubs electrical length  $\theta_s$ . A simple tuning carried out with Agilent ADS<sup>30</sup> revealed that the electrical length  $\theta_s$ should be set to 23° at 0.4 GHz.

Currently, rough initial values for  $C_p$ ,  $\theta$  and  $\theta$ s are available. The filter response simulated using the following parameters— $C_p$ = 3.1 pF,  $\theta$  29° at 1.5 GHz,  $\theta$ s = 23° at 0.4 GHz—is illustrated in Figure 2. As a result, the cut-off frequencies obtained are 0.4 and 1.45 GHz, respectively. The simple design method described above is sufficient for a rough estimate of the filter's parameters. Note that the simulated filter suffers also from a poor matching in the passband, with a return loss reaching only 8 dB at approximately 1.3 GHz. However, the return loss will be improved in the second step of the design when the filter will be optimized.

For the second step consisting of a whole optimization of the complete filter, a microstrip technology is considered. A Rogers<sup>TM</sup> RO4003 substrate with relative permittivity  $\varepsilon_r = 3.38$ , substrate thickness  $h = 813 \mu m$  and dielectric losses tan = 0.0027 has beenadopted. Also, the T junctions, surfacemounted capacitors, soldering pads and via holes models are taken into account. Complete models taking into account the parasitic series elements with an inductance of 0.35 nH and a resistance of  $0.25 \Omega$  are considered to get



**Thin Film Engineering.** DLI has extensive experience and can assist in tailoring ceramic/metallization systems to your design to achieve maximum performance. DLI is capable of meeting as small as 0.0005" line width and spacing with 0.0001" tolerance.

Lithography	Thickness	Pattern line & width spacing
Gold	≤150 µ"	$\leq$ 0.5 $\pm$ 0.1 mil
Gold	150-300 μ"	$1.0 \pm 0.2  \mathrm{mil}$
Copper	50-600 μ"	$3.0 \pm 0.4  \mathrm{mil}$
Nickel	50-125 μ"	$3.0 \pm 0.4  \mathrm{mil}$

All filters employ DLI's high-K ceramics which allow for size reduction and extreme temperature stability compared to alumina and PWB materials. Solder surface mount and chip and wire filters are all possible.



www.dilabs.com

#### Dielectric Laboratories, Inc.

2777 Route 20 East, Cazenovia, NY 13035 USA Phone: (315) 655-8710

Fax: (315) 655-0445 Email: sales@dilabs.com DLI is the preeminent global supplier of Single-Layer and Multi-Layer Capacitors, Build to Print Thin Film circuits and Custom Thin Film application-specific ceramic components such as Filters, Gain Equalizers and Resonators.



#### 

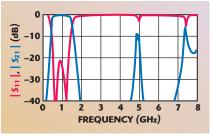


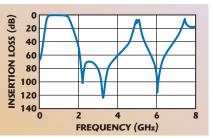
Fig. 3 Simulated response of the proposed UWB semi-lumped bandpass filter.

more accurate simulation responses. In order to maximize the degrees of freedom and improve filter performance, the series transmission lines' electrical length and the capacitors' value are not considered as equal anymore.

The UWB filter is optimized using Agilent ADS.<sup>30</sup> The transmission line's characteristic impedance has been set to 120  $\Omega$ , leading to a strip width W equal to 250 µm. The value for the series capacitors added in the near- and far-end of the UWB bandpass filter to improve the low stop-band rejection is fixed at 6.8 pF, leading to a small impedance compared to 50  $\Omega$ , keeping unchanged the low cut-off frequency. **Table 1** lists the electrical lengths and capacitor's values obtained after optimization for the UWB filter. Figure 3 gives the simulation results to 8 GHz, using the parameters' values given in Table 1. As illustrated, the return loss is better than 20 dB in the whole passband; the insertion loss is limited to 0.2 dB at the center frequency. The shape factor, defined between -3 and -20 dB, equals 1.3:1. In the simulated response, a spurious frequency occurs at approximately 5 GHz, leading to an out-of-band rejection level of -40 dB to only 4.5 GHz, that is 4.5 times the center frequency. The study of the spurious origin is carried out in the next section where a simple original technique to reject theses spurious frequencies is suggested.

#### SPURIOUS ANALYSIS AND IMPROVEMENT

The basic principle of spurious suppression is based on the transmission zeros repartition in the frequency



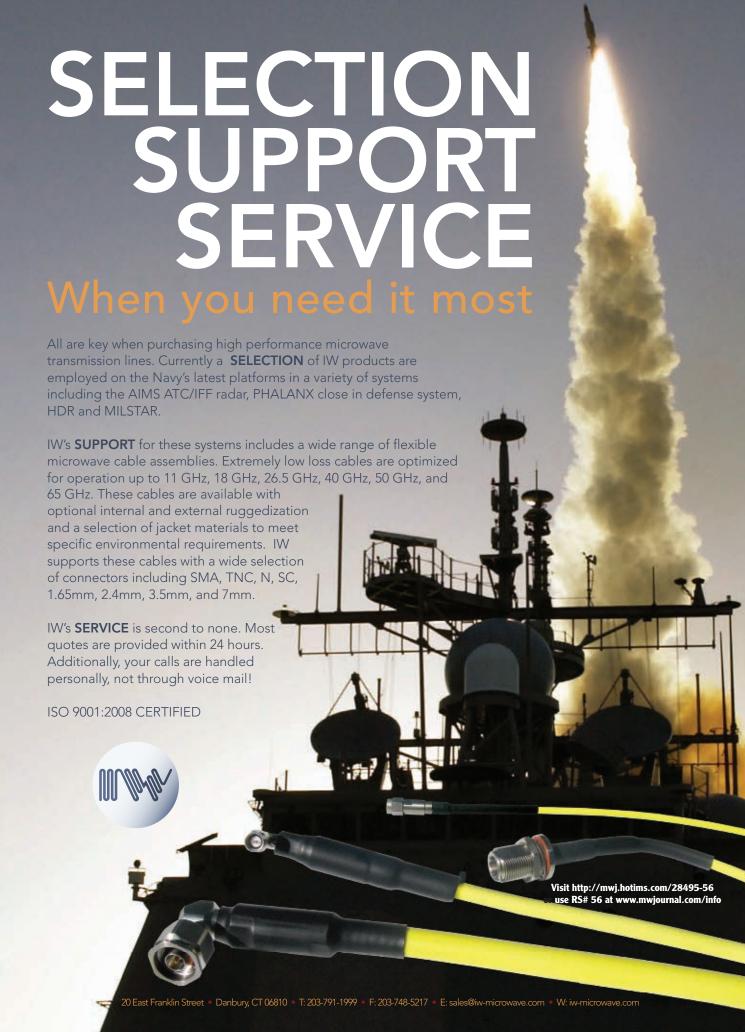
▲ Fig. 4 Transmission zeros of the UWB bandpass filter up to 8 GHz.

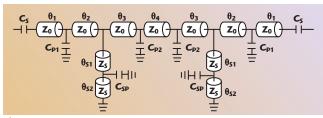
response. As illustrated in *Figure 4*, three transmission zeros are observed respectively at 2.2, 3.2 and 6 GHz. A possible solution to reject the spurious frequencies and improve the rejection band width could be to move the transmission zeros, either to push the 3.2 GHz transmission zero to higher frequencies, or to pull the 6 GHz transmission zero to lower frequencies. Therefore, the study of the origin of these transmission zeros has to be carried out first.

Transmission zeros located at 2.2 and 3.2 GHz are due to the resonance of the LC shunt circuit formed by the SMT capacitor and the parasitic inductances. This parasitic inductance is the sum of the intrinsic SMT capacitor, the soldering pads and the via holes inductances. Considering the capacitor's model and the via hole's dimensions, its value  $L_{\rm s}$  can be estimated to be 1.3 nH. The transmission zero location is then easily calculated using the expression of the LC resonant frequency:

$$f_{\rm r} = \frac{1}{2\pi\sqrt{\rm L_sC_{\rm pi}}} \tag{2}$$

Indeed, the 2.2 GHz transmission zero is introduced by the resonant circuit formed by the 3.9 pF capacitor and the series parasitic inductance  $L_s$  = 1.3 nH, while the 3.2 GHz transmission zero is related to the 1.8 pF capacitor. As the high cut-off frequency is controlled by the LC circuit, the lower transmission zeros could not be moved. A modification of these transmission zeros will affect the passband response of the UWB filter.





▲ Fig. 5 UWB filter equivalent circuit with capacitively loaded stubs.

The transmission zero appearing at 6 GHz is due to the short-circuited stub resonance that presents a  $180^{\circ}$ 

electrical length near 6 GHz. A solution for spurious suppression would be to pull this transmission zero to lower frequencies. This could be easily achieved by increasing the stub electri-

cal length. However, as the low cut-off frequency is fixed by the stub's length, the low frequency electrical length

should not be modified. Thus, capacitively loaded stubs could be successfully used for spurious suppression, leading to the whole UWB bandpass filter equivalent electrical circuit given in Figure 5. A capacitively loaded stub will behave as an unloaded stub at low frequency because the capacitor's susceptance is high, so that the stub's behavior remains unchanged. When the frequency increases, the loading capacitor becomes significant compared to the stub's transmission line distributed capacitor, and the wave velocity in the loaded stub will decrease, leading to a lower resonant frequency for the stub.

Using Agilent ADS,<sup>30</sup> the UWB filter with capacitively loaded stubs has been optimized. The electrical lengths  $(\theta_{s1} \text{ and } \theta_{s2})$  and the stub's loading capacitor C<sub>sp</sub> optimized values have been set to 5° and 11° and 0.4 pF, respectively. The equivalent electrical length of both loaded  $(\theta_s)$  and unloaded  $(\theta_s)$ stubs are plotted in Figure 6. While the unloaded stub electrical length increases proportionally versus frequency, the loaded stub electrical length increases quickly with frequency, leading to a lower resonant frequency of 4.2 GHz. Thus, the transmission zero will be shifted to lower frequencies. In the lower band, the electrical length for both loaded and unloaded stubs are quite similar. The filter passband remains quite unchanged with the capacitively loaded stubs configuration.

Figure 7 compares the UWB filter insertion loss with both loaded and unloaded stubs. Whereas the filter response remains unchanged in the passband, the loading capacitor effect appears for higher frequencies. When the capacitively loaded stubs are used, the third transmission zero that was located at 6 GHz occurs now at 3.8 GHz, while the first two transmission zeros



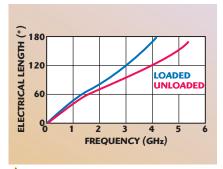


Fig. 6 Comparison of the electrical length of the capacitively loaded and unloaded stubs.

#### Gain more insight, measure real-time.

#### The R&S®FSVR realtime spectrum analyzer

The R&S®FSVR is the first real-time spectrum analyzer with complete all-round capabilities. It offers everything a conventional spectrum and signal analyzer does – plus real-time measurement functions. That means you're ready for anything, from broadband spectral analysis to the detection of very short sporadic interference signals. You get:

- I Spectrum measurements with no time gaps, with 40 MHz analysis bandwidth and up to 30 (110) GHz
- Realtime functions including
  - Triggering on events in the spectrum (frequency mask trigger)
  - Persistence mode for fast evaluation of time-variable spectra
  - Spectrogram to show the spectrum versus time
- All the functions of the R&S®FSV signal and spectrum analyzer

www.rohde-schwarz.com/ad/FSVR/mwj

Up to 7 | 13.6 or 30 GHz

See the RESTRE live at:



**DE&SCHWARZ** 

The Driving Force in

Spectrum Analysis

Visit http://mwj.hotims.com/28495-118 or use RS# 118 at www.mwjournal.com/info

due to LC resonance remain fixed. Consequently, the high frequency rejection band, defined below an attenuation of -40 dB, is enlarged to about 6.5 GHz, that is more than eight times the filter's center frequency of 0.77 GHz.

#### UWB FILTERS REALIZATION AND MEASUREMENTS

In this section, several UWB filters with 3 dB bandwidth of 142 percent centered at 0.77 GHz are realized and

measured. The photograph of the realized filters is shown in *Figure 8*. Filters with loaded and unloaded stubs have been fabricated. For filters with loaded stubs, SMT and patch capacitors are considered. SMT capacitors with a 0402 case (0.5 mm by 1 mm) have been used. All the realized filters are 3.7 cm in length.

First, measured and simulated results of the UWB filter with unloaded stubs are given in *Figure 9*. A good

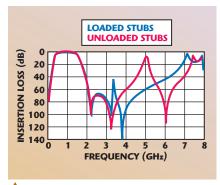


Fig. 7 Simulated insertion loss of the UWB filter with loaded and unloaded stubs.

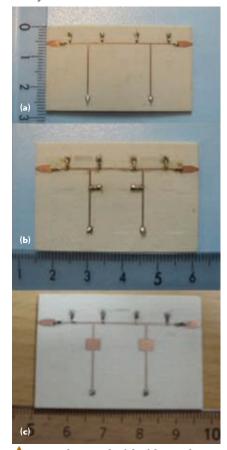


Fig. 8 Photograph of the fabricated filters: (a) unloaded stubs, (b) stubs loaded with SMT capacitors and (c) stubs loaded with patched capacitors.

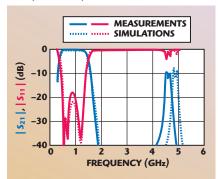
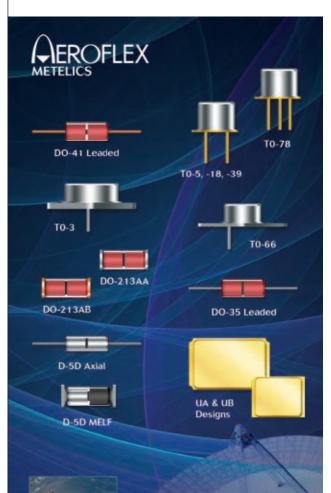


Fig. 9 Simulated and measured results for the UWB filter with unloaded stubs.

#### Demanding JANS Diodes Demand A Flexible Source!



Aeroflex Metelics now offers JANS qualified parts for your most demanding space and military applications.

#### JANS Product Portfolio:

Our MIL-PRF-195900 JANS qualifications include hard glass switching diodes, (/578 and /609) and zeners (/435). Both product families are available in industry standard axial and MELF package configurations.

Further JANS qualifications will be announced soon for additional zener families, TC zeners, current regulators and Schottky diodes.

#### Certifications:

- JANS certified diode line
- JAN, JANTX, JANTXV certified transistor line
- ISO9001:2008 certified

888-641-7364 www.aeroflex.com/JANmj

PASSION FOR PERFORMANCE.

## Explore the Limits. T&M Solutions for Aerospace and Defense.

Today's aerospace and defense technologies demand ever more sophisticated test and measurement solutions to stretch the limits of what is feasible. As a full-range supplier, Rohde & Schwarz offers a broad portfolio that proves its capabilities in even the most demanding applications. Our leading-edge expertise in microwave, RF and EMC technology helps customers assess performance, optimize platforms and get the most out of systems. Convince yourself.

www2.rohde-schwarz.com/ad/space\_SMU/mwj



Technological highlights: signal generation

- Frequency range up to 43.5 GHz
- Excellent spectral purity, e.g. typ. -120 dBc (1 Hz) at 10 GHz, 10 kHz offset
- I High output power, e.g. typ. +25 dBm at 20 GHz
- Flexible pulse generation for radar applications
- Easy replacement of legacy instruments



Visit http://mwj.hotims.com/28495-119 or use RS# 119 at www.mwjournal.com/info

agreement is observed in the filter passband. A wideband of 1.1 GHz is achieved leading to the expected bandwidth of 142 percent. The measured return and insertion loss are found to be higher than 18 dB and lower than 0.3 dB over the passband, respectively. The first spurious response appears around 4.5 GHz. A slight shift of about 400 MHz is observed between simulations and measurements. This shift is

probably due to the capacitor's model that is not sufficiently accurate at high frequencies. The measured rejection band, if a minimum of 40 dB attenuation is considered, extends to approximately 4.2 GHz, that is 5.4 times the center frequency.

Measurements of both filters with unloaded and loaded with SMT capacitors stubs are compared in *Figure* 10. While the bandwidth is quite the

same for the two topologies, the return loss is improved to 20 dB with the capacitively loaded stubs. With the introduction of SMT capacitors, the first spurious peak is shifted from approximately 4.5 to 6.7 GHz. The measured rejection band (a minimum 40 dB attenuation is still considered) extends to approximately 6 GHz when capacitively stubs are used, that is more than eight times the center frequency, showing a significant improvement.

Next, *Figure 11* shows the comparison between the measurement results to 8 GHz, for filters with stubs loaded by SMT and patch capacitors. With patch capacitors, the return loss is better than 18 dB in the passband and the rejection band is slightly enlarged from 6 to 6.6 GHz. It can be concluded that capacitively loaded stubs can be successfully used for spurious suppression.

For miniaturization purposes, bended stubs could be used. This technique could not be easily achieved with stubs loaded by patch capacitors. Therefore, a filter with bended stubs loaded by SMT capacitors was fabricated. *Figure 12* shows a photograph of the miniaturized filter. The miniaturization improvement with bended

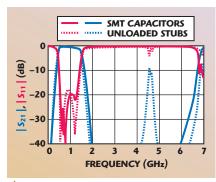


Fig. 10 Measured frequency responses for UWB filters with unloaded and loaded with SMT capacitor stubs.

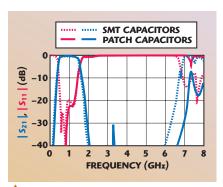
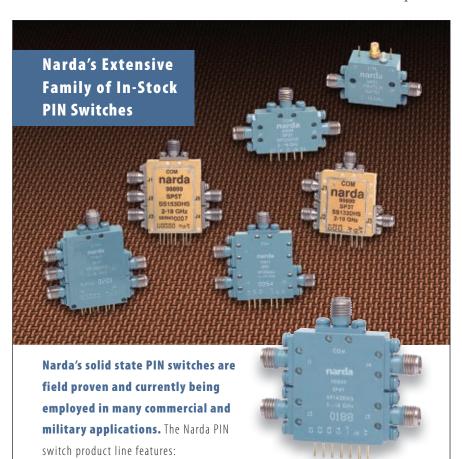


Fig. 11 Measured frequency responses for UWB filters with capacitively loaded stubs.



narda microwave-east

Model SP143DHS

Solid State Switch

435 Moreland Road, Hauppauge, NY 11788 Tel: 631.231.1700 • Fax: 631.231.1711 e-mail: nardaeast@L-3com.com

Engineering, without compromise.

Very Small Package Size

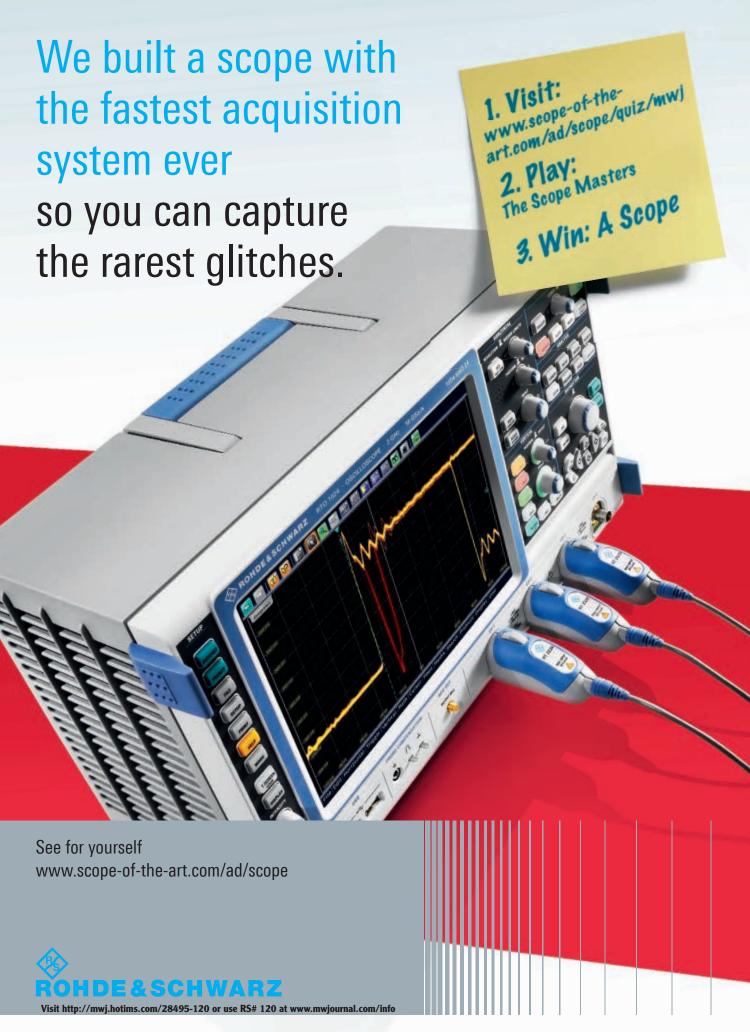
■ SPST — SP6T Models

Fast Switching Times

Low Insertion NoiseIntegral TTL Drivers

Hermetically Sealed Packages

www.nardamicrowave.com/east



#### **Proven Switching Solutions**

Whether it's high speed or high power, low loss or high isolation, single throw or 24 throw, reflective or absorptive, Paciwave has you covered. High performance, low video leakage

solid state switches, from 10 MHz to 40 GHz, in industry-standard or custom packaging. Power handling to 200 Watts CW, 2 kW peak. Phase and amplitude matched. Deliveries from 45 days ARO. Designed for Military Tactical environments. Call us today and tell us what you need.



Other Paciwave Products Include: Switch Matrices, Switch Filter Banks, Digital Controlled Attenuators, DLVAs, Custom Integrated Assemblies

#### *PACIWAVE, INC.*

Microwave Custom Components & Subsystems

764 San Aleso Ave., Sunnyvale, CA 94085 USA web: www.paciwave.com

Visit http://mwj.hotims.com/28495-98

PRECISION
GRADE
Test Cables, Adapters, Connectors

www.rfp2.com
fech@rfindustries.com
(858)549-6340, (800)233-1728

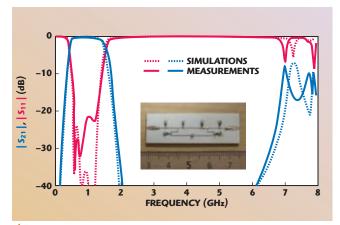


Fig. 12 Simulated and measured response for the UWB filter with bended capacitively loaded stubs.

stubs reaches 55 percent (in terms of surface area) compared to the filter with straight stubs. A good agreement between measurement and simulation results is observed. The return loss is better than 22 dB and the rejection band extends to approximately 6 GHz.

#### **CONCLUSION**

In this article, a new topology of semi-lumped UWB bandpass filter has been proposed. It is based on the combination of low-pass and high-pass filters. The synthesis method of the bandpass filter has been developed and validated by simulations. Filters centered at 0.77 GHz with a relative bandwidth of 142 percent have been designed and fabricated. Simulated and measured results have shown a good agreement in terms of return loss (better than 18 dB) and insertion loss (lower than 0.3 dB). A spurious suppression technique, using capacitively loaded stubs, has been carried out and has demonstrated its efficiency to eliminate spurious responses up to more than eight times the center frequency. A miniaturization better than 55 percent has also been achieved by a simple stub bending.

#### References

- FCC, "Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission System," *Technical Report ET-Docket* 98-153, 14 February 2002.
- H. Ishika and K. Araki, "A Design of Tunable UWB Filters," 2004 International Workshop on Ultra Wideband Systems Digest, Kyoto, Japan, pp. 424-428.
- K.S. Chin, L.Y. Lin and J.T. Kuo, "New Formulas for Synthesizing Microstrip Bandpass Filters with Relatively Wide Bandwidths," *IEEE Microwave and Wireless Components Letters*, Vol. 14, No. 5, May 2004, pp. 231-233.
- J.T. Kuo and E. Shih, "Wideband Bandpass Filter Design with Threeline Microstrip Structures," 2001 IEEE MTT-S International Microwave Symposium Digest, pp. 1593-1593.
- Y.A. Kolmakov and I.B. Vendik, "Compact Ultra-wideband Bandpass Filter with Defected Ground Plane," 2005 European Microwave Conference Digest, pp. 21-24.
- M.K. Mandal and S. Sayal, "Compact Wideband Bandpass Filter," *IEEE Microwave and Wireless Components Letters*, Vol. 16, No. 1, January 2006, pp. 46-48.
- L. Zhu, S. Sun and W. Menzel, "Ultra-wideband (UWB) Bandpass Filters Using Multiple-mode Resonator," *IEEE Microwave and Wireless Components Letters*, Vol. 16, No. 11, November 2005, pp. 796-799.
- J. Gao, L. Zhu, W. Menzel and F. BöGelsack, "Short-circuited CPW Multiple-mode Resonator for Ultra-wideband (UWB) Bandpass Filter," *IEEE Microwave and Wireless Components Letters*, Vol. 16, No. 3, March 2006, pp. 104-107.

## Dependable RF Solutions





Custom designs with NO NRE Charges!!

JFW Products Include:

**RF Switches** 

**RF Matrix Switches** 

**Programmable Attenuation Systems** 

**Fixed Attenuators & Terminations** 

**Programmable Attenuators** 

**RF Test Accessories** 

Rotary Attenuators RF Power Dividers



#### JFW Industries, Inc.

**5134 Commerce Square Drive** 

Indianapolis, IN 46237

Toll Free 877-887-4JFW (4539)

Call 317-887-1340

Email-sales@jfwindustries.com

Web-www.jfwindustries.com

#### **ES MICROWAVE LLC.**

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



#### ES Microwave, LLC

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

Visit http://mwj.hotims.com/28495-43



- S. Sun and L. Zhu, "Capacitive-ended Interdigital Coupled Lines for UWB Bandpass Filters with Improved Out-of-band Performances," IEEE Microwave and Wireless Components Letters, Vol. 16, No. 8, August 2006, pp. 440-443.
- S.T. Li and Q.X. Chu, "A Compact UWB Bandpass Filter with Improved Upper-stopband Performance," 2008 International Conference on Microwave and Millimeter Wave Technology Digest, pp. 363-365.
- S.W. Wong and L. Zhu, "Ultra-wideband (UWB) Microstrip Bandpass Filters with Improved Upper-stopband and Miniaturized Size," 2007 Asia-Pacific Microwave Conference Digest.
- S.W. Wong and L. Zhu, "EBG-embedded Multiple-mode Resonator for UWB Bandpass Filter with Improved Upper-stopband Performance," *IEEE Microwave and Wireless Components Letters*, Vol. 17, No. 6, June 2007, pp. 421-424.
   R. Li and L. Zhu, "Compact UWB Bandpass Filter Using Stub-loaded
- R. Li and L. Zhu, "Compact UWB Bandpass Filter Using Stub-loaded Multiple-mode Resonator," *IEEE Microwave and Wireless Components Letters*, Vol. 17, No. 1, January 2007, pp. 40-43.
   J.T. Kuo, Y.C. Chiou and E. Cheng, "High Selectivity Ultra-wideband
- J.T. Kuo, Y.C. Chiou and E. Cheng, "High Selectivity Ultra-wideband (UWB) Multimode Stepped-impedance Resonators (SIR) Bandpass Filter with Two-layer Broadside-coupled Structure," 2007 Asia-Pacific Microwave Conference.
- H. Wang and L. Zhu, "Aperture-backed Microstrip Line Multiplemode Resonator for Design of a Novel UWB Bandpass Filter," 2005 Asia-Pacific Microwave Conference.
- W.T. Wong, Y.S. Lin, C.H. Wang and C.H. Chen, "Highly Selective Microstrip Bandpass Filters for Ultra-wideband (UWB) Applications," 2005 Asia-Pacific Microwave Conference.
- H. Shamman and J.S. Hong, "A Novel Ultra-wideband (UWB) Bandpass Filter (BPF) with Pairs of Transmission Zeroes," *Microwave and Wireless Components Letters*, Vol. 17, No. 2, February 2007, pp. 121-123.
- P. Cai, Z. MA, X. Guan, X. Yang, Y. Kobayashi, T. Anada and G. Hagiwara, "A Compact UWB Bandpass Filter Using Two-section Opencircuited Stubs to Realize Transmission Zeros," 2005 Asia-Pacific Microwave Conference.
- X. Gong, J. Wang and W. Wang, "An Improved Design Method for UWB Filter Using Two-section Open-circuited Stubs," 2007 International Conference on Microwave and Millimeter Wave Technology Proceedings.
- K. Li, D. Kurita and T. Matsui, "An Ultra-wideband Bandpass Filter Using Broadside-coupled Microstrip-coplanar Waveguide Structure," 2005 IEEE MTT-S International Microwave Symposium Digest, pp. 675-678.
- H. Wang, L. Zhu and W. Menzel, "Ultra-wideband Bandpass Filters with Hybrid Microstrip/CPW Structure," *IEEE Microwave and Wireless Components Letters*, Vol. 15, No. 12, December 2005, pp. 844-846
- T.N. Kuo, S.C. Lin and C.H. Chen, "Compact Ultra-wideband Filters Using Composite Microstrip-coplanar-waveguide Structure," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 54, No. 10, October 2006, pp. 3772-3778.
- R. Li and L. Zhu, "Ultra-wideband (UWB) Bandpass Filters with Hybrid Microstrip/slotline Structures," *IEEE Microwave Wireless Components Letters*, Vol. 17, No. 11, November 2007, pp. 778-781.
- R. Li and L. Zhu, "Compact UWB Bandpass Filter on Hybrid Microstrip/Slotline Structure with Improved Out-of-band Performances," 2008 International Conference on Microwave and Millimeter Wave Technology.
- Y.S. Lin, W.C. Ku, C.H. Wang and C.H. Chen, "Wideband Coplanarwaveguide Bandpass Filters with Good Stopband Rejection," *IEEE Microwave Wireless Components Letters*, Vol. 14, No. 9, September 2004, pp. 422-424.
- C.L. Hsu, F.C. Hsu and J.T. Kuo, "Microstrip Bandpass Filter for Ultra-wideband (UWB) Wireless Communications," 2005 IEEE MTT-S International Microwave Symposium Digest, pp. 679-682.
- W. Menzel, M. Tito and L. Zhu, "Low-loss Ultra-wideband (UWB)
   Filters Using Suspended Stripline," 2005 Asia-Pacific Microwave
   Conference, December 2005.
- D. Kaddour, J.D. Arnould and P. Ferrari, "A Semi-lumped Microstrip UWB Bandpass Filter," *International Journal of Microwave and Wireless Technologies*, Vol. 1, No. 1, February 2009, pp. 57-64.
- D. Kaddour, E. Pistono, J.M. Duchamp, J.D. Arnould, H. Eusebe, P. Ferrari and R.G. Harrison, "A Compact and Selective Low-pass Filter with Reduced Spurious Responses Based on CPW Tapered Periodic Structures," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 54, No. 6, June 2006, pp. 2367-2375.
- 30. ADS, Agilent Technologies Inc., Palo Alto, CA.

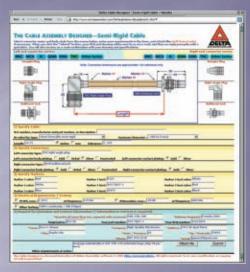
## Value Added and Cable Assemblies

Now you can rely on Delta, a source of high-quality RF connectors for over fifty years, for all of your cable assembly needs, as well as other connector-related value-added products:

- Flexible and semi-rigid cable assemblies from high-volume, low-cost to sophisticated high-frequency types, using our fully automated cutting and stripping equipment for consistent and repetitive quality results. Short order quantities as well as volume production globally, from our manufacturing sites in the USA, Taiwan and China.
- One-piece body designs to support attenuator housing needs.
- Transmission line and antenna assemblies; other RF related subassemblies.
- Our new state-of-the-art, fully automated electroplating facility (NADCAP certification in process) is designed to serve all your plating requirements for RF components—not just connectors. Advanced plating software and in-house X-ray capabilities assures your plating specifications are consistently achieved. (Complementary processes such as vapor degreasing and contact crimping / pretinning are also available.) More information, including plating types and specifications, at www.deltaelectroplating.com

Let us be your "one-stop-shop" for adding value to your supply chain.

#### www.DeltaRF.com



Our website offers the unique Cable Assembly Designer tool to assist with all your cable assembly needs. Simply select the cable type, connectors, testing and marker requirements and click to send the RFQ to us.



Delta Electronics Mfg. Corp. Tel: (978) 927-1060 • Fax: (978) 922-6430 P.O. Box 53 • 416 Cabot St. Beverly, MA 01915 USA



Delta Microwave Electronics (Nanjing) Co., Ltd. Tel: +86 25 84195408 • Fax: +86 25 84195407 No. 9 Tianquan Road, Qilin Industrial Park (South Zone), Tangshan Street, Jiangning District, Nanjing 211135, China







# A 1.7 TO 2.7 GHZ TRANSMISSION-LINE GAN HEMT POWER AMPLIFIER FOR WIRELESS APPLICATIONS

n the next generation wireless communication systems, it is required that the power amplifier should be able to handle multiple frequency bands and multiple operating standards. In addition, high efficiency, low cost and compact size are very important if the power amplifier is employed in active antenna array systems or mobile handsets. Its broadband property is also very useful for future software-defined radio platforms in microcell or macrocell applications based on a single-bit RF pulsed-train signal transmission. The bandwidth limitation in power amplifiers usually comes from the device's low transition frequency and large output capacitance; therefore, silicon LDMOS FET technology has been the preferred choice up to 2.2 GHz. As an alternative, GaN HEMT technology enables high efficiency, high breakdown voltage, high power density and significantly higher broadband performance, due to higher transition frequency and smaller periphery, resulting in smaller input and output capacitances and less parasitics.

A very broadband power amplifier design generally employs an input lossy LCR matching circuit to minimize the input return loss and output power variations over very wide frequency bandwidths, with an LC output network to compensate for the device output reactance.<sup>1,2</sup> However, it is very difficult to keep efficiency at a high level over an entire frequency range. As a result, the drain efficiency usually ranges from 30 percent (in a frequency range from 3 to 9 GHz) to 45 percent or less (in a frequency range from 0.5 to 2.5 GHz, for high frequency bandwidths). To increase the efficiency of a broadband power amplifier, different Class E techniques can be implemented into the power amplifier load network. For a conventional Class E load network, with a shunt capacitance and a series inductance, a poweradded efficiency above 50 percent has been achieved within the frequency range from 1.9 to 2.4 GHz.<sup>3</sup> To increase the high-efficiency frequency bandwidth, the broadband Class E technique based on a reactance compensation principle, with a combination of series and shunt resonant circuits, can be used.<sup>4</sup> In this case, a power-added efficiency over 53 percent was observed in a 2.1 to 2.7 GHz frequency bandwidth with output power variations from 9.3 to 12.7 W, at a supply voltage of 40 V.<sup>5</sup>

ANDREI GREBENNIKOV Alcatel-Lucent, Dublin, Ireland

#### Flexible Coax Solutions... They're All Right Here



Advantage Connectors



LMR®- DB Flexible Watertight Coaxial Cable



LMR® Bundled Cable



Hardware, Accessories and Installation Tools

Fire Retardant LMR®-LLPL Plenum and LMR® - FR Riser Coaxial Cables

A Full Line of Coaxial Cables, Connectors, Hardware Accessories and Tools Plus Over 60 Years Experience. Visit our website for your free catalog!





World Headquarters: 358 Hall Avenue, Wallingford, CT 06492 • Tel: 203-949-8400, 1-800-867-2629 Fax: 203-949-8423 International Sales: 4 School Brae, Dysart, Kirkcaldy, Fife, Scotland KY1 2XB UK • Tel: +44(0)1592655428 China Sales: No. 318 Yuan Shan Road, Shanghai, China 201108 • Tel: 86-21-51761234 Fax: 86-21-64424098 timesmicrowave.com

#### **CIRCUIT DESIGN**

**Figure 1** shows the input matching circuit equivalent representations intended to provide a complex-conjugate matching over a wide frequency range. The series resistor R<sub>corr</sub> is usually used to make the power amplifier unconditionally stable both at high and low operating frequencies. However, in conjunction with the optimized capacitance C<sub>corr</sub>, it can provide a reactance compensation and impedance matching when the input circuit of the transistor is equivalently represented by an RL circuit, as shown. In this case, the circuit input impedance  $Z_{in}$  can be written as

$$Z_{\rm in} = \frac{R_{\rm corr}}{1+j\omega R_{\rm corr}C_{\rm corr}} + R_{\rm in} + j\omega L_{\rm in}(1)$$

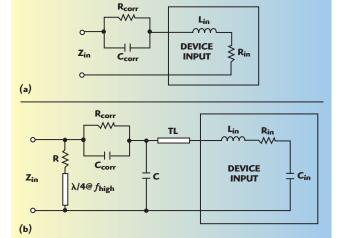


Fig. 1 Input matching equivalent circuits representations.

Setting  $ImZ_{in} = 0$ ,  $L_{in}$  is given by:

$$L_{in} = \frac{R_{corr}C_{corr}}{1 + (\omega R_{corr}C_{corr})^2}$$
 (2)

The real part of the input impedance  $\mathrm{ReZ}_\mathrm{in}$  can be rewritten as

$$\operatorname{Re} Z_{\text{in}} = R_{\text{in}} + \frac{L_{\text{in}}}{R_{\text{corr}} C_{\text{corr}}}$$
(3)

This means that, by proper selection of the parameters of the correction circuit elements  $R_{corr}$  and  $C_{corr}$ , the real part of the input impedance  $ReZ_{in}$  can be increased to a desired level. For example, for  $L_{in}=1.4~\mathrm{nH}$  and  $R_{in}=5~\Omega$ , the resistance  $ReZ_{in}$  becomes equal to 50  $\Omega$  when  $R_{corr}$ 

=  $10 \Omega$  and  $C_{corr}$  = 3.1 pF.

According the datasheet for a 5 W Nitronex GaN HEMT de-NPTB00004. input circuit can be equivalently represented by a series RLC circuit, as shown. Here, the input impedance becomes real and equal to 5  $\Omega$ at an operating frequency of approximately 1.85 GHz.6 The equivalent input series inductance  $L_{\rm in}$  and capacitance  $C_{\rm in}$  can be determined from two equations:  ${\rm Im}Z_{\rm in}$  = -23.8  $\Omega$  at 900 MHz and  ${\rm Im}Z_{\rm in}$  = 21.0  $\Omega$  at 3.5 GHz. The quality factor of the input circuit at the bandwidth frequency center,  $f_0$  = 2.2 GHz, is  $Q_{\rm in}$  =  $\omega_0 L_{\rm in}/R_{\rm in}$  = 3.87, which means that the achievable frequency bandwidth at the -3 dB power level can be approximately estimated as  $\Delta f = f_0/Q_{\rm in}$  = 568.5 MHz.

In addition, it is necessary to take into account that the effect of the parasitic input resistance will increase at higher frequencies, resulting in a lower real part of the device transfer admittance  $Y_{21} = g_m/(1 + j\omega R_{in}C_{in})$ , where  $g_m$  is the device transconductance. Therefore, an additional LC matching circuit with optimized parameters can be added to the device input, which helps to improve the input broadband matching since the real part of the device input impedance is sufficiently small. Also, to compensate for excessive capacitive input reactance, a lossy shunt RL circuit with a transmission line having a quarter wavelength at the high band-

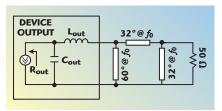


Fig. 2 Output matching circuit equivalent representation.

#### **Ultra-compact Converters from Spinnaker**

#### **Broadband Block Downconverter**

- Model No. SCC-2040-X4
- Downconverts 20-40 GHz to 6-16 GHz
- Integrated LO, 1.0 Deg RMS Noise
- 4 Channels, Phased Matched
- Internal/External Reference Switch
- Small 6"x 3.5"x 0.5" Module

At **Spinnaker Microwave**, our products are designed with one thing in mind – your specifications.

We pride ourselves on delivering quality signal sources custom tailored to your unique application – military, industrial or commercial.

#### Arbitrary Waveform Converter/Exciter

- Model No. SMS-ACX
- Supports up to 1 GHz Arbitrary Modulation
- Internal/External DAC or DDS Signal Generation
- 10 MHz to 14 GHz, Single Output
- -50 dBc Spurious
- Down to 1 µsec Tuning Speed
- Small 4.7"x 4.6"x 1.7" Package





3281 Kifer Rd, Santa Clara, CA 95051 • Tel: 408-732-9828 • Fax: 408-732-9793 • www.spinnakermicrowave.com



## magic bullet

The data is in. SV Microwave's SMP and SMPM connectors are the remedy when critical applications call for high frequency performance, ultra-reliable mating and lower cost than GPOs™. Plus, our SMP and SMPM bullets and shrouds mate perfectly with other top tier suppliers, so you can trust every connection from your stockroom. We also specialize in customized float mount connections when you need that exact amount of tension.

To learn more about our SMPs and SMPMs visit our web page at www.svmicrowave.com/smp



#### **Electrical**

Frequency:

SMP DC to 40 GHz **SMPM** DC to 65 GHz Nominal Impedance: 50 Ohms VSWR Bullets: 1.10:1 max: DC to 23 GHz

1.15:1 max: 23 to 26.5 GHz 1.70:1 max: 26.5 to 40 GHz

1.20:1 max: DC to 18 GHz

VSWR Cabled: 1.35:1 max: 18 to 26.5 GHz 1.70:1 max: 26.5 to 40 GHz

#### **Environmental**

Thermal Shock:

MIL-STD-202, Method 213 Shock. Condition I (100 Gs)

Vibration: MIL-STD-202, Method 204 Condition D (20 Gs)

Barometric Pressure: MIL-STD-202, Method 105 (Altitude) Condition C (70,000 ft.) (190 VRMS)

MIL-STD-202, Method 107

Condition B, (High Temp. +165°C)

Available at: www.arrownac.com



www.svmicrowave.com | 561-840-1800 x128

Visit http://mwj.hotims.com/28495-134 or use RS# 134 at www.mwjournal.com/info



#### Is it really this good? YES!

Model	Frequency	Gain, Typ.
GSA804-89	1 MHz - 4 GHz	12.5 dB
GSA804-12	1 MHz - 4 GHz	12.5 dB
+20 dBm	(P-1) • +40 dBm	(IP3)

- Production Quantities in Stock
  EAR99
  - RoHS Packaging •
  - Available in Die Form •

#### GraSen Technology, LLC.

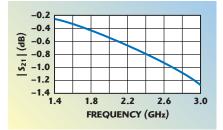
1541 The Alameda, San Jose, CA 95126 +1-408-213-6940 sales@grasentechnology.com www.grasentechnology.com

Visit http://mwj.hotims.com/28495-48

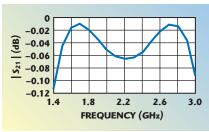
# R&K RF High Power Amplifier MODEL: CA509MBW6-7373R All Solid State Amplifier. (300W×128parallel) Frequency Range: 509MHz±3MHz Output Power: 20kW (min,) @P-1dB Forced Air Cooling, Best MTBF Design.



R&K Company Limited
721-1 MAEDA, FUJI-City, SHIZUOKA-Pref. 416-8577 JAPAN
Tel: +81-545-31-2600 http://rk-microwave.com
Fax: +81-545-31-1600 E-mail: info@rkco.jp



▲ Fig. 3 Small-signal frequency response of the load network.



▲ Fig. 4 Optimized small frequency response of the load network.

width frequency  $f_{\rm high}$  is often used in broadband microwave power amplifiers, which further improves the input return loss. <sup>7,8</sup>

Figure 2 shows the equivalent representation of the power amplifier load network, where the device output contains the parasitic shunt capacitance  $C_{out}$  and series inductance  $\hat{L}_{out}$ , the negative effect of which on the frequency response shown in Figure 3 must be eliminated over an entire operating frequency range. The values of Cout and Lout can be evaluated similarly using the measured output device impedances at the same two boundary frequencies. The load resistance R<sub>I</sub>, which should terminate the device output to deliver a fundamental frequency output power  $P_{out} = 4$ W or 36 dBm to the load, can be estimated based on a conventional Class B mode as:

$$R_{out} = \frac{V_{dd}^2}{2P_{out}}$$
 (4)

which results in a value of 50  $\Omega$  for  $V_{dd}$  = 20 V. As a result, the output load network can represent a mixed lumped-distributed low pass  $\pi$ -type circuit with an inductive short series transmission line and a capacitive open-circuit stub. An additional short-circuited transmission line is necessary to supply DC power to the device. **Figure 4** shows the optimized small-signal frequency response of the



Fig. 5 Test board of broadband GaN HEMT power amplifier.

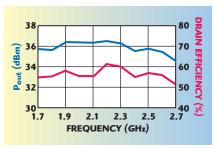


Fig. 6 Output power and drain efficiency of the amplifier.

entire load network over a very wide frequency range. In this case, an efficiency improvement can be achieved by using a Class E load network with reactance compensation technique when a short-circuited transmission line together with the device output reactance provides the required inductive impedance at the fundamental frequency and capacitive reactances at the second and high-order harmonics.<sup>4</sup>

#### **IMPLEMENTATION AND TEST**

The broadband transmission-line hybrid GaN HEMT power amplifier was fabricated on a 30 mil thick RO4350 substrate. Figure 5 shows the test board of this power amplifier using a 5 W Nitronex GaN HEMT RF power transistor NPTB00004. The broadband input matching circuit, output load network, and gate and drain bias circuits (having bypass capacitors at their ends) are fully based on the 50  $\Omega$  microstrip lines of different optimized electrical lengths according to the theoretical predictions and computer optimization using ADS simulation.

Figure 6 shows the test results with an output power of  $36 \pm 0.5$  dBm and a drain efficiency of  $57 \pm 3$  percent over most part of the operating frequency range from 1.7 to

#### Integrated Microwave Assemblies



#### Advanced Technology - Extensive Experience - Superior Performance



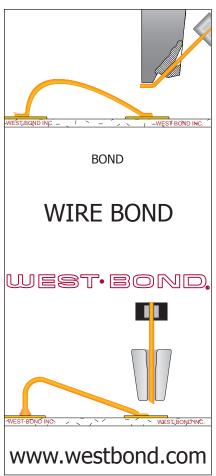
Communications & Power Industries' Beverly Microwave Division (BMD) offers product technology that includes Integrated Microwave Assemblies and Control Components. BMD's broad experience and extensive capabilities in the areas of high power microwave component design for military and non-military radar,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

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

Communications & Power Industries
Beverly Microwave Division

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

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



Visit http://mwj.hotims.com/28495-147



#### Buyer's Guide

Use this invaluable reference source for locating companies, their products and services.

Is your company in the guide?

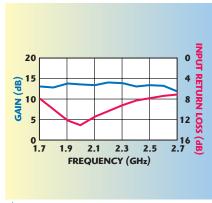


Fig. 7 Power gain and input return loss of the amplifier.

2.7 GHz (with a gate bias voltage  $V_g$  = -1.3 V, a quiescent current  $I_q$  = 50 mA and a drain supply voltage  $V_{dd}$  = 20 V), achieved without any tuning of the broadband input matching circuit and load network. In this case, a power gain of approximately 13 dB and an input return loss better than 6.5 dB were measured, as shown in **Figure 7**. It should be noted that, according to the load-pull data for a 5 W Nitronex GaN HEMT device NPTB00004, its typical drain efficiency of approximately 55 percent can only be achieved at 2.5 GHz.<sup>6</sup>

#### **CONCLUSION**

A low-cost and efficient solution for a broadband transmission-line GaN HEMT power amplifier, based on a 5 W Nitronex NPTB00004 device in a plastic package, is analyzed and described. This power amplifier can be used in various wireless applications covering simultaneously different communication standards such as DCS1800, PCS1900, CDMA2000, W-CDMA or LTE. The theoretical analysis is based on a simple analytical estimation of the parameters of the input lossy matching circuit and nominal output resistance with further computer optimization of the circuit parameters of the entire power amplifier schematic. The test board with the implemented broadband transmission-line GaN HEMT power amplifier was measured and a drain efficiency over 52 percent and a flat output power of approximately 36 dBm at a low supply voltage of 20 V have been achieved across the wide range of operating frequencies from 1.7 to 2.7 GHz. ■

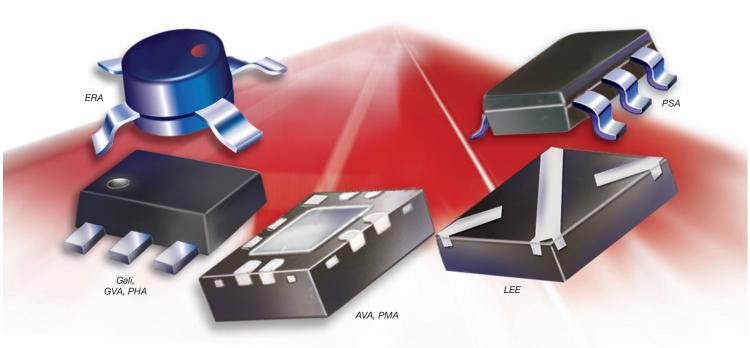
#### References

- Y.F. Wu, R.A. York, S. Keller, B.P. Keller and U.K. Mishra, "3 to 9 GHz GaN-based Microwave Power Amplifiers with L-C-R Broadband Matching," *IEEE Microwave and Guided* Wave Letters, Vol. 9, No. 8, August 1999, pp. 314-316.
- K. Krishnamurthy, D. Green, R. Vetury, M. Poulton and J. Martin, "0.5 to 2.5, 10 W MMIC Power Amplifier in GaN HEMT Technology," 2009 IEEE Compound Semiconductor Integrated Circuits Symposium Digest.
- 3. H. Xu, S. Gao, S. Heikman, S.I. Long, U.K. Mishra and R.A. York, "A Highefficiency Class E GaN HEMT Power Amplifier at 1.9 GHz," *IEEE Microwave and Wireless Components Letters*, Vol. 16, No. 1, January 2006, pp. 22-24.
- A. Grebennikov and N.O. Sokal, Switchmode RF Power Amplifiers, Newnes, Elsevier, Maryland Heights, MO, 2007.
- M.P. van der Heijden, M. Acar and J.S. Vromans, "A Compact 12 W Highefficiency 2.1 to 2.7 GHz Class E GaN HEMT Power Amplifier for Base Stations," 2009 IEEE MTT-S International Microwave Symposium Digest, pp. 657-660.
- Nitronex Corp., NPTB00004 Datasheet, NDS-002 Rev. 2, September 2008
- K.B. Niclas, "On Design and Performance of Lossy Match GaAs MES-FET Amplifier," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 30, No. 11, November 1982, pp. 1900-1906.
- Y. Ito, M. Nii, Y. Kohno, M. Mochizuki and T. Tagaki, "A 4 to 25 GHz 0.5 W Monolithic Lossy Match Amplifier," 1994 IEEE MTT-S International Microwave Symposium Digest, pp. 257-260.

Andrei Grebennikov received his Dipl. Ing. degree in radio electronics from the Moscow Institute of Physics and Technology and his PhD degree in radio engineering from the Moscow Technical University of Communications and Informatics in 1980 and 1991, respectively. He obtained long-term academic and industrial experience working with the Moscow Technical University of Communications and Informatics (Russia), the Institute of Microelectronics (Singapore), M/A-COM (Ireland), Infineon Technologies (Germany/Austria) and Bell Laboratories (Ireland) as an engineer, researcher, lecturer and educator.

### MMIC AMPLIFIERS

DC to 20 GHz from 73¢ qty.1000



NF<sub>from</sub> 0.5 dB, IP3<sub>to</sub> +48 dBm, Gain 10<sub>to</sub> 30 dB, Pout to +30 dBm

**Think of all you stand to gain.** With more than 120 catalog models, Mini-Circuits offers one of the industry's broadest selection of low-cost MMIC amplifiers. Our ultra-broadband InGaP HBT and PHEMT amplifiers offer low noise figure, high IP3, and a wide selection of gain to enable optimization in your commercial, industrial or military application.

Our tight process control guarantees consistent performance across multiple production runs, so you can have confidence in every unit. In fact, cascading multiple amplifiers often produce less than 1dB total gain variation at any given frequency. These MMIC amplifiers can even meet your most critical size and power consumption requirements with supply voltages as low as 2.8 V, and current consumption down to 20 mA, and packages as small as SOT-363.

Visit our website to select the amplifier that meets your specific needs. Each model includes pricing, full electrical, mechanical, and environmental specifications, and a full set of characterization data including S-Parameters. So why wait, place your order today and have units in your hands as early as tomorrow.

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



P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

The Design Engineers Search Engine finds the model you need, Instantly • For detailed performance specs & shopping online see minicircuits.com



# POWER SUB-MINIATURE CONNECTORS FOR SPACE APPLICATIONS

he well-known standard SMA connector is used worldwide in large quantities and in a variety of applications. For space applications, however, this type of connector is severely limited in its microwave CW power capability. This is because the SMA connector's design is not optimized for corona, multi-paction and simple overheating effects. Hence, for any application with 10 W or more CW power,

space grade TNC connectors have to be used that are much larger, heavier and, in many cases, oversized for the application.



Fig. 1 An SMA and a PSM chassis connector shown from above.



 $\blacktriangle$  Fig. 2 Connectors shown from the side mated with a 50  $\Omega$  termination (SMA) and a cable connector for the EZ141 cable (PSM).

#### **ESA INITIATIVE**

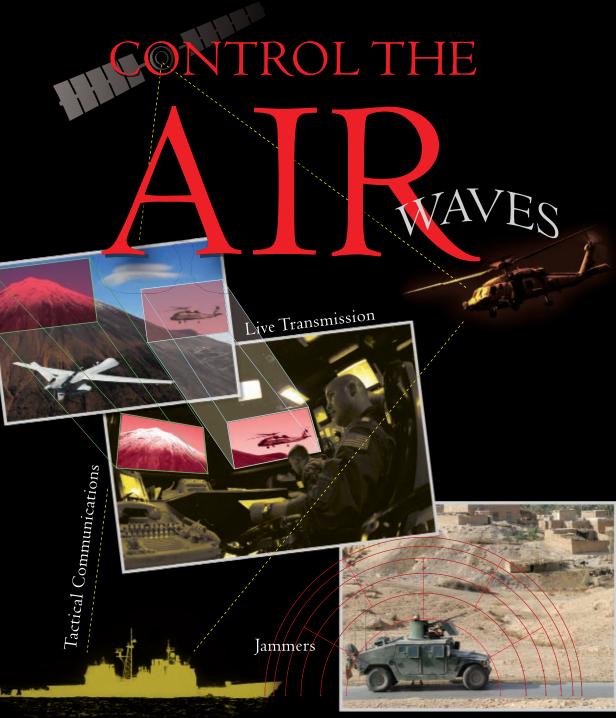
Under the auspices of the European Space Agency (ESA), a European consortium comprising **HUBER+SUHNER** (Switzerland), LEMA/EPFL (Switzerland), TU Darmstadt (Germany) and ESTEC/ESA (Netherlands) was created and charged with the investigation and development of small-sized, high-power coaxial connectors. The project duration for the theoretical studies, design and manufacturing of prototype hardware and the power testing was two years.

From this research, HUBER+SUHNER has developed a space connector that has the dimensions of a standard SMA connector, but in terms of power capability comes close to the TNC connector. This new male connector is called Power Sub-Miniature (PSM) and is fully optimized with regard to RF-breakdown, corona, multi-paction and passive intermodulation effects as well as thermal power dissipation (patents are pending).

Figure 1 shows a SMA and PSM chassis connector from above, while Figure 2 shows both connectors from the side mated with a 50 termination (SMA) and a cable connector (PSM). The chassis connectors shown in Figure 1 have the same ½ inch mechanical footprint. The interface dimensions, however, are different: the PSM has an inner conductor with a diameter of 1.7 and 5.5 mm for the dielectric, whereas the SMA has a 1.27 mm diameter inner conductor and the dielectric is 4.1 mm in diameter. Additionally, the PSM connector has no air gaps inside, preventing corona and multi-paction effects. The outside diameters of the SMA and PSM cable connectors or terminations shown in Figure 2 are the same.

HUBER+SUHNER AG Herisau, Switzerland

い M 



efficiency \* linearity \* complex PA solutions





**1179**500-2700 MHz, 100 Watt



**1178**2000-6000 MHz, 35 Watt



2126 20-500 MHz, 1000 Watt



www.EmpowerRF.com



Visit http://mwj.hotims.com/28495-41 or use RS# 41 at www.mwjournal.com/info

#### **HIGH POWER TESTING**

The test requirements for the PSM connector for L-, C- and Ku-band space applications are listed in *Table 1*. Roughly 80 percent of these requirements have already been tested successfully. The first PIM measurements showed less than -173 dBc for  $2 \times 40$  W carrier powers at 1.8 GHz.

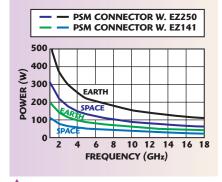
Corona, PIM and multi-paction are normally determined by the connector, whereas the power handling

capability of a cable assembly can be limited either by the connector or by the coaxial cable. Figure 3 shows the maximum power that an EZ141 and EZ250 cable can handle in both space and Earth environments. The cables have a coating that has a radiation efficiency  $\varepsilon$  close to 1. The larger cable can handle more power than the smaller one; however, it is much heavier. Thus, the requirement is for an individually (weight) optimized

cable assembly for any application.

#### **STRATEGY**

To address this requirement, HUBER+SUHNER's approach was to take a small, lightweight connector (PSM) with an interface designed for all required power levels and to have different cable entries for the different cables to be used. These cables are dependant on the power-frequency requirements; therefore, the



▲ Fig. 3 Microwave CW power capability of a cable assembly with EZ141 and EZ250 coaxial cable in Earth and space environments (modelled).

Log Linearity, 18-40 GHz SDLVA

-24 -36 -36

Log Accuracy, 18-40 GHz SDLVA

-36 -36

GHz ■18.0 ■24.0 ■29.0 ■34.0 ■40.0

#### **TABLE I** TEST REQUIREMENTS FOR THE PSM CONNECTOR FOR SPACE APPLICATIONS Corona Levels to be measured are: L-band: 40 W CW (+3 dB) C-band: 30 CW (+3 dB) Ku-band: 30 CW (+3 dB) PIM Levels to be measured are: L-band: -140 dBm with two carriers of 50 W each. Order 3. Ku-band: -145 dBm with two carriers of 80 W each. Order 3. Carriers shall be chosen at lower and upper band edges. High power (CW) L-band: 50 W CW (+3 dB) and 200 W pulsed (+6 dB) and Multi-pactor C-band: 50 CW (+3 dB) and 180 pulsed (+6 dB) (recommended minimum Ku-band: 50 W CW (+3 dB) and 150 W pulsed (+6 dB) duty cycle 2%)

#### High Performance 18-40 GHz SDLVA!

# NEW!

#### **MSDA 81840**

- High Dynamic Range
- Excellent Log Accuracy
- Fast Video Response
- Military Temperature Range
- Hermetically Sealed
- Reverse Voltage Protection

#### Best in Class Log Accuracy and Linearity into the Millimeter Wave Range

From Microsemi's RF Integrated Solutions team comes this new full-featured Successive Detection Log Video Amplifier for applications requiring an extended dynamic range in a highly ruggedized housing.

Provides signal sensitivity approaching the thermal noise floor, while maintaining excellent thermal stability for early warning radar receivers, threat detection equipment, electronic countermeasures and missile guidance systems.

Microsemi RFIS is AS-9100 and ISO-9001 Certified, delivering components and subassemblies from 100 MHz to 110 GHz.

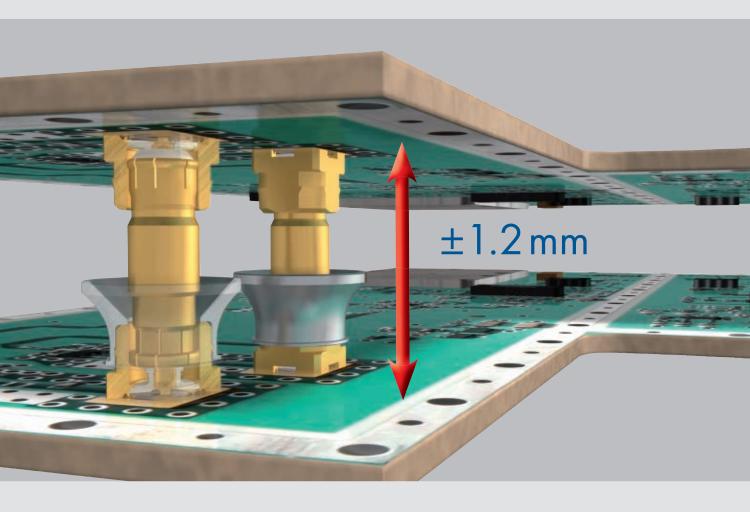


www.microsemi-rfis.com

Amplifiers / Frequency Multipliers / LO Distribution Assemblies / Converters / Build-to-Print Hybrid Chip and Wire Modules

© 2010 Microsemi Corporation







#### «MBX - best in class for mechanical float»



- Axial float ±1.2 mm
- Power up to 260W
- Robust and reliable design

#### Benefits

- Lower total cost of ownership
- Suitable for low weight modules
- Secure mating and assembling

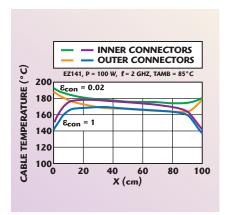
The new MBX connector series is based on the extensive experience gained with the world renowned HUBER+SUHNER® MMBX board-to-board connector solution.

#### USA and Canada

Toll free 1-866 HUBER SUHNER (1-866-482-3778) Fax 1-802-878-9880

#### **HUBER+SUHNER AG**

9100 Herisau Switzerland Phone +41 71 353 4111 info@hubersuhner.com



▲ Fig. 4 Distribution of the inner and outer cable temperature along a 1 m long cable assembly (modelled).

optimum cable assembly is achieved for most applications. Of course, the useful cable limit is reached when the cable diameter becomes equal to the diameter of the connector and a ½ inch cable like the EZ250 comes close to meeting these criteria. The result is one type of connector that, dependent on the power-frequency and weight

requirements, can accommodate different cable types.

#### THERMAL CONSIDERATION

When two cables are connected to a housing or a chassis without a good heat path, the connector can cause severe problems if it is not properly coated. Figure 4 shows the distribution of the inner and outer conductor temperature along a 1 m long coaxial cable assembly. The upper set of curves describes a cable assembly with two shiny gold-coated PSM connectors with poor emissivity of only 2 percent, while the lower set of curves is for a cable assembly with connectors that have a special coating that has an emissivity of 100 percent. The emissivity of the cable (in Figure 4) is assumed to be 100 percent, although tests showed that a value of greater than 50 percent has been measured. Figure 4 also shows that connectors with poor emissivity can heat up more than the cable and limit the handling power of the cable assembly.

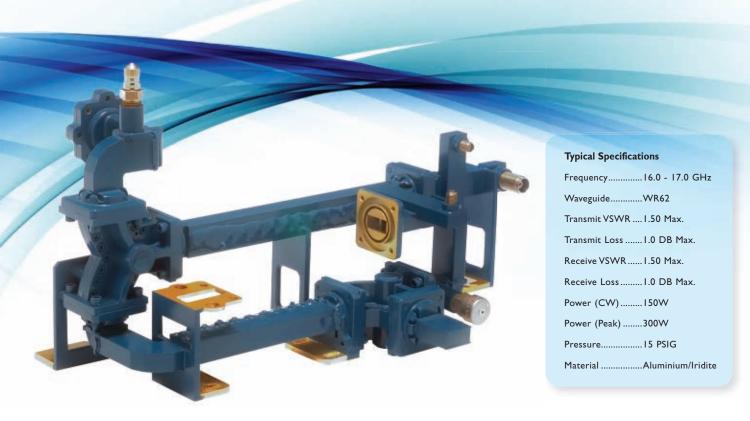
#### **CONCLUSION AND OUTLOOK**

As multicarrier technology is increasingly being used in satellites, the necessity for cables and connectors in space-flight applications to meet demanding weight, power handling capabilities and exhibit low passive intermodulation is becoming a vital consideration. Therefore, the demand is for connectors to be optimized with regard to RF-breakdown, corona, multi-paction and passive intermodulation effects as well as thermal power dissipation. The first test results of HUBER+SUHNER's new power sub-miniature connector show that a small, lightweight connector for high power handling is achievable and work to develop the connector further is ongoing.

HUBER+SUHNER AG, Herisau, Switzerland, Tel: +41 71 353 41 11, www.hubersuhner.com.

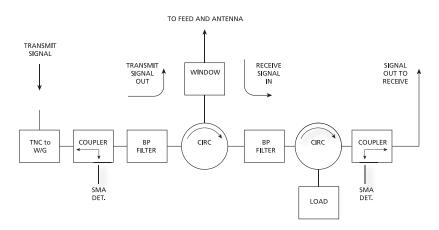


#### Precisely the way you want it.



#### Choose components or integrated front end assemblies.

Precision manufacturing has made MDL the industry leader in passive waveguide components and subassemblies. And we have remained the leader for 50 years because of our attention to detail and our single source capabilities. Our engineers use the latest in SolidWorks, Ansoft HFSS and our proprietary software to design to your specifications – precisely. Call an MDL specialist today or visit us online at **mdllab.com**.



WAVEGUIDE CAST BENDS & TWISTS

WAVEGUIDE FEED ASSEMBLIES

MONOPULSE COMPARATORS

ROTARY JOINTS

MICROWAVE FILTERS

ROTARY SWITCHES

WAVEGUIDE TO COAX ADAPTERS

WAVEGUIDE PRESSURE WINDOWS

COMMERCIAL WAVEGUIDE ASSEMBLIES

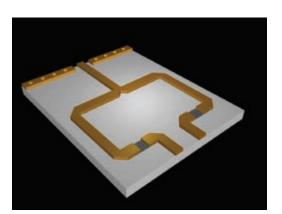


#### Microwave Development Laboratories

135 Crescent Road Needham Heights, MA 02494

V: 781-292-6680/6684 F: 781-453-8629 E-mail: mdlsales@mdllab.com www.mdllab.com





# INTEGRAL PLANAR RESISTORS SAVE CIRCUIT BOARD SPACE

lanar resistors fabricated as part of a printed-circuit-board (PCB) laminate material provide circuit designers the means of saving board space and assembly costs at the same time. The resistors are formed on special resistive layers that are bound to a PCB dielectric material, such as polytetrafluoroethylene (PTFE). The PCB dielectric is also laminated with electro-deposited copper for forming transmission lines and other circuit features in stripline and microstrip technologies, in addition to the embedded resistors. Rogers Corp., for example, offers a number of PCB laminates with thin-film resistive foils, including its RT/duroid® laminate and its ceramic-filled thermoset-based RO4000® series laminates.

Designing a circuit using integral planar resistors can save the cost of assembling chip or surface-mount resistors to a PCB as well as the cost of the resistors themselves. By minimizing chip resistor attachment and solder joints, it is also possible to improve the reliability of a high frequency circuit by using planar resistors that are integral to the PCB.

Rogers RT/duroid 6202PR<sup>TM</sup> laminate is a high-performance glass-reinforced PTFE material with dielectric constant (Dk) of about 3.00 measured in the z-axis at 10 GHz that

supports high frequency applications well beyond 40 GHz. With a dissipation factor of only 0.0020 at 10 GHz, signal loss from the material is extremely low, making it ideal for such circuits as filters, couplers and power dividers as well as active circuits. The laminates are available fabricated with 0.5 and 1 oz. electrodeposited copper as the base material (formed on the dielectric) with an added resistive layer for forming integral planar resistors.

The resistive layers are available in different thicknesses that yield different resistivities, including 10, 25, 50, 100 and 250  $\Omega$ /square, for forming resistors of various sizes and resistance values. The nature of these resistive foils is that resistor tolerances are dependent upon the thickness. The lowest resistivity value (10  $\Omega$ /square) is produced by the thickest resistive foil, while the thinnest foil yields the highest resistivity value (250  $\Omega$ /square). The typical variations in the resistance value for a 0.5  $\times$  0.5 in. resistor formed from these films are  $\pm 3$  percent for a film with resistivity of 10  $\Omega$ /square and  $\pm 10$  percent for a film with 250  $\Omega$ /square resistivity.

Factors to consider when designing circuits with integral planar resistors include possible

ROGERS CORP. Chandler, AZ

# MILLIMETER WAVE RECTANGULAR TE<sub>10</sub> WAVEGUIDE INFORMATION

WG Band	Waveguide Frequency Range (GHz)	Wavelength Rangeλo (mil)	Wavelength Rangeλo (mm)	Guide Wavelength Range (λg/λο)	Waveguide Impedance Range (᠒)	TE <sub>10</sub> Cutoff Freq (GHz)	TE <sub>10</sub> Cutoff λc (mil)	TE <sub>10</sub> Cutoff λc (mm)	Internal Dimensions (mils)	Internal Dimensions (mm)
WR-28	26.5 - 40.0	445.4 - 295.1	11.313-7.495	1.650-1.177	621.9- 443.6	21.1	260.0	14.22	280.0 × 140.0	7.112 x 3.556
WR-22	33.0 - 50.0	357.7 - 236.1	966'5 - 580'6	1.661-1.177	626.0- 443.6	26.3	448.0	11.38	224.0 x 112.0	5.690 x 2.845
WR-19	40.0 - 60.0	295.1 - 196.7	7.495 - 4.997	1.613-1.173	608.3- 442.4	31.4	376.0	9.55	188.0 x 94.0	4.775 x 2.388
WR-15	50.0 - 75.0	236.1 - 157.4	5.996 - 3.997	1.657-1.181	624.8- 445.1	39.9	296.0	7.52	148.0 x 74.0	3.759 x 1.880
WR-12	0.06 - 0.09	196.7 - 131.1	4.997 - 3.331	1.690-1.186	637.2- 447.1	48.4	244.0	6.20	122.0 x 61.0	3.099 x 1.549
WR-10	75.0 - 110.0	157.4 - 107.3	3.997 - 2.725	1.620-1.185	610.9- 446.7	29.0	200.0	5.08	100.0 x 50.0	2.50 × 1.270
WR-08	90.0 - 140.0	131.1 - 84.3	3.331 - 2.141	1.746-1.177	658.1 - 443.6	73.8	160.0	4.06	80.0 x 40.0	2.032 x 1.016
WR-06	110.0- 170.0	107.3 - 69.4	2.725 - 1.763	1.771-1.183	667.7 - 445.9	8.06	130.0	3.30	65.0 x 32.5	1.651 x 0.826
WR-05	140.0- 220.0	84.3 - 53.6	2.141 - 1.363	1.777-1.176	669.7 - 443.3	115.7	102.0	2.59	51.0 x 25.5	$1.295 \times 0.648$
WR-04	170.0- 260.0	69.4 - 45.4	1.763 - 1.153	1.695-1.177	638.8- 443.9	137.2	86.0	2.18	43.0 x 21.5	1.092 x 0.546
WR-03	220.0- 325.0	53.6 - 36.3	1.363 - 0.922	1.627-1.183	613.5- 445.9	173.6	68.0	1.73	34 0 x 17 0	$0.864 \times 0.432$
WR-02.8	260.0- 400.0	45.4 - 29.5	1.153 - 0.749	1.708-1.177	643.8- 443.6	210.8	26.0	1.42	28.0 x 14.0	$0.711 \times 0.356$
WR-02.2	325.0- 500.0	36.3 - 23.6	0.922 - 0.600	1.771-1.185	667.7 - 446.7	268.2	44.0	1.12	22.0 x 11.0	0.559 x 0.279
WR-01.9	400.0- 600.0	29.5 - 19.7	0.749 - 0.500	1.587-1.169	598.3- 440.6	310.6	38.0	0.97	19.0 x 9.5	0.483 x 0.241
WR-01.5	500.0- 750.0	23.6 - 15.7	0.600 - 0.400	1.620-1.175	610.9- 442.8	393.4	30.0	0.76	15.0 x 7.5	$0.381 \times 0.191$
WR-01.2	600.0- 900.0	19.7 - 13.1	0.500 - 0.333	1.746-1.194	658.1 - 450.1	491.8	24 0	0.61	12.0 x 6.0	$0.305 \times 0.152$
WR-01.0	750.0- 1100.0	15.7 - 10.7	0.400 - 0.273	1.620-1.185	610.9- 446.7	590.1	20.0	0.51	10.0 × 5.0	$0.254 \times 0.127$



Innovation in Millimeter Wave Measurements

300 Digital Drive ◆ Morgan Hill, CA 95037 ◆ Tel: (408) 779-2698 ◆ Fax: (408) 778-0491 ◆ email: info@omlinc.com ◆ www.omlinc.com Outside US: Radar Systems Technology • Tel: (650) 949-8041 • Fax: (650) 949-8082 • email: sales@rst-radar.com Visit http://mwj.hotims.com/28495-97 or use RS# 97 at www.mwjournal.com/info changes in resistance value due to environmental conditions, such as humidity and changing temperature. However, when RT/duroid laminates with resistive layers were subjected to an environment with 95 percent humidity at +40°C, the maximum change in resistance value for any circuit tested was 2 percent or less after 240 hours exposure. As with dielectric materials, these resistive foils can be characterized by their temperature coefficient of resistance (TCR), which is a measure of the

change in resistance versus temperature. For the  $10~\Omega/\text{square}$  resistive foils with RT/duroid materials, the maximum TCR was -20 ppm/°C. For 250  $\Omega/\text{square}$  resistitive foils used with RT/duroid materials, the maximum TCR was +100 ppm/°C. In an analysis of aging effects, the change in resistance for all of the different values of resistive foils was 1 percent or less after 1,000 hours at +70°C.

These resistive foils are typically formed of such materials as nickel-

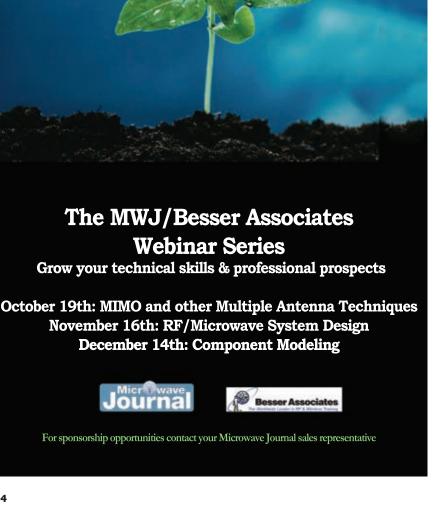
phosphorous (NiP) and chromium silicon monoxide ( $CrSiO_2$ ), which can be laser trimmed or chemically etched to form resistors of a desired value. With laser trimming, resistor values as tight as  $\pm 1$  percent can be realized.

In contrast to PTFE-based RT/ laminates, cost-effective RO4003C™ and RO4350B™ laminates are woven-glass-reinforced, ceramic-filled thermoset materials designed to be processed with the standard fabrication processes used for FR-4 and other low-cost PCB materials. They feature excellent dimensional stability during the fabrication process, lending themselves to reliable manufacturing models. RO4003C laminates feature a Dk of  $3.38 \pm 0.05$ at 10 GHz, with dissipation factor of 0.0027 at 10 GHz and 0.0021 at 2.5 GHz. RO4350B laminates have a Dk of  $3.48 \pm 0.05$  at 10 GHz with dissipation factor of 0.0037 at 10 GHz and 0.0031 at 2.5 GHz. Both materials offer excellent electrical performance in high frequency circuits, with the outstanding z-axis stability needed for forming reliable multilayer circuits.

Unfortunately, the resistive foils that provided excellent results with RT/duroid laminates did not show the same strong adhesion to the company's newer lines of RO4003C and RO4350B laminate materials. By experimenting with different resistive foils, however, Rogers' engineers were able to locate a thin-film resistive foil compatible with the RO4003C and RO4350B thermoset materials.

The RoHS-compliant resistive foil that is used with the RO4003C and RO4350B laminates is a true thin film, with thicknesses ranging from 0.01 to 0.1  $\mu m$  and sheet resistance values of 25 through 1000  $\Omega/s$ quare. The material's sheet resistance exhibits strong isotropic character, with variations of less than  $\pm 5$  percent for most resistance values. Its low TCR minimizes changes in resistance during the material lamination process as well as during normal PCB processing, with excellent thermal stability even for high-power active circuits, such as amplifiers.

Rogers Corp., Advanced Circuit Materials Division, Chandler, AZ (480) 961-1382, www.rogerscorp.com.



GROWTH

RS No. 300

# RF. Microwave Goaxial connector & Cable Assembly

why CAN NOT miss

Frontlynk®
Bridging Gaps
Building Gaps
LLOUGIAUK®

\*Short lead time.

- \*Accurate cross-examination skills
- \*High flexibility in manufacture and delivery
- \*Best Customized Solutions





Visit http://mwj.hotims.com/28495-45 or use RS# 45 at www.mwjournal.com/info



1.85 mm Connector

DC to 67 GHz; VSWR ≤ 1.2

2.4 mm Connector

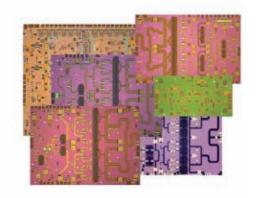
DC to 50 GHz; VSWR ≤ 1.2

2.92 mm Connector

DC to 40 GHz; VSWR ≤ 1.2

3.5 mm Connector

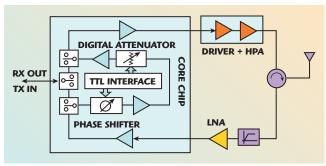
DC to 34 GHz; VSWR ≤ 1.2



# T/R Module Solution for X-BAND PHASEDARRAY RADAR

nited Monolithic Semiconductors (UMS) has a considerable heritage in the design and production of MMIC solutions for space and defense programs. This extensive experience has been used to design state-of-the-art chipset for phased-array radar for defense, space and communication applications. The basic building block for such systems is a T/R module (see *Figure 1*) containing MMICs for control and amplification for both transmit and receive paths.

The company's X-band T/R module solutions, composed of a low noise amplifier



📤 Fig. 1-T/R module block diagram.

(LNA), a core chip and a set of high efficiency high power amplifiers (HPA) from 8 to 10 W are based on in-house fully qualified and space evaluated processes. A high volume, single recess 0.25 µm gate length PHEMT process is used for the LNA and core chips. Two processes are used for the power amplifiers: a double recess 0.25 µm gate length power PHEMT process offering high power density (850 mW/ mm) and high efficiency, and a GaInP/GaAs HBT process with high power density (3.5 W/ mm) and high efficiency. This technology has been optimized for high reliability and includes specific features to reduce the junction temperature and increase the thermal stability of the device.

#### **LNA AND CORE CHIPS**

The CHA1014 is a 7 to 14 GHz, 50  $\Omega$  matched LNA designed to be used with the

UNITED MONOLITHIC SEMICONDUCTORS SAS France

## **RF Channel Simulation**

## When communications really count

DOPPLER • DELAY • PATH LOSS • NOISE • INTERFERENCE



The RT Logic T400CS Channel Simulator adds dynamic, phase-continuous, physics-compliant signal and carrier Doppler shift, delay, path loss, noise and interference to the signals you test with.



Develop and test realistically, thoroughly, quickly and easily, under the most punishing RF and complex motion conditions imaginable - *without ever leaving the lab*.

- Flight and ground system assurance
- Performance and functional verification
- Compliance and regression testing







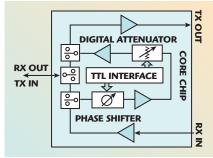
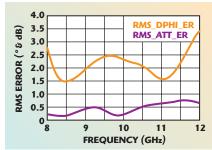


Fig. 2 Core chip block diagram.



▲ Fig. 3 Phase shifter RMS phase error and attenuator RMS attenuation error.

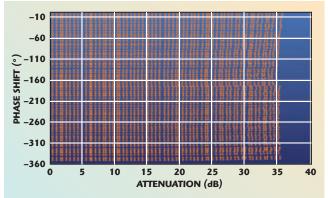
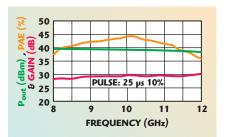


Fig. 4 Phase shift vs. attenuation diagram.



▲ Fig. 5 CHA7115 linear gain, output power and PAE @ 3 dBc.

CHC3014 multifunction chip or in more general-purpose applications. It includes two amplification stages and a biasing circuit that compensates the spread in the technology. The LNA presents a very flat linear gain of 17 dB, a 1.5 dB noise figure, very good matching, better than 14 dB, and a +10 dBm output power at 1 dB gain compression.

The CHC3014, whose schematic is presented in *Figure* 2, is a 22.7 mm<sup>2</sup> transmit receive core chip including a 6-bit phase shifter, a 6-bit attenuator and two tuning bits chain gain tuning. The phase shifter and attenuator can be used in both Tx and Rx modes. A three-port switch with a Rx input, a Tx output and a common Rx output and Tx input port enables the commutation between three modes: Rx, Tx and

neutral. The switch is matched to  $50~\Omega$  for all modes. The CHC3014 integrates parallel interfaces for the control functions, enabling easy implementation.

The device also includes buffer stages to provide 12 dB gain in Rx mode and a high Tx mode gain of 25 dB with very good matching. The

return losses in all states are better than  $14\,\mathrm{dB}$  in Rx mode and  $12\,\mathrm{dB}$  in Tx mode. The phase shifting is  $0^\circ$  to  $360^\circ$  with a phase step of  $5.625^\circ$ . The peak phase error is typically better than  $\pm 6^\circ$ , with a RMS error of  $2^\circ$ , associated with a low amplitude variation of  $\pm 1\,\mathrm{dB}$ .

The 6-bit attenuator provides a high attenuation range of 34.5 dB and a very good accuracy with an attenuation error of typically -1.5 to +1 dB (0.3 dB RMS). It also presents a very low phase variation versus attenuation setting; lower than 10° in any attenuation state. The 2-bit tuning attenuator with 2 dB step offers ±0.3 dB attenuation error and ±2° of phase variation. The core chip performances are presented in *Figures* 3 and 4.

The output power is 19 dBm in Tx mode and 16.5 dBm in Rx mode. The Tx path has been designed for a very high robustness against overdrive. A very wide input power range, from 0 to 16 dBm, can be used as a standard saturated operating mode.

#### **HIGH POWER AMPLIFIERS**

The X-band chipset includes a family of robust and efficient HPAs that are designed to deliver an output power from 8 to 10 W at 3 dB gain

compression with a very high power added efficiency and a high robustness against power overdrive or mismatch.

The CHA7115 and CHA7215 three-stage amplifiers are 30 percent frequency band amplifiers that are compatible with the CHC3014. They present a high linear gain of 28 dB. The output power delivered is 8 W for the CHA7115 and 9 W for the CHA7215 with a high power added efficiency of 40 and 35 percent, respectively. The performance of the CHA7115 is shown in *Figure 5*. The chip sizes are 15.2 and 16.55 mm<sup>2</sup>.

A 10 W power chain is also available with the 1 W driver CHA5014 and the 10 W HPA CHA8100, used together with the CHC3014. These two amplifiers integrate on-chip high impedance biasing control circuits and digital interfaces. The use of the biasing control circuit results in significant advantages; for example, efficient limitation of current variation due to temperature or technological spread and very good linearization of the collector current control.

Due to its high impedance, the decoupling in the circuit environment is straightforward. An integrated TTL interface connected to the control circuit using external bonding wires enables the switching of the HPA with a current consumption lower than 1 mA.

The CHA5014 and CHA8100 are 25 and 15 percent frequency band two-stage amplifiers, respectively, presenting 20 and 18 dB linear gain. The CHA5014 output power at 1 dB gain compression is 29 dBm with an associated power added efficiency of 35 percent. It also offers high power and efficiency compensation versus temperature, lower than 0.2 dB for power and lower than three points for PAE, in a 120°C temperature range. The CHA8100 provides 10 W at 3 dB gain compression and up to 11 W in saturation with a power added efficiency above 40 percent, as shown in Figure 6.

The robustness constraints versus overdrive or mismatch were parts of the targeted performances, as was the power and efficiency, and were an integral part of the design approach from the beginning. This results in a family of very high performance HPAs

## Three words you've never heard from us: "Sorry, that's obsolete."



At Aeroflex / Metelics our commitment is to support your program needs for as long as you need your devices. Today, we call it Product Lifeline Assurance. But for over 30 years, it's just how we've been doing business. While our competitors regularly change manufacturing strategies and discontinue products-forcing you into unscheduled and unfunded redesigns-we remain committed.

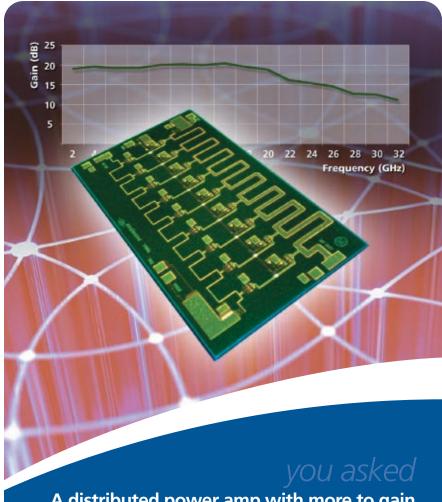
In short, we promise:

- To stand behind our policy not to obsolete products.
- To be the benchmark for consistency in your supply chain strategy.
- Wherever possible, to replace competitors' obsolete devices offering assurance on these devices, too.

Product Lifeline Assurance. Support you can rely on for your high performance diodes, passive and integrated devices, and custom semiconductors.

www.aeroflex.com/metelicsPLA

A passion for performance.



# A distributed power amp with more to gain We delivered

More gain. More power. Same DC power consumption. Endwave has done it again. Whether you need higher gain to ensure your Radar meets peak saturated output power, DC coupled RF ports to enable your optical communications link, or superior linearity for your EW or SIGINT application, Model EWH2001ZZ is the ideal device. This distributed power amplifier boasts flat gain from DC beyond 20 GHz, better PAE, and lower junction temperatures monitored by on-chip sensors. Call us for a quotation today.

- 0 to 20 GHz frequency range
- P1dB output power of +26 dBm (typ)
- Gain of +18 dB (typ)
- Output IP3 of +33 dBm (typ)
- Supply voltage of +8V @270 mA
- Input/output impedance of 50 ohms
- Die measures 3.12 x 1.63 x 0.1 mm
- Temperature sensing is built in

Starting at \$74.00 each per 1,000 pieces

Endwave. Plug us in.

www.endwave.com



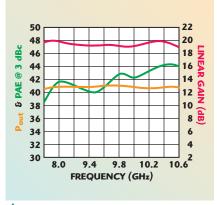


Fig. 6 CHA8100 linear gain, output power and PAE @ 3 dBc.

in terms of power, efficiency and robustness. All these HPAs can support up to 6 dB gain compression at -40°C on a load mismatch of 2:1.

#### CONCLUSION

UMS has developed a complete solution for high performance T/R modules based on internal fully qualified and space evaluated processes. This highly integrated solution (maximum system integration, reduced size) has been fully evaluated in production, is cost effective, easy to implement and suited for phased-array radar applications with high robustness and integrated TTL interface on chip.

United Monolithic Semiconductors SAS, France, Tel: +33 (0)1 69 33 04 72; E-mail: mktsales@ums-gaas.com;

UMS GmbH, Germany, Tel: +49 731 505 3002; E-mail: mktsales@ums-gaas.com;

UMS USA Inc., USA, Tel: (978) 905-3165; E-mail: sales@us.ums-gaas.com;

UMS, PR China, Tel: +86 21 6103 1703; E-mail: mktsales@ums-gaas.com.

RS No. 301

# MMIC AMPLIFIERS

## 50 MHz to 20 GHz

Base Station Repeaters TD-SCDMA SMR Radio Wireless LAN ESM EDGE ELINT REOG DES DOCSIS ECM WIMAX V SAT WCDMA Rader TMA Defense Electronics Direct Broadcast Wireless Communication ot-to-Pt Radio nstrumentation AVA-24+ \$19.95 ea. (Qty.1-9)

MON; **COVER 50 MHz to 20 GHz WITH ONLY 2 AMPLIFIERS!** 

A wide operating bandwidth can mean a tradeoff in performance. Not with these amplifiers. With just two Mini-Circuits MMICs, you can cover the entire spectrum from 50 MHz to 20 GHz, with outstanding electrical performance — making them an exceptional value for their price.

The PHA-1+ is a highly advanced E-pHEMPT amplifier poised to be a workhorse for your wireless applications. Why? It offers ultra-high dynamic range but with low noise, and has among the highest IP3 performance (42 dBm typical at 2 GHz) of any amplifier in its class. The PHA-1+ has good input and output return losses over an extremely broad frequency range (50 MHz to 6 GHz) and can work without external matching components - saving you cost, design time and board space. The PHA-1+ is ideal for use in LTE and TD-SCDMA systems. ACLR and EVM data is available on our website.

The AVA-24+ can cover 5 to 20 GHz with excellent gain flatness (+/- 0.8 dB) across its entire frequency range, with integrated matching circuits and bias circuit in an easy-to-use surface-mount package. Its high isolation (37dB typical) makes it very useful as a buffer amplifier. This design approach makes the AVA-24+ an extremely flexible MMIC that is simple and straightforward to use.

Full electrical, mechanical and environmental specifications for both of these models, as well as characterization data including S-parameters and performance curves, are available at minicircuits.com. These models are in stock for immediate shipment. Mini-Circuits... Your partners for success since 1969



P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

The Design Engineers Search Engine finds the model you need, Instantly • For detailed performance specs & shopping online see minicipality.



# 1000 W AMPLIFIER FOR S-BAND LINEAR ACCELERATOR APPLICATIONS



John Titizian, President and Founder of Integra Technologies Inc.



Visit www.mwjournal.com to read this in-depth interview.

The S-band has long been an application space servicing both commercial and military radars and now supports communications (WiMAX and cordless telephony) and ISM (microwave ovens and linear accelerators). The IBA2856S1KW from Integra is the first amplifier designed for RF pulsed power for S-band linear accelerator or linac applications. The current technologies established by the existing S-band linear accelerators include tube transistors (TWT), most often high power klystrons. The pulsed klystrons produce extreme amounts of pulsed power often in the megawatts range yet are difficult to manufacture and with few manufacturers are getting hard to come by. The industry will continue to use klystrons for the MW final output stage; these klystrons require a 1 KW driver. There is a market for a 1 KW driver solution using highly reliable and cost-effective solid-state technology as TWT replacements.

Integra Technologies has designed a multiple stage line-up that produces more than 35 dB of gain across the band at full RF output

power. The IBA2856S1KW amplifier is characterized at center frequency 2.856 GHz and exhibits  $\pm$  20 MHz bandwidth. The amplifier is characterized over the entire bandwidth with a strict droop specification of 0.8 dB. The rise and fall times are both below 100 ns.

Several transistors are combined in parallel of the final output stage to produce a minimum of 1000 W of pulsed RF output power. The amplifier is able to produce 1200 W of pulsed RF output power, which is needed when the gain of the klystron is low. However, in many instances only 1000 W is required and the extra headroom in performance translates to the reliability of the amplifier as the transistors are not working very hard to produce the 1 KW of power.

Integra offers two discrete bipolar devices: the IB2856S30 (30 W output power device used as a driver) and the IB2856S250 (250 W output power device used as a final device) characterized at spot frequency 2.856 GHz

INTEGRA TECHNOLOGIES INC. El Segundo, CA



Dynawave has earned respect over the past 25 years by solving the most challenging interconnect problems where size, weight, power, loss, phase stability, flexure and other design concerns are critical.

With the expanded talent, experience and capabilities of Dynawave Cable in the design & manufacturing of low loss, RF/MW cable, together, we can address a broader range of interconnect needs in an extremely cost effective manner.

#### **RF MICROWAVE CONNECTORS**

SMP - 40GHz 1.85mm - 65GHz SMPM - 50GHz

Type N - 18GHz

SMPSM - 60GHz TNC - 18GHz

SMA - 26.5GHz In Series Adapters

- 50GHz SSMA - 46GHz

Between Series BMA - 26.5GHZ Adapters - 40GHz

BMAM - 38GHz

2.92mm - 40GHz

2.4mm - 50GHz

#### **LOW LOSS CABLE**

DynaFlex® Series:

Series DF 100 "Best All Around

Performance<sup>a</sup>

Series DF 200

"Best Phase/Loss

Performance<sup>2</sup>

Series DF 300

"Best Weight Performance"

Series DF 400

"Best Flexure Performance"

D-Flex™ - 18GHz

D-Flex™ Microporous - 40GHz

Cable Assemblies - 65GHz

Semi-rigid Cable Assemblies - 65GHz



Please contact us with your application, and allow us to provide you a precise solution:

WWW.DYNAWAVE.COM 978 469-0555



WWW.DYNAWAVECABLE.COM 978 469-9448



Dynawave Incorporated | 135 Ward Hill Avenue | P.O. Box 8224, Haverhill, MA 01835 | Tel (978) 469-0555 | Fax (978) 521-4589 | sales@dynawave.com ISO 9001: 2008. Certificate No. 10002306 QM08



## **FeaturedWhitePapers**

The information you need, from the technology leaders you trust.



#### **Agilent Technologies**

EMC Pre-compliance Testing: Making Conducted and Radiated Emissions Measurements
Application Note

White Paper, Agilent



Application Guide to RF Coaxial Connectors and Cables

Michael J. Hannon, Pat Malloy, AR Worldwide

Analysis and Design of the Rectangular Microstrip Patch Antennas for TM<sub>0n0</sub> Operating Mode

Pasquale Dottorato, Consultant

Problem of Physical Non-realizable Equivalent Current Amplitude Distributions in Waveguide Antenna Feeding Slots

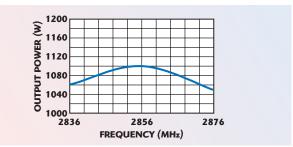
Michal Grabowski, Cobham Antenna Systems

Simulation of Multipath Fading Effects in Mobile Radio Systems

Firas Mohammed Ali Al-Raie, Polytechnic Higher Institute of Yefren, Libya

Check out these new online Technical Papers featured on the home page of Microwave Journal and the MWJ white paper archive in our new Technical Library (www.mwjournal.com/resources)





▲ Fig. 1 IBA2856S1KW output power vs. frequency.

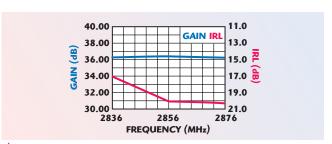


Fig. 2 IBA2856S1KW gain and input return loss vs. frequency.

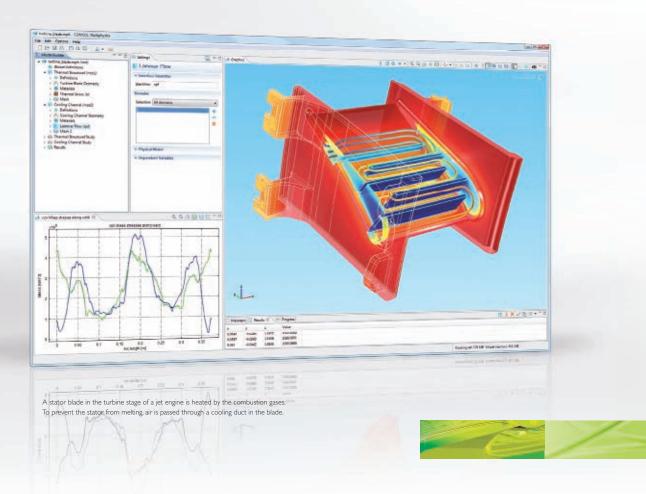
and pulse conditions (12 us pulse width and 3 percent duty cycle) for S-band RF electron beam guns. Using these two devices, Integra leveraged multiple technologies including LDMOS, used in the pre-driver and driver stages, to produce higher gain than the bipolar technology can support. Integra utilizes multiple technologies in combination with the design of the pallets, which results in an optimum amplifier for RF power sources within linear accelerators.

The IBA2856S1KW is an easy to use, four-stage, 1000 W solid-state amplifier for S-band applications. Utilizing a combination of LDMOS and bipolar technology achieves over 35 dB of gain while delivering more than 1 KW of RF pulsed output power across the frequency band of operation from 2.836 to 2.876 GHz. The devices are enclosed within a chassis with dimensions 8" × 12" × 1.25" and mounted on an aluminum heatsink for excellent thermal performance and reliability. Both the input and output connectors are of the SMA type and the DC voltage is both 28 and 40 V. As reliability is a chief concern, the output is protected with a RF circulator. The amplifier is capable of handling a maximum of 12 A of peak current.

RF characterization of the IBA2856S1KW amplifier was conducted with 28 V of drain bias on the LDMOS driver stages and 40 V of collector bias on the bipolar final stages. The amplifier was characterized with pulsed input signal conditions with a 12 µs pulse width and 3 percent duty cycle. The electrical performance of the IBA2856S1KW is shown in *Figure 1*. The curve shows output power performance exceeding 1000 W across the frequency band of operation between 2.836 and 2.876 GHz. *Figure 2* displays the power gain and input return loss figures for the amplifier. The power gain exceeds 35 dB and the IRL better than 17 dB across the operating frequency band.

Integra Technologies Inc., El Segundo, CA (310) 606-0855, www.integratech.com.





## Capture the Concept.

With COMSOL Multiphysics® you are empowered to build the simulations that accurately replicate the important characteristics of your designs. The key is the ability to include all physical effects that exist in the real world. This multiphysics approach delivers results—tangible results that save precious development time and spark innovation.

Watch tutorial
www.comsol.com/showcase









## **Application Notes**VENDOR**VIEW**

For engineers involved in LTE product design and development who need to meet tight schedules as they bring high-performing LTE products to market, Agilent has two new application notes on LTE design and test. "TD-LTE E-UTRA Base Station Transmit ON/OFF Power Measurement" describes the LTE TDD E-UTRA base station transmit ON/OFF power measurement—also known as the power-versus-time measurement—as provided in the Agilent N9082A LTE TDD measurement

application. "Using SystemVue to Integrate a Flexible R&D Testbed for LTE" describes an integrated solution for testing wireless communication systems based on the quickly evolving LTE standard.

Agilent Technologies Inc., Santa Clara, CA (800) 829-4444, www.agilent.com.

RS No. 250



## EMC and RF Testing Catalog

**VENDORVIEW** 

AR has created a new catalog that combines product information from six different brochures for all of AR RF/Microwave Instrumentation. The catalog is easy to use, with "find-it-fast" charts and color coding to help get right to whatever you need for RF and EMC testing. It is available for free download, either in full or by section, at www. ar-worldwide.com.

AR Worldwide, Souderton, PA (215) 723-8181, www.ar-worldwide.com. RS No. 252



## New Literature VENDORVIEW

Hittite's Microwave Solutions brochure features a broad portfolio of microwave and millimeter-wave products to meet the demanding requirements of communication, test & measurement and sensor applications. Hittite's Military & Space Solutions brochure features technically innovative, high performance, quality products, and highlights custom solutions for military

and space environments. Also available is the 2010 Designer's Guide Catalog on CD-ROM with full product specifications for over 850 products. Sign up today to receive the latest product releases at www.hittite.com; click on "My Subscription."

Hittite Microwave Corp., Chelmsford, MA (978) 250-3343, www.hittite.com.

RS No. 254

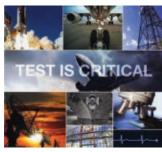


#### **Product Catalogue**

Anapico Ltd. is pleased to announce its new product catalogue, which presents Anapico's newest high-performance RF and microwave signal generators and analyzers. The brochure highlights features and applications for the new instruments. Visit www.anapico. com for further details about the all new products and to download the product brochure.

Anapico Ltd., Zurich, Switzerland +41 44 440 00 51, www.anapico.com.

RS No. 251



#### Switching Solutions Capability Brochure

The new switching solutions capability brochure describes new capabilities, features and benefits of the company's signal switching and signal conditioning products, including RF and microwave interface units (RFIU) for automated test equipment (ATE). The ASCORbrand switching solutions are being used to help companies increase

their ATE performance and throughput, maximize utilization of test assets, and increase yield with proven consistency and reliability.

Giga-tronics Inc., San Ramon, CA (925) 328-4650, www.gigatronics.com.

RS No. 253



## RF and Microwave Tool

IFI presents its new brochure, "The RF & Microwave Tool Box," as a reference to aid engineers in their work. The informative piece includes tutorials, application notes, selection guides, block diagrams, formulas and reference charts for TWT amplifiers, solid-state amplifiers, antennas and more. E-mail sales@ifi.com to request your free copy or visit IFIs website at www. ifi.com for more information on its complete product and service offerings.

Instruments for Industry, Ronkonkoma, NY (631) 467-8400, www.ifi.com.

RS No. 255

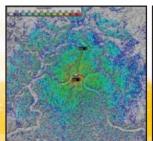
## CROWD CONTROL

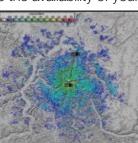
## Is your RF equipment its own worst enemy?

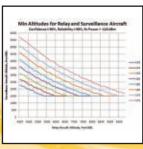
The complex missions of the modern warfighter require a variety of critical communication links. Multiple transmitters and receivers in close proximity must operate simultaneously and without degradation from self-generated (cosite) interference. Pole/Zero can provide a comprehensive evaluation of your platform's cosite communication vulnerabilities, ensuring full range communications performance in the most crowded electromagnetic environments.

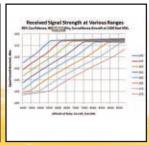


Pole/Zero is an industry leader in high dynamic range RF communications solutions with over 20 years of experience. We will partner with your team to analyze the communications environment at any point over the entire life cycle of your platform, providing the information necessary to cost-effectively maximize the availability of your communication links/channels.









ELEBRATING

#### Use Pole/Zero Cosite Interference Analysis Results to Determine:

- Optimal communications hardware selection
- Minimum channel frequency separation determination
- Optimal platform antenna placement
- Minimum link budget margins

Put Pole/Zero's 20+ years of experience to work for you.







513.870.9060 • support@polezero.com www.polezero.com





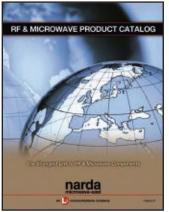


## Amplifier Catalog VENDORVIEW

MITEQ's new 186-page AFS/JS Amplifier products catalog (C-41) provides a comprehensive listing of standard designs for: octave band, multi-octave band, ultra-wideband, moderate band, low-noise waveguide and fiber optic amplifiers. MITEQ offers over 2000 low noise amplifiers in the same catalog. The catalog is divided into frequency, category, specialized amplifiers and typical JS series amplifier performance sections. Included as well are the company's capabilities to customize in accordance with your specifications.

MITEQ Inc., Hauppauge, NY (631) 436-7400, www.miteq.com.

RS No. 256



## Product Catalog VENDORVIEW

This latest version of the company's RF and microwave product catalog features more than 500 products in stock for immediate delivery as well as hundreds of others available with short response times. "Catalog 31" is available in either printed form or on CD. The new 520-page catalog is the 31st in Narda's more than 50-year history, and features helpful technical information for specifying Narda products as well as complete technical specifications. It also includes summaries of Narda's growing family of

Integrated Microwave Assemblies (IMA) as well as its industry-leading RF safety products.

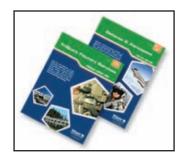
Narda Microwave - East,
Hauppauge, NY (631) 231-1700, www.nardamicrowave-east.com.

RS No. 257



#### **Product Brochure**

TDK is a leader in the design, development and manufacture of total product for the EMC testing industry. TDK offers a complete range of solutions, including automated test systems, anechoic chambers, software, antennas and test products. For more information or a .pdf of the brochure, e-mail: emcsolutions@tdktca.com.



## Product Brochures VENDORVIEW

In need of GaAs/GaN foundry services? DoD accredited 'Trusted Foundry' services? High-performance SAW/BAW filters and oscillators? RF/microwave MMICs? Innovative discretes and modules? Wideband RF transistors including COTS? If so, connect with TriQuint and download the company's latest Foundry and Defense & Aerospace product brochures today.

TriQuint Semiconductor Inc., Hillsboro, OR (503) 615-9000, www.triquint.com.

RS No. 259

TDK RF Solutions Inc., Cedar Park, TX (512) 258-9478, www.tdkrf.com.

RS No. 258



# CELEBRATING 10 YEARS OF QUALITY, PERFORMANCE AND RELIABILITY IN PRECISION COAXIAL CONNECTORS



Including These Connector Series							
1.85mm 2.4mm	DC-65 GHz DC-50 GHz		DC-40 GHz DC-34 GHz		DC-18 GHz DC-40 GHz		

#### ISO 9001:2000

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



Manufacturer of Precision Coaxial Connectors
4343 Fortune Place, Suite A, West Melbourne, FL 32904
Phone: 321-409-0509 Fax: 321-409-0510
sales@sgmcmicrowave.com
www.sgmcmicrowave.com



## IMS2011 in Baltimore: A Perfect Match

## **◆IEEE** Final Call for Papers



#### Deadline for Paper Submission: Friday, December 3, 2010

IEEE MTT-S 2011 International Microwave Symposium
Baltimore Convention Center
June 5-10, 2011
www.ims2011.org

The IEEE Microwave Theory & Techniques Society (MTT-S) International Microwave Symposium for 2011 (IMS2011) will be held in Baltimore, Maryland, as the centerpiece of Microwave Week 2011, and is scheduled from Sunday, June 5 through Friday, June 10, 2011.

IMS2011 offers technical paper sessions, interactive forums, plenary and panel sessions, workshops, short courses, industrial exhibits, application seminars, historical exhibits, and a wide array of other technical and social activities including a guest program. The Awards Banquet and Crab Feast are two of the highlights of the social activities. Collocated with IMS2011 are the RFIC Symposium (www.rfic2011.org) and the ARFTG Conference (www.arftg.org), which comprise the Microwave Week 2011 technical program.

PAPER SUBMISSION INSTRUCTIONS: Authors are invited to submit technical papers describing original work on radio-frequency, microwave, and millimeter-wave theory and techniques. The deadline for submission is **December 3, 2010**. Late papers will not be reviewed. Please refer to the IMS2011 website (www.ims2011.org) for complete submission information.

**INVITATION TO SUBMIT PAPERS IN EMERGING TECHNICAL AREAS:** IMS2011 enthusiastically invites submission of papers that report state-of-theart progress in technical areas that are outside the scope of the listed areas below, or that may be new to the Symposium but are of interest to our attendees. Authors who have other original research results that are of interest are encouraged to submit to IMS2011 by selecting one of the Emerging Technical Areas.

**STUDENT PAPER COMPETITION:** Students are encouraged to submit papers which will be evaluated using the same standards as all contributed papers, and will be eligible for the Student Paper Competition. Please consult the IMS2011 website (www.ims2011.org) for full details.

INVITATION TO SUBMIT PROPOSALS FOR SPECIAL SESSIONS, WORKSHOPS, AND SHORT COURSES: The Symposium invites proposals for Special Sessions (including focused, honorary, etc.), Workshops, Panel and Rump Sessions, and Short Courses (ranging from introductory to expert level). Special Sessions on topics that will be of high interest to the Symposium or particular relevance to the microwave community in the Washington DC/Baltimore area are solicited. Please consult the IMS2011 website (www.ims2011.org) for instructions on preparing a proposal. Proposals must be received by September 17, 2010.

		Some Impo	rtant Dates		
Sep. 17, 2010	Dec. 3, 2010	Jan. 31, 2011	Mar. 11, 2011	Mar. 18, 2011	Jun. 5-10, 2011
Friday	Friday	Monday	Friday	Friday	Sun. – Fri.
Proposal Submission Deadline	Paper Submission Deadline	Paper Disposition Notification	Manuscript Submission Deadline	Notes Submission Deadline	Microwave Week
for Workshop, Short Course, Special Session, Panel and Rump Session	all submissions must be made electronically	authors will be notified via e-mail and on the website	for the final manuscript of accepted papers and copyrights	electronically upload both color and B&W versions of Workshop Notes	IMS2011, RFIC2011, 77 <sup>th</sup> ARFTG, and Exhibition



#### Visit www.ims2011.org for an expanded description of these Technical Areas

Microwave Field and Circuit Techniques

- 1. Field Analysis and Guided Waves
- 2. Frequency-Domain EM Analysis Techniques
- B. Time-Domain EM Analysis Techniques
- 4. CAD Algorithms and Techniques
- . Linear Device Modeling
- 6. Nonlinear Device Modeling
- 7. Nonlinear Circuit and System Simulation Passive Components
- 8. MEMS Components and Technologies
- 9. Transmission Line Elements
- 10. Planar Passive Filters and Multiplexers
- 11. Non-planar Passive Filters and Multiplexers
- 12. Active, Tunable, and Integrated Filters
- 13. Ferroelectric, Ferrite, and Acoustic Wave Components
- 4. MEMS Components and Technologies
  Active Components
- 15. Semiconductor Devices and Monolithic ICs
- 16. Signal Generation
- 17. Frequency Conversion and Control
- 18. HF, VHF, and UHF Technologies and Applications
- 19. Power Amplifier Devices and Circuits
- 20. High-Power Amplifiers
- 21. Low-Noise Components and Receivers
- 22. Millimeter-Wave and THz Components and Technologies
  - Systems and Applications
- 23. Microwave Photonics
- 24. Signal Processing Circuits at GHz Speeds
- 25. Packaging, Interconnects, MCMs and Integration 26. Instrumentation and Measurement Techniques
- 27. Biological Effects and Medical Applications
- 28. Arrays as Antennas and Power Combiners
- 29. Radar and Broadband Communication Systems
- 30. Wireless and Cellular Communication Systems
- 31. Sensors and Sensor Systems
- 32. RFID Technologies
- 3. High Power Microwave Industrial Applications

**Emerging Technical Areas** 

- 34. RF Nanotechnology
- 5. New Technologies and Applications
- 36. Innovative Systems



## **IEEE Radio and Wireless Week**

16 - 19 JANUARY 2011, PHOENIX, AZ, USA









http://www.radiowirelessweek.org/

Register Now! http://www.radiowirelessweek.org/

# Start The New Year With A Week of Wireless 16-19 January 2011 in Phoenix, AZ

Join us in Phoenix, Arizona for the 2011 IEEE Radio and Wireless Week (RWW) which now includes three all new conferences. In addition to the Radio and Wireless Symposium (RWS) and IEEE Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems (SiRF), the IEEE MTTS and RWW have created three new conferences to fill a void in the society's conference offerings. This first being the IEEE Topical Conference on RF/Microwave Power Amplifiers (PAWR), the society's first conference publishing an archival digest dedicated to the topic of power amplifiers. The second new conference is the IEEE Topical Conference on Biomedical Wireless Technologies, Networks & Sensing Systems (BioWireleSS) targeting one of the most exciting and rapidly growing areas due to the potential of wireless medical devices. The third new conference is the IEEE Topical Conference on Wireless Sensors and Sensor Networks (WiSNet), which utilizes technologies from the RWS, PAWR, and SiRF to develop new applications related to BioWireleSS, consumer, commercial, and military sensor markets.

#### **RWW 2011 Highlights**

IEEE Radio and Wireless Symposium

IEEE Topical Conference on Wireless Sensors and Sensor Networks

IEEE Topical Conference on Biomedical Wireless Technologies, Networks & Sensing Systems

IEEE Topical Conference on RF/microwave Power Amplifiers

I Ith Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems

**35 Technical Oral Sessions** - Mon - Wed, 17-19, Jan., 2011 Interactive Poster Sessions - Mon/Wed, 17,19, Jan., 2011 Student Paper Competition Finals - Mon, 17, Jan., 2011 Workshops - Sunday afternoon, 16, Jan., 2011

- "Inter- and Intra-vehicle Wireless Communications & Networking"
- "Wireless Communications for Smart Grid"
- "Wireless Biomedical Applications"
- "ZigBee Applications"

#### **Panel Sessions**

"Ultra-wideband (UWB) Technology: Past, Present, and Future" "Cell Phone Tower Myths and Misconceptions"

Joint RWW/SiRF Plenary - Tue, 18, Jan., 2011 Joint RWW/SiRF Banquet - Tue, 18, Jan., 2011 Exhibits – Mon-Wed, 17-19, Jan., 2011

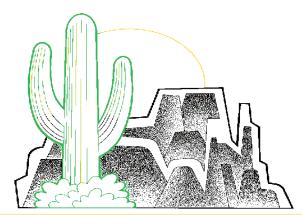
#### **Distinguished Lecturer Talks**

Inkjet-Printed Paper/Polymer-Based "Green" RFID and Wireless Sensor Nodes: The Final Step to Bridge Cognitive Intelligence, Nanotechnology and RF?

Dr. Manos Tentzeris, GEDC Associate Director for RFID/Sensors Research, Georgia Institute of Technology

Relay Node Placement in Wireless Sensor Networks
Prof. Guoliang (Larry) Xue, Arizona State University

More to be announced soon!!!



ORAL PRESENTATIONS - POSTERS - WORKSHOPS - PANELS - EXHIBITIONS HTTP://WWW.RADIOWIRELESSWEEK.ORG

## **NEW WAVES**

FOR MORE NEW PRODUCTS, VISIT WWW.MWJOURNAL.COM/BUYERSGUIDE

FEATURING VENDORVIEW STOREFRONTS



### **Components**

#### **Data Converters**



This pair of low power, high speed 14-bit analog-todigital converters (ADC) incorporates the JES-D204A data converter serial interface standard. The JES-D204A standard

was developed to allow designers of high-speed communications and data acquisition systems to extend transmission lengths while improving signal integrity and simplifying printed-circuit board layout. The AD9644 dual and AD9641 14-bit 80 MSPS (mega samples per second) ADCs use half the power of competing products and 25 percent less board area further expanding ADIs portfolio of high-speed ADCs supporting the JESD204A standard.

Analog Devices Inc., Norwood, MA (781) 329-4700, www.analog.com.

RS No. 216

#### **Hybrid and Directional Couplers**



Anaren Inc. announced that it has officially launched its Xinger®-III brand line of 3 dB hybrid and directional cou-

plers for wireless infrastructure applications. At ¼ the size of the company's previous generation parts (Xinger-II components remain popular and in production), the design and unique manufacturing processes behind the new Xinger-III offer the same power handling, among other advantages. **Anaren Inc.**,

East Syracuse, NY (315) 432-8909,

www.anaren.com.

RS No. 217

## Low Pass Filter VENDORVIEW

The  $\mod e\,l$  AE1706L8769 is a lumped-element low pass filter that is designed for applications at L-band frequencies. The AE1706L8769



has a cut-off frequency of 1706 MHz, insertion loss over its passband of less than 0.6 dB, return loss greater than 18 dB, and rejection at 3300 MHz greater

than 40 dB and greater than 65 dB at 4800 MHz. It is designed for surface-mount applications and measures 1.5"  $\times$  0.5"  $\times$  0.4". The AE1706L8769 is available for immediate delivery.

Anatech Electronics, Garfield, NJ (973) 772-4242, www.anatechelectronics.com. **RF Directional Couplers** 



Aviel Electronics, a division of RF Industries, designs and manufactures RF directional couplers with

uncommon interfaces such as the HN female shown in the photo. The HN coaxial interface is a high-voltage version of the N interface and is used in specialized applications. Other interfaces are available. Model number Z-344, shown in the picture, operates in a frequency range of 700 to 850 MHz with power handling capability of 40 KW peak power (120 W average power). Insertion loss is less than 0.2 dB and VSWR is less than 1.1 for both the main and secondary lines. Forward coupling is 43 dB isolation. Reverse coupling is 33 dB isolation.

Aviel Electronics, Las Vegas, NV (877) 805-7381, www.avielelectronics.com.

RS No. 219

#### **MEMS Si Cavity Filter**



The MEMS Si cavity filter series combines high performance with small size. These filters are made on a Silicon substrate chip and oper-

ate from 4 to 35 GHz. They are designed as replacements for traditional cavity filters. The filter series features a percentage bandwidth of 2 to 35 percent, a shapefactor: K40/3 2:1 and remote rejection of 70 dBc. The smallest size of the MEMS Si cavity filter in the series measures 6.2 by 3.2 by 0.4 mm, which makes them especially suitable for microwave and millimeterwave applications, requiring both high performance and small size.

Bowei Integrated Circuits Co. Ltd., Shijiazhuang, China +86 311 83933891, www.cn-bowei.com.

RS No. 220

## Surface-mount Fixed Attenuator VENDORVIEW



The QFA series is designed for passive fixed attenuation from 36 to 50 GHz. Being passive in nature, there is no signal distortion, phase shift or time delay. The attenuator

structure is internally tuned for optimum performance beyond Ka-band, with the added benefit of being a truly symmetrical, bi-directional attenuator. The QFA is available in surfacemount packaging and suitable for pick and place applications. The QFA was developed to address commercialization of point-to-point radios, high frequency transceivers and phased array radar. The device comes in two styles, microstrip and coplanar, with excellent frequency response from 36 through 50 GHz.

EMC Technology, Stuart, FL (772) 600-1360, www.emct.com.

RS No. 221

## Low Noise Programmable Dividers VENDORVIEW



These two new ultra low noise programmable frequency dividers are ideal for use in signal generation architectures

found in test equipment, laboratory systems and various military applications that operate from 100 MHz to 15 GHz. The HMC862LP3E and HMC905LP3E are SiGe BiCMOS low noise programmable frequency dividers in SMT packages. The HMC862LP3E can be programmed to divide from N = 1, 2, 4, 8 in the 100 MHz to 15 GHz input frequency range. The HMC905LP3E can be programmed to divide from N = 1, 2, 3, 4 in the 400 MHz to 6 GHz frequency range. The HMC905LP3E are each conveniently housed in a miniature  $3\times3$  mm RoHS compliant QFN leadless SMT package.

Hittite Microwave Corp., Chelmsford, MA (978) 250-3343, www.hittite.com.

RS No. 222

#### **Directional Microwave Couplers**



This new family of compact stripline directional microwave couplers operates in a

frequency range from 0.3 to  $18\,^\circ$ GHz. The new family includes six models that deliver 10 or 30 dB of coupling within three frequency ranges including those of 0.3 to 8 GHz, 0.3 to 12.4 GHz and 0.3 to 18 GHz.

Krytar Inc., Sunnyvale, CA (408) 734-5999, www.krytar.com.

RS No. 223

## Power Splitter/Combiner VENDORVIEW



This four-way, in-phase splitter and combiner covers a wide frequency range between 250 to 6000 MHz,

making this splitter now suitable for GPS, GSM, DCS and PCS frequency bands, in addition to WiFi, Bluetooth and 802.11a uses. This model also features good insertion loss and amplitude and phase unbalance, and is packaged in a 3.5" × 4.5" enclosure with built-in SMA con-

# TINY TOUGHEST MIXERS UNDER THE SUN



Rugged, tiny ceramic SIM mixers from ea. qty. 1000 offer unprecedented wide band, high frequency performance while maintaining low conversion 0.2"x 0.18" loss, high isolation, and high IP3.

Over 21 models IN STOCK are available to operate from an LO level of your choice, +7, +10, +13, and +17 dBm. So regardless of the specific frequency band of your applications, narrow or wide band, there is a tiny SIM RoHS compliant mixer to select from 100 kHz to 20 GHz. Built to operate in tough

environments, including high ESD levels, the SIM mixers are competitively priced for military, industrial, and commercial applications. Visit our website to view comprehensive performance

data, performance curves, data sheets, pcb layouts, and environmental specifications. And, you can even order direct from our web store and have it in your hands as early as tomorrow!

Mini-Circuits... Your partners for success since 1969

U.S. Patent #7,027,795 OROHS compliant



P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

2 The Design Engineers Search Engine finds the model you need, Instantly • For detailed performance specs & shopping online see minicircuits.com

nectors for ease of use. The very wide bandwidth performance of the ZN4PD1-63W+ enables this splitter/combiner to be used in a wide range of applications including broadband systems such as test, measurement and defense/ aerospace. However, this model covers a variety of narrow band applications including GSM, GPS, DCS and PCS applications, in addition to WiFi, Bluetooth, 802.11a, U-NII and ISM applications.

Mini-Circuits, Brooklyn, NY (718) 934-4500, www.minicircuits.com.

RS No. 224

#### **High Power Fixed Terminations VENDORVIEW**

Models 368BNM and 369BNM are high power terminations that are ruggedly constructed, conservatively rated, and operate up to 18 GHz. The model 368BNM operates from 2 to 18 GHz, handles 500 W average and up to 5 kW



peak RF power, has a maximum VSWR of 1.45, measures 12" × 3" and weighs 6.5 lb. The mod-

el 368BNM covers 700 MHz to 18 GHz and handles 175 W average and up to 10 kW peak RF power. Its maximum VSWR is 1.2:1 and it measures  $13" \times 2.4"$ , and weighs 2.5 lb. Both models use Type-N female connectors; others can be specified. Both attenuators are available from Narda for immediate delivery.

Hauppauge, NY (631) 231-1700, www.nardamicrowave.com/east.

RS No. 225

#### **Dual Directional Coupler**

Pulsar model C40-22-481-6N is a new 40 dB coupler capable of handling power levels of 200 W CW over the frequency range of 200 to



2000 MHz with 0.4 dB insertion loss. Directivity is greater than 20 dB and coupling variation with frequency is ±1.0 dB. Maximum VSWR is

1.80:1. In-line connectors are either SMA or Type N female and coupled ports have SMA female connectors. Housing dimensions are 3.0"  $\times$  2.6"  $\times$  1.0".

Pulsar Microwave, Clifton, NJ (973) 779-6262, www.pulsarmicrowave.com.

RS No. 226

#### Connection Kit



This new R2CT connection kit provides a waterproof, sealed connection for fiber-to-the-antenna (FTTA), remote radio head equipment and similar outapplica-

tions where a protected interface is needed. The field-installable kit provides low-cost sealing at the transceiver-to-cable interface and ensures robust mechanical and environmental performance. The kit is designed for optical systems using SFP transceivers and duplex LCterminated fiber-optic cable. The kit can be reused, allowing cables and transceivers to be changed in the field, including front-panel swapping of transceivers. The kits can also be assembled over existing cables.

Radiall USA Inc., Chandler, AZ (480) 682-9400, www.radiall.com.

RS No. 227

#### Waveguide Broadwall Coupler



RLC Electronics offers a standard range of multi-ȟole broadwall directional couplers covering the frequencies from

40 to 2.6 GHz in standard waveguide sizes. The electrical characteristics of high directivity and coupling flatness are achieved by using a precise machined coupling hole pattern and a precision load in the secondary arm. Non-standard configurations or selected electrical parameters are available on request.

RLC Electronics Inc., Mount Kisco, NY (914) 241-1334, www.rlcelectronics.com.

RS No. 228

#### **High Performance Filters**



Sinclair duces the FP20603 Series of VHF low loss high selectivity high power compact band-

pass filters. Featuring a compact design that fits into a 19" EIA 3U high rack mount for single or dual units, these filters cover a range of 132 to 174 MHz with 1 or 2 MHz passband. An impressive 150 W power handling capability makes them ideal for filtering both receiving and transmitting channels. They can also be easily paired for duplexing or diplexing applications within the same rack space.

Sinclair Technologies, Aurora, Ontario, Canada (800) 263-3275, www.sinctech.com.

RS No. 229

#### **PIN Diodes V**VENDORVIEW



Skyworks Solutions Inc. has introduced two high power (> 20 W) series or shunt PIN diodes for T/R switch applications. In addition, the low thermal resis-

tance package makes these devices ideal for large signal switch and attenuator applications. These series or shunt devices combine very low insertion loss, good isolation, unprecedented

series diode power handling and low distortion in a very small package, and are designed for high-volume commercial, industrial and military radio communications systems such as land mobile radios, tactical radios, avionics and infrastructure markets.

Skyworks Solutions Inc., Woburn, MA (781) 376-3000, www.skyworksinc.com.

RS No. 230

#### **Custom Microwave/RF Kits**



SRI Connector Gage announces custom precision RF kits for the microwave industry. Kits can contain any

variety or quantity of high frequency connectors and adapters that the company produces. From SMA to ZMA and everything in between, SRI can provide one-stop shopping by sourcing the cables.

SRI Connector Gage, Melbourne, FL (800) 881-9689, www.sriconnectorgage.com.

RS No. 231

#### Oven-controlled Crystal Oscillator



The new 10 MHz OX-045 ultra low noise oven-controlled crystal oscillator (OCXO) offers close in phase perfornoise

mance. The OX-045 is capable of meeting -140 dBc/Hz at a 10 Hz offset in a 50×50 mm hermetic package. The temperature performance is also state-of-the-art with stability better than 4.5 ppb from 0° to 70°C. The OX-045 is an excellent product for low phase noise needs for test equipment, satellite communication and radar applications.

Vectron International, Hudson, NH (888) 328-7661, www.vectron.com.

RS No. 232

### **Amplifiers**

#### **High Power Broadband Amplifier**



AML announces the immediate availability of a high power broadband amplifier model AML618P4202. This amplifier operates over 6

to 18 GHz with industry best DC to RF efficiency. Output P1dB is +35 dBm (3 W) minimum. Gain is 42 dB minimum with flatness within ±2.5 dB maximum. DC current at +12 VDC is under 2.5A. Dimensions are 2.85"L  $\times$ 1.5"W  $\times$  0.5"H. Operating temperature range of -54° to +85°C is available as an option.

AML Communications Inc., Camarillo, CA (805) 388-1345, www.amlj.com.

RS No. 233

## PIN DIODE SWITCHES

### **FEATURES:**

- Multioctave bands 0.2 to 18 GHz
- Reflective or Absorptive
- Current or TTL control
- Low insertion loss
- High isolation



Frequency Range (GHz)	Model Number	Insertion Loss (dB, Max.)	Isolation (dB, Min.)	VSWR (Max.)	Rise/Fall Time (ns, Typ.) (	On/Off Time ns, Typ.)	On/Off Time (ns, Max.)	DC Power Positive/Negative (mA, Max.)	
SPST								The Parket of th	
0.2 – 2	SW1-002020RN1NF	1.7	70	1.6:1	10/10	20	35	35/70	
2-8	SW1-020080RN1NF	2	80	1.7:1	10/10	20	35	35/70	
4 – 12	SW1-040120RN1NF	2.2	80	1.7:1	10/10	20	35	35/70	
2 – 18	SW1-020180RN1NF	3	80	2:1	10/10	20	35	35/70	
1 – 18	SW1-010180RN1NF	3	70	2:1	10/10	20	35	35/70	
SP2T									
0.2 - 2	SW2-002020RN1NF	1.5	70	1.6:1	10/10	20	35	60/60	
2 – 8	SW2-020080RN1NF	1.8	80	1.7:1	10/10	20	35	60/60	
4 – 12	SW2-040120RN1NF	2.2	80	1.7:1	10/10	20	35	60/60	
2 – 18	SW2-020180RN1NF	2.8	80	2:1	10/10	20	35	60/60	
1 – 18	SW2-010180RN1NF	3	70	2:1	10/10	20	35	60/60	
SP3T									
0.2 – 2	SW3-002020RN1NF	1.6	70	1.6:1	20/20	150	180	85/85	
2 – 8	SW3-020080RN1NF	1.9	80	1.7:1	20/20	150	180	85/85	
4 – 12	SW3-040120RN1NF	2.4	90	1.7:1	20/20	150	180	85/85	
2 – 18	SW3-020180RN1NF	3	80	2:1	20/20	150	180	85/85	
1 – 18	SW3-010180RN1NF	3.1	70	2:1	20/20	150	180	85/85	
	2.1.2 2.12.20.11111			100				33,33	

Note: The above models are all reflective switches. Absorptive models are also available, please contact MITEQ.







For additional information or technical support, please contact our Sales Department at (631) 439-9220 or e-mail components@miteq.com



100 Davids Drive, Hauppauge, NY 11786 (631) 436-7400 FAX: (631) 436-7430

www.miteq.com

#### New Products

#### Solid-state Power Amplifier



Model BHE25869-50 is a solid-state Class "AB" linear amplifier that operates over the full 2500 to 6000 MHz frequency band and delivers a minimum of 50 W. The amplifier uses the latest Gallium Nitride (GaN) technology and is packaged in a standard rack mountable enclosure measuring  $19^{\circ}\times 22^{\circ}\times 5.25^{\circ}$ .

Comtech PST, Melville, NY (631) 777-8900, www.comtechpst.com.

RS No. 234

#### **Low Noise Amplifier**

The EWT-90-0058 low noise amplifier covers the frequency range of 1920 to 1980 MHz



and features a small-signal gain of 31 dB minimum, 1.35 dB noise figure and +13 dB output 1 dB compression point. This design can

be optimized for operation over sub-bands ranging from 200 to 3000 MHz. This unit also has an available option for two outputs. Input

voltage range is +12 to +15 VDC at 100 mA. The overall size is  $2.55" \times 1.62" \times 0.53"$ .

EWT Inc.,

Salisbury, MD (410) 749-3800, www.ewtfilters.com.

RS No. 235

#### **L-band Power Amplifier**



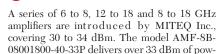
The KU PA 1940 is a 40 W L-band power amplifier that has been developed for both digital and analog applications. The PA's fre-

quency range is 1,700 to 2,200 MHz; it has a typical output power (P1dB) of 30 W (CW) and a typical input power (P1dB) of 50 mW. The KU PA 1940's good efficiency and thereby reduced power consumption results in a longer running time for the battery powered systems. The power amplifier measures 80 by 59 by 20 mm, is housed in a high-quality milled aluminum case and has a monitor for observing the output power.

Kuhne electronic GmbH, Berg, Germany +49 (0) 9293 800 939, www.kuhne-electronic.de.

RS No. 236

## **Broadband Power Amplifiers**VENDOR**VIEW**



er over full band of 8 to 18 GHz, with over



40 dB gain and ±2.5 dB flatness. Noise figure is less than 4 dB, port VSWR is less than 2:1, and it draws about 3A from a

single +12 to +15 V DC supply. The housing has a footprint of only 3" by 1.9" and 0.9" high with SMA connectors. Heatsink and other control features are also available as options.

MITEQ Inc.,

Hauppauge, NY (631) 436-7400, www.miteq.com.

RS No. 237

#### **High Power RF Amplifier**



Ophir's model 5088 is a 600 W broadband amplifier that covers the 0.01 to 200 MHz frequency range.

This amplifier utilizes Class AAB linear power that provides high output power and is one of the smallest RF power amplifiers in this power and frequency range.

Ophir RF,

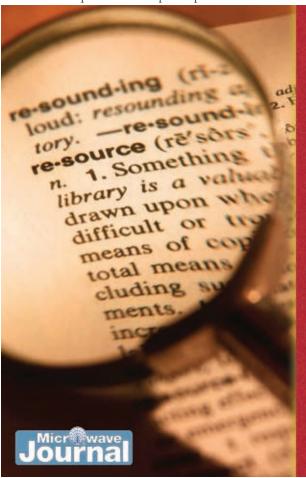
Los Angeles, CA (310) 306-5556, www.ophirrf.com.

RS No. 238

### WiFi Front-end Module



RFMD announced availability of the RF5365 WiFi front-end module (FEM). The highly



# The NEW mwjournal.com Resources section

New and archived content for the well-informed

Webinars on demand

White Papers/Technical Library

Expert Advice Blogs

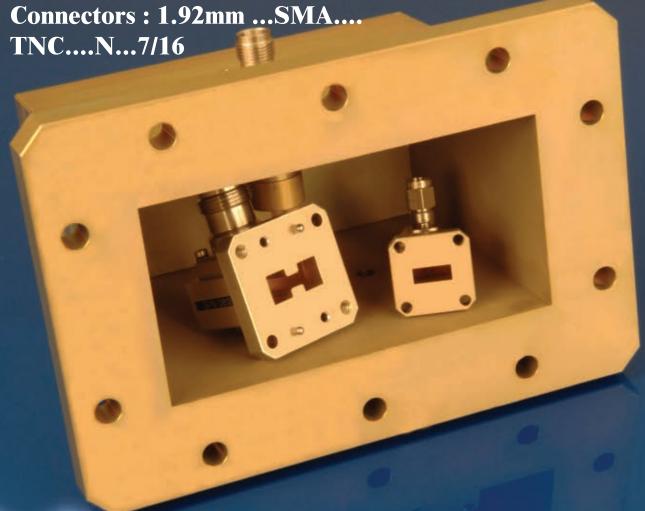
Executive Interviews

@ www.mwjournal.com/resources

# Bland Small, we have 'em all

Almost any Waveguide to almost any Coax Connector

WG Materials: Aluminum, Copper, Brass



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

#### NEW PRODUCTS

integrated RF5365 FEM satisfies the need for aggressive size reductions for typical 802.11b/g front-end designs and greatly reduces the number of components outside the core chipset. RFMD's RF5365 FEM integrates a 802.11b/g power amplifier with a single pole three throw (SP3T) switch for 2.4 to 2.5 GHz ISM band applications. By integrating SP3T switch functionality, the RF5365 is able to route WLAN and Bluetooth® receive/transmit signals to two system-on-chip (SoC) transceivers, accommodating a common implementation in high-performance consumer electronics and handset/handheld WiFi applications.

RF Micro Devices Inc., Greensboro, NC (336) 664-1233, www.rfmd.com.

RS No. 239

#### 25 W Solid-state Power Amplifier



Stealth Microwave introduces the SM2560-44GN, a GaN SSPA with industry-leading efficiency (32 to 42 percent across the band). This

model operates in a frequency range from 2.5 to 6 GHz. The use of the latest GaN devices allows for superior gain flatness, along with an advanced RS-485 PA monitoring and control interface. MCU-controlled temperature compensation and gain control is standard and rugged construction allows for operation in harsh environments.

Stealth Microwave, Ewing, NJ (609) 538-8586, www.stealthmicrowave.com.

RS No. 240

#### Antenna

#### Antenna Kit

This complete antenna kit covers the broadest frequency range available in a small, rugged, deployable package. The EM-6003 kit features



three all new passive antennas that set standards in the field. The EM-6857 "Club" provides omnidirectional coverage over a frequency range greater than 20 MHz to GHz. The EM-

6945 "Vector" hand-held LPA provides directionality and sensitivity over the frequency range of 500 MHz to 25 GHz. The EM-6904 "Hockey Puck" whip antenna provides coverage down to 1 kHz and extends up over 100 MHz. Kits can also be custom configured to hold customer-supplied equipment, simplifying packaging for travel to and from mission sites.

Electro-Metrics, Johnstown, NY (518) 762-2600, www.electro-metrics.com.

RS No. 241

#### Sources

#### **Voltage-controlled Oscillator**

The VCO2-1750 is a fundamental mode reflection oscillator that utilizes a silicon bipolar transistor and hyper-abrupt silicon varactor diodes to create a highly linear VCO with wideband tuning characteristics. The device is useful for many wireless applications where high frequency and linear modulation is required. The device is very repeatable from unit to unit and is assembled in an ISO 9000 qualified manufacturing facility with the latest surface-mount equipment. Every unit is DC and RF tested with the company's fully automated computerized test stands to provide the highest reliability and guaranteed performance. Size:  $0.50^{\circ}\times0.50^{\circ}\times0.10^{\circ}$ .

AABroadBand, Annapolis, MD (443) 926-4861, www.aabroadband.com.

RS No. 242

#### Voltage-controlled Oscillator

Crystek's CVCO55CC-1490-1550 voltage-controlled oscillator (VCO) operates from 1490 to



1550 MHz with a control voltage range of 1.0 to 10 V. This VCO features a typical phase noise of -115 dBc/Hz at 10 kHz offset

and has excellent linearity. Output power is typically +5 dBm. Engineered and manufactured in the USA, the model CVCO55CC-1490-1550 is packaged in the industry-



## The NEW 1.8 to 6 GHz Range



- Guaranteed minimum P1dB power levels of 30W, 50W and 100W available
- 5 Year fully expensed Warranty
- Proven upgrade topology
- Powered by GaN transistor technology

# Continuing Amplifier Innovation From MILMEGA

Designed to bring the intrinsic benefits of Gallium Nitride transistor technology to the lab environment while extending current lab capability with the minimum of fuss. The new MILMEGA 1.8 to 6 GHz range allows easy addition of amplifier power to meet all your stringent test requirements to 6 GHz. With the flexibility and ease of use that you would expect from a MILMEGA product, the new 1.8 to 6 GHz range further enhances our reputation for going the extra mile to deliver what customers demand, with the quality and reliability competitors aspire to.

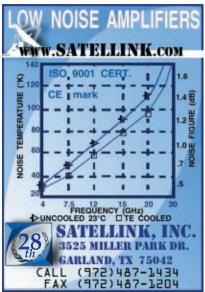
Find out more at www.milmega.co.uk

Designers and Manufacturers of High Power Microwave and RF Amplifiers



Visit http://mwj.hotims.com/28495-74 or use RS# 74 at www.mwjournal.com/info

## MICRO-AD Visit http://mwj.hotims.com/28495-(RS#)



RS 125



**RS 126** 



Cost-Effective SMP-MAX RF Coax Connectors

- . Misalignment tolerance up to .094" (2.4mm): That's five times more than the standard SMP!
- Up to a 3º tilt
- . Operating frequency range of DC-6 GHz
- Low 1.2 VSWR
- Handles up to 300 watts of power

For more information and a FREE SMP-MAX go to www.radiall.com or call 1 480 682 9400





RS 101

#### **Material Testers** Measure $\varepsilon$ , $\mu$ , Insertion loss



Model 1000T Operating Band ~0.1 to 5 GHz Calibration Standards Holders for Solids, Liquids & Thin Shielding Materials MU-EPSLN<sup>TM</sup> software www.damaskosinc.com (610)358-0200 fax(610)558-1019

**RS 32** 

#### **Modco Dual Band Synthesizers** in a 0.6 inch square package.

The PDM832-1920VI is a dual band Synthesizer designed to operate at 832MHz and

1920MHz. It offers exceptional Phase Noise of -120dBc @ 10kHz, -98dBc @ 10kHz offset respectively and +1dBm



Power Output. PDF sampling sidebands are -75dBc, frequency isolation is -30dBc and Locktime is 3mS. Operating temperature range is -45 to +85 Degree C Package is 0.6 inch square and 0.138 inch in height. Custom designs and 0.5" square single band models are available.

www.modcoinc.com

standard  $0.5" \times 0.5"$  SMD package. Input voltage is 8 V. with a maximum current consumption of  $35\ \mathrm{mA}.$  Pulling and pushing are minimized to 2.5MHz and 1.5 MHz/V, respectively. Second harmonic suppression is -15 dBc typical.

Crystek Corp., Fort Myers, FL (239) 561-3311, www.crystek.com.

RS No. 243

#### VSAT Frequency Synthesizer



The SLX-1450 operates in the VSAT Block I IF frequency band from 950 to 1450 MHz in an ultra-miniature surface-mount package of 0.5" square. The unit features 25 kHz

step size, +7 dBm output power and +5 VDC supply voltage with extremely low power consumption (< 55 mA). Locked to an external 10 MHz reference, the SLX-1450 exhibits low phase noise (<-85 dBc/Hz at 100 kHz) and operates over -30° to +70°C. SLX units are available from 50 to 6000 MHz as fixed frequency up to octave bandwidths. Custom units feature external references from 5 to 125 MHz, select supply voltages (+3, +3.3 or +5 VDC), 10 kHz to 10 MHz step sizes and optional wide operating temperature range (-40 $^{\circ}$  to +85 $^{\circ}$ C).

EM Research Inc., Reno, NV (775) 345-2411, www.emresearch.com.

RS No. 244

#### Coaxial Resonator Oscillator

The MCR845-855MC is an 845 to 855 MHz coaxial resonator oscillator (CRO) that provides



exceptional phase noise of -125 dBc at 10 kHz offset. Vcc of 3.3 V and Icc of 12 mA. It is ideal for portable applications where

mum energy consumption is a factor. Modco Inc.

Sparks, NV (775) 331-2442, www.modcoinc.com.

RS No. 245

#### **Opto-Electronic Oscillator**



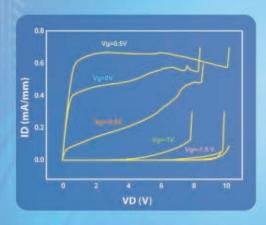
This compact opto-electronic oscillator (OEO) offers extremely low phase noise and low vibration and acceleration sensitivity for signal source modules required in high-frequency, high performance applications. Available in any

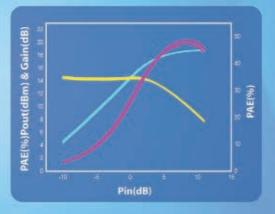
## O.1µm GaAs pHEMT Technology

WIN is the world's largest and leading 6" GaAs foundry

- 0.1µm gate length of pHEMT technology
- 10V off-state BV for power application
- Single recess for high performance
- 500 mW/mm output power of 3.5 V @ 29 GHz
- 450 pF/mm capacitor for design flexibility







#### Comparison of WIN's millimeter wave pHEMT technologies

	PP-15	PL-15	MP-15	PP-10
Vto (V)	-1.2	-0.7	-0.8	-0.9
Idss (mA/mm)	500	260	400	460
Idmax (mA/mm)	650	500	600	660
GM (mS/mm)	495	550	700	700
VGD (V)	10	9	12	10.5
fT (GHz)	85	95	105	128
Fmax (GHz)	180	160	180	180
P1dB (mW/mm)	670 (5V)	242 (3V)	722	380 (3.5V)
Psat (mW/mm)	820 (5V)	312 (3V)	322	500 (3.5V)
Gain (dB)	11	12.6	724	14.6
PAE (%)	50	39	3.22	47

WIN
SEMICONDUCTORS

Visit http://mwj.hotims.com/28495-149 or use RS# 149 at www.mwjournal.com/info

Tel:+886-3-397-5999 E-mail:sales@winfoundry.com Fax: +886-3-397-5069

http://www.winfoundry.com





RS 110

## Punctual....



Why are AST's delivery times better? At AST we pride ourselves on telling our potential new customers that we have never been a day late. Our manufacturing techniques and our ability to keep many standard switches in stock, means that you will never have to wait for a switch again. In fact, in small quantities, we can ship to you in 1 business week. Come and see why AST is the only punctual switch provider.



RS 1







Modco announces its MCS Series CRO's. Low Vcc of 3.3V and current consumption of 13ma and makes it ideal for battery powered applications. Model Number MCS1400-1470CR tunes 1400-1470MHz with a Vt of 0.3-2.7V It provides 0dBm output power. Phase Noise is -110dBc @ 10kHz Pushing is 0.2MHz per volt and Pulling is 0.9MHz. Many models are available. www.modcoinc.com

RS 91



output frequency between 10 to 12 GHz (consult factory for other frequencies). Compact OEO offers typical phase noise performance levels of better than -140 dBc/Hz at 10 kHz offset from the carrier. Compact OEO is offered with a variety of scalable features and options.

OEwaves, Pasadena, CA (626) 449-5000, www.oewaves.com.

RS No. 246

#### **Voltage-controlled Oscillator**

This new RoHS compliant voltage-controlled oscillator (VCO) model V940ME28-LF is designed for C-band. The V940ME28-LF operates at 5840 to 6040 MHz with a tuning voltage range of 0.5 to 4.5 VDC. This VCO features a



typical phase noise of -85 dBc/Hz at 10 kHz offset and a typical tuning sensitivity of 85 MHz/V. The V940ME28-LF

is designed to deliver a typical output power of 0.5 dBm at 5 VDC supply while drawing 28 mA (typical) over the temperature range of -40° to 85°C. This VCO features typical second harmonic suppression of -15 dBc and comes in Z-Comm's standard MINI-14S package measuring  $0.5^{\circ}\times0.5^{\circ}\times0.22^{\circ}$ .

Z-Communications Inc., San Diego, CA (858) 621-2700, www.zcomm.com.

RS No. 247

### Test Equipment

## Handheld Analyzers VENDORVIEW



Anritsu Co. introduces an onscreen coverage mapping option for its "E" Series Spectrum Master™, Site Master™ and Cell

Master™ handheld analyzers. The option has been developed to help wireless service providers, public safety users, land mobile radio operators and government officials verify system coverage and perform spectrum clearing before installing new radio services. With the option installed on one of the industry leading analyzers, users can map RSSI and ACPR levels. Intuitive color coding simplifies interpretation. The update rate can be set in seconds or in distance, depending on user preference. Both indoor and outdoor mapping is supported with the option.

Anritsu Co., Morgan Hill, CA (408) 778-2000, www.anritsu.com.

RS No. 248

# Better performance. Less effort.

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



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

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

leach resistant alloy are featured for long term reliability.

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

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

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



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







# Special Design Topics in Digital Wideband Receivers

James Tsui

Wideband Receivers offers engineers a thorough examination of special, more advanced aspects of digital wideband receiver design and builds on fundamental resources on the topic, helping the reader to gain a more comprehensive understanding of the subject. The book also presents a detailed look at a complete receiver design and discusses the detection of exotic signals and provides guidance on designing receivers used in electronic warfare (EW).

The book starts by presenting a complete receiver design including the encoder. Four types of receiver design are included: digital instantaneous frequency measurement; conventional fast Fourier transform (FFT) operation; multiple FFT operations; and polyphase filter. It introduces ideas in other fields to EW receiver designs and generates detailed information on some of the ideas discussed in the book. Finally the book discusses the detention of exotic signals limited to bi-phase shift keying (BPSK) and frequency modulated (FM or chirp) signals.

All the topics in this book are closely related to EW receiver design, but only some are discussed in detail. It is written at an upper undergraduate or graduate level so it is aimed at researchers and managers working in the EW and communications fields. It covers relatively deep levels of understanding in some sections, which means some background in microwave engineering is needed.

Special Design Topics in Digital Wideband Receivers builds on the first edition and expands to cover encoders and several other areas of receiver

design that were not viable when the first edition was published. It is a good reference book and provides practical examples with simulated data. From frequency modulation and bi-phase shifting keys, to parameter encoders in electronic warfare receivers and the use of the simulation and probability density function to predict the false alarm parameter, this book focuses on critical topics and techniques that help the reader design digital wideband receivers for high performance.

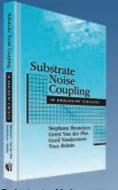
#### To order this book, contact:

Artech House 685 Canton St., Norwood, MA 02062 (781) 769-9750 ext. 4030;

16 Sussex St., London SW1V 4RW, UK +44 (0) 20 7596-8750

> 430 pages; \$139, £86 ISBN: 978-1-60807-029-9

## The Latest "Words" in RF & Microwave Design



Substrate Noise Coupling in Analog/RF Circuits Stephane Bronckers & Geert Van der Plas

ISBN: 978-1-59693-271-5 Price: \$139/£86 Discrete Oscillator Design Incaract Inc

Discrete Oscillator Design: Linear, Nonlinear, Transient, and Noise Domains

ISBN: 978-1-60807-047-3 Price: \$139/£85



Radio Frequency Integrated Circuit Design, Second Edition John W.M. Rogers & Calvin Plett

ISBN: 978-1-608783-979-8 Price: \$149/£89



An Engineer's Guide to Automated Testing of High-Speed Interfaces

Jose Moreira & Hubert Werkmann

ISBN: 978-1-60783-983-5 Price: \$118/£92

#### Visit ArtechHouse.com for complete descriptions and to order

Order at www.artechhouse.com or contact the office nearest you: US FAX Purchase orders and credit card orders to 1-781-769-6334 PHONE Toll-Free 1-800-225-9977, ext. 4030 or 1-781-769-9750 E-MAIL artech@artechhouse.com UK FAX Purchase orders and credit card orders 24 hours a day to +44 (0)20 7630-0166 PHONE +44 (0)20 7596-8750 E-MAIL artech-uk@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

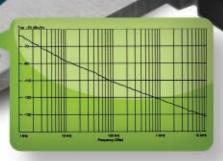


Model	Frequency Range (MHz)	Tuning Voltage ( VDC )	DC Blas VDC @1[Typ.]	Phase Noise @ 10 kHz (dBc/Hz) [Typ.]	Size (Inch)
DCO Series	D) V				
DCO50100-5	500 - 1000	0.3 - 15	+5 @ 28 mA	-100	0.3 × 0.3 × 0.1
DCO7075-3	700 - 750	0.5-3	+3 @ 10 mA	-108	0.3 × 0.3 × 0.1
DCO80100-3	800 - 1000	0-3	+3 @ 15 mA	-105	0.3 x 0.3 x 0.1
DC080100-5	800 - 1000	0.5 - 8	+5 @ 21 mA	+3 @ 15 mA -105 +5 @ 21 mA -111 +5 @ 30 mA -95 +8 @ 24 mA -115 +5 @ 35 mA -90 +3 @ 35 mA -89 +5 @ 35 mA -89	
DCO100200-5	1000 - 2000	0.5 - 24	+5 @ 30 mA	-95	0.3 × 0.3 × 0.1
DCO1198-8	1195 - 1205	0.5 - 8	+8 @ 24 mA	-115	0.3 x 0.3 x 0.1
DCO170340-5	1700 - 3400	0.5 - 24	+5 @ 24 mA	-90	0.3 x 0.3 x 0.1
DCO200400-5 DCO200400-3	2000 - 4000	0.5 - 18			0.3 x 0.3 x 0.1
DCO300600-5 DCO300600-3	3000 - 6000	0.5 - 18	+5 @ 35 mA +3 @ 35 mA		0.3 x 0.3 x 0.1
DCO400800-5 DCO400800-3	4000 - 8000	0.5 - 18	+5 @ 35 mA +3 @ 35 mA	-78 -76	0.3 x 0.3 x 0.1
DCO432493-5 DCO432493-3	4325 - 4950	0.5 - 11	+5 @ 17 mA +3 @ 17 mA	-88 -86	0.3 × 0.3 × 0.1
DCO450820-5	4500 - 8200	0.5 - 14	+5 @ 22 mA	-77	0.3 x 0.3 x 0.1
DCO473542-5 DCO473542-3	4730 - 5420	0.5 - 22	+5 @ 20 mA +3 @ 20 mA	-88 -86	0.3 x 0.3 x 0.1
DCO490517-5 DCO490517-3	4900 - 5175	0.5-5	+5 @ 22 mA +3 @ 22 mA	-88 -86	0.3 x 0.3 x 0.1
DCO495550-5 DCO495550-3	4950 - 5500	0.5 - 12	+5 @ 22 mA +3 @ 22 mA	-87 -85	0.3 x 0.3 x 0.1
DCO579582-5	5780 - 5880	0.5 - 10	+5 @ 27 mA	-91	0.3 x 0.3 x 0.1
DCO608634-5 DCO608634-3	6080 - 6340	0.5-5	+5 @ 22 mA +3 @ 22 mA	-86 -84	0.3 x 0.3 x 0.1
DCO615712-5 DCO615712-3	6150 - 7120	0.5 - 18	+5 @ 22 mA +3 @ 22 mA	-85 -83	0.3 x 0.3 x 0.1

Model	Frequency Range ( GHz )	Tuning Voltage ( VDC )	DC Blas VDC @ I [Typ.]	Phase Noise @ 10 kHz (dBclHz) [Typ.]	Size (Inch)
DXO Series					
DXO810900-5 DXO810900-3	8.1 - 8.925	0.5 - 15	+5 @ 26 mA +3 @ 26 mA	-82 -80	0.3 x 0.3 x 0.1
DXO900965-5 DXO900965-3	9,0 - 9.65	0.5 - 12	+5 @ 22 mA +3 @ 22 mA	-80 -78	0.3 x 0.3 x 0.1
DXO10701095-5	10.70 - 10.95	0.5 - 15	+5 @ 21 mA	-82	0.3 x 0.3 x 0.1
DXO11441200-5	11.44 - 12.0	0.5 - 15	+5 @ 23 mA	-82	0.3×0.3×0.1
DXO11751220-5	11.75 - 12.2	0.5 - 15	+5 @ 24 mA	-80	0.3 × 0.3 × 0.1

#### **Features**

- Exceptional Phase Noise Dimensions: 0.3" x 0.3" x 0.1"
- **Excellent Tuning Linearity**
- Models Available from 4 to 12 GHz High Immunity To Phase Hits
- Lead Free RoHS Compliant
- Patented Technology



For additional information, contact Synergy's sales and application team. Phone: (973) 881-8800 Fax: (973) 881-8361 E-mail: sales@synergymwave.com 201 McLean Boulevard, Paterson, NJ 07504

Visit Our Website At WWW.SYNERGYMWAVE.COM



RS No.	Advertiser	Page No.	WEB ADDRESS	RS No.	Advertiser	PAGE No.	WEB ADDRESS
1	Advanced Switch Technology	172	http://mwj.hotims.com/28495-1	71	Microsemi	138	http://mwj.hotims.com/28495-71
2	Advanced Test Equipment Rentals	114	http://mwj.hotims.com/28495-2	72	Microwave Circuits	58	http://mwj.hotims.com/28495-72
3	Aeroflex / Control Components	33	http://mwj.hotims.com/28495-3	73	Microwave Development Laborato		http://mwj.hotims.com/28495-73
4,5	Aeroflex / Metelics	120,149	http://mwj.hotims.com/28495-4	74		4,144,154,166,168	
6 7	Aeroflex / Weinschel Aethercomm	67 73	http://mwj.hotims.com/28495-6 http://mwj.hotims.com/28495-7	74 75,76,77,	Milmega Limited Mini-Circuits	169 4-5,16,31	http://mwj.hotims.com/28495-74
8	Agilent Technologies, Inc.	41	http://mwj.hotims.com/28495-8	78,79,80,	Willin-Circuits	43,51,52,	
9	Akon, Inc.	113	http://mwj.hotims.com/28495-9	81,82,83,		63,71,83,	
10	AML Communications Inc.	39	http://mwj.hotims.com/28495-10	84,85,86,		135,151,163,	
11	Anaren Microwave	20-21	http://mwj.hotims.com/28495-11	152		177	http://mwj.hotims.com/28495-75
12	Anatech Electronics, Inc.	86	http://mwj.hotims.com/28495-12	87,88,89	MITEQ Inc.	89,165,COV 3	http://mwj.hotims.com/28495-87
13	Ansoft Corporation AR RF/Microwave Instrumentation	27	http://mwj.hotims.com/28495-13	90,91	Modco, Inc.	170,172	http://mwj.hotims.com/28495-90
14	Artech House	69 174	http://mwj.hotims.com/28495-14 www.ArtechHouse.com	92,93	Narda Microwave-East, an L3 Communications Co.	34,122	http://mwj.hotims.com/28495-92
15	Astrolab, Inc.	111	http://mwj.hotims.com/28495-15	94	Networks International Corporation		http://mwj.hotims.com/28495-94
16	AWR	55	http://mwj.hotims.com/28495-16	95	Nexyn Corporation	78	http://mwj.hotims.com/28495-95
17	AWT Co., Ltd.	126	http://mwj.hotims.com/28495-17	96	Norden Millimeter Inc.	82	http://mwj.hotims.com/28495-96
18	B&Z Technologies, LLC	29	http://mwj.hotims.com/28495-18	97	OML Inc.	143	http://mwj.hotims.com/28495-97
19	Carlisle Interconnect Technologies	13	http://mwj.hotims.com/28495-19	98	Paciwave, Inc.	124	http://mwj.hotims.com/28495-98
20 21	Ciao Wireless, Inc. Cobham Defense Electronic Systems	44 s 11	http://mwj.hotims.com/28495-20 http://mwj.hotims.com/28495-21	99 100	Pascall Electronics Limited Phase Matrix, Inc.	50 108	http://mwj.hotims.com/28495-99 http://mwj.hotims.com/28495-100
22	Coilcraft	35	http://mwj.hotims.com/28495-22	100	PLANAR LLC	170	http://mwj.hotims.com/28495-101
23	Coilcraft CPS	173	http://mwj.hotims.com/28495-23	102	Pole/Zero Corporation	157	http://mwj.hotims.com/28495-102
24	Coleman Microwave Company	100	http://mwj.hotims.com/28495-24	103	Pulsar Microwave Corporation	104	http://mwj.hotims.com/28495-103
25	COMSOL, Inc.	155	http://mwj.hotims.com/28495-25	104	R&K Company Limited	132	http://mwj.hotims.com/28495-104
26	Comtech PST Corp.	30	http://mwj.hotims.com/28495-26	105	Radiall	170	http://mwj.hotims.com/28495-105
27	CPE Italia	172	http://mwj.hotims.com/28495-27	106	Reactel, Incorporated	48	http://mwj.hotims.com/28495-106
28 29	CPI Beverly Microwave Division Crystek Corporation	133 36	http://mwj.hotims.com/28495-28 http://mwj.hotims.com/28495-29	107 108	Remcom Renaissance Electronics Corporati	97 on 105	http://mwj.hotims.com/28495-107 http://mwj.hotims.com/28495 108
30	CST of America, Inc.	25	http://mwj.hotims.com/28495-30	100	RF Precision Products,	011 100	http://mwj.noums.com/20493 106
31	CTT Inc.	85	http://mwj.hotims.com/28495-31	100	Division of RF Industries	124	http://mwj.hotims.com/28495-109
32	Damaskos Inc.	170	http://mwj.hotims.com/28495-32	110	RF TEC Mfg., Inc.	172	http://mwj.hotims.com/28495-110
33	Delta Electronics Mfg. Corp.	127	http://mwj.hotims.com/28495-33	111	RFcore Co., Ltd.	116	http://mwj.hotims.com/28495-111
34	Dielectric Laboratories Inc.	115	http://mwj.hotims.com/28495-34	112,113	RFHIC	68,70	http://mwj.hotims.com/28495 112
35,36	Ducommun Technologies	42,102	http://mwj.hotims.com/28495-35	114	RFMD	87	http://mwj.hotims.com/28495-114
37 38	Dynawave Incorporated Eastern Wireless TeleComm, Inc.	153 95	http://mwj.hotims.com/28495-37 http://mwj.hotims.com/28495-38	115 116	Richardson Electronics, Ltd. RLC Electronics, Inc.	91 23	http://mwj.hotims.com/28495-115 http://mwj.hotims.com/28495-116
39	Elektrobit Ltd.	140	http://mwj.hotims.com/28495-39	117	Rogers Corporation	65	http://mwj.hotims.com/28495-117
40	EM Research, Inc.	90	http://mwj.hotims.com/28495-40	118,119,120	Rohde & Schwarz GmbH	119,121,123	http://mwj.hotims.com/28495-118
41	Empower RF Systems, Inc.	137	http://mwj.hotims.com/28495-41	121	Rosenberger	60	http://mwj.hotims.com/28495-121
42	Endwave	150	http://mwj.hotims.com/28495-42	122,123	RT Logic	75,147	http://mwj.hotims.com/28495-122
43	ES Microwave, LLC	126	http://mwj.hotims.com/28495-43	124	Santron Inc.	99	http://mwj.hotims.com/28495-124
44	ESM Cable Corporation	158	http://mwj.hotims.com/28495-44	125	Satellink, Inc.	170	http://mwj.hotims.com/28495-125
45 46	Frontlynk Technologies Inc. G.T. Microwave Inc.	145 88	http://mwj.hotims.com/28495-45 http://mwj.hotims.com/28495-46	126 127	Sector Microwave Industries, Inc. SGMC Microwave	170 159	http://mwj.hotims.com/28495-126 http://mwj.hotims.com/28495-127
47	GGB Industries, Inc.	3	http://mwj.hotims.com/28495-47	128	Skyworks Solutions, Inc.	59	http://mwj.hotims.com/28495-128
48	GraSen Technology, LLC.	132	http://mwj.hotims.com/28495-48	129	Spacek Labs Inc.	92	http://mwj.hotims.com/28495-129
49	Herotek, Inc.	80	http://mwj.hotims.com/28495-49	130	Special Hermetic Products, Inc.	54	http://mwj.hotims.com/28495-130
50,51,52	Hittite Microwave Corporation	77,79,81	http://mwj.hotims.com/28495-50	131	Spectrum Elektrotechnik GmbH	167	http://mwj.hotims.com/28495-131
53	Huber + Suhner AG	139	http://mwj.hotims.com/28495-53	132	Spinnaker Microwave, Inc.	130	http://mwj.hotims.com/28495-132
	IEEE MTT-S International	160	varancimo 2011 org	133 134	State of the Art, Inc.	118	http://mwj.hotims.com/28495-133
	Microwave Symposium IEEE Radio and Wireless Week	161	www.ims2011.org www.radiowirelessweek.org	135,136	SV Microwave, Inc. Synergy Microwave Corporation	131 57,175	http://mwj.hotims.com/28495-134 http://mwj.hotims.com/28495-135
54	IMT (a Vitec Group Company)	101	http://mwj.hotims.com/28495-54	138	Teledyne Coax Switches	93	http://mwj.hotims.com/28495-138
55	ITT Microwave Systems	46	http://mwj.hotims.com/28495-55	137	Teledyne Cougar	28	http://mwj.hotims.com/28495-137
56	IW Inc. (Insulated Wire)	117	http://mwj.hotims.com/28495-56	138	Teledyne Relays	93	http://mwj.hotims.com/28495-138
57	Jersey Microwave	38	http://mwj.hotims.com/28495-57	139	Teledyne Storm Products	103	http://mwj.hotims.com/28495-139
58	JFW Industries, Inc.	125	http://mwj.hotims.com/28495-58	140	Times Microwave Systems	129	http://mwj.hotims.com/28495-140
59 60	JQL Electronics Inc. K&L Microwave, Inc.	6 7	http://mwj.hotims.com/28495-59 http://mwj.hotims.com/28495-60	141 142	TRAK Microwave Corporation United Monolithic Semiconductors	106 109	http://mwj.hotims.com/28495-141 http://mwj.hotims.com/28495-142
61	KR Electronics, Inc.	172	http://mwj.hotims.com/28495-61	143	Universal Microwave Components	103	http://mwj.noums.com/20455-142
62	Krytar	32	http://mwj.hotims.com/28495-62	1.10	Corporation	76	http://mwj.hotims.com/28495-143
63	Linear Technology Corporation	15	http://mwj.hotims.com/28495-63	144	Weinschel Associates	112	http://mwj.hotims.com/28495-144
64	Lorch Microwave	47	http://mwj.hotims.com/28495-64	145	Wenzel Associates, Inc.	94	http://mwj.hotims.com/28495-145
65,66	M/A-COM Technology Solutions	18,19	http://mwj.hotims.com/28495-65	146	Werlatone, Inc.	COV 4	http://mwj.hotims.com/28495-146
67	Massachusetts Bay Technologies, Ir		http://mwj.hotims.com/28495-67	147	West Bond Inc.	134	http://mwj.hotims.com/28495-147
68 69	Maury Microwave Corporation MECA Electronics, Inc.	9 COV 2	http://mwj.hotims.com/28495-68 http://mwj.hotims.com/28495-69	148,149 150	Win Semiconductors Corp. Wright Technologies	8,171 172	http://mwj.hotims.com/28495-148 http://mwj.hotims.com/28495-150
70	Microlab	00 V Z	144.//1110g.110g.115.0011/20450-05	151	Xi'an Forstar S&T Co., Ltd.	62	http://mwj.hotims.com/28495-151
.0	(a Wireless Telecom Group Compa	ny) 61	http://mwj.hotims.com/28495-70	101	0.000. 001 00, 10.	-	
			•				

#### Visit mwjournal.com/info and enter RS# to request information from our advertisers

### SALES REPRESENTATIVES



#### **CARL SHEFFRES**, PUBLISHER

Eastern and Central Time Zones Chuck Boyd Northeast Reg. Sales Mgr. (New England, Upstate NY, Eastern Canada) Eastern Canada) 685 Canton Street Norwood, MA 02062 Tel: (781) 769-9750 FAX: (781) 769-5037 cboyd@mwjournal.com

Michael Hallman Michael Hallman Eastern Reg. Sales Mgr. (Mid-Atlantic, Southeast, Midwest) 4 Valley View Court Middletown, MD 21769 Tel: (301) 371-8830 FAX: (301) 371-8832 mhallman@mwjournal.com

#### Pacific and Mountain Time Zones Wynn Cook

Western Reg. Sales Mgr. PO Box 23200 San Jose, CA 95153 Tel: (408) 224-9060 FAX: (408) 224-6106 wcook@mwjournal.com

#### International Sales

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

#### Germany, Austria, and Switzerland

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

#### Israel

Oreet Ben Yaacov Oreet International Media 15 Kineret Street 51201 Bene-Berak, Israel Tel: +972 3 570 6527 FAX: +972 3 570 6526 obenyaacov@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

**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

#### **ED KIESSLING**, TRAFFIC MANAGER

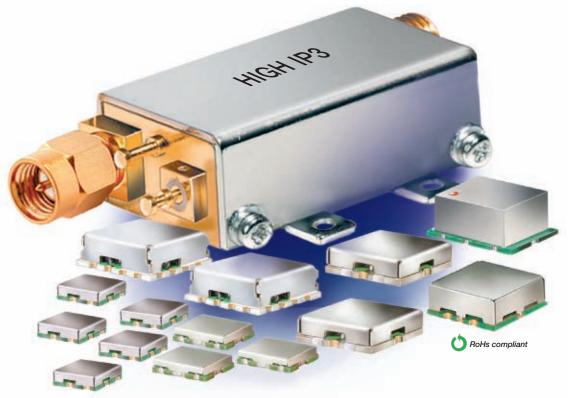
China

Michael Tsui ACT International Tel: 86-755-25988571 Tel: 86-21-62511200 FAX: 86-10-58607751 michaelT@actintl.com.hk

Hong Kong Mark Mak ACT International Tel: 852-28386298 markm@actintl.com.hk

# Constant Impedance

## 10MHz to 7GHz



\$395 from **3**ea. qty. 25

Voltage Variable Attenuators (VVAs) deliver as high as 40 dB attenuation control over the 10 MHz through 7.0 GHz range. Offered in both 50 and 75 Ω models these surface-mount and coaxial low-cost VVAs require no external components and maintain a good impedance match over the entire frequency and attenuation range, typically 20 dB return loss at input and output ports. These high performance units offer insertion loss as low as 1.5 dB, typical IP3 performance as high as +56 dBm, and minimal phase variation low as 7°.

Mini-Circuits VVAs are enclosed in shielded surface-mount cases as small as 0.3" x 0.3" x 0.1". Coaxial models are available with unibody case with SMA connectors. Applications include automatic-level-control (ALC) circuits, gain and power level control, and leveling in feedforward amplifiers. Visit the Mini-Circuits website at www. minicircuits.com for comprehensive performance data, circuit layouts, environmental specifications and real-time price and availability.

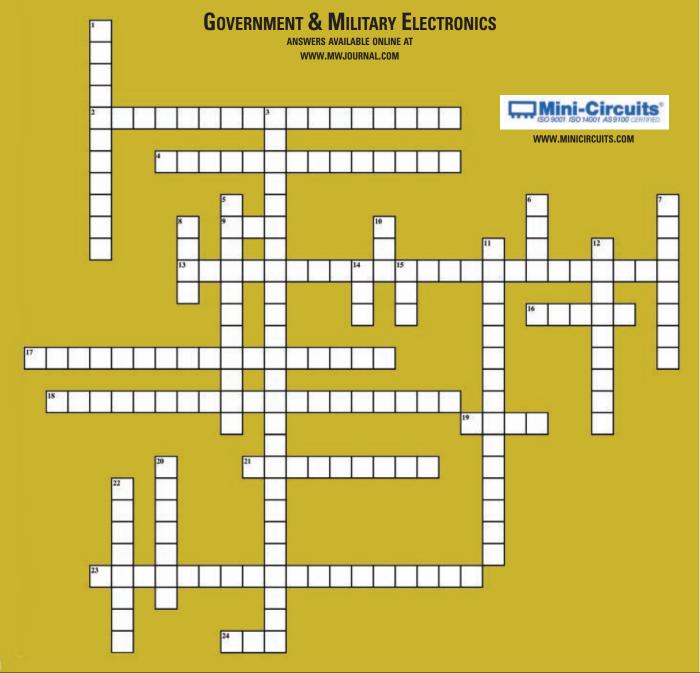
Mini-Circuits...Your partners for success since 1969



P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

2 The Design Engineers Search Engine finds the model you need, Instantly • For detailed performance specs & shopping online see minicircuits.com





#### **A**cross

- 2 EW (2 words)
- **4** A wireless communication system that changes its transmission or reception parameters to communicate efficiently avoiding interference with other channels being used (2 words)
- 9 Electronic Counter Measures
- **13** Technique for estimating the location of a radio emitter based on signal observations from other points based on timing (4 words)
- ${\bf 16}$  The fraction of a complete wave cycle corresponding to an offset in the displacement from a specified reference point at time = 0
- 17 Designing the input impedance of an electrical load or the output impedance of its corresponding signal source in order to maximize the power transfer and minimize reflections (2 words)

- **18** DoD (3 words)
- 19 Active Electronically Scanned Array
- **21** Beams of the far field radiation pattern that are not the main beam (2 words)
- 23 SIGINT (2 words)
- **24** Wide band gap material gaining use for very high power, broadband amplifiers

#### Down

- 1 10 log(SNR<sub>in</sub>/SNR<sub>out</sub>) (2 words)
- 3 IMD (2 words)
- **5** A signal processing technique used in sensor arrays for directional signal transmission or reception (2 words)
- 6 Short for Frequency Difference Of Arrival
- **7** A device that allows bi-directional communication over a single channel

- 8 Commercial off-the-shelf components
- 10 Short for software-defined radio
- 11 Optimization method that allows minimization of mainlobe width for a specific sidelobe level in beam forming (hyphenated)
- 12 Short for Military Satellite Communications
- 14 Short for European Defense Agency
- 15 Electronic Support Measures
- **20** The transmission of radio signals that disrupt communications by decreasing the signal to noise ratio
- **22** Any signal present in the output spectrum that is not present at the input

POWET SATCOM Optic Cryogenic LOW LOW Noise Noise LOW Phase Noise Limiting In Line Space Qualified Space Qualified HINDERSON AND THE PARTY OF THE 1111111111111111 For additional information or technical support,







100 Davids Drive, Hauppauge, NY 11788 (631) 436-7400 FAX: (631) 436-7430

www.miteq.com



- JAMMING
- COMMUNICATIONS
- CO-SITE MANAGEMENT

REQUIRE,

#### **SOPHISTICATED SOLUTIONS**

- MORE POWER
- GREATER BANDWIDTH
- LESS LOSS
- SMALLER PACKAGES
- POWER COMBINERS/DIVIDERS
- 90° HYBRID COUPLERS
- 0°/180° HYBRID JUNCTIONS
- DIRECTIONAL COUPLERS

DESIGNED TO MEET THE MOST STRINGENT OPERATING CONDITIONS.

Werlatone, Inc. 17 Jon Barrett Road Patterson, New York 12563 Main 845.278.2220 845.278.3440 sales@werlatone.com